Environmental Economics Key Sectors and Carbon Hot Spots in Indian Economy

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ABSTRACT

The present study allows the identification of the key sectors in terms of output generation and carbon hot spots responsible for CO_2 emission in Indian economy. The hot spot approach shows the contribution of the various sectors to CO_2 direct emissions and footprints from a production perspective and allows us to identify the sectors that deserve more consideration for mitigation policies. The input output methodology is used to identify key sectors in terms of output with both high backward and forward linkages in conventional input output framework while CO_2 'hot-spots' are identified in downstream and upstream supply chains in single region, India using environmental input output framework. The hotspot methodology added to the key sector analysis has allowed us to study the emission intensity and multipliers with respect to single pollutant CO_2. The inter-industry national input output tables of Indian economy denominated in million dollars for the period 1995-2011and Environment Accounts which provides data on energy use, CO_2 emissions and emissions to air at the industry level for the year 1995 and 2009 are obtained from World Input Output Database and have been used for the purpose of the key sector analysis and the carbon hotspot analysis respectively. Thus, the study enables the comparative analysis of key sectors in terms of output generation and carbon emissions for each industry within the Indian economy.

JEL classification: C67, Q40, Q43.

1. INTRODUCTION

In any economy all goods and services produced are directly and/or indirectly associated with energy-use and, according to the type of fuel utilized, with CO_2 (Carbon dioxide) emissions as well. For a developing economy like India, its contribution to historical emissions of GHG gases

of anthropogenic nature is hardly 4% and its per capita emissions are still amongst the lowest in the world (Planning commission 2011) but still, it is a significant contributor of greenhouse gases (GHGs) in the atmosphere. The major sources of GHGs in India are fossil-fuel combustion, industrial process, fertilizer application, rice cultivation and livestock (Pal and Pobit, 2014). Thus, there is an increased pressure on developing countries like India to participate, in the global mitigation efforts to stabilize the climate. Thus, a methodology is developed in this paper that allows the identification of the key sectors in terms of output generation and the sectors responsible for carbon emissions in Indian economy. The hot spot approach shows the contribution of the various sectors to direct emissions of CO_2 and carbon footprints as the study focuses only on single pollutant CO_2. The direct emissions for this study are the CO_2 emissions generated by a sector to meet its own final demand and demand from all other sectors of the economy while footprints are the total volume of CO_2 embodied in all the sectors that appear in the upstream supply chain of a sector. A point on a sector's downstream or upstream supply chain that embodies emissions above some acceptable level may also be considered as a 'hot-spot'. Thus, the analysis allows us to identify the sectors that deserve more consideration for mitigation policies. The input output methodology is used to identify key sectors and CO_2 'hot-spots' in downstream and upstream supply chains in single region, India. The inter-industry input output tables of Indian economy denominated in million dollars obtained from World Input Output Database (Timmer et al, (2015), have been used for the purpose of analysis. The general objective of the study is to identify key sectors in terms of output generation and carbon hot spots in Indian economy. The specific objectives of the study are:

- To identify key industries in terms of output with both high backward and forward linkages in conventional input output framework.
- To identifying CO_2 'hot-spots' in down and upstream supply chains using environmental input output framework.

Next section details the literature review on linkages and hotspots in input output analysis followed by section 4 on methodology and data employed. Section 5 shows and discusses the empirical results. Section 6 discusses conclusion and policy implications based on the analysis.

2. REVIEW OF LITERATURE

The input output analysis describes and explains the level of output of each sectors of a given national economy in terms of its relationships to the corresponding level of activities in all the other sectors (Leontief, 1970). Various studies have focused on measuring inter-industry linkages to identify key industries for facilitating the process of economic development since 1950. This classical concept was first introduced by Hirschman (1958) in Strategy for Economic Development to study the industrial interdependence. Since the linkage concept is based on industrial interdependence the best way to calculate sectoral linkages is with the help of Input-Output tables. Consequently, the I-0 tables began to be used quite early by Poul N. Rasmussen

(1958) and Chenery and Tsunehiko Watnabe (1958) for establishing the linkage between the sectors in an economy. Input Output frameworks have also been widely used to study the emissions of industrial sectors either in specific economies or globally. Environmentally-extended input-output analysis (EEIO) is a long-established technique that continues to grow in popularity as a method for evaluating the relationship between economic activities and downstream environmental impacts (Kizes, 2013). Zhang et al (2014) analyze the energy flows for the entire city of Beijing and its 30 economic sectors and finds that the traditional heavy industries remain the most energy-intensive sectors in the economy. However, the transportation and service sectors have contributed most to the rapid increase in overall energy consumption. On the other hand Alcantara (2003) designs a methodology based on the elasticities of the demands of final energy consumption to determine the key sectors in the final energy consumption. Information on the development of new, global-scale input-output databases that are useful for EEIO applications can be found in several reviews (Minx et al 2009; Wiedmann, 2009).

3. DESCRIPTON OF DATA

The study uses World Input-Output Database (Timmer et al., 2015) for the purpose of the analysis. The importance of database lies in the fact that it provides time-series of input-output tables for forty countries worldwide covering the period from 1995 to 2011. This includes the values of input-output transactions among 35 industries for 27 EU countries and 13 other major countries in the world. The data is expressed in millions of dollars. The identification of key industries in terms of output generation has been done for the period 1995-2011and for identifying carbon hotspots the analysis has been carried for two years 1995 and 2009.Thus, identification of key output generation industries and carbon emission analysis are facilitated with the help of two wide datasets obtained from WIOD.

- National Input Output tables (NIOT) in current dollars at purchaser's prices for 35 industries for Indian economy. The classification of industries is based on ISIC Rev 3.1.

- Environment Accounts from WIOD (Genty, 2012) which provides data on energy use, CO_2 emissions and emissions to air at the industry level. However, the study focuses only on single pollutant which is carbon emission.

4. METHODOLOGY

The methodology undertaken in this study to accomplish the objectives of the study is as follows:

- In the beginning, Leontief (1936) demand driven model in open input output framework for single region is constructed following the methodology presented with Miller and Blaire (2009).

- Then, the supply driven input output model by Ghosh (1958) relating sectoral output to primary inputs is constructed.
- Key sectors with above average linkages are identified using conventional Rasmussen (1958) method for measuring backward linkages indices and Ghosh (1958) supply driven model for measuring forward linkages indices.
- Finally, the conventional input output table is extended to environmental input output framework using sectoral emission output coefficients with the help of satellites emission data from WIOD (Genty, 2012) that breaks down the emissions of each sector included in the main input output data tables by fuel type and emissions((Katris, 2015). Since the study focuses on single pollutant CO_2, The environmental framework helps to identify carbon hot spots.

4.1 National Input Output Framework

I-O tables record sales by one producing sector to another and to the final users. The rows of the inter industry transactions table describe the distribution of an industry's output throughout the economy, while the columns describe the composition of inputs required by a particular industry to produce its output.

An input output framework with n industries for an economy can be expressed as a system of linear equations by the following expressions:

$$X_i = \sum_{j=1}^{n} X_{ij} + Y_i \qquad\qquad i = 1,2,3 \qquad\qquad\qquad (1)$$

where, X_{ij} is the output of sector i consumed by sector j ,to all types of consumption and for final consumption denoted as Y_i. Further the proportion of each input to the output of sector j is denoted by

$$a_{Lij} = X_{ij}/X_j \qquad\qquad i, j = 1,n \qquad\qquad\qquad (2)$$

a_{Lij}'s are called input or technical coefficients and give the direct input requirement of the i_{th} sector for producing one unit of output of j_{th} sector excluding the indirect effects involved in production process.

Thus, above mentioned equation (1) can now be formulated with equation (2) as so called Leontief production function Equation (3):

$$X_i = \sum_{j=1}^{n} a_{L,ij} X_j + Y_i \qquad\qquad i = 1 ,n \qquad\qquad\qquad (3)$$

where, X is endogenous and the column final demand (sum total of all components of final demand), Y is exogenous. In matrix notation equation (3) can be written as

$$X = A_L X + Y \qquad\qquad\qquad\qquad\qquad (4)$$

where, A_L is the n x n coefficient matrix consisting of standardized elements of a_{Lij}, obtained by dividing each element of the column of the flow matrix by the total input of the buying sector. This equation is a fundamental equation of the open Leontief model.

Further, equation (4) can be written as:

$$X = (I-A_L)^{-1} * Y = L_{ij} Y \tag{5}$$

where, Y is a diagonal matrix and $(1-A_L)^{-1}$ is and n x n matrix known as Leontief (1936) Inverse or Output multiplier, gives both direct and indirect requirements of inputs. While direct inputs are those purchased by the sector under consideration, indirect inputs are those purchased by all other sectors in which production has to adjust in order to supply inputs to specific sector.

Similarly, the Ghosh model is a set of linear equations. By contrast it is given by:

$$X_j = \Sigma b_{ij} X_i + V_j \tag{6}$$

Where, X_j is total input for activity j, V_{ij} the primary input (or the value added) of the same sector, and b_{ij} is the output coefficient of sector j to sector i. Thus, in matrix form it can be represented as:

$$X' = (I-B)^{-1} * V = L_{ij}^* V \tag{7}$$

Where, $(I-B)^{-1}$ is called Ghosh inverse (Ghosh, 1958).

4.2 Identification of Key Industries: Rasmussen Method

Rasmussen (1956) method based on the use of matrix multipliers is used to identify strategically important sectors of Indian economy. The analysis is based on measuring the employment backward and forward linkages and prioritizing the investment in those industries, having both linkages greater than one (Hirschman, 1958).

Backward linkage

Backward linkage of an industry j measures the changes in output of all the industries resulting from unit increase in the output of sectors j. The inter-industry comparison of backward linkages can be made by constructing an index of backward linkage which can be represented as

$$U_j = (1/n) \Sigma_j L_{ij} / (1/n^2) \Sigma_{j=1}^n L_{ij} \tag{8}$$

where, the numerator represents the average of the total of column which belongs to industry j in closed Leontief model which measures the direct and indirect changes in output of all industries to meet the increases of final demand by one unit from industry j, whereas the denominator refers to average total change in output to meet the increased of final demand by one unit.

Forward Linkage

Forward linkage of industry i measures the change in the output in industry i, resulting from unit increase in production of all the sectors. To facilitate the inter-industry comparison, Rasmussen's (1956) proposes to normalize the forward linkages based on Ghosh (1958) inverse correspondingly.

$$U_i = (1/n) \Sigma_i L^*_{ij} / (1/n^2) \Sigma^n_{i=1} L^*_{ij} \tag{9}$$

where, the numerator refers to average of the total of row which belongs to i sector in Ghosh model, which measures the direct and indirect changes in output of industry i, when the final demand grows for all sectors by one unit. On the other hand, the denominator shows the average of averages for all the industries. The industry having both forward and backward linkages above one is identified as key industry.

4.3 'Hot-spot' detection in Environmental Input Output Framework

The methodology for hot spot detection is similar to one adopted in the thesis by Katris (2015). The conventional input output framework is extended to environment input output framework by using the sectoral emission data. Firstly the output –emissions coefficient for each sector is calculated which is given by

$$e_{ij} = E_j / X_j \qquad i=j \tag{10}$$

where, E_j total CO_2 emission from industry j and X_j is gross output of industry *j*. To generate output-emissions multipliers and the environmental IO, E matrix which contains the emission coefficients along the diagonal is pre-multiplied to the Leontief inverse from equation (5) that gives us the basic equation for the environmental Input output model.

$$EX = E(I - A_L)^{-1} * Y \tag{11}$$

The emission multiplier of industry j or the type 1 output-emission multipliers of industry j gives the total CO_2 emissions generated by all the sectors to meet one monetary unit worth of sector *j* final demand.

$$Em = \sum^n_{i=1} e_{ij*} (I-A_L)^{-1} \tag{12}$$

Thus, the sum of the elements down a column is the CO_2 emissions Type I multiplier. Following the same procedure as before, by post-multiplying (12) with the matrix of final demand Y, we get CO_2 emissions matrix (Cem).

$$Cem = \sum^n_{i=1} e_{ij*} (I-A_L)^{-1} Y \tag{13}$$

It provides a decomposition of the CO_2 emissions generated by each sector, revealing the embodied emissions in the different components of each sector's downstream and upstream supply chain along the row and column respectively. The sum of the rows in the matrix gives the

direct emissions of CO_2 for each sector while the column sum gives the carbon footprint. Analyzing the elements of (13) enables the 'hot spots' detection in downstream and upstream supply chains. Thus, the following two types of 'hot spots' can be identified from the above analysis.

- Type (A) hot spot by focusing on the elements along the row within (13) and identify those industries that generate directly significantly more emissions compared to other industries in Indian economy.
- Type (B) hotspot by focusing on the elements down the column within (13) and identify those industries that generate more carbon foot print compared to other industries in an economy.

5. RESULTS AND DISCUSSION

5.1 Results for key sectors in Indian economy

The appendix table A gives the results for forward linkage coefficients for all 35 industries along with their ranks during 1995-2011. The table below shows top 15 industries in terms of high forward linkage coefficients. The results reveal that Mining and quarrying, Wood and Products of Wood and cork, Coke, Refined petroleum and nuclear fuel, Chemicals and chemical products, Rubber and plastics, Basic metals and fabricated metals, Electricity gas and water supply, Sale, maintenance and Repair of motor vehicles and motorcycles; retail sale of fuel, Post and communication and Financial intermediation are the sectors with high forward linkages coefficients under the entire period of study, with Mining and quarrying and Electricity ,gas and water supply with highest coefficients. Mining and quarrying with forward linkage coefficient of 1.82 in 1995 and 1.49 in 2011, implies that with unit change in production of all the sectors, the output of this industry is changed by 1.82 units and 1.49 units, respectively. Sale, maintenance and repair of motor vehicles and motor cycles and Whole sale trade and commission trade except for motor vehicles and motor cycles; repair of household goods also show high forward linkages in substantial part of the study. Thus, these industries are dependent on other industries in terms of supplying intermediate inputs to them.

Table 1: Top 15 sectors in terms of high forward linkage coefficients during 1995-2011

WIOD Sector	SECTORS	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
C	Mining and Quarrying	√(1)	√(1)	√(1)	√(1)	√(1)	√(1)	√(1)	√(1)	√(1)	√(2)	√(2)	√(4)	√(3)	√(3)	√2)	√(2)	√(2)
20	Wood and Products of Wood and Cork	√(7)	√(6)	√(5)	√(4)	√(5)	√(6)	√(3)	√(4)	√(7)	√(6)	√(8)	√(7)	√(9)	√(7)	√(9)	√(8)	√(10)
21t22	Pulp, Paper, Paper, Printing and Publishing		√(8)	√(8)	√(8)	√(7)	√(10)	√(8)	√(7)	√(6)	√(4)	√(4)	√(2)	√(2)	√(2)	√(3)	√(3)	√(3)
23	Coke, Refined Petroleum and Nuclear Fuel	√(6)	√(5)	√(6)	√(5)	√(3)	√(5)	√(4)	√(3)	√(3)	√(3)	√(3)	√(3)	√(4)	√(4)	√(4)	√(5)	√(6)
24	Chemicals and Chemical Products	√(8)	√(7)	√(7)	√(7)	√(8)	√(9)	√(9)	√(10)	√(12)	√12)	√(12)	√(12)	√(12)	√(12)	√(12)	√(15)	√(15)
25	Rubber and Plastics	√(13)	√(13)	√(10)	√(10)	√(10)	√(11)	√(11)	√(12)	√(11)	√(11)	√(11)	√(11)	√(11)	√(11)	√(11)	√(11)	√)11)
26	Other Non-Metallic Mineral				√(15)			√(10)	√(9)	√(10)	√(9)	√(9)	√(8)	√(8)	√(8)	√(10)	√(10)	√(9)
27t28	Basic Metals and Fabricated Metal	√(4)	√(3)	√(3)	√(3)	√(4)	√(4)	√(5)	√(6)	√(8)	√(10)	√(10)	√(10)	√(10)	√(10)	√(8)	√(7)	√(7)
30t33	Electrical and Optical Equipment					√(2)												
E	Electricity, Gas and Water Supply	√(2)	√(2)	√(2)	√(2)	√(2)	√(3)	√(2)	√(2)	√(2)	√(1)	√(1)	√(1)	√(1)	√(1)	√(1)	√(1)	√(1)
F	Construction																	
50	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	√(10)	√(12)	√(13)	√(13)	√(12)	√(14)	√(15)	√(14)			√(13)	√(13)	√(15)	√(15)	√(15)	√(14)	√(14)
51	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	√(11)	√(11)	√(11)	√(11)	√(13)	√	√(13)	√(15)	√(14)	√(15)	√(14)	√(14)	√(13)	√(13)	√(13)	√(12)	√(12)
52	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	√(12)	√(10)	√(12)	√(12)	√(14)	√(15)	√(14)	√(16)	√(15)	√(14)	√(15)	√(15)	√(14)	√(14)	√(14)	√(13)	√(13)
60	Inland Transport	√(14)	√(14)	√(14)	√(14)													
62	Air Transport	√(15)	√(15)	√(15)	√(15)		√(13)		√(13)	√(13)	√(13)							
63	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	√(16)		√(16)			√(11)	√(12)	√(12)	√(11)	√(5)	√(7)	√(5)	√(5)	√(5)	√(5)	√(4)	√(4)
64	Post and Telecommunications	√(9)	√(9)	√(9)	√(9)	√(9)	√(8)	√(7)	√(8)	√(9)	√(8)	√(7)	√(9)	√(7)	√(9)	√(7)	√(9)	√(8)
J	Financial Intermediation	√(5)	√(4)	√(4)	√(6)	√(6)	√(8)	√(6)	√(5)	√(4)	√(5)	√(6)	√(6)	√(6)	√(6)	√(6)	√(6)	√(5)
P	Private Households with Employed Persons	√(3)																

Note: Symbol '√' marks the sector having high values of forward linkage coefficients in particular year and the values in brackets (..) indicates the corresponding rank of the sectors in particular year .

The appendix table B gives the results for backward linkage coefficients for all 35 industries along with their ranks during 1995-2011. The table below shows top 15 industries in terms of high backward linkage coefficients. The results reveal that Food, beverages and tobacco, Textiles and textiles product, Chemicals and chemical products, Rubber and plastics, Basic metals and fabricated metals, Electricity gas and water supply and Transport equipment are the sectors with high backward linkages coefficients under the entire period of study with Food and beverages, Rubber and plastics and Pulp, paper, printing and publishing gaining status of most strategically important sectors after 2000. Food, beverages and tobacco with forward linkage coefficient of 1.28 in 1995 and 1.44 in 2011, implies that with the unit change in the production of the sector, the output of all the industries is changed by 1.28 units in 1995 and by 1.44 units in 2011 respectively.

Table 2: Top 15 sectors in terms of high backward linkages coefficients during 1995-2011

WIOD Sector Code	SECTORS	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
15t16	Food, Beverages and Tobacco	√(9)	√(8)	√(10)	√(9)	√(5)	√(3)	√(3)	√(3)	√(3)	√(3)	√(2)	√(2)	√(2)	√(1)	√(2)	√(2)	√(2)
17t18	Textiles and Textile Products	√(8)	√(9)	√(8)	√(8)	√(4)	√(4)	√(4)	√(5)	√(6)	√(5)	√(6)	√(3)	√(4)	√(6)	√(6)	√(5)	√(6)
19	Leather, Leather and Footwear	√(6)	√(4)	√(4)	√(4)	√(3)	√(5)	√(7)	√(9)	√(9)	√(7)	√(4)	√(4)	√(3)	√(5)	√(5)		√(3)
20	Wood and Products of Wood and Cork	√(11)	√(12)	√(11)	√(11)	√(14)	√(15)						√(15)					
21t22	Pulp, Paper, Paper , Printing and Publishing	√(7)	√/(7)	√		√(5)	√(6)	√(6)	√(6)	√(4)	√(4)	√(3)	√(5)	√(5)	√4	√(3)	√(4)	√(4)
23	Coke, Refined Petroleum and Nuclear Fuel																√(14)	
24	Chemicals and Chemical Products	√(10)	√(10)	√(9)	√(10)	√(10)	√(8)	√(5)	√(7)	√(5)	√(6)	√(8)	√(8)	√(8)	√(10)	√(10)	√(9)	√(10)
25	Rubber and Plastics	√(3)	√(3)	√(5)	√(3)	√(2)	√(2)	√(2)	√(2)	√(1)	√(1)	√(1)	√(1)	√(1)	√(2)	√(1)	√(1)	√(1)
26	Other Non-Metallic Mineral	√(15)		√(15)				√(14)	√(14)	√(12)	√(12)	√(12)	√(11)	√(12)	√(11)	√(12)	√(11)	√(12)
27t28	Basic Metals and Fabricated Metal	√(4)	√(5)	√(3)	√(7)	√(9)	√(9)	√(11)	√(8)	√(8)	√(9)	√(5)	√(6)	√(6)	√(13)	√(4)	√(3)	√(5)
29	Machinery, Nec	√(5)	√(6)	√(6)	√(6)	√(8)	√(7)	√(8)	√(6)	√(7)	√(8)	√(9)	√(9)	√(9)	√(8)	√(8)	√(7)	√(8)
30t33	Electrical and Optical Equipment						√(11)	√(10)	√(9)	√(10)	√(10)	√(10)	√(10)		√(10)	√(9)	√(9)	√(8)	√(9)
34t35	Transport Equipment	√(2)	√(2)	√(1)	√(1)	√(1)	√(1)	√(1)	√(1)	√(2)	√(2)	√(7)	√(7)	√(7)	√(7)	√(7)	√(6)	√(7)
36t37	Manufacturing, Nec; Recycling	√(1)	√(1)	√(2)	√(2)	√(7)	√(11)	√(10)	√(12)									
E	Electricity, Gas and Water Supply	√(12)	√(11)	√(12)	√(12)	√(12)	√(12)	√(12)	√(11)	√(11)	√(11)	√(11)	√(10)	√(11)	√(12)	√(11)	√(10)	√(11)
F	Construction	√(14)	√(14)	√(14)	√(15)						√(14)	√(14)	√(13)	√(13)	√(13)	√(13)	√(13)	√(12)	√(13)
H	Hotels and Restaurants	√(13)				√(15)	√(13)	√(13)	√(13)	√(13)	√(13)	√(13)	√(14)	√(12)	√(14)	√(14)	√(15)	√(15)	√(15)
60	Inland Transport		√(15)	√(17)	√(14)				√(15)		√(15)	√(15)	√(15)	√(14)	√(15)	√(15)	√(14)	√(13)	√(14)
N	Health and Social Work		√(13)	√(13)	√(13)	√(13)	√(14)											

Note: Symbol '√' marks the sector having high values of backward linkage coefficients in particular year and the values in brackets (..) indicates the corresponding rank of the sectors in particular year.

Table 3 which has been derived from appendix table A and table B, shows that the key sector for the Indian economy during the entire period of study are Wood and products of wood and cork, Pulp, paper, printing and publishing, Chemicals and chemical products, Rubber and plastics, Basic metals and fabricated metals, Electricity, gas and water supply, Inland transport. Other non-metallic mineral is also a key sector but its backward and forward linkages coefficient doesn't make it to the highest 15 linkages coefficients. Another interesting observation is the emergence of the Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies sector as a key sector after 2000 and Air transport losing its position as a key sector

after 2003. These key sectors are the most strategically important sectors of Indian economy because of having positive spillover effects on the overall production in the economy.

Table 3: Common key sectors in terms of both high backward and forward linkages in terms of output generation during 1995-2011.

WIOD Sector code	SECTORS	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
20	Wood and Products of Wood and Cork	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
21t22	Pulp, Paper, Paper , Printing and Publishing	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
23	Coke, Refined Petroleum and Nuclear Fuel	√	√	√	√											√	√	√
24	Chemicals and Chemical Products	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
25	Rubber and Plastics	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
26	Other Non-Metallic Mineral	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
27t28	Basic Metals and Fabricated Metal	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
E	Electricity, Gas and Water Supply	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
60	Inland Transport	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
62	Air Transport	√	√	√	√	√	√			√	√							
63	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies							√	√	√	√	√		√	√	√	√	√
O	Other Community, Social and Personal Services	√																
P	Private Households with Employed Persons	√	√	√														

Note: Symbol '√' marks common key sector with high values of both forward and backward linkages coefficients in particular year.

5.2 Results of CO_2 emissions hot spots detection in upstream and downstream supply chain for the years 1995 and 2009.

This section discusses the direct CO_2 emissions and footprints of Indian economic sectors for the years 1995 and 2009 to identify the type (A) and type (B) carbon hot spots respectively. Further, Type (C) hotspots are identified from the downstream supply chain of the sector with highest direct emissions and upstream supply chain of the sector with the highest carbon footprint for the years 1995 and 2009.

5.2.1 Direct CO_2 emissions

The results from Table 4 show, the top 15 most polluting sectors of the Indian economy in terms of direct emissions of CO_2 in 1995. The sector 'Electricity, gas and water supply' has been identified as the highest CO_2 emitter. Column six showing the carbon intensity is nothing but output- emission coefficients for each of the sector in table 1 obtained from equation (10). The final column of total output has been obtained from sum of the rows elements of each sector in

equation (5). From column 5 it can be seen that percentage share in direct emissions for Electricity, gas and water supply, Other non-metallic mineral and Basic metals and fabricated metal is 65.55% and thus these three sectors are classified as type (A) hotspots. The reasons identified for this relatively higher emissions in the first two Type (A) hot spots sectors is the relatively higher CO2 emission intensity of 14.26 and 4.55. While in case of third type (A) hot spot sector that is, Basic metals and fabricated metal high emissions results from high value of total output in column 8.

Thus, carbon emission intensity cannot be the sole driver of high direct emissions of CO_2 for a particular sector. This point becomes more clear when sectors 'Hotels and restaurants' and 'Mining quarrying' having relatively higher emission intensity among the non–hot spot sectors generate less direct emissions than Agriculture, hunting, forestry and fishing and Inland transport sectors (sectors with low emission intensity among non –hot spot sectors) because the volume of production in column 8 is lower for the former sectors.

Table 4: Top 15 Direct emitters (Row sum in 13) for the year 1995

WIOD Sector Code	Rank	Sector	Direct Emissions (Kt of CO_2)	% share of Total Direct Emission	CO_2 Emission intensity (Kt of	Total Final Demand (Y_j)	Total output ($m)
E	1	Electricity, Gas and Water Supply	335033.93	49.56	14.26	2757.74	23499.37
26	2	Other Non-Metallic Mineral	54958.03	8.13	4.55	4501.60	12071.25
C	3	Basic Metals and Fabricated Metal	53124.74	7.86	1.14	39141.31	46536.90
24	4	Chemicals and Chemical Products	40208.04	5.95	1.49	9130.127	27044.935
AtB	5	Agriculture, Hunting, Forestry and Fishing	31723.31	4.69	0.29	73000.45	110571.73
60	6	Inland Transport	29050.86	4.30	0.67	19728.70	43234.27
C	7	Mining and Quarrying	22612.78	3.34	2.98	1141.88	7592.92
H	8	Hotels and Restaurants	18671.09	2.76	1.72	9367.45	10827.99
23	9	Coke, Refined Petroleum and Nuclear Fuel	18232.24	2.70	0.90	4565.50	20344.04
15t16	10	Food, Beverages and Tobacco	14248.16	2.11	0.34	34165.83	42316.74
17t18	11	Textiles and Textile Products	10833.14	1.60	0.27	26251.15	39449.33
21t22	12	Pulp, Paper, Paper , Printing and Publishing	6635.39	0.98	0.65	4411.52	10130.45
F	13	Construction	6061.44	0.90	0.12	41993.69	49049.11
34t35	14	Transport Equipment	2343.71	0.35	0.08	18498.50	29372.66
20	15	Wood and Products of Wood and Cork	921.75	0.14	0.12	1785.39	7740.07
		Total Emission of top 15 industries	644658.61	95.35			
		Emissions by rest of the industries	31420.61	4.65			
		Total Direct Emissions	676079.22	100.00			

Source: Author's own calculation.

In table 5, the top 15 direct emitters remain same in the year 2009 although the quantity of total direct emissions generated by them has increased from 644658.61 Kt of CO_2 in 1995 to 1653329 Kt in 2009. From column 5, it can be seen that percentage share in total direct emissions for Electricity, gas and water supply, and Basic metals and fabricated metal and Mining and

quarrying is 65.55% and identified as type (A) hotspots. Further, type (A) hotspot in 1995, 'Other Non-metallic mineral' has been replaced by Mining and Quarrying type (A) hotspot in 2009. Among the three Type (A) hotspots recognized, carbon emission intensity given by column 5 is not the sole reason for high direct emissions by Basic metals and fabricated metals as it is in case of other two type (A) carbon hotspots. The high value of total final demand in the sector is the major driver of high direct emissions by the sector. Thus analyzing emission intensity along with total final demand helps in drawing conclusion regarding the major driver for CO_2emissions by a particular sector.

Table 5: Top 15 Direct emitters (Row sum in 13) for the year 2009

WIOD Sector Code	Rank	Sector	Direct Emissions (Kt of CO_2)	% share of total direct emission	CO_2 Emission intensity(Kt of CO2/$m	Total Final Demand (Yj)	Total output. ($m)
E	1	Electricity, Gas and Water Supply	812874.51	49.17	12.49	11281.92	65068.59
27t28	2	Basic Metals and Fabricated Metal	122430.00	7.41	0.76	39141.31	160455.36
C	3	Mining and Quarrying	108726.94	6.58	2.63	12879.62	41301.38
26	4	Other Non-Metallic Mineral	89049.42	5.39	2.46	2539.37	36168.52
15T16	5	Food, Beverages and Tobacco	67762.66	4.10	0.53	101653.95	127099.98
AtB	6	Agriculture, Hunting, Forestry and Fishing	50449.30	3.05	0.18	170781.12	273470.89
23	7	Coke, Refined Petroleum and Nuclear Fuel	47740.16	2.89	0.43	25498.08	111126.42
24	8	Chemicals and Chemical Products	47060.11	2.85	0.54	33361.00	86874.02
60	9	Inland Transport	33428.65	2.02	0.17	89438.29	196046.76
H	10	Hotels and Restaurants	20276.81	1.23	0.43	39724.18	46767.47
F	11	Construction	11966.46	0.72	0.04	246441.36	297747.88
20	12	Wood and wood products	11833.55	0.72	1.07	1831.83	11049.46
34t35	13	Transport equipment	11090.70	0.67	0.15	50492.51	72593.24
17t18	14	Textiles and Textile Products	10540.32	0.64	0.12	64581.74	89669.66
21t22	15	Pulp, Paper, Paper , Printing and Publishing	8737.51	0.53	0.43	39724.18	20111.89
		Total Emission of top 15	1453967.11	87.94			
		Emissions by other sectors	199362.36	12.06			
		Total Emission	1653329.47	100.00			

Source: Author's own calculation

5.2.2. CO₂ footprints

The results from Table 6 show, the top 15 sectors of the Indian economy in terms of carbon footprints in 1995. The elements in Column five are the column sums for each sector in CO_2 Emission matrix given as equation (13).There are seven type (B) hotspots identified in terms of high carbon foot prints. These sectors are construction, agriculture, hunting, forestry and fishing, Electricity gas and water supply, Textiles and textile products, Inland transport, Food, beverages and tobacco and finally transport equipment. The footprint and direct emission ranks reveals that the construction sector has the highest carbon footprint followed by Agriculture, hunting, forestry among others, indicating that the emissions in these sectors are higher to meet the final demand rather than their direct emissions. Thus, these sectors themselves generate less pollution from their production activities.

In quest to identify the reason behind the high footprint of each of the type (B) hot spot identified sectors, we use column seven of table 6 which gives the emission multiplier for each sector taken from equation (11). This column is the column sum of the elements of each sector in (11) and the column 8 of total final demand. The emission multiplier for electricity, gas and water supply is highest followed by other non-metallic mineral but footprint for each of these sectors is lower than the Construction and Agriculture, hunting, forestry and fishing. Thus, the relatively higher footprint in the latter sectors is due to high value of total final demand. Thus emission multiplier is not the sole driver of high footprints in the sectors but final demand also plays an important role in identifying type (B) hotspots.

Table 6: Top 15 sectors in terms of carbon footprint (Column totals in (13)) along with emission multipliers for the year 1995

Footprint rank	Direct emission rank	Wiod sector code	Sector	Foot print (Kt of CO2	% share of total domestic footprint of Indian sectors	Emission Multiplier (Kt of CO2/$m of final demand	Total Final Demand (Yj)
1	14	F	Construction	82479.34	12.20	1.96	41993.69
2	5	AtB	Agriculture, Hunting, Forestry and Fishing	57853.74	8.56	0.79	73000.45
3	1	E	Electricity, Gas and Water Supply	54282.32	8.03	19.68	2757.74
4	11	17t18	Textiles and Textile Products	52304.24	7.74	1.99	26251.15
5	6	60.00	Inland Transport	51286.05	7.59	2.60	19728.70
6	10	15t16	Food, Beverages and Tobacco	49292.32	7.29	1.44	34165.83
7	18	34t35	Transport Equipment	47332.48	7.00	2.56	18498.50
8	4	24	Chemicals and Chemical Products	30682.96	4.54	3.36	9130.13
9	24	36t37	Manufacturing, Nec; Recycling	30266.02	4.48	2.61	11604.80
10	2	26	Other Non-Metallic Mineral	30175.04	4.46	6.70	4501.60
11	20	29	Machinery, Nec	29550.97	4.37	2.30	12864.38
12	8	H	Hotels and Restaurants	26299.62	3.89	2.81	9367.45
13	3	27t28	Basic Metals and Fabricated Metal	26015.11	3.85	3.75	6933.86
14	12	21t22	Pulp, Paper, Paper , Printing and Publishing	11284.77	1.67	2.56	4411.52
15	28	30t33	Electrical and Optical Equipment	10610.66	1.57	1.48	7191.00
			Total Emission of top 15	589715.63	87.23		
			Emissions by other sectors	86363.59	12.77		
			Total Emission	676079.22	100.00		

Source: Author's own calculations

Table 7 shows, the top 15 sectors of the Indian economy in terms of carbon footprints in 2009.There are two type (B) hot spots identified in terms of high carbon foot prints. They are construction and Electricity gas and water supply. The construction sector has highest footprint rank but low rank in direct emissions which reveals that the sector themselves generate less pollution from its production activities and all other sectors generate high emissions in order to meet the final demand for construction sector. The emission multiplier in column 7 of table 9 shows that the emission multipliers for Electricity, gas and water supply is highest followed by Mining and Quarrying but footprint for each of these sectors is lower than the Construction, implying high footprint in the latter due to high value of total final demand in the sector.

Table 7: Top 15 sectors in terms of carbon footprint (Column totals in (13)) along with emission multipliers for the year 2009

Footprint rank	Direct emissions rank	WIOD sector code	Sector	Foot print(Kt of CO_2	% share of total domestic footprint of indian	Type 1 EmissionS Multiplier (Kt of CO_2/$m of	Total Final Demand (Yj)
1	11	F	Construction	329874.97	21.98	1.34	246441.36
2	1	E	Electricity, Gas and Water Supply	185051.09	12.33	16.40	11281.92
3	5	15t16	Food, Beverages and Tobacco	101653.95	6.77	1.25	101653.95
4	3	27t28	Basic Metals and Fabricated Metal	111319.23	7.42	2.84	39141.31
5	9	60	Inland Transport	92084.40	6.14	1.03	89438.29
6	6	AtB	Agriculture, Hunting, Forestry and Fishing	84385.12	5.62	0.49	170781.12
7	14	17t18	Textiles and Textile Products	77927.13	5.19	1.21	64581.74
8	13	34t35	Transport Equipment	69086.22	4.60	1.37	50492.51
9	8	24	Chemicals and Chemical Products	55824.94	3.72	1.67	33361.00
10	20	30t33	Electrical and Optical Equipment	52573.79	3.50	1.10	48008.05
11	17	29.00	Machinery, Nec	44426.96	2.96	0.00	35065.18
12	10	H	Hotels and Restaurants	41561.21	2.77	1.05	39724.18
13	2	C	Mining and Quarrying	41441.50	2.76	3.22	12879.62
14	7	23	Coke, Refined Petroleum and Nuclear Fue	39729.71	2.65	1.67	25498.08
15	28	36t37	Manufacturing, Nec; Recycling	23293.65	1.55	0.35	65772.93
			Total carbon footprints of top 15	1350233.85	89.98		
			Emissions by other sectors	150417.56	10.02		
			Total	1500651.41	100.00		

Source: Author's own calculations

Conclusion:

The hotspot methodology added to the key sector analysis has allowed us to study the emission intensity and multipliers with the respect to single pollutant CO_2. The inter-industry input output tables of Indian economy denominated in million dollars obtained from World Input Output Database (Timmer et al, (2015), have been used for the purpose of analysis covering the period from 1995 to 2011. The key sector analysis identify eleven sectors during the period 1995- 2011 with both high backward and forwards linkages namely Wood and products of wood and cork, Pulp, paper, printed and publishing, Coke, refined petroleum, and Nuclear fuel, Chemicals and chemical products, Rubber and plastics, Other non-metallic mineral, Basic metals and fabricated metals, Electricity, Gas and Water supply, Inland transport, Air transport and Other supporting

auxiliary transport. These key sectors are the strategically important sectors of Indian economy because of having large spillover effects on the overall production in the economy.

The analysis of direct CO_2 emissions and footprints of Indian economy for the two time periods 1995 and 2009 gives Type (A) and Type (B) hot spots. Type (A) hot spot identify those industries that generate directly significantly more emissions compared to other industries in Indian economy whereas Type (B) hotspot identify those industries that generate more carbon foot print compared to other industries in an economy. The results show that for both the year 1995 percentage share in direct emissions for Electricity, gas and water supply, Other non-metallic mineral and Basic metals and fabricated metal is 65.55% and thus these three sectors are classified as type (A) hotspots. The reasons identified for this relatively higher emissions in the first two Type (A) hot spots sectors is the relatively higher CO_2 emission intensity. While in case of third type (A) hot spot sector that is, Basic metals and fabricated metal high emissions results from high value of total output. Further, type (A) hotspot in 1995, 'Other Non-metallic mineral' has been replaced by Mining and Quarrying type (A) hotspot in 2009.

There are seven type (B) hotspots identified in terms of high carbon foot prints for the year 1995. These sectors are construction, agriculture, hunting, forestry and fishing, Electricity gas and water supply, Textiles and textile products, Inland transport, Food, beverages and tobacco and finally transport equipment. The footprint and direct emission ranks reveals that the construction sector has the highest carbon footprint followed by Agriculture, hunting, forestry among others, indicating that the emissions in these sectors are higher to meet the final demand rather than their direct emissions. Thus, these sectors themselves generate less pollution from their production activities. Whereas for the year 2009, there are two type (B) hot spots identified in terms of high carbon foot prints. They are construction and Electricity gas and water supply. The key sector analysis identifies the important sector that have potential of generating output in other sectors of the economy while hotspot analysis identified the emission generated by these sector The results of the study will be useful for policy makers in developing climate mitigation policies. The study could be extended to multiregional or inter regional input output analysis.

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Appendix:

Appendix table A shows the Forward linkages Coefficients (Ui) for 35 industries along with corresponding ranks during 1995-2011.

WIOD Sector	SECTORS	1995		1996		1997		1998		1999		2000		2001		2002	
		Ui	Rank	Ui	Rank	Ui	Rank	Ui	Rank	Ui	Rank	Ui	Rank	Ui	Rank	Ui	Rank
AtB	Agriculture, Hunting, Forestry and Fishing	0.90	27	0.88	27	0.89	28	0.88	27	0.86	27	0.86	25	0.85	25	0.86	25
C	Mining and Quarrying	1.82	1	1.79	1	1.82	1	1.81	1	1.80	1	1.73	1	1.73	1	1.71	1
15t16	Food, Beverages and Tobacco	0.67	32	0.66	32	0.67	32	0.67	31	0.68	32	0.69	31	0.69	31	0.71	31
17t18	Textiles and Textile Products	0.92	25	0.90	26	0.92	27	0.87	28	0.82	29	0.79	28	0.77	27	0.75	28
19.00	Leather, Leather and Footwear	0.89	28	0.87	28	0.92	26	0.89	26	0.90	25	0.85	27	0.82	26	0.78	27
20.00	Wood and Products of Wood and Cork	1.37	7	1.35	6	1.38	5	1.37	4	1.35	5	1.31	6	1.38	3	1.35	4
21t22	Pulp, Paper, Paper , Printing and Publishing	1.08	18	1.22	8	1.23	8	1.22	8	1.20	7	1.20	10	1.24	8	1.27	7
23.00	Coke, Refined Petroleum and Nuclear Fuel	1.40	6	1.37	5	1.38	6	1.36	5	1.42	3	1.35	5	1.37	4	1.38	3
24.00	Chemicals and Chemical Products	1.26	8	1.24	7	1.26	7	1.23	7	1.20	8	1.21	9	1.23	9	1.23	10
25.00	Rubber and Plastics	1.12	13	1.11	13	1.17	10	1.16	10	1.13	10	1.20	11	1.20	11	1.20	12
26.00	Other Non-Metallic Mineral	1.08	19	1.07	17	1.07	18	1.03	18	1.09	15	1.04	17	1.20	10	1.23	9
27t28	Basic Metals and Fabricated Metal	1.57	4	1.53	3	1.57	3	1.52	3	1.40	4	1.41	4	1.36	5	1.32	6
29.00	Machinery, Nec	0.91	26	0.90	25	0.95	25	0.95	23	0.90	24	0.98	22	0.97	21	0.99	18
30t33	Electrical and Optical Equipment	0.87	29	0.86	29	0.84	29	0.90	25	0.91	23	1.60	2	0.98	19	0.98	20
34t35	Transport Equipment	0.96	23	0.95	23	0.99	23	0.98	21	0.96	21	0.98	21	0.98	20	0.99	19
36t37	Manufacturing, Nec; Recycling	0.93	24	0.91	24	0.96	24	0.93	24	0.84	28	0.85	26	0.91	22	0.85	26
E	Electricity, Gas and Water Supply	1.72	2	1.69	2	1.71	2	1.68	2	1.60	2	1.58	3	1.58	2	1.56	2
F	Construction	0.70	31	0.70	31	0.73	31	0.73	30	0.71	31	0.57	34	0.73	29	0.74	30
50.00	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	1.16	10	1.14	12	1.15	13	1.14	13	1.09	12	1.08	14	1.10	15	1.10	14
51.00	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	1.16	11	1.14	11	1.15	11	1.14	11	1.09	13	1.08	16	1.10	13	1.10	15
52.00	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	1.16	12	1.14	10	1.15	12	1.14	12	1.09	14	1.08	15	1.10	14	1.10	16
H	Hotels and Restaurants	0.72	30	0.72	30	0.73	30	0.73	29	0.75	30	0.74	30	0.75	28	0.75	29
60.00	Inland Transport	1.11	14	1.09	14	1.11	14	1.10	14	1.04	18	1.01	20	1.01	17	1.00	17
61.00	Water Transport	1.09	17	1.07	18	1.08	17	1.07	17	1.06	17	1.03	18	1.01	16	0.97	21
62.00	Air Transport	1.10	15	1.08	15	1.10	15	1.09	15	1.09	16	1.08	13	0.61	32	1.12	13
63.00	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	1.10	16	1.08	16	1.09	16	1.08	16	1.10	11	1.11	12	1.17	12	1.22	11
64.00	Post and Telecommunications	1.19	9	1.17	9	1.20	9	1.18	9	1.19	9	1.25	8	1.24	7	1.25	8
J	Financial Intermediation	1.41	5	1.38	4	1.39	4	1.36	6	1.32	6	1.31	7	1.33	6	1.33	5
70.00	Real Estate Activities	1.01	21	0.99	21	1.00	21	0.61	32	0.89	26	0.78	29	0.70	30	0.63	32
71t74	Renting of M&Eq and Other Business Activities	0.99	22	0.98	22	0.99	22	0.98	22	1.01	19	1.01	19	1.00	18	0.94	22
L	Public Admin and Defence; Compulsory Social Security	0.57	35	0.57	35	0.57	35	0.57	35	0.57	35	0.57	34	0.57	35	0.57	35
M	Education	0.57	34	0.57	34	0.57	34	0.57	34	0.58	34	0.58	33	0.58	34	0.58	34
N	Health and Social Work	0.58	33	0.58	33	0.58	33	0.58	33	0.58	33	0.59	32	0.59	33	0.59	33
O	Other Community, Social and Personal Services	1.01	20	1.00	20	1.00	20	0.98	20	0.94	22	0.91	24	0.89	24	0.86	24
P	Private Households with Employed Persons	1.69	3	1.02	19	1.03	19	1.02	19	0.97	20	0.93	23	0.90	23	0.87	23

Source: Author's own calculation

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Appendix table A shows the Forward linkages Coefficients (Ui) for 35 industries along with corresponding ranks for the period 1995-2011.

WIOD Sector Code	SECTORS	2003 UI	Rank	2004 UI	Rank	2005 UI	Rank	2006 UI	Rank	2007 UI	Rank	2008 UI	Rank	2009 UI	Rank	2010 UI	Rank	2011 UI	Rank
AtB	Agriculture, Hunting, Forestry and Fishing	0.89	23	0.89	23	0.88	25	0.89	22	0.89	22	0.87	22	0.88	24	0.86	24	0.85	24
C	Mining and Quarrying	1.72	1	1.50	2	1.50	2	1.39	4	1.43	3	1.41	3	1.55	2	1.52	2	1.49	2
15t16	Food, Beverages and Tobacco	0.74	30	0.74	29	0.73	29	0.74	28	0.74	28	0.74	27	0.74	29	0.72	29	0.71	30
17t18	Textiles and Textile Products	0.77	29	0.78	26	0.78	27	0.80	26	0.80	26	0.79	25	0.81	26	0.81	26	0.80	26
19	Leather, Leather and Footwear	0.83	27	0.86	24	0.91	20	0.93	20	0.97	19	0.92	19	0.98	19	0.95	19	0.93	20
20	Wood and Products of Wood and Cork	1.32	7	1.36	6	1.32	8	1.34	7	1.28	9	1.34	7	1.34	9	1.33	8	1.28	10
21t22	Pulp, Paper, Paper , Printing and Publishing	1.34	6	1.38	4	1.39	4	1.43	2	1.45	2	1.42	2	1.45	3	1.42	3	1.40	3
23	Coke, Refined Petroleum and Nuclear Fuel	1.40	3	1.41	3	1.40	3	1.43	3	1.42	4	1.39	4	1.45	4	1.39	5	1.35	6
24	Chemicals and Chemical Products	1.22	12	1.19	12	1.18	12	1.17	12	1.18	12	1.17	12	1.24	12	1.17	15	1.15	15
25	Rubber and Plastics	1.24	11	1.23	11	1.22	11	1.22	11	1.23	11	1.24	11	1.30	11	1.27	11	1.24	11
26	Other Non-Metallic Mineral	1.26	10	1.29	9	1.29	9	1.31	8	1.30	8	1.32	8	1.33	10	1.32	10	1.31	9
27t28	Basic Metals and Fabricated Metal	1.31	8	1.27	10	1.26	10	1.24	10	1.25	10	1.30	10	1.34	8	1.34	7	1.33	7
29	Machinery, Nec	0.99	19	0.94	19	0.90	22	0.88	23	0.87	23	0.89	21	0.91	22	0.92	22	0.90	22
30t33	Electrical and Optical Equipment	0.99	20	0.90	21	0.90	23	0.81	25	0.82	25	0.85	24	0.78	27	0.81	25	0.78	27
34t35	Transport Equipment	1.00	18	0.96	18	0.89	24	0.87	24	0.83	24	0.86	23	0.88	23	0.89	23	0.87	23
36t37	Manufacturing, Nec; Recycling	0.87	26	0.76	27	0.67	31	0.64	31	0.64	31	0.66	30	0.68	31	0.71	31	0.69	31
E	Electricity, Gas and Water Supply	1.60	2	1.58	1	1.56	1	1.56	1	1.56	1	1.55	1	1.59	1	1.57	1	1.54	1
F	Construction	0.73	31	0.73	30	0.73	30	0.72	29	0.71	29	0.73	28	0.74	28	0.75	28	0.74	28
50	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	1.15	16	0.66	31	1.15	13	1.15	13	1.15	15	1.15	15	1.19	15	1.18	14	1.15	14
51	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	1.15	14	1.15	15	1.15	14	1.15	14	1.15	13	1.15	13	1.19	13	1.18	12	1.15	12
52	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	1.15	15	1.15	14	1.15	15	1.15	15	1.15	14	1.15	14	1.19	14	1.18	13	1.15	13
H	Hotels and Restaurants	0.77	28	0.75	28	0.73	28	0.69	30	0.69	30	0.69	29	0.72	30	0.71	30	0.72	29
60	Inland Transport	1.03	17	1.07	16	1.09	17	1.10	17	1.11	17	1.10	17	1.14	17	1.13	17	1.10	17
61	Water Transport	0.96	21	1.03	17	1.08	18	1.12	16	1.12	16	1.12	16	1.15	16	1.14	16	1.12	16
62	Air Transport	1.21	13	1.18	13	1.15	16	1.10	18	1.10	18	1.10	18	1.13	18	1.13	18	1.10	18
63	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	1.35	5	1.35	7	1.37	5	1.36	5	1.36	5	1.36	5	1.40	5	1.40	4	1.36	4
64	Post and Telecommunications	1.31	9	1.32	8	1.33	7	1.30	9	1.31	7	1.31	9	1.35	7	1.33	9	1.32	8
J	Financial Intermediation	1.37	4	1.36	5	1.36	6	1.36	6	1.36	6	1.35	6	1.39	6	1.38	6	1.36	5
70	Real Estate Activities	0.58	34	0.58	34	0.58	34	0.58	34	0.58	34	0.58	33	0.58	34	0.58	34	0.58	34
71t74	Renting of M&Eq and Other Business Activities	0.90	22	0.80	25	0.78	26	0.74	27	0.75	27	0.78	26	0.84	25	0.81	27	0.83	25
L	Public Admin and Defence; Compulsory Social Security	0.57	35	0.57	35	0.57	35	0.57	35	0.57	35	0.57	35	0.57	35	0.57	35	0.57	35
M	Education	0.58	33	0.58	33	0.58	33	0.58	33	0.58	33	0.58	32	0.58	33	0.58	33	0.58	33
N	Health and Social Work	0.59	32	0.59	32	0.59	32	0.59	32	0.59	32	0.59	31	0.60	32	0.59	32	0.60	32
O	Other Community, Social and Personal Services	0.88	25	0.90	22	0.91	21	0.92	21	0.91	21	0.91	20	0.95	21	0.93	21	0.93	21
P	Private Households with Employed Persons	0.88	24	0.91	20	0.92	19	0.95	19	0.95	20	0.57	34	0.97	20	0.95	20	0.94	19

Source: Author's own calculation

Appendix table B shows Backward Linkages Coefficients (Uj) for 35 industries along with corresponding ranks for the period 1995-2011.

WIOD Sector Code	SECTORS	1995		1996		1997		1998		1999		2000		2001		2002	
		Uj	Rank	Uj	Rank	Uj	Rank	Uj	Rank	Uj	Rank	Uj	Rank	Uj	Rank	Uj	Rank
AtB	Agriculture, Hunting, Forestry and Fishing	0.78	27	0.76	27	0.77	27	0.76	27	0.77	26	0.77	27	0.77	27	0.78	24
C	Mining and Quarrying	0.83	26	0.83	26	0.80	26	0.77	26	0.76	28	0.77	26	0.79	26	0.76	28
15t16	Food, Beverages and Tobacco	1.28	9	1.26	8	1.26	10	1.26	9	1.24	5	1.26	3	1.27	3	1.30	3
17t18	Textiles and Textile Products	1.30	8	1.26	9	1.30	8	1.27	8	1.26	4	1.25	4	1.25	4	1.24	5
19	Leather, Leather and Footwear	1.32	6	1.32	4	1.34	4	1.30	4	1.28	3	1.25	5	1.23	7	1.20	9
20	Wood and Products of Wood and Cork	1.19	11	1.18	12	1.19	11	1.19	11	1.08	14	1.07	15	1.06	17	1.06	17
21t22	Pulp, Paper, Paper , Printing and Publishing	1.30	7	1.28	7	1.32	7	1.30	5	1.24	6	1.23	6	1.24	6	1.24	4
23	Coke, Refined Petroleum and Nuclear Fuel	1.11	16	1.08	17	1.04	20	1.04	19	0.84	25	0.78	25	0.90	22	0.88	22
24	Chemicals and Chemical Products	1.25	10	1.24	10	1.30	9	1.24	10	1.21	10	1.21	8	1.24	5	1.22	7
25	Rubber and Plastics	1.37	3	1.35	3	1.33	5	1.36	3	1.30	2	1.32	2	1.33	2	1.33	2
26	Other Non-Metallic Mineral	1.11	15	1.07	19	1.11	15	1.10	16	1.05	18	1.05	18	1.10	14	1.09	14
27t28	Basic Metals and Fabricated Metal	1.35	4	1.31	5	1.34	3	1.27	7	1.21	9	1.21	9	1.20	11	1.20	8
29	Machinery, Nec	1.33	5	1.30	6	1.32	6	1.28	6	1.23	8	1.23	7	1.22	8	1.23	6
30t33	Electrical and Optical Equipment	1.09	18	1.07	18	1.10	16	1.03	20	1.20	11	1.20	10	1.20	9	1.17	10
34t35	Transport Equipment	1.42	2	1.40	2	1.42	1	1.39	1	1.35	1	1.36	1	1.35	1	1.34	1
36t37	Manufacturing, Nec; Recycling	1.44	1	1.42	1	1.42	2	1.37	2	1.23	7	1.20	11	1.20	10	1.13	12
E	Electricity, Gas and Water Supply	1.19	12	1.18	11	1.18	12	1.18	12	1.15	12	1.14	12	1.16	12	1.15	11
F	Construction	1.12	14	1.11	14	1.12	14	1.10	15	1.07	16	1.07	16	1.09	16	1.08	16
50	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	0.76	30	0.75	30	0.74	30	0.72	29	0.71	31	0.71	31	0.72	31	0.57	34
51	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	0.76	29	0.75	28	0.74	29	0.72	31	0.71	30	0.71	30	0.72	30	0.72	30
52	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	0.76	28	0.75	29	0.74	31	0.72	30	0.71	32	0.71	32	0.72	32	0.72	31
H	Hotels and Restaurants	1.12	13	1.08	16	1.09	18	1.09	17	1.08	15	1.10	13	1.10	13	1.12	13
60	Inland Transport	1.09	19	1.09	15	1.10	17	1.10	14	1.06	17	1.06	17	1.10	15	1.09	15
61	Water Transport	0.92	24	0.91	24	0.92	24	0.92	24	0.91	21	0.93	21	0.96	21	0.96	21
62	Air Transport	1.05	20	1.04	20	1.05	19	1.05	18	1.02	19	1.03	19	1.06	18	1.04	18
63	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	0.97	23	0.96	23	0.97	21	0.96	21	0.96	20	0.98	20	1.01	20	1.02	19
64	Post and Telecommunications	0.71	32	0.71	32	0.69	32	0.70	32	0.72	29	0.76	29	0.75	29	0.75	29
J	Financial Intermediation	0.73	31	0.74	31	0.75	28	0.76	28	0.76	27	0.76	28	0.77	28	0.77	27
70	Real Estate Activities	0.65	34	0.65	34	0.65	34	0.65	34	0.64	34	0.64	34	0.65	34	0.65	33
71t74	Renting of M&Eq and Other Business Activities	0.90	25	0.89	25	0.91	25	0.90	25	0.86	22	0.87	22	0.87	23	0.87	23
L	Public Admin and Defence; Compulsory Social Security	0.57	35	0.57	35	0.57	35	0.57	35	0.57	35	0.57	35	0.57	35	0.57	35
M	Education	0.68	33	0.68	33	0.68	33	0.68	33	0.68	33	0.68	33	0.67	33	0.67	32
N	Health and Social Work	1.10	17	1.12	13	1.17	13	1.17	13	1.12	13	1.08	14	1.04	19	0.97	20
O	Other Community, Social and Personal Services	1.00	22	0.97	21	0.96	22	0.92	22	0.85	23	0.83	23	0.82	24	0.78	25
P	Private Households with Employed Persons	1.00	21	0.97	22	0.96	23	0.92	23	0.85	24	0.83	24	0.82	25	0.78	26

Source: Author's own calculation

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Appendix table B shows Backward Linkages Coefficients (U$_j$) for 35 industries along with corresponding ranks for the period 1995-2011.

WIOD Sector Code	Sectors	2003		2004		2005		2006		2007		2008		2009		2010		2011	
		U$_j$	Rank	U$_j$	Rank	U$_j$	Rank	U$_j$	Rank	U$_j$	Rank	U$_j$	Rank	U$_j$	Rank	U$_j$	Rank	U$_j$	Rank
AtB	Agriculture, Hunting, Forestry and Fishing	0.79	25	0.78	24	0.78	26	0.77	23	0.76	26	0.76	27	0.76	27	0.73	26	0.73	27
C	Mining and Quarrying	0.80	24	0.77	25	0.78	25	0.77	25	0.78	24	0.78	25	0.77	25	0.74	25	0.74	25
15t16	Food, Beverages and Tobacco	1.32	3	1.30	3	1.28	2	1.27	2	1.28	2	1.29	1	1.28	2	1.44	2	1.44	2
17t18	Textiles and Textile Products	1.25	6	1.24	5	1.22	6	1.24	3	1.24	4	1.23	6	1.24	6	1.34	5	1.34	6
19	Leather, Leather and Footwear	1.22	9	1.21	7	1.23	4	1.22	4	1.25	3	1.23	5	1.25	5	1.12	16	1.37	3
20	Wood and Products of Wood and Cork	1.05	17	1.02	17	1.01	17	1.00	15	1.00	17	1.01	16	1.03	17	1.11	17	1.10	17
21t22	Pulp, Paper, Paper , Printing and Publishing	1.27	4	1.26	4	1.24	3	1.22	5	1.24	5	1.23	4	1.26	3	1.35	4	1.35	4
23	Coke, Refined Petroleum and Nuclear Fuel	0.92	21	0.92	21	0.95	18	0.91	20	0.94	20	0.92	19	1.05	16	1.16	14	1.14	16
24	Chemicals and Chemical Products	1.25	5	1.23	6	1.22	8	1.19	8	1.19	8	1.18	10	1.18	10	1.27	9	1.26	10
25	Rubber and Plastics	1.37	1	1.35	1	1.33	1	1.29	1	1.29	1	1.28	2	1.34	1	1.46	1	1.46	1
26	Other Non-Metallic Mineral	1.16	12	1.13	12	1.13	12	1.10	11	1.12	12	1.13	11	1.14	12	1.22	11	1.21	12
27t28	Basic Metals and Fabricated Metal	1.22	8	1.20	9	1.23	5	1.22	6	1.22	6	1.26	3	1.25	4	1.35	3	1.35	5
29	Machinery, Nec	1.24	7	1.21	8	1.20	9	1.17	9	1.18	9	1.21	8	1.21	8	1.29	7	1.29	8
30t33	Electrical and Optical Equipment	1.20	10	1.18	10	1.18	10	0.57	34	1.16	10	1.20	9	1.19	9	1.28	8	1.28	9
34t35	Transport Equipment	1.36	2	1.31	2	1.22	7	1.20	7	1.20	7	1.22	7	1.21	7	1.30	6	1.30	7
36t37	Manufacturing, Nec; Recycling	1.09	16	0.95	20	0.88	22	0.95	18	0.96	19	0.89	21	0.84	22	0.81	22	0.83	22
E	Electricity, Gas and Water Supply	1.16	11	1.15	11	1.15	11	1.14	10	1.15	11	1.13	12	1.14	11	1.22	10	1.22	11
F	Construction	1.12	14	1.10	14	1.10	13	1.08	13	1.09	13	1.12	13	1.12	13	1.19	12	1.19	13
50	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	0.72	31	0.70	30	0.69	28	0.68	31	0.67	29	0.66	29	0.67	30	0.60	30	0.60	30
51	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	0.72	30	0.70	32	0.69	30	0.68	29	0.67	30	0.66	28	0.67	29	0.60	28	0.60	29
52	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	0.72	32	0.70	31	0.69	29	0.68	30	0.67	28	0.66	30	0.67	28	0.60	29	0.60	28
H	Hotels and Restaurants	1.13	13	1.11	13	1.09	14	1.08	12	1.08	14	1.09	14	1.07	15	1.15	15	1.15	15
60	Inland Transport	1.10	15	1.08	15	1.08	15	1.06	14	1.07	15	1.07	15	1.10	14	1.16	13	1.17	14
61	Water Transport	0.97	20	0.96	19	0.94	20	0.92	19	0.92	21	0.92	20	0.94	19	0.95	19	0.95	19
62	Air Transport	1.04	18	0.98	18	0.95	19	0.97	17	0.97	18	0.93	18	0.92	20	0.91	20	0.92	20
63	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	1.04	19	1.02	16	1.02	16	0.99	16	1.00	16	1.01	17	1.01	18	1.05	18	1.05	18
64	Post and Telecommunications	0.77	27	0.75	27	0.80	24	0.78	22	0.82	23	0.85	23	0.82	23	0.80	23	0.80	23
J	Financial Intermediation	0.78	26	0.77	26	0.76	27	0.75	26	0.76	27	0.76	26	0.76	26	0.73	27	0.73	26
70	Real Estate Activities	0.66	34	0.66	34	0.66	34	0.65	32	0.65	34	0.65	31	0.65	31	0.58	31	0.58	32
71t74	Renting of M&Eq and Other Business Activities	0.87	23	0.83	22	0.81	23	0.77	24	0.78	25	0.79	24	0.80	24	0.78	24	0.79	24
L	Public Admin and Defence; Compulsory Social Security	0.57	35	0.57	35	0.57	35	0.57	35	0.57	35	0.57	35	0.57	35	0.48	35	0.48	35
M	Education	0.67	33	0.66	33	0.66	33	0.65	33	0.65	33	0.65	32	0.65	32	0.58	32	0.58	31
N	Health and Social Work	0.92	22	0.79	23	0.89	21	0.87	21	0.87	22	0.85	22	0.86	21	0.84	21	0.84	21
O	Other Community, Social and Personal Services	0.75	29	0.71	28	0.68	32	0.70	27	0.67	31	0.65	33	0.64	33	0.57	33	0.57	33
P	Private Households with Employed Persons	0.75	28	0.71	29	0.68	31	0.70	28	0.67	32	0.65	34	0.64	34	0.57	34	0.57	34

Source: Author's own calculation