Chinas' temporal emissions from final demand of domestic and imported goods.

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Abstract*:*

Final demand is the main culprit for a country's emissions. In order to curb a country's emissions it's essential to develop a deep understanding of final demand and its categories. In this study we have decomposed Chinas' emissions from final demand of domestic and imported goods in to relevant categories of Household, Government and Capital. We have also argued, to correctly understand final emissions distinction should be made between emissions from intermediate, final and total imported emissions moreover proposed possible accounting treatments for all three. Production and consumption-based emissions from final demand are on rise since 2002 onwards while emissions from final-imports have actually decreased over the years. Capital formation with 39% is the major final demand category for domestic goods. While household with 52% is for final imports. The gap between total and final import emissions has increased resulted from growing demand of intermediate imports and decreased demand of finished (final) imports. Production-based emissions are always greater than consumption-based with an ever increasing split between the two. This further decomposition will be helpful to further understand Chinas' final emissions which can help managers and policy makers to effectively and efficiently design carbon mitigation policies.

Keywords

Input-output analysis; Embodied carbon emissions; Final demand; Imports

1. Introduction

CO_2 Emission mitigation is a common global welfare problem, which should be paid close attention to by everyone [1]; [2]. Current rate of global GHG emissions can affect the worldwide environment [3]. Causes of GHG emissions profit people by providing them with consumable goods and services [4]. But pose biggest health problems of current century [5].

Global warming is mainly caused by carbon emissions released from burning of fossil fuel [6]. Pursuing many nations to impose mechanisms for decrease in consumption of fossil fuels [7]. As a matter of fact many nations have achieved reductions in CO_2 emissions and some have fulfilled their Kyoto protocol [8]. Which might be owing to the fact that these countries have outsourced their carbon intensive emissions [9]; [7].

Two type of approaches production (similar to IPCC and other international agreements) and consumption-based are extensively employed for calculation of global GHG emissions [10]. The type of accounting approach adopted deeply influence allocation of CO_2 emissions responsibility [11]. Hence there is an international debate on approaches and allocation of responsibility for GHG emissions [12]; [13]. Calculations under PBA are uncomplicated but it neglects global transport and carbon leakage problems [14]. On other hand consumption- based approach is much fairer when assigning emissions accountability [15]; [16]. Consumption based policy is objective and cost efficient [17]. And it may be needed for sustainable environment [18]. It can help abate worldwide air contamination [19], stimulate ecological comparative advantages and dispersal of technology [20]. Consumption-based approach would pursue importers towards mitigation projects in regions from where they import merchandises [21]. Consumption-based approach also have some disadvantages which may be eliminated by exercising shared responsibility [14]; [21]; [22].

Input-output model using consumption-based approach is widely employed for calculation of embodied emissions [23] .There are two types multiple region (MRIO) and single region (SRIO) model [24]. Consumption-based MRIO is an international trade flow model for allocating responsibility of global emissions from all over the world to the place of final consumption [25]. Peters [21] further divided consumption based MRIO in to two approaches: EEBT (emissions embodied in bilateral trade) approach [26]; [27]; [28]; [29]; [30]; [20]; [31] and MRIO (multi regional input-output) approach [32]; [14]; [7]; [33]; [34] ; [35]; [36]; [37]; [38]; [39] . The distinction between the two is in handling of imports for intermediate usage with former failing to distinguish between imports for intermediate and final use [21], meaning only considering last stop or final supplier of imports on other hand multi-regional approach takes in to consideration import supply chains between all regions [40]. SRIO model calculates embodied emissions from regional industries [39] and treats imports as domestically manufactured goods [41]; [42]. Su & Ang [43] decomposed SRIO in to non-competitive [44]; [45]; [46] and competitive [47]; [48]; [49].

The main reason of conducting embodied emissions studies is to split production emissions in to various categories of final emission [43]. Although there is already much literature on Chinas' embodied emissions specifically temporal emissions see table but most of existing literature fails to provide, carbon emissions from both final demand for domestic and final imported goods in to its respective categories i.e. Household, Government and Capital (see **Error! Reference source not found.**). As a matter of fact final demand for imported goods has no relation with intermediate processes of a country or region so emissions from final imports should be calculated separately from main IO model (intermediate matrix) i.e. they in no way impact intermediate demand for domestic and imported goods, intermediate imports demand is totally independent of final demand for imported goods. In most of the literature Emissions from total imports (Intermediate plus final) are presented rather than from final imports. As a matter of fact Intermediate imports are considered as domestic inputs which after reprocessing are converted to outputs [41]. So it's much more appropriate to treat emissions from intermediate imports embodied in to final demand for domestic goods including exports separately from final demand for imported goods.

Existing literature on embodied emissions fails to split final emissions in to relevant categories of both domestic and imported final emissions. It's much more proper to distinguish between intermediate and final imports and then to treat intermediate imports emissions as embodied in final demand for domestic goods. By distinguishing between embodied emissions from final domestic goods demand and final imports demand we will be in a much better position first to understand real final demands' embodied emissions i.e. total embodied emissions of final demand for domestic and imported goods. And by developing understanding of these two main heads and their respective categories of final demand policy makers will be in a more comfortable position to tailor made mitigation policies according to distinction and/or similarities between embodied emissions from main heads of final demand.

Table 1. Recent literature on temporal emissions of China.

Sources	Period	Method
[50]	2000-2014	Temporal and spatial decomposition analysis
[51]	2005-2015	IPAT
[52]	1980-2010	IPCC guideline
[53]	1980-2014	ADF and VECM
[54]	1997-2012	IO model
[55]	1996-2012	IDA and LMDI
[35]	1997 & 07	MRIO
[56]	1980-2002	SDA and IO
[57]	1995-2000	SDA and IO
[58]	1985-2007	LMDI
[59]	2002-2007	MRIO
[60]	1990-2007	Space-for-time substitution method
[61]	2007	Ecological IO model
[62]	1990 & 95	RAINS-ASIA simulation model

[1] Note: IPAT represents impact of population, affluence and technology, IPCC= Intergovernmental panel on climate change, ADF= Augmented Dickey-Fuller, VECM= Vector error correlation model, IO= Input-output, IDA= Index decomposition analysis, LMDI= Logarithmic mean divisia index, MRIO= Multiple-region input-output and SDA= Structural decomposition analysis.

In this paper we have presented carbon emissions from final domestic demand for domestic goods and final domestic demand for imported goods in to their relevant categories. We have considered temporal emissions of China for the period of 1995-2009 as a case example[1].The rest of the paper is organized in the following manner. Section 2 presents Materials and Methods, section 3 is portrays results and in section 4 we have discussed our work.

[1] China is world largest carbon emitter under both production and consumption based approaches [14].

2. Materials and methods

2.1 Materials

The main source of our data including IO tables and environmental accounts are from world input-output database [68].There are two releases 2013 and 2016, we have utilized 2013 releases' environmental accounts [69] and national IO tables [70]; [71] for the years1995-2009, Under release 2013 following sub-categories are available: 'World, national & regional IO tables', 'environmental accounts' and 'Socio- economic information'. Many scholars have considered WIOD as a reliable source of information for environmental problems [72]; [73]; [74]; [7]; [24]; [10].

2.2 Methods

Wassily W. Leontief [63] is considered to be the author of input-output model presented as:

$$X = AX + F \qquad (1)$$

By isolating X we have,

$$X = (I - A)^{-1} F \qquad (2)$$

Where X represents total yield or output of an economy, I represents an $n \times n$ identity matrix, A is technology matrix[2] whose element $a_{ij} = \frac{x_{ij}}{x_j}$ equals total output entailed from sector i for production of one element at sector j, $L = (I - A)^{-1}$ represents Leontief inverse matrix, F equals vector of final demand or external demand. Where $A = A^D + A^M$.

National input out tables provided by WIOD database uses non-competitive imports assumption meaning intermediate imports are treated separately from intermediate domestic goods. We have to add intermediate imports to the original domestic technology matrix so;

$$X + IM = \left(I - \left(A^D + A^M\right)\right)^{-1} F^{DD} + E \qquad (3)$$

Where, A^D is a technology matrix of intermediate demand for domestic goods, A^M is a technology matrix of domestic intermediate demand for imported goods, IM is intermediate imports, F^{DD} domestic final demand for domestic and E is exports or external demand for domestic goods.

Final local demand for domestic goods F^{DD} can be further decomposed as:

$$F^{DD} = HF^{DD} + GF^{DD} + CF^{DD} = \sum_{i=1}^{n} F_i^{DD} = \sum_{i=1}^{n} HF_i^{DD} + \sum_{i=1}^{n} GF_i^{DD} + \qquad (4)$$

Where HF^{DD}, GF^{DD} and CF^{DD} represent the domestic final demand of household, Government and Capital for domestic goods

Similarly final demand for imported products in to its relevant categories can be further decomposed as:

$$F^M = HF^M + GF^M + CF^M = \sum_{i=1}^{n} F_i^M = \sum_{i=1}^{n} HF_i^M + \sum_{i=1}^{n} GF_i^M + \sum_{i=1}^{n} CF_i^M \qquad (5)$$

Where F^M is the domestic final demand for imported goods and HF^M GF^M plus CF^M represent the domestic final demand of households, government and capital for imported goods.

If $\varphi = [\varphi_1, \varphi_2, \varphi_3, \ldots, \varphi_n]$ is a vector of direct sectoral intensities obtained by dividing direct sectoral emission by sectoral output then by multiplying φ with X we can get the total production-based carbon emissions embodied in final demand for domestic goods and services including from domestic final demand and form exports.

$$C = \varphi (I - A)^{-1} \hat{F}^{DD} + \hat{E} \qquad (6)$$

Where C is a vector of total production-based emissions, $\wedge$ sign represents that the vectors of $\hat{F}^{DD}$, $\hat{E}$ have been diagonalized.

Similarly non-competitive production based emissions can be presented as:

$$C^* = \varphi \left(I - A^D\right)^{-1} \hat{F}^{DD} + \hat{E} \qquad (7)$$

Where C^* represents non-competitive production based emissions. A^D Represents domestic technology coefficient matrix without intermediate imports.

By multiplying φ with F^M we can get emissions from final demand for imported goods. For final imports emission intensity based on avoided emissions is used which is the emissions responsibility embedded in the imported goods is applied as if these were produced within in boundary

[2] A Matrix is also referred as: intermediate demand [35], technology matrix [47] and direct requirement matrix [41] in related literature.

of imported country not according to the country form where goods are imported from [64]; [65]; [66].In other words exporting country emission intensity is considered same as importing country (domestic) emission intensity [41].

$$C^M = \varphi(\hat{F}^M) = \sum_{i=1}^{n} \varphi_i \sum_{i=1}^{n} \hat{F}_I^M \tag{8}$$

Where C^M represents emission from final demand of imported goods. Based on our argument that final imports have no relation with intermediate production process (technology matrix). We calculated emissions form final imports directly by multiplying them with direct sectoral intensities. Below we have calculated imports under conventional method which in our view represents emissions from total imports rather than form final demand of imported goods.

$$C^{M*} = \varphi(I - A^M)^{-1} FM \tag{9}$$

Where C^{M*} represents total imports carbon emission and FM represents total quantity of final demand for imported goods.

Consumption-based emissions are equal to emissions embodied in final demand for domestic goods (production-based emissions) minus emissions from exports (external demand for domestic goods) plus emissions from imports [67] which in our case will be emissions from final imports[3].

$$\overline{C} = C - C^E + C^M \tag{10}$$

Where $\overline{C}$ is total consumption based emissions and C, C^E, C^M represent production-based emissions from domestic demand, emissions from exports and imports respectively.

Non-competitive consumption-based emissions can be presented by:

$$\overline{C}^* = C^* - C^{E*} + C^{M*} \tag{11}$$

Where $\overline{C}^*$ represents non-competitive consumption-based emissions, C^{E*} represent non-competitive exports and C^{M*} represent total imports.

We have not considered direct emissions from households in our paper in line with [67].

[3]In order to avoid double counting when calculating consumption-based emissions we have just added emissions from final domestic demand of imported goods instead of emissions from total imports. Because of the fact that embodied emissions from intermediate imports are already been embedded in to final demand categories for domestic goods.

3. Results

3.1 Emissions from final demand

3.1.1 Category wise emission from final demand of domestic goods

By using equation 6 we can get the embodied emissions from final demand for domestic goods. Final demand for domestic goods can be categorized under two main heads final domestic demand for domestic goods and external demand for domestic goods i.e. exports. Final domestic demand for domestic goods can be further divided in to relevant sub-categories of final demand in our case: Household, Government and Capital formation[4]. Table 2. Contains the yearly category wise emissions embodied in final demand of domestic goods including both domestic and external demand. Final emissions from government demand of domestic goods is the lowest of all sub-categories from 1995-2009. Embodied final household emissions actually remained greater than embodied exports emissions before exports finally crossed household in 2004 and remained greater until 2009. Meanwhile embodied household emissions moved very closely with embodied capital emissions and actually crossed the capital emissions by small margin during 2000 and 2001. From 2002 onwards the gap between household emissions and capital is ever increasing till 2009. This could be owing to the fact of massive increase in china's capital formation over the years.

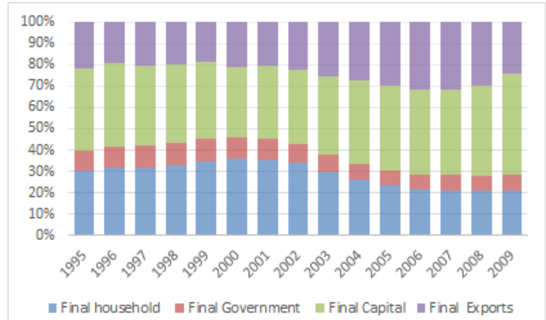

Figure 1. % emissions from final demand for domestic goods.

On other hand embodied emissions from exports remained below of that of capital all the time. Overall capital formation with 39% share of all embodied emissions is the biggest contributor towards Chinas emissions from final demand for domestic goods. Followed by embodied emissions from final household demand and final exports with 27% and 26% of all emissions respectively. Least

[4] By capital formation we mean capital plus Inventory from WIOD.

share was from government with only 8% of all embodied emissions.

3.1.2 Category wise emission from final demand of imported goods

Author By using equation eight we can get the estimated emissions from final demand for imported goods. China's emissions from final demand of imported products are actually dropping over the years. Government emissions from final demand of imported goods are the least of all other related sub-categories. Emissions from final capital were greater than final households' form 1995-1999 with exception of 1997 were embodied emissions from capital fall slightly below of households' embodied emissions. From 1999 onwards Capital's embodied emissions became not only less than that of household emissions but also are shrinking overtime. On other hand household emissions are more or less increasing from 1999 onwards with its peak from 2003-2004 at 12020.099, 13071.120 million tons of embodied emissions. Approaching 2009 embodied emissions from household's final demand for imported goods have declined a bit. Hyped household emissions in first phase could be due to China opening up its markets and the decline (2008-2009) may be related to the fact that more are more foreign companies are now running their operations in mainland China. Household with an average of 52% is the highest contributor towards China's final imported embodied emissions from 1995-2009. Followed by final capital emissions of 45% while government only contributed 3%.

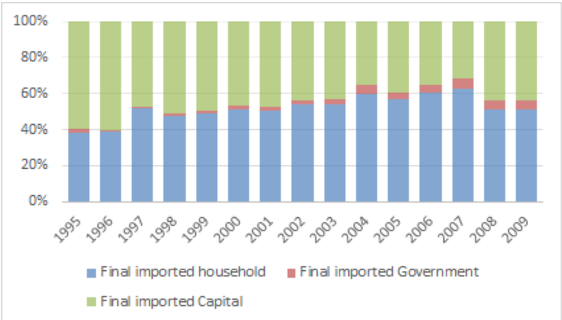

Figure 2. % emissions from final demand for imported goods.

3.2 Emissions from total and final imports

By using equations eight and nine we can get estimated emissions from final and total imports. China's emissions from total imports have increased drastically from 1995,s levels. With 1995 emissions at 133.82 million tons, lowest point 1999 at 108.49 million tons and highest point 2008 at 259.73 million tons. From 2004 onwards China's total imports emission crossed 200 million tons and remained above ever since. On other hand China's emissions from final imports are constantly decreasing with 1995's 23.88 million tons to be the highest and 1997 with 14.75 million tons to be the lowest. On other hand emissions from total imports from 2002 onward never fall below 1995 levels and with few exceptions are generally on rise. This has led to ever widening gap between final and total imports. This increasing gap between final and imported goods could be attributed to rapid development of Chinese local industries. Which in return have reduced Chinas' dependence on finished goods from abroad and increased demand for intermediate imports in the form of raw material and semi-finished goods. Table 2. Contains the details of emissions from total and final imports.

Table 2. Carbon emission from final and total imports (Millions of ton).

Years	Final imports	Total imports
1995	23.87	133.82
1996	21.06	119.66
1997	14.75	114.66
1998	18.12	115.78
1999	15.83	108.49
2000	14.81	123.84
2001	16.57	117.81
2002	19.70	137.47
2003	22.25	172.99
2004	21.94	210.49
2005	18.40	220.65
2006	17.99	217.97
2007	17.07	226.07
2008	19.53	259.73
2009	19.35	227.48

3.3 Production and consumption-based emissions

By Employment of equations 6,7,10 and 11 will allow us to measure production and consumption-based emissions. Chinas production-based emissions are always larger than it's consumption-based. While due to the embodiment of intermediate imports to final demand under our approach production-based emissions are greater than non-competitive production-based and consumption-based emissions are greater than non-competitive consumption-based emissions. It's obvious that no matter whichever approach is applied for calculating Chinas emissions, production-based emissions are always higher than consumption-based emissions (See figure 1. For details)

Emissions from 1996 to 1997 dropped from 2895.10 million-tons to 2862.13 million-ton for

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production-based and 2249.07 million-tons to 2358.59 million-ton for consumption based. This decrease in emissions may be triggered by Asian financial crisis which started in 1997 and continued in to 1998 particularly hitting East Asian countries and Hong Kong with minor effects over main land China [75]. With economy stabilizing a bit in 1998 resulted in an increased production and consumption based emissions to 3025.627 and 2447.96 million-tons. Slight reductions in carbon emissions can be observed from 1999-2001, 1999 with the lowest production emissions of 2909.65 million-tons, gradually increasing through years 2000 and 2001 to 2913.89 and 2951.87 respectively but remaining below the levels of 1998.

For consumption based a slightly different pattern can be observed emissions dropped to 2377.04 million-tons during 1999 and keep on declining through year 2000 to 2319.47 million tons this further decline could have been caused due to drop in final imported emissions from 15.83 million-tons (1999) to 14.81 million-tons in 2000.Than climbed a bit to 2363.51 million-ton before crossing that of 1998 in 2002 with a total of 2498.14 million-ton. Some scholars partly blame this reduction in emissions from 1997 onwards on Asian financial crisis [76]. But owing to the fact that mainland China was not much affected by Asian financial crisis and it seemed to have back to normal during 1980,s so these reductions are more because of changes in China's policies towards use of coal and sources of energy [77].After 2002 rapid increase in both production and consumption-based emissions can be observed till 2009. Our results are fairly in line with [54] which shows china's emissions to be almost constant from 1997- 2002 and a rapid jump in emissions form 2002 onwards. Also almost similar patterns can be observed form the study conducted by [55] and [78]. Production-based emissions though increasing tend to smoothened a bit while approaching 2009.

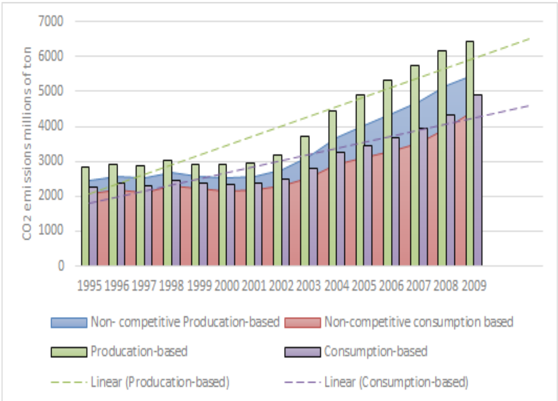

Figure 3. Production vs Consumption-based emissions.

4. Discussion

In the wake of growing international pressure its utmost important for China to curb its carbon emissions. For that it has to first fully understand the causes of its carbon emissions and then advise mitigation policies accordingly. If final consumption is the ultimate cause for emissions its utmost vital to fully understand Chinas' final demand categories and related factors in order to properly device mitigation policies. This paper is an attempt to further understand Chinas' embodied emissions in to relevant categories of final demand for domestic and imported goods. While China is the main focal point the study was also conducted to point out general lack of splitting embodied emissions into relevant categories i.e. Household, Government and capital for final domestic plus imported goods and services in related literature.

For embodied emissions from final demand for domestic goods. Capital formation was the biggest player with almost 39% of all emissions from 1995-2009 followed by Households, Exports and Government with 27%, 26% and 8% of total emissions. For embodied emissions from final demand of imported goods Household with 52% of total embodied emissions from 1995-2009 was the greatest contributor followed by Capital with 45% while government had almost negligible emission percentage of 3%.

The gap between embodied emissions from final and total imports is ever increasing. The growing gap between embodied final imported and total emissions indicate that China has moved from a primary economy to industrialized economy where it is no longer much dependent on finished products and services instead it will import raw material and/or semi-finished goods and is capable of employing local expertise to convert it in to final product or service as also supported by the constant decrease in Chinas' emissions from final demand of imported goods. Emissions from final imports actually never have crossed 1995 levels remaining at 88.19%, 61.80%, 75.89%, 66.28%, 62.05%, 69.40%, 82.51%, 93.21%, 91.88%, 77.08%, 75.36%, 71.49%, 81.81% and 81.04% of 1995,s levels from 1996-2009.

Irrespective of the fact which ever approach is adopted China's production-based emissions are always greater than its consumption based emissions. While emissions from 1995-2002 are fairly constant with few exceptions from 2002 onwards both production and consumption based emissions have drastically increased with ever increasing gap between production and consumption-based emissions. This increasing gap between the two approaches could be due to the fact embodied emissions from Chinas exports including both competitive and non-competitive from 1995 onwards have increased much more drastically than that of china's total imports with an average increase of 172.69%, 164.83% for competitive and non-competitive exports as compared to 126.67% for total imports . While emissions from final demand for imported goods over time actually decreased to 77.00% of 1995,s emission levels. Approaching 2009 this rapid increase trend slowed down a bit for production-based emissions. Production-based embodied emissions are always greater than non-competitive PBA similarly consumption-based are always greater non-competitive CBA.

Future researchers can employ our model to analyze carbon emissions based on final demand at international level, provincial level or city level. Also the historical period studied in our research was from 1995-2009 more current data related to Chinas' carbon emissions can also be employed.

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