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Structural Transformation and its Environmental Consequences in India and China : An Analysis within an Augmented Input Output Framework

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Abstract

In this paper, household sector is assumed to have carbon emission and by endogenising the household sector in the Input - Output model, we have tried to capture the implication of carbon emission from household consumption and impact of consumption multiplier on pollution as well. It is observed that most of the production sectors in India and China, over the period 2000-2010, experience change in the technological process(taking account of direct and indirect effect) such that total carbon intensities become smaller . This is , of course, encouraging as it suggests that both the countries are moving toward advanced technology with reduced carbon intensities. While decomposing the change in total (direct plus induced) pollution intensity of exports over the period 2000 – 2010 into three components namely the 'effect of change in direct pollution intensity', the 'effect of change in production structure' and the 'effect of change in export composition', it is observed that both in India and China, change in direct pollution intensity and change in technology are reducing the total pollution intensity but the change in export composition is increasing the total pollution intensity when household sector is treated as exogenous. The same trend is followed in India when household sector is edogenised but for China, along with export composition , the production structure now started to contribute to the total pollution intensity. While in India, the dominance of consumption multiplier matters for cancelling out the positive pollution impact of the sectors like 'Electricity' and 'Transport', it may not be so in China. Again, some exportable commodities may not be directly electricity /transport intensive but inputs in these sectors may be highly electricity /transport intensive . As a result, export and consequently domestic production of these sectors ultimately contributes to carbon emission as transportation and electricity are emission intensive . So trade composition is to be targeted taking account of the need of growth potential with minimum carbon emission. .

JEL Classification : O33, Q56

Key Words : Household Consumption, Environmental Pollution, Input-Output Model

I INTRODUCTION :

Environmental Pollution is a byproduct of economic development process in general and of industrialisation in particular. Pollution, in its many forms, related to any production or consumption process in measurable emission of carbon dioxide or other green house gases expressed in carbon dioxide equivalents is generally used as an environmental indicator to understand and quantify the emissions. In India and China, domestic energy consumption (Rural and Urban) is responsible for a significant percent of carbon emission frequently unnoticed and too often disregarded . Undesirable by-products (as well as certain valuable , but unpaid for natural inputs) are linked directly to the network of physical relationship that govern the day-to-day operation of our economic system. The technical interdependence between the levels of desirable and undesirable outputs can be described in terms of structural coefficients similar to those used to trace the structural interdependence between all the regular branches of production and consumption. Assuming that the basic conceptual framework of a static Input output model is familiar to the readers, we now present below the augmented I-O framework (similar to that introduced by Leontief (1968). But a major departure is that in our exercise household sector is also assumed to have carbon emission and by endogenising household sector, we have made an attempt to capture the implication of carbon emission from household consumption and impact of consumption multiplier on pollution as well . Let us have N production sectors and I household sector in the economy . Interdependence pattern in production among N sectors of the economy is reflected in the N*N transaction flow matrix . As usual , final demand by different categories like Private Final Consumption Expenditure(PFCE), Govt. Final Consumption Expenditure(GFCE), Gross Domestic Capital Formation(GDCF) , Net Exports are depicted by column vectors . Now ,in the bottom we may add one row , the elements of which capture the undesired byproduct " pollutant " generated in the processing of the corresponding production sector . We like to take account of the fact also that household consumption is also susceptible to generate pollutant CO_2 in cooking , air conditioning etc . Often , the amount is also quite significant . As household sector is generating pollutants , input-output model with household sector treated as endogenous, the expanded input-output matrix with an additional row with household income as the elements the and an additional column having household consumption as elements is considered as the preferred variant . Carbon emission coefficients for the relevant sectors will be the exogenous row . The balance relations are outlined in the methodology.

So, resorting to an augmented input-output framework, this paper aims to capture the direct, indirect and induced pollution effect of economic activity/activities in a sector through its repercussion on other related economic activities. It is possible that production or consumption of a particular product itself does not directly generate pollutant or generates very little pollutant but indirectly through its input requirement in the successive rounds of repercussion contributes to significant amounts of pollutants . So , to formulate any trade/ domestic investment policy compatible with the growth and distribution objective on the one hand and minimisation of pollution effect on the other, it is essential that we have to use a sort of framework like input output model . The technical interdependence between the levels of desirable and undesirable outputs can be described in terms of structural coefficients similar to those used to trace the structural interdependence between all the regular branches of production and consumption . Such externalities can be incorporated into the conventional input output picture of a national economy and , second , to demonstrate that –once this has been done –conventional input output computations can yield concrete replies to some of the factual questions that should be asked and answered before a practical solution can be found to problems raised by modern technology and uncontrolled economic growth .

The existing economic literature regarding the environmental consequences of household consumption is very limited. Basically, we do not find any direct impact study of household consumption on environment. As far as Indian economy is concerned, T.V. Ramachandra and Shwetmala(2012) focuses on the state wise carbon emissions (CO_2, CO and CH_4), using region specific emission factors and state wise carbon sequestration capacity. Anubhuti Bhatnagar(2016) observed that although the global emissions fell to0.5% in 2014, there is a need to drastically alter the current path of development because the burden of climate change is disproportionately high on developing countries such as India. Yongzhong Feng and others (2012) highlighted that the development of rural household biogas in China is growing steadily, and the technology standard projects have been established. Jiahai Yuan and others (2012) observed the low carbon transition of the electric power sector in China using a multi-level perspective (MLP) of niches, socio-technical regime, and landscape, as well as literature on innovation systems.

As indicated earlier, in our present exercise, we have made an endeavour to explore empirically the direct, indirect and induced (direct + indirect) pollution effect of economic activity/activities in a sector through its successive rounds of repercussion on other related economic activities. The results may generate useful insight in understanding the nature of trade off between economic growth and environment protection in the propagation of chain effect (captured by celebrated Leontief multiplier mechanism) of any initiation of either growth or environment damage) . Augmenting the input-output model by endogenising the household sector, we may project also the working of the Keynesian multiplier process being spread in the economy initiated by environment damaging growth stimulus and engineered by induced consumption of the household sector .

II Methodology :

We proceed to present the methodological framework of our exercise as follows :

Leontief open input-output model obviously seems a useful analytical tool here and it is widely used for analyzing of economy wise impact consequent to any sort of final demand. Total output from each industry equals total inter-industrial demand plus the final demand. So, we have the balance relations as follows:

$$X_i = \sum_{j=i}^{m} X_{ij} + F_i \text{ ....(1)}$$ where X_i = Output in the i^{th} sector(in value terms),

F_i = Final Demand in the ith sector (in value terms) and X_{ij} = input flow from i^{th} sector to j^{th} sector

Assuming a production function with fixed coefficients ,

$$X_{ij} = a_{ij}.X_j \text{ ....(2) where } a_{ij} = X_{ij}/X_j$$

By substituting (2) in (1) , gross output or sales of sector i can be expressed as :

$$X_i = \sum_{j=i}^{m} a_{ij}.X_j + F_i \text{ ....(3)}$$

Therefore, $X = AX + F$ where $X= (X_i)$, $A = (a_{ij})$ and $F = (F_i)$

Or, $F = X – AX = IX – AX = (I – A)X$

Or, $X = (I-A)^{-1}.F$……………..(4)

In the equation (4) if F is prescribed from outside, the required gross output levels X's get determined. For our present purpose it is not the entire Final Demand but the export part of the final demand which is relevant.

Let $X_{ij}(m)$ = Imported input of i^{th} sector to jth sector, if $X_{ij}(t)$ = total supply of input of i^{th} sector to j^{th} sector and $X_{ij}(d)$ = domestically produced input of i^{th} sector to j^{th} sector then we may write $X_{ij}(d) = X_{ij}(t) - X_{ij}(m)$

Now, let p and P denote the pollution coefficient and pollution level respectively. Following the Input Output model, the balance equations are –

$$a_{11}X_1+a_{12}X_2 + \ldots\ldots\ldots + a_{1n}X_n \quad + a_{1H}.H_i \quad + F_1 \quad = \quad X_1$$

$$a_{21}X_1 + a_{22}X_2 + \ldots\ldots\ldots + a_{2n}X_n \quad + a_{2H}.H_i \quad + F_2 \quad = \quad X_2$$

$$\ldots\ldots\ldots \quad \ldots\ldots\ldots \quad \ldots\ldots\ldots\ldots\ldots$$

$$a_{n1}X_1 + a_{n2}X_2 + \ldots\ldots\ldots + a_{nn}X_n \quad + a_{nh}.H_i \quad + F_n \quad = \quad X_n$$

$$a_{H1}X_1 + a_{H2}X_2 + \ldots\ldots\ldots + a_{Hn}X_n \quad + \quad 0 \quad = \quad H_i$$

$$a_{p1}X_1 + a_{p2}X_2 + \ldots\ldots\ldots + a_{pn}X_n \quad + a_{nh}.H_i \quad = \quad P$$

As pollutants are essentially in physical quantities and all the producing sectors are in value terms, for solving the system, we treat pollutant quantities (carbon emission coefficients : CO_2 equivalent of total tons of carbon emissions per unit value of output of respective sectors as exogenous (outside the technical coefficient matrix) . So including household sectors, we have the expanded (N+1) X (N+1) sectoral matrix and let us denote it by A* .

We have now $A^*X + F = X$, where X is the output vector and F is the final demand vector excluding household consumption. An emission coefficient row (carbon emission per unit of respective output) which is $(n+2)^{th}$ row is required to predict carbon emission. So, for given final demand category vector, we may obtain gross output requirement vector as follows.

$$(I-A^*)^{-1} * F = X$$

Now pre multiplying X by the emission coefficients row, we may obtain total carbon emission in tons (say physical quantities) for a given final demand vector as follows :

$p^*(I-A^*)^{-1}*F = P$ where p^* = emission coefficient row , P = Carbon emission generated consequent to final demand F (defined by total quantity and sectoral composition as well)

So, any final demand category basket (say export) with certain sectoral composition and with a given aggregate value will generate a certain quantity of carbon emission as byproduct which may be essentially different by quantity with same aggregate value of export but with different sectoral composition . So our model will determine the pollution intensity of different trade packages . In the same way, it is possible to determine trade intensity of govt. consumption and capital formation also .Different categories of final demand are expected to have different pollution intensities as different categories of final demand are essentially of different sectoral composition.

A Decomposition Framework :

We have computed pollution intensity of export based on data of these economies for the years 2000 and 2010. Further, we also discuss here a framework for the decomposition of the inter country differences in the pollution intensity of export.

Let, C_1 and C_2 be two countries. So, $p(C_1)$ and $p(C_2)$ be the direct pollution intensity vector for the country, C_1 and C_2 respectively.

Let, $A_d(C_1)$, $A_d(C_2)$, $e(C_1)$, $e(C_2)$ be the corresponding domestic I-O matrices and export share vector respectively. Then, we may write

$p(C_2).(I-A_d)^{-1}{}_{C2}.e(C_2) - p(C_1).(I-A_d)^{-1}{}_{C1}.e(C_1)$ = Total difference in pollution Intensity of Export between the countries C_1 and C_2 .

Now, we like to separate out the contribution of difference in direct pollution intensity in the total inter country difference in pollution intensity between the countries C_1 and C_2 assuming unchanged domestic I-O matrix and export vector.

So, for the above, we may compute as follows allowing pollution intensity vector to change from $p(C_1)$ to $p(C_2)$.

$$p(C_2).(I-A_d)^{-1}{}_{C1}.e(C_1) - p(C_1).(I-A_d)^{-1}{}_{C1}.e(C_1)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Next, we may like to separate out the contribution of difference in domestic production structure reflected in A_d matrix assuming unchanged direct pollution intensity and export vector. Obviously, the computation will be in the following way allowing only $A_{d(}C_{1)}$ to be changed to $A_{d(}C_{2)}$.

$$p(C_1).(I-A_d)^{-1}{}_{C2}.e(C_1) - p(C_1).(I-A_d)^{-1}{}_{C1}.e(C_1) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

In an analogous way, we separate out the contribution of inter country difference in sectoral export share, the computation for which will be as follows allowing only $e(C_1)$ to changed to $e(C_2)$.

$$p(C_1).(I-A_d)^{-1}{}_{C1}.e(C_2) - p(C_1).(I-A_d)^{-1}{}_{C1}.e(C_1) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Now, the total decomposition exercise can be expressed in the following way

$$p(C_2).(I-A_d)^{-1}{}_{C2}.e(C_2) - p(C_1).(I-A_d)^{-1}{}_{C1}.e(C_1)= \{p(C_2).(I-A_d)^{-1}{}_{C1}.e(C_1)- p(C_1).(I-A_d)^{-1}{}_{C1}.e(C_1) \} +$$

(contribution of direct import intensity difference)

$$\{p(C_1).(I-A_d)^{-1}{}_{C2}.e(C_1)-p(C_1).(I-A_d)^{-1}{}_{C1}.e(C_1)\} + \{p(C_1).(I-A_d)^{-1}{}_{C1}.e(C_2)-p(C_1).(I-A_d)^{-1}{}_{C1}.e(C_1)\}.$$

(contribution of domestic production structure difference) (contribution of difference in the export composition)

III Data Base :

To construct carbon emission coefficient row, we have proceeded as follows :

The shift project data portal provides information related to carbon emission from the major carbon generating sectors like Electricity/Heat , Transport, Agriculture, Manufacture and Construction, Fuel Combustion and Household Consumption for India and China for the years 2000 and 2010 . So , we have aggregated the 2000 and 2010 input output tables for India and China constructed by OECD accordingly. (I-O tables of OECD reduced to 5x5 sectors). The sectors in our aggregated table are Agriculture , Fuel Combustion, Manufacture, Electricity and Transport.

Now, as the sectoral total outputs are in value terms in 2000 and 2010 input output tables for both India and China , applying these sectoral carbon emissions in million tons to the sectorall outputs in value terms, we obtain the sectoral carbon emission coefficients ie emission of carbon million tones per unit of value output in various sectors in 2000 and 2010 for both India and China.

IV Results of the Study :

This section focuses on the results of our empirical study. Our model has two versions (1) treating household consumption as endogenous and (2) treating household sector as exogenous . As we have already noted that household consumption also generates carbon emission the model (1) has additional purpose to serve . Not only that it also is capable of accommodating consumption multiplier magnifying the pollution impact.

The table-1 suggests that, as regards direct carbon emission, the sector ‘ Electricity’ is responsible for the maximum generation of the undesirable byproduct ie .21 percent in 2000 and 13 percent in 2010 of its output in India . But for China , it is 13 percent in 2000 and surprisingly significantly low in 2010. ‘Transport’ is another sector for which the direct pollution coefficient is significant both in India and China for the years 2000 and 2010.

Table-1 : Direct Pollution Coefficients of India and China , 2000, 2010 (Million Tones of Carbon Emission per Millions US Dollar of Sectoral Output)

No	Sectors	India		China	
		2000	2010	2000	2010
1	Agriculture	0.004117	0.001486	0.002528	0.000982
2	Fuel Combustion	0.003849	0.000798	0.005495	0.001957
3	Manufacture	0.000371	0.000164	0.000458	0.000191
4	Electricity	0.021914	0.013779	0.01358	0.00700
5	Transport	0.004229	0.001511	0.002263	0.000595

Source: Author’s own calculations

The table-2 presents direct and induced carbon emission in million tones of carbon emission per millions US dollar of sectoral output. It is observed from the table that the sector 'Electricity' is responsible for the maximum generation of the pollutant (direct and induced) ie .28 percent in 2000 and 17 percent in 2010 of its output in India . As far as China is concerned , it is 17 percent in 2000 and 10 percent in 2010. 'Fuel Combustion' is another sector for which the direct pollution coefficient is significant both in India and China for the years 2000 and 2010.

Table-2 : Direct and Induced Pollution Coefficients of India and China , 2000, 2010 (Million Tones of Carbon Emission per Millions US Dollar of Sectoral Output)

No	Sectors	India		China	
		2000	2010	2000	2010
1	Agriculture	0.005067	0.002012	0.004275	0.001713
2	Fuel Combustion	0.00648	0.001762	0.008441	0.003475
3	Manufacture	0.002512	0.000958	0.00307	0.001464
4	Electricity	0.028907	0.017282	0.017164	0.010976
5	Transport	0.007221	0.002856	0.005555	0.002086

Source: Author's own calculations

We have also computed the direct , indirect and induced pollution intensities of various sectors (endogenising the household sector) for the years 2000 and 2010 for the countries like India and China , and the results are shown in the tables -3 and 4.

The results shown in table -3 highlights that direct carbon intensities are significantly larger for the sectors like Electricals, Transport and Fuel Combustion both in the years 2000 and 2010 for India as well as China . The carbon intensity rankings for the sectors follow the same pattern as observed in case of direct carbon intensities(household not endogenised)

Table-3 : Direct Pollution Coefficients (Household Endogenised) of India and China , 2000, 2010 (Million Tones of Carbon Emission per Millions US Dollar of Sectoral Output)

No	Sectors	India		China	
		2000	2010	2000	2010
1	Agriculture	0.004117	0.001486	0.002528	0.000982

2	Fuel Combustion	0.003849	0.000798	0.005495	0.001957
3	Manufacture	0.000371	0.000164	0.000458	0.000191
4	Electricity	0.021914	0.013779	0.01358	0.007
5	Transport	0.004229	0.001511	0.002263	0.000595
6	Households	0.000209	0.000077	0.00036	0.000156

Source: Author's own calculations

Table -4 highlights that direct and induced carbon intensities are also significantly larger for the sectors like Electricals, Transport and Fuel Combustion both in the years 2000 and 2010 for India and China . The carbon intensity rankings for these sectors also follow the same pattern as observed in case of direct and induced carbon intensities(household not endogenised).

Table-4 : Direct and Induced Pollution Coefficients (Household Endogenised) of India and China , 2000, 2010 (Million Tones of Carbon Emission per Millions US Dollar of Sectoral Output)

No	Sectors	India		China	
		2000	2010	2000	2010
1	Agriculture	0.017419	0.005293	0.006853	0.003952
2	Fuel Combustion	0.017062	0.004587	0.010937	0.005683
3	Manufacture	0.013765	0.003867	0.005603	0.003726
4	Electricity	0.040611	0.020457	0.019694	0.01322
5	Transport	0.016638	0.005609	0.008039	0.004299
6	Households	0.012037	0.003178	0.002617	0.002274

Source: Author's own calculations

Table-5 decomposes the total (direct plus indirect) change in Pollution Intensity of exports over the period 2000-2010 for India and China into three components namely the effect of change of direct pollution intensity, the effect of change of production structure and the effect of chance of export compositions when household sector is not endogenised. It is observed from the table that both in India and china, change in direct pollution intensity and change in technology are reducing the total pollution intensity while the change in export composition is increasing the total pollution intensity.

Table-5 : The Decomposition of total (direct plus indirect)change in Pollution Intensity of Exports over the period 2000-2010(Household not endogenised)

	Components of Decomposition	India	China
A	Total Pollution Intensity Change	309.5476	1761.826
a)	Contribution of change of Direct Pollution Intensity	-71.3745	-508.418
b)	Contribution of change in Technology assuming Sectoral export share Unchanged	-21.8942	-790.643
c)	Contribution of change in Sectoral Share of Export assuming Technology Unchanged	402.8163	3060.886
B	Sum(a+b+c)	309.5476	1761.826

Source: Author's own calculations

Table-6 decomposes the total (direct plus indirect) change in Pollution Intensity of exports over the period 2000-2010 for India and China into the same three components namely the effect of change of direct pollution intensity, the effect of change of direct and indirect pollution intensity and the effect of chance of export compositions when household sector is endogenised. It is observed from the table that in India change in direct pollution intensity and change in technology are reducing the total pollution intensity while the change in export compositions is increasing the total pollution intensity. But for China, we find that though the change in direct pollution intensity is reducing the total pollution intensity, but the change in production structure and export compositions are increasing the total pollution intensity (when household sector is endogenised).

Table-6 : The Decomposition of total (direct plus indirect)change in Pollution Intensity of Exports over the period 2000-2010(Household endogenised)

	Components of Decomposition	India	China
A	Total Pollution Intensity Change	886.6164	5007.514
a)	Contribution of change of Direct Pollution Intensity	(-)372.414	(-)1520.52
b)	Contribution of change in Technology assuming Sectoral export share Unchanged	(-)550.285	(+)830.6713

c)	Contribution of change in Sectoral Share of Export assuming Technology Unchanged	(+)1809.315	(+)5697.363
B	Sum(a+b+c)	886.6164	5007.514

Source: Author's own calculations

The above results suggests that most of the other sectors experience change in the technological process(taking account of direct and indirect effect) such that total carbon intensities become smaller . This is , of course encouraging as it suggests that we are moving toward advanced technology with reduced carbon intensities . But we have to be cautious of the fact our projection with household exogenous reveals that carbon intensities (direct plus indirect) are larger for some sectors for the year 2010 compared to that of 2000 (as could be expected) for these two countries . The two contrasting set of results for total carbon intensities seem to suggest the implicit fact . Electricity as being a strongly carbon generating sector works as the dominating carbon multiplier agent in the production circuits and effectively contributes positively to the size of total pollution intensities of most of the production sectors . Now, when household sector is endogenised , as household sectors least pollution intensive sector ,in the expanded model as the household consumption multiplier is significantly larger than the Leontief multiplier (as far as Indian economy is concerned) , household pollution intensity dominates in the expanded circularity and in spite of increased carbon intensities of most of the production sectors (direct , as well as direct plus indirect) in carbon intensities get reduced when we incorporate induced consumption multiplier in calculating total carbon intensities. But for China, though household sector's direct carbon intensity is low, household sector may not dominate in the expanded multiplier effect as household consumption multiplier may not be significantly larger to cancel out the positive pollution effect of Electricity. Hence, production structure contributes to the total pollution intensity of exports of China when household sector is endogenised. .

V Conclusion :

We tried in this paper to trace the direct and indirect carbon intensity effect of various production sectors in India and China in a multi sector framework. The major findings are-

1) Most of the production sectors in India and China experience change in the technological process(taking account of direct and indirect effect) such that total carbon intensities become smaller . This is , of course encouraging, as it suggests that both the countries are moving towards advanced technology with reduced carbon intensities .

2) Though India and China have more or less same type of production structure, but the impact of consumption multiplier on pollution for a given production structure for exportable commodities is not same for both the countries. When household sector is exogenous, both in India and China, while direct pollution intensity and the technology contribute to the reduction in total pollution intensity of exports , the export composition increases the pollution intensity of exports. The working of consumption multiplier (when household sector is endogenised) changes the above situation to some extent for China only as we find that not only the export composition but also the production structure now contributes to the increase of total pollution intensity of exports. While in India, the dominance of consumption multiplier matters for cancelling out the positive pollution impact of the sectors like ‘Electricity’ and ‘Transport’, it may not be so in China.

It is also to be kept in mind that some exportable commodities may not be directly electricity /transport intensive but inputs in these sectors may be highly electricity /transport intensive . As a result export and consequently domestic production of these sectors ultimately contributes to carbon emission as transportation and electricity are emission intensive . So trade composition needs be targeted taking account of the need of growth potential with minimum carbon emission .

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