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Energy Use and Export Behaviour in the Indian Economy: An Input-Output Based Analysis

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Abstract: Developing countries, like India, face the twin challenges of sustainable growth and high import dependency due to direct energy imports. The presence of less energy intensive commodities in the export basket not only improves cost competitiveness along with environmental compliance, but can also be effective in lowering the net energy liability of a country. This paper analyses the changes in sector-wise energy intensity *vis-a-vis* the evolving export structure to assess the energy intensity of India's exports by using a constant price hybrid Input-Output model. The analysis clearly highlights the importance of services as a less energy intensive sector with significant export presence. Within the manufactured products category, particularly important are other manufacturing (including textiles and wearing apparel), agriculture, processed food and mining, due to the export potential alongside improved energy intensity over time. At the same time, increasing intensity and export share of basic metals and non-ferrous metal products draw attention for efforts to improve energy efficiency. The findings reject the proposition that India's export basket is dominated by energy intensive sectors.

Keywords: Embodied energy, energy intensity, export structure, hybrid Input-Output model
JEL Classification: C67, D57, Q40

1. Introduction

Globally, the energy intensity of countries differs due to varying environmental standards which are in turn based on the energy profile of a country. In addition, the capacity for efficiency improvements from lower energy intensity also varies between the developing and developed countries due to the difference in energy sources and the consumer/producer preferences for environmentally favourable options (Neumayer, 2001). The relative strict enforcement of the environmental or minimum efficiency standards in countries raises operation costs in the jurisdiction area leading to reallocation of production activity to the lesser regulated regions. As a result, energy intensive industries shift to countries with softer environmental regulations. Increasing production in energy intensive industries in the destination country can be either due to domestic requirements,

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earlier sourced through exports; or production for consumption abroad embodied in trade. In fact, energy embodied in global trade has not only increased rapidly, but rather faster in comparison to direct energy exports (Cui, Peng, & Zhu, 2015). Further due to its embodied nature, energy trade also occurs along with economic growth which involves changes in merchandise and services trade pattern. Furthermore, globalisation permits the countries to produce and consume different goods (Wagner, 2010). Thus, trade in energy is embodied in all the goods and services which are traded. The situation becomes even more complex and sensitive for countries that have high direct imports with a dissimilar structure in the case of exports.

In recognition of economic development achieved through international trade, the estimation of energy content of exports and imports has become an area of contemporary research to assess the net energy balance of a country. Although both exports and imports provide crucial stimulus for economic growth, the significant link between exports and output expansion is well established in literature for major developing countries like India (Rajput, Bhutani, & Kumar, 2014; Ray, 2011) and China (Tsen, 2006). Furthermore, many causality studies have established the link between exports and energy consumption (Zeng, Qi, & Chen, 2011; Nanji, Chukwa, & Nanji, 2013). Thus, energy consumption supports exports and growth. However, consumption of clean and lower intensity energy use also supports exports (Li, 2014).

Traditionally, trade performance, particularly of the exports, is linked to competitiveness of the domestic sector. However, increasing environmental consciousness has introduced an additional parameter related to energy embodied in the exported product. The environmental competitiveness of a product is related to its energy intensity measured as the energy required to produce one unit of output. Products with relatively low energy intensity are tagged as ‘green products’ in comparison to products with higher energy intensity which are tagged as ‘grey’ or ‘dirty products’. Although the concept of environmental competitiveness has not featured explicitly into export competitiveness, various measures such as the carbon tax and non-tariff barriers are already in place to address issues related to cross-border trade of energy intensive goods. The changing energy content of exports partially reflects the country-level adjustments as an initiative towards sustainable development (Amador, 2011). Further, higher energy content also has implications in terms of cost competitiveness *vis-a-vis* the competing countries with lower energy intensity as exporting countries compete with domestic producers in the destination market along with the third-country exporters. In fact, studies have acknowledged the contribution of exports in causing an increase in energy use of an economy (Tandon & Ahmed, 2015).

The energy outflow in the form of exports affects the transfer of embodied pollution among the trading partners, which can re-define a country’s mitigation commitments (Su, And, & Low, 2013). The attempts to address climate change are essentially centred on efficient use of resources such as through lower intensity of energy use. However, the behaviour of overall energy intensity of a country provides limited understanding in terms of specific industries and agents of demand such as domestic consumers or exports (Isabel, Jacob, & Wang, 2015). Changing structure of trade can have different implications in terms of energy intensity of the exports. For instance, findings of the studies on migration of polluting industries to the less developed countries have been inconclusive.

While some confirm poorer countries export more of energy intensive products (Kellogg, 2007), others argue that technology in exporting sectors is advanced compared to the domestic productive sectors thereby lowering energy intensity in exports (Wagner, 2010). Therefore, it becomes important to study the changing energy intensity in the export basket of a country. This is particularly important for developing countries like India which face the twin challenge of sustainable growth and high import dependency due to direct energy imports. The presence of less energy intensive commodities in the export basket not only improves cost competitiveness along with environmental compliance but can also be effective in lowering the net energy liability of a country.

Studies related to embodied energy use are primarily distinguished into two categories. The focus of the first category is on estimating energy use. The relatively wider second category is dedicated to identifying the sources of change in energy use in a decomposition framework. In most cases, the analysis is primarily at an aggregate country level. However, attempts to study the energy content of the exported products, *per se*, are rather few. Important among these is the analysis by Amador (2011) on the energy content of manufactured exports of 30 countries including India. However, the study again rests on a decomposition framework that only marks the relative differences in energy content *vis-a-vis* the world average, aggregated across four major manufacturing categories. Therefore, there has been a notable gap in the existing literature with regard to analysis of energy intensity of the export basket.

The energy intensity of the Indian economy has declined and is expected to decline further (Planning Commission, 2013). Despite this, it performs unsatisfactorily in comparison to the developed and developing economies such as the US and China. A wide range of inter-state and inter-firm variation in energy intensity of manufacturing firms indicates the potential for further improvement (Goldar, 2010). The initial trade liberalisation reforms aimed at improving competitiveness of domestic manufacturing through easier and cheaper access to imports, and increased market opportunities in the form of exports. As a result, not only did the structure of domestic output change, but compositional changes are also reflected in the import and export baskets. International trade plays an important role in India's total energy consumption. On one hand, India's import dependency on crude oil has worsened over time, while on the other hand the rising exports of petroleum products have helped in reducing the net energy imports. Besides the exports of direct energy products such as petroleum products, energy is also embodied in the export of non-energy products. Such products, however, have different energy intensities that vary widely. Therefore, a study of India's sector-wise energy intensity and export structure is useful to assess the energy implications for export expansion. Energy changes induced by shifts in export patterns can be helpful to unscramble the energy liabilities at the country level.

An immediate query emerges regarding the future policy to produce for exports in order to achieve high economic growth within a sustainable ecological environment. Thus, it becomes useful to study the export composition from an energy perspective which further has the potential in terms of strengthening the presence of green or greener commodities in the export basket. The present paper attempts to bridge the earlier gap essentially in three ways. First, the study has a wider coverage of economy-wide sectors including services and agriculture. This is particularly relevant in the Indian context due to the service-led exports which have lower energy intensity. Second, the study provides an inter-sectoral comparison of energy intensity based on real flows to address the issue of volatility in international energy prices. Third, the study refines the estimates of energy intensity with the inclusion of non-thermal electricity as a source of primary energy. Against this backdrop, the authors attempt to assess the following research proposition: India's export basket is dominated by energy intensive sectors.

The rest of the paper is structured into the following sections. Section 2 presents a review of literature. The methodological details are given in Section 3. This is followed by results and discussion in Section 4. This section presents results of sector-wise energy intensity and analyses the energy intensity of different exporting sectors. The paper concludes in Section 5.

2. Review of Literature

The value and volume of international trade has been traditionally determined by costs and competitiveness, respectively. More recently, the emissions embodied in traded goods have also been acknowledged to influence trade flows. Studies have acknowledged that trade flows lead to reallocation of polluting activities, beside the conventional factors of production namely labour and capital. This has an environmental externality which is manifested as carbon leakage. The shift in emission burden from one country to another can be either through migrating the industrial activity or through a higher proportion of consumption being met by dirty products manufactured offshore. The latter constitutes exports of the producing country.

The importance of energy in the form of embodied carbon emissions has been acknowledged by Kejun, Cosbey and Murphy (2008) who argued that embodied energy has implications for the trade regime as environmental compliance adds to cost which in turn affects competitiveness. Copeland (2000) admitted that interaction between trade and environmental agreements is unavoidable. In a recent study Peters, Minx, Weber and Edenhofer (2011) highlighted the importance of monitoring emission transfers via international trade while also paying attention to territorial emission statistics. Using Input-Output (I-O) methods, Huichao and Wang (2010) also emphasise transfer of energy (carbon emissions) through international trade.

Conceptually, country level energy use, and hence emissions, consists of two separable parts, arising from domestic demand and exports. Heredeen and Bullard (1976), in their much referred work on the US economy, determined the energy embodied in trade of goods and services while emphasising the importance of energy embodied in non-energy goods besides the energy sectors. They accrued energy imbalance from trade in non-energy goods to the currency value of gross and net flows as well as the relative energy intensities of imports and exports. More importantly for comparable values of flows, the energy intensities could account for the imbalance in energy trade. The offshore reallocation of polluting or energy intensive industries does not ensure a reduction in global emissions unless accompanied by improvements in energy intensity (Bhattacharya & Nanda, 2012). In fact, the host countries may also suffer from imposition of carbon taxes.

In fact, energy intensity of exports can be different from the domestically produced goods as suggested in a recent study by Isbael et al. (2015) for China. The findings indicate that the energy intensive firms are more likely to export with a greater export share in the production, thereby acknowledging a weaker enforcement of environmental regulations on export oriented activities (SEPA, 2006). In a different analytical framework, Amador (2011) showed an increase in energy content of exports from developing countries such as China and India, in comparison to the world average. Decomposition of the results for India indicated a positive contribution of energy intensity and trade structure effects in the low-tech and med-low-tech categories. However, the trade structure effect contributed to lower the energy content of exports in medium-high tech and high-tech categories. But the analysis, based on nominal terms, is inadequate to capture technology effects needed to assess the changing emission intensity of sectors. It becomes necessary to conduct the analysis based on real energy flows in a country- specific study. The study is also constrained by the broad manufacturing categories which ignore the contribution of the relatively less energy intensive sectors such as the exports of services.

Two studies specifically analysed energy intensity of Indian manufacturing. Goldar (2010) noted a decline in energy intensity due to an increase in real energy price and technological improvements. The author also found lower intensity of the foreign firms in energy intensive industries as compared with the domestic firms indicating the possibility of spillovers. Similarly, Sahu and Narayanan (2010) also indicate lower energy intensity of foreign firms. The authors observed a significant contribution of technology imports in lowering energy intensity. Both studies however, lack an analysis of the energy intensity from the export perspective. This becomes even more important in view of their findings on foreign firms that are also likely to be export oriented. Another study by Goldar, Bhanot, and Shimpo (2011) attempted to analyse emission intensity from trade flows against the background of export competiveness based on revealed comparative advantage. They identified agricultural, service and textiles exports for potential export promotion due to lower emission intensity and presence of revealed comparative advantage. However, the study lacks an inter-temporal perspective on emission intensity.

With the above in mind, the authors are motivated to study the energy intensity of India's exports. The analysis of changing energy intensity along with the evolving export structure will be useful to assess the energy intensity of India's exports.

3. Methodology and Data

We adopt the constant price hybrid I-O model to estimate energy intensity of different sectors (Miller & Blair, 2009). In the standard I-O model, the intersectoral relationships among sectors are expressed in the form of linear equations that constitute a system of simultaneous equations representing all activities in money flows (Leontief, 1936).[1] It assumes homogeneity of output for a given sector which in turn implies identical pricing across the different using sectors. However, this assumption could be unrealistic for specific commodities such as energy. The problem is avoided by using physical quantities which are independent of prices. Moreover, energy intensity of a sector, measured in terms of physical quantity of energy required per unit of output, is also representative

[1] The intersectoral transactions for the American economy were initially represented in physical units such as tonnes or numbers. The data on physical output is not readily available. Hence, the I-O transactions are widely presented in terms of commodity flows in money values.

of the technologically changes reflected as the change in input use and fuel substitution.

The I-O models represent demand flows of goods and services as intermediates and final consumption. In an economy with n sectors, the output of each sector **(X)** is either consumed as an intermediate good (**Z**) in the production process of another sector, or is consumed as a final good **(Y).** The intersectoral flows are represented in a matrix, Z (of dimensions $n X n$) such that

$$Z = [X_{ij}], \text{ where } i,j = 1,2, ..., n \quad (1)$$

The elements of **Z,** i.e., X_{ij} are the flows from sector i to the sector j. The corresponding technical coefficient matrix, **A** (n X n), is defined as

$$A = [X_{ij}] \ni: a_{ij} = \frac{X_{ij}}{X_j}, \text{ where } i,j = 1,2, ..., n \quad (2)$$

Thus,

$$A = Z * \hat{X}^{-1} \Rightarrow Z = A * \hat{X} \quad (3)$$

where $\hat{\mathbf{X}}$ is the diagonal matrix of the sector outputs. The intersectoral relations are represented through the technical coefficient matrix, **A** whose ij^{th} element shows the amount of input from the i^{th} sector required to produce one unit output of the j^{th} sector. Additionally, the matrix **L** is defined such that

$$L = (I - A)_{-1} = [r_{ij}], \text{ where } i,j = 1,2, ..., n \quad (4)$$

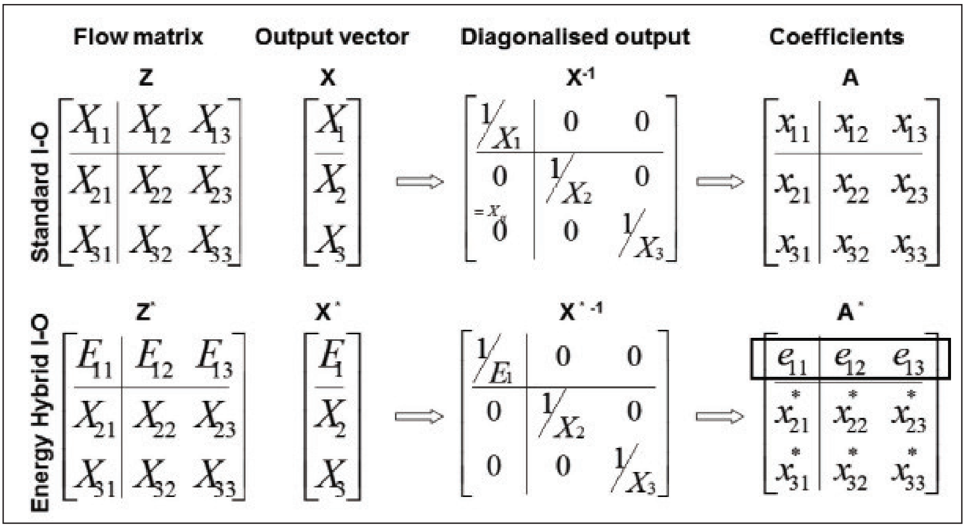
The matrix **L,** called the Leontief inverse, is also referred to as the total requirement matrix.

For a hybrid I-O model, the comparable matrices in hybrid (mixed) units are obtained by substituting rows corresponding to the energy sectors with the rows that have transactions in physical quantities. The energy rows trace the use of energy commodities in other remaining sectors of the economy. The hybrid I-O matrices notated as Z*, A* and L*, are comparable to the standard I-O matrices for the commodity flows (Z), technical coefficients (A) and the Leontief inverse (L), respectively. The matrices Z and Z* differ in the energy rows that contain money values in **Z** but are replaced with the corresponding quantities in Z*. Similarly the matrices A & A* and L & L* differ only in the energy rows. A comparison of standard I-O model and the hybrid I-O model is summarised in Box 1.

The variable E represents energy flows corresponding to X, but measured in physical quantities. All coefficients in the standard I-O are measured as x_{ij}, which replace the value of i^{th} input required for one rupee of j^{th} output; the coefficients in hybrid I-O are measured as the (i) quantity of i^{th} input per unit of j^{th} output measured in quantity (e_{11}); (ii) quantity of i^{th} input per unit value of j^{th} output (e_{12},e_{13}); (iii) value of i^{th} input per unit of j^{th} output measured in quantity, (x_{21}^*,x_{31}^*), and (iv) value of i^{th} input per unit value of j^{th} output (x_{22}^*, etc.). Only the first two are relevant and meaningful for analysis of energy intensity.

Using Equations (3) and (4), the direct and total (including direct and indirect) energy requirements are specified using the following matrix equations.[2]

[2] Refer Miller & Blair (2009).



Box 1. Comparison between hybrid and standard I-O model.
Note: Illustrative representation for a three sector economy with Sector 1 representing energy sector, while Sectors 2 and 3 are non-energy sectors.
Source: Based on Miller & Blair (2009).

$$A^{*} = Z^{*} \hat{X}^{*-1} \quad (5)$$

$$L^{*} = (I - A^{*})^{-1} \quad (6)$$

3.1 Sectors of Analysis

The energy and energy intensive sectors are identified for the analysis. In order to capture the technology coefficients precisely, sectors with similar production technology are grouped together. While forming a broader group, homogeneity amongst the sectors, in terms of input use and output disposition, is the basic criterion for sector choice. The availability of price indices required to deflate the transaction flows is another important consideration.

The energy sectors are identified as primary and secondary.[3] Renewables such as electricity from hydro and nuclear sources are classified as primary energy. Examples of secondary energy include electricity obtained from coal. The existing studies on India have conspicuously ignored electricity generated from primary sources, particularly hydroelectricity. Further, hydroelectricity generation has a significant share of 26.2% in installed capacity.[4] Hydroelectricity also accounts for 16.7% of the total generation.[5]

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[3] Primary energy generally represents the new energy, generally in the form of extracted resources, entering into the production system. Fossil fuels such as coal, lignite, crude oil and natural gas are examples of primary energy. On the other hand, secondary energy refers to a transformed or processed form of primary (or another secondary) energy.

[4] As on March 2007, *Source:* CEA (2015).

[5] CSO, Energy Statistics (2013, 2014).

Hence, there has been a gap in the existing literature with respect to consideration of primary electricity as a source of energy.

In this paper, we identify three primary energy sectors viz. coal & lignite; natural gas & crude petroleum, and non-thermal electricity. Data on coal & lignite sector is consistently reported in the Input-Output Transaction Tables (IOTTs). However, the natural gas & crude petroleum sector is not comparable over time. Therefore, to keep the sectoral scheme comparable across the years, natural gas & crude petroleum is considered as one sector. Using the input structure from Pal, Ojha, Pohit and Roy (2015), the composite electricity sector is further disaggregated into non-thermal and thermal electricity. The row of composite electricity is split in the proportion of corresponding outputs. It is important to note that electricity output is supplied as a homogenous product (irrespective of the generation source) to other sectors. Thus, it is less important to examine output disposition separately for non-thermal and thermal electricity generation (Pradhan, Saluja & Parida, 2014). Nevertheless, inclusion of primary electricity further helps by providing robust estimates of electricity intensity that account for the contribution of hydro power as a non-fossil resource. The mapping between sectors of analysis and IOTT is presented in Table 1.

The present paper defines energy intensity as the quantity of energy required to produce one unit output of a given sector. Total energy intensity of a sector is the sum of the intensities of each of the three primary energy forms. For the hybrid I-O analysis, energy quantity is measured in million tonne of oil equivalent (mtoe) by using available conversions factors from various energy forms. The conversion factor for coal, lignite, natural gas and electricity is computed separately per unit of output as 0.41, 0.2865, 0.9 and 0.086, respectively.[6] Further, the proportion of non-thermal electricity such as hydro and nuclear electricity is estimated at 21.3 and 16.9% for the years 1993-94 and 2007-08, respectively.[7]

The conversion of a primary energy like coal into secondary energy such as thermal electricity involves loss of energy during the transformation process. The use of conversion efficiencies provides the actual requirements of the primary energy into the system. This is further used to validate the energy conservation equation of the hybrid I-O model. Using the conversion efficiencies for hydro and nuclear power at 85 and 33% respectively, the model conforms to the energy conservation equation for both the years of analysis.[8, 9]

3.2 Time Frame

The analysis refers to the years 1993-94 and 2007-08, benchmarked to the corresponding IOTTs (Central Statistics Office (CSO), 2000; 2012). The base year 1993-94, also signifies

[6] Output of coal and lignite is measured in thousand tonne, natural gas is measured in million cu mtr and electricity is measured in billion kwh. Source: CSO, Energy Statistics (2011).

[7] Ministry of Petroleum and Natural Gas (1993-94; 2010-11).

[8] The conversion efficiency varies across sources of generation due to variations in technology and input use. For instance, conversion efficiency for coal varies from 32-42%, for gas from 33-38%, for oil from 38-44%, for hydro electricity from 85-90% and for nuclear power from 33-36% (Mukherjee, 2012; Eurelectric, 2003).

[9] Conversion efficiencies for coal & lignite and natural gas & crude petroleum sectors as obtained from the I-O based computations are consistent with alternate sources.

Table 1. Mapping scheme with the input-output sectors - disaggregate sectors

S.No	Sector	Sector code	IOTT codes			
			1993-94		2007-08	
1	Coal & lignite	col	023	(1)	027	(1)
2	Natural gas & crude petroleum	oil	024	(1)	028-029	(2)
3	Non-thermal electricity#	nte	part 100	(1)	part 107	(1)
4	Thermal electricity	ele	part 100	(1)	part 107	(1)
5	Agriculture & allied	agr	001-022	(22)	001-024, part 025*, 026	(26)
6	Mining	min	025-032	(8)	030-037	(8)
7	Food, beverages & tobacco	pfd	033-040	(8)	038-045	(8)
8	Paper, paper products & newsprint	ppp	052-053	(2)	057-058	(2)
9	Chemicals, rubber & plastics & products	crp	056-057, 060-068	(11)	061-062, 065-073	(11)
10	Non-metallic mineral products	nmm	069-071	(3)	074-076	(3)
11	Basic metal & metal products	fmp	072-074, 076-077	(5)	077-079, 081-082	(5)
12	Non-ferrous basic metals	nfm	075	(1)	080	(1)
13	Machinery & equipment	ome	078-090	(13)	083-094	(12)
14	Other manufacturing	omf	041-051, 054-055, 091-098, 105-115	(21)	046-056, 059-060, 095-105	(24)
15	Construction	cns	099	(1)	106	(1)
16	Transport services	tpt	103-104	(2)	109-113	(5)
17	Other services	svs	102,105-115	(12)	108, 114-130	(18)
18	Petroleum products	p_g	058, 101	(2)	063, part 025*	(1)
19	Coal tar products	ctp	059	(1)	064	(1)

Includes hydro and nuclear power
* In order to maintain a consistent scheme of sector aggregations across the years, the gobar gas component of forestry & fishing sector is compiled along with the petroleum product sector that includes gasworks.
Note: Figures within parenthesis are the number of sectors aggregated.
Source: Based on CSO, 2000 and 2012.

relevance as the initial year of economic reforms. The sector specific reforms in particular were also introduced around this time. The year 2007-08 as a terminal year points to the importance of second generation reforms in place since the early 2000s, notably the dismantling of the Administered Pricing Mechanism which directly affected the fuel pricing. This had implications on upstream and downstream industries in the economy.

3.3 Deflation Methodology

It is important to deflate the nominal flows in order to obtain energy intensity of a sector. The methodology for deflating the IOTT at 1993-94 base year prices is based on Celasun (1984). This has two advantages. First, it allows for a double deflation through deflating the inputs and outputs using separate deflators. Second, the methodology is useful to convert the nominal technology coefficients directly into real technology coefficients. The conversion process is rather demanding in terms of data requirements as it makes use of separate price indices for gross output, exports and imports which is important to improve the precision of computations. The data are available from Office of the Economic Adviser, Department of Commerce & Industry, Department of Industrial Promotion, Reserve Bank of India and National Account Statistics.

4. Results and Discussion

We initiate the discussion with the analysis of changing energy use across sectors of the economy. The changing composition of the export basket is discussed before we finally analyse energy intensity of the sector-wise exports. The discussion maintains a focus on energy intensity of India's key exporting sectors.

4.1 Changes in Sector-wise Energy Intensity

Energy intensity of each of the 19 sectors is shown in Table 2 for the reference years. Our results on lower energy intensity of Indian manufacturing conform to findings of earlier studies by Goldar (2010) and Sahu and Narayanan (2010) and the increasing importance due to services (Kalirajan, Anbumozhi, & Singh, 2010). Although studies acknowledge that energy intensity of Indian manufacturing has improved over time, the discussion in the paper contributes by not only separately discussing the behaviour of energy intensity for each activity within the broad manufacturing category but also provides a complete

Table 2. Sector-wise energy intensity and export structure.

S.No.	Sector	Energy intensity				Shares in exports (%)	
		1993-94		2007-08		1993-94	2007-08
1	Coal & lignite	1.047469	(3)	1.033650	(4)	-	-
2	Natural gas & crude petroleum	1.024490	(4)	1.056017	(2)	0.2	0.5
3	Non-thermal electricity#	2.546551	(2)	1.042429	(3)	-	-
4	Thermal electricity	3.508195	(1)	1.382745	(1)	-	-
5	Agriculture & allied	0.000011	(19)	0.000006	(18)	6.5	2.9
6	Mining	0.000022	(17)	0.000008	(17)	1.2	5.2
7	Food, beverages & tobacco	0.000023	(16)	0.000012	(16)	5.3	2.5
8	Paper, paper products & newsprint	0.000064	(10)	0.000030	(13)	0.5	0.2
9	Chemicals, rubber & plastics & products	0.000061	(11)	0.000028	(14)	7.8	7.3
10	Non-metallic mineral products	0.000099	(7)	0.000059	(9)	7.3	0.5
11	Basic metal & metal products	0.000092	(8)	0.000110	(8)	3.2	4.5
12	Non-ferrous basic metals	0.000071	(9)	0.000166	(7)	0.5	1.7
13	Machinery & equipment	0.000043	(13)	0.000032	(12)	4.4	4.5
14	Other manufacturing	0.000034	(15)	0.000021	(15)	27.1	14.2
15	Construction	0.000040	(14)	0.000044	(10)	-	-
16	Transport services	0.000059	(12)	0.000034	(11)	10.0	9.2
17	Other services	0.000011	(18)	0.000006	(19)	24.8	38.8
18	Petroleum products	0.000362	(5)	0.000256	(6)	1.2	7.3
19	Coal tar products	0.000316	(6)	0.000425	(5)	-	-

- Insignificant.

Notes: 1. Figures in parenthesis show the sector ranks.
2. Energy intensity of energy sectors (1-4) measured in mtoe per mtoe; for remaining sectors (5-19) in mtoe per mrs (million rupees).

Source: Authors' computations.

economy-wide analysis by including agriculture, processed food, mining, transport, service and energy sectors.

The energy sectors are the most intensive users of energy.[10] Energy intensity of thermal electricity, with highest intensity, decreased mainly due to reductions in coal intensity.[11] This is attributed to adoption of cleaner technologies such as coal beneficiation after coal washing became mandatory.[12] The energy intensity of natural gas & crude petroleum worsened due to non-commensurate drilling results (Planning Commission, 2002). Energy intensity of non-thermal electricity improved due to renovations of the existing plants and recent capacity additions that have better performance efficiency (World Energy Council, 2013). A reduction in energy intensity is also observed for the coal & lignite sector due to improved plant availability from coal beneficiation and reduced transportation from the location of supercritical thermal plants at the pithead location (The Hindu, 2000). Energy intensity worsened for coal tar products, a secondary source of energy, due to below normal levels of performance, widely varying technologies across foundries and low quality of coal (Bhagat, 2002; Ganguly, Rao & Guha, 1933). The petroleum product sector registered a decline in energy intensity primarily due to the improved intensity of crude oil.

The top ranking non-energy sectors in terms of energy intensity include non-ferrous basic metals, basic metal & metal products, and non-metallic mineral products. They constitute the core manufacturing sectors and include many energy intensive industries such as iron, aluminum and cement which provide essential inputs into the downstream purchasing industries e.g. the machinery & equipment for the construction, transport, food processing sectors among others. Energy intensity of the former two sectors is observed to have worsened particularly for the non-ferrous basic metal sector. The non-ferrous basic metal sector includes energy intensive activities such as production of aluminum and products that use coal-based captive plants operating at inefficient levels (Bhushan, 2010). The worsening of energy intensity in the basic metal sector is mainly due to low quality coal used in the iron and steel industry despite the replacement of traditional methods with the newer direct reduced iron (DRI). At the same time, a relatively low share of steel production from scrap explains higher energy intensity. Energy intensity decreased for the non-metallic mineral sector which includes cement production. This is due to lower intensity of both coal and electricity use (Planning Commission, 2002; IBEF, 2013a). Changes in the construction sector are relatively insignificant.[13] Energy intensity of the transport services improved due to fuel substitution towards CNG and increasing use of diesel which benefits from cross subsidisation (EBTC, 2013). Also, lower intensity

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[10] Energy intensity refers to total energy intensity including the direct and embodied energy intensity of a sector.

[11] Improvement in energy intensity of a sector means lower requirement of energy to produce one unit of output. Thus, decreasing energy intensity is considered an improvement in energy intensity. Similarly, increasing energy intensity is considered as worsening of energy intensity.

[12] The Ministry of Environment and Forests notified that power stations beyond 1000 km radius form the coal sources and located in sensitive, residential and urban areas must use coal with ash content not in access of 34%. This mandated washing of coal.

[13] Steel production from scrap is less energy intensive as compared with that from the raw material. In India, the share of scrap-based steel production has been at 18% as compared with 33% in the world during 2007 (Trudeau, Tam, Graczyk, & Taylor, 2011).

of coal is a result of increasing electrification and dieselisation of Indian railways. The decrease in energy intensity of machinery & equipment is due to mixed behaviour of intensity of various energy inputs (Sahu & Narayanan, 2010). The lowering of energy intensity in the paper & paper product sector is attributed to integrated mills that make use of recovered heat from the production process in ancillary activities such as drying of paper. The decline in energy intensity of the chemicals, rubber & plastics is on account of the substitution and change in feedstock from coal-based naphtha to natural gas for production of ammonia in the fertiliser industry (IRADe, 2007). The improved energy intensity of the other manufacturing sector is due to technology changes. This sector includes various production activities such as the textile and apparel industry which upgraded technology due to modernisation and investment promotion. The government initiatives for technology improvements include the National Textile Policy and the Technology Upgradation Fund Scheme (TUFS) (IBEF, 2013b; Mukherjee & Mukherjee, 2012). The food processing sector registered a decline in energy intensity from greater use of refinement equipment such as driers that use agricultural residue, by-products and solar energy (Kachru, 2010). The use of energy efficient furnaces in the sugar processing industry has also contributed to lower direct energy requirements of the food processing sector. For instance, steam consumption has declined from 60-70% to 35-40% in the sugar processing industry (Rao, 2014). The lower energy intensity of the mining sector is primarily due to lower electricity intensity, a result of using efficient heavy earth moving machinery such as power shovels for improved drilling precision in the extraction of ores (Jayanthu, Rammohan, & Chandramohan, 2014). The agriculture sector shows marginal improvements. The improved energy intensity of the service sector is a result of energy saving measures and technology improvement that increase profitability of the business (BAIN, 2013).

Our findings from the sector-wise energy intensity are consistent with those noted by Goldar et al. (2011). The energy sectors are the most energy intensive sectors. This is obvious due to self consumption in primary energy sectors and the use of feedstock or raw material in the secondary energy sectors such as thermal electricity and petroleum products. The manufacturing sectors lead with highest energy intensity among the non-energy sector. Among these, the non-metallic minerals (e.g. glass and cement), basic metals & products (e.g. iron and steel), and non-ferrous (e.g. aluminum) have the highest energy-use intensity. The production system in these sectors is also resource intensive. Within manufacturing, the energy intensity of 'other manufacturing' is found to be the least. This is due to the aggregation of relatively less intensive activities such as textiles including handlooms with almost insignificant carbon footprint, readymade garments, carpet weaving, gems & jewellery. These sectors are important due to their high employment potential, particularly for the low skilled labour activities. The energy intensity of non-transport services is observed to be low. These include banking, financial, hospitality, health, education and other services which have a widely varying skill content from highly skilled labour force of the IT and ITES sectors to the semi-skilled drivers and cooks employed in the tourism sector. The agriculture and mining sectors are least energy intensive although they are resource intensive in nature mainly employing an unskilled labour force.

4.2 Changing Structure of India's Exports[14]

During the reference period from 1993-94 to 2007-08, India's export structure transformed, with services expanding from nearly one-third to almost half of the total exports (Figures 1a and b). The growth is attributed to an increase in exports of high value non-transport services that are primarily software exports (IT) and business process outsourcing (ITES) which include the call centre operations. India's early exports of software were in the form of onsite programming. However, the firms quickly established a global reputation and moved to higher value-added exports through offsite consultancy, system integration and management services to more than 60 countries (Bhatnagar, 2006). But the growth and trade behaviour of services also varied (Banga, 2005). The service sector initially benefited from the lack of an integrated policy for the sector. It is a success story of private initiatives with a supporting role played by the government through provision of exemptions and tax holidays, etc.[15]

The expansion in service exports occurred at the cost of manufactured exports with a corresponding decline in export share from 56 % to 35% over the period. The manufacturing sector remains regulated despite overall de-licensing of the industry and continues to be constrained by inflexible labour laws that thwart private sector participation in world markets, differential benefits based on firm size and infrastructure bottlenecks. Lack of demand-based product diversification also prevents manufactured exports from taking off in the world market (Prasad, Satish, & Singh, 2014). Participation in RTAs subjected specific products to an inverted duty structure which prevented the growth of domestic

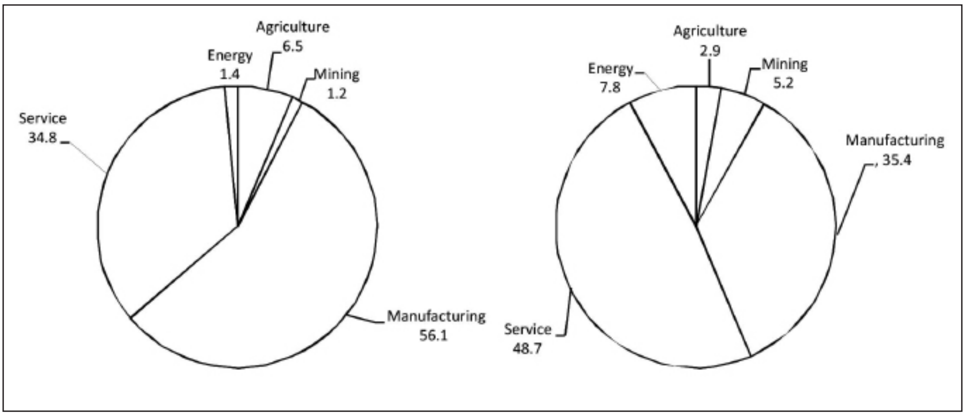

Figure 1a. Export structure, 1993 **Figure 1b.** Export structure, 2007

Note: Computations of export shares based on nominal price IOTTs.
Source: CSO (2000, 2012).

[14] Although available from alternate sources such as Directorate General of Commercial Intelligence and Statistics (DGCI &S), World Integrated Trade data (WITS), we analyse the export structure based on CSO to maintain comparability between sectors for which energy intensity has been computed.

[15] In 1998, the government ended the Internet monopoly and opened the domestic long distance gateway to private operators while the international long distance gateway was opened in 2002. This provided better bandwidth for software operations.

manufacturing, which in turn affected export growth in these categories. For instance, domestic production of aluminum products, capital goods, chemicals, electronics, steel, textiles and tyres suffered due to lower tariffs on finished goods *vis-à-vis* raw material imports. A large part of manufactured exports belongs to the low technology category which includes light machinery, textile, apparels and gems & jewellery (Anand, Kochhar, & Mishra, 2015). In addition, India's exports of textiles and leather have cost disadvantages in comparison to LDCs such as Bangladesh that benefit from duty free access. Despite the increase in exports of medium and high technology products, India's performance is relatively low compared with other emerging markets. The medium technology exports from India include chemicals, intermediate inputs for manufacture of automobiles, construction and mining industries. The high technology manufactured exports include pharmaceuticals, telecommunication transistors, and equipment for aircrafts, power and the automobile industry.

During the period, the energy sector saw significant expansion in exports due to growing exports of petroleum products. The increasing private sector participation in petroleum refining has made India an important exporter of petroleum products. While the efficient refineries such as the Jamnagar refinery have contributed towards India's becoming a refining hub. The presence of countries with a large demand such as Japan, South Korea and China in the neighbourhood have also contributed to a rise in exports of petroleum products. At the same time, regulated domestic markets make it more profitable to export petroleum products (Goldar et al*.,* 2011).[16] The export potential of electricity is very low, due to both domestic shortage as well as difficulties in transmission. Exports from the remaining energy sectors namely, coal & lignite, natural gas & crude petroleum, and coal tar products are also insignificant.

The export performance of primary sectors such as agriculture has been constrained by both lack of stable export policy for agricultural products and domestic shortages (Prasad et al., 2014). Major issues include a continued skewed cropping pattern, cost inefficiencies resulting from small farm size, fragmented supply chain which also adds to wastage, inadequate transport, storage and processing infrastructure. Although the share of mining exports increased over time, the sector faces supply constraints due to mining restrictions. Mining products such as low grade iron ore which have a low domestic demand, have a huge export potential to countries with a high demand such as China. However, high export taxes and additional freight cost add to exporters' cost.

Thus, India's export growth is lopsided with the expansion of service exports along with a contribution from the energy sector. However, this comes with a pinch of salt. Despite its star performance, the service sector has limited employment opportunities for unskilled labour. The export significance of the tertiary sector (i.e. services) occurred at the cost of contraction in exports shares of the secondary (i.e. manufacturing) and primary (i.e. agriculture) exports. And, the export achievement of the energy sector, although encouraging, is on account of increasing imports of crude oil, which cannot be discounted due to the effect on balance of payments. However, manufactured exports are important for the following reasons: (i) as the key to reduce merchandise trade deficit (Sekhani, 2015); (ii) vast employment potential to absorb the unskilled labour force

[16] However, this expansion is on the strength of high imports of crude oil.

presently locked in the low-wage agriculture in addition to the multiplier effect for job creation in services (IBEF); and (iii) a disproportionately large contribution to lower energy intensity when compared with the energy sector which has the highest energy intensity but a relatively lower share in both output and exports (Helper, Kruegar, & Wial, 2012).

Typically, the manufacturing sectors include the non-primary sectors, other than agriculture and mining. Due to their longer and nested supply chains, compared with primary agriculture and extraction industries in the mining sector, manufacturing sectors tend to be indirect users of energy. The observations are confirmed by high total energy intensities of the manufacturing and processing sectors, next only to the energy sectors of the economy as also indicated by other studies (Lin & Sun, 2010; Goldar et al., 2011). Therefore, it becomes necessary to consider the energy implications of policy encouragement to the manufacturing sector. The following sub-section has a similar focus.

4.3 Energy Intensity and Export Structure

In view of globalisation as a source of economic growth and the tradeoff between growth and environment, it has become essential to study the effect of trade on environment. The effects of trade on economics can be positive and negative. Positive effects occur if trade, particularly exports, encourages technology innovation and compliance with environmental norms. On the other hand, circumvention of environmental regulations, due to increased costs from use of efficient technology can lead to negative effects (Frankel, 2009). Thus, even though exports are often hailed as an engine of economic growth, there could be an environmental externality attached. The concept of sustainable growth emphasises the need for sustainable development to meet the growing energy requirements with minimum externality for the environment and ecology. Therefore, in the context of exports as a growth driver, it becomes important to evaluate the energy intensity of different exporting sectors.

Among the highly energy intensive sectors, petroleum products emerged with a significant export presence during the period (Figure 2). Exports of petroleum products are cost competitive due to lower manufacturing wages, low capital and cash operating costs, and access to a skilled workforce (Khan, 2011). Although the sector itself has high energy intensity, the same improved during the period. In fact improved intensity of petroleum products, as a result of the rapidly changing technology, is also indicative of the cost competitiveness that has been driving exports. Thus, petroleum products face a ropewalk due to cost advantage and the energy intensive nature of the exports as also suggested by Goldar et al. (2011). However, it is also necessary to note that the export surplus is jointly due to increased availability of crude oil from the improvements in domestic refining and increased imports. Increasing outflows of energy, which are on the strength of imports, underscore the need to assess the net energy liability from the sector and from country at an aggregate level. In fact, accounting for energy outflows in exports of petroleum products can be instrumental in shaping India's energy balance with the bilateral trade partners.

Within the broad manufacturing sector, the export significance of each of the less energy intensive sectors declined during the period. This includes paper, paper products & newsprint; machinery & equipment; chemicals, rubber & plastics and products; other manufacturing, and food, beverages and tobacco. While improved intensity is a good

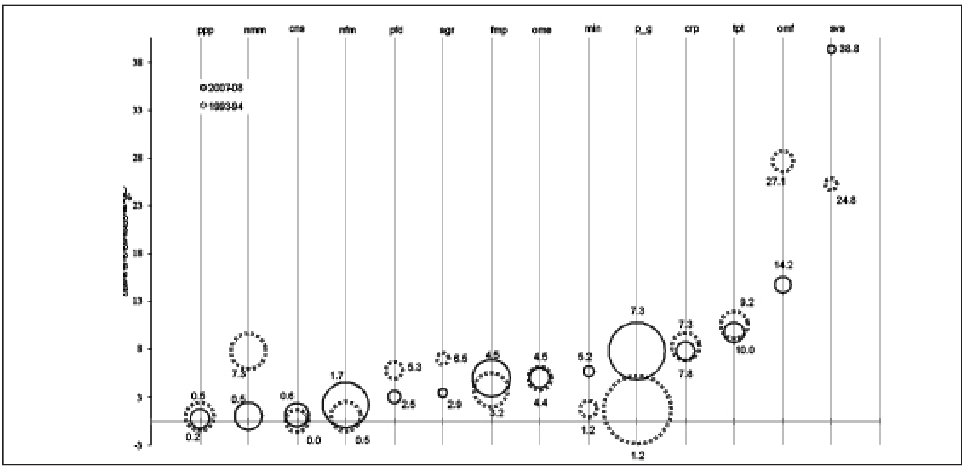

Figure 2. Sector wise energy intensity and export shares

Notes: 1. Sector description: ppp- paper, paper products & newsprint; nmm- non-metallic mineral products; cns- construction; nfm- non-ferrous basic metals; pfd- food, beverages & tobacco; agr- agriculture & allied; fmp- basic metal & metal products; ome- machinery & equipment; min- mining; p_g- petroleum products; crp- chemicals, rubber & plastics & products; tpt- transport services; omf- other manufacturing and svs- other services. 2. Sectors are indicated along the horizontal axis from left to right in increasing order of export shares during 2007-08.
Source: Authors' computations."

signal of lower energy content of overall exports, the failure to expand exports of this sectors indicates a missed opportunity to introduce more environmentally favourable products in the basket of exports. At the same time, two of the three most intensive manufacturing sectors *viz.* basic metal and metal products and non-ferrous basic metals, increased in export significance alongside worsening of respective energy intensity. The basic metal sector is predominantly characterised by the iron and steel industry which is yet to adopt advanced production technology (Biswas, Banerjee, Kumari, Choudhary, & Kukreja, 2014). Similarly the non-ferrous basic metal sector, which includes products of metals such as aluminum, also faces a technology challenge. Efficiency in production can be increased through domestic innovation. Industries in these sectors benefited from the changing industrial policy which encouraged private participation, provided exemption from compulsory licensing, prioritised automatic approval for foreign equity and facilitated trade, which in turn has led to increased exports. Therefore, promotion of the products will increase energy intensity of the export basket as also underscored by Goldar et al. (2011). The other sector, *viz*. non-metallic minerals, registered diminishing exports although the energy intensity improved. The decline in exports is due to falling cement exports owing to rising domestic demand. Cement exports are also limited due to the low value high density nature of the product despite a free trade environment. Improved energy intensity is a result of state-of-the art equipment and use of alternative fuels, e.g. agro and plastic wastes in the kiln.

Although exports of construction services are insignificant, transport services have an export potential through the movement of cargo goods by air or sea route. In view of declining and lowest energy intensity of other services (including IT and ITES), and the increasing export share of other services, it is clear that India's total exports have turned environmentally friendly.

The primary sectors namely, agriculture and mining have low energy intensities but high export potential due to the resource rich and wide cropping nature of Indian agriculture. The significance of agricultural exports has also been underscored by Goldar et al. (2011) in view of the export potential in a competitive sector with relatively low emissions. The corresponding low export shares hint towards opportunities for export expansion in a resource-rich country in sectors with low energy requirements.[17] India's agricultural exports exhibit revealed comparative advantage as also indicated by the larger share in world agricultural exports compared to India's manufactured exports (Goldar et al., 2011). Although the composition of agricultural exports changes with global opportunities and domestic trade policy, exports are dominated by rice (basmati), marine products, oil meals, spices, sugar, and cotton. Agri-exports have tremendous export potential which can be useful to balance merchandise deficit without increasing energy intensity of the overall exports as also mentioned by Goldar et al. (2011). Despite being one of the leading food producers of the world, the performance of India's food processing sector is disproportionately low due to constraints such as poor infrastructure needed for transportation, high wastage due to poor, inadequate and obsolete storage facilities and supply chain inefficiencies. Nevertheless, specific processed products e.g. dried and preserved vegetables, exhibit comparative advantage and export potential. Exports from the mining sector primarily comprise iron ore, alumina and chromite. Although the energy intensity of the mining sector is low, the associated changes in land use should also be considered for their environmental impacts from the associated activities such as change in land use and air pollution and water used in washeries.

While Figure 2 is helpful to analyse the changing energy intensity along with the transformation of the export basket, it must be noted that an intensive sector with relatively low export share, e.g. petroleum products, could contribute to neutralise the advantage from the significant exports of the less intensive services such as services. Therefore, the overall energy content of the export basket should be assessed by considering the quantum of exports. This is, however, beyond the scope of the present work.

Nevertheless, the present study contributes by analysing the sector-wise energy intensity of India's export basket. The analysis clearly highlights the presence of services as a less energy intensive sector with significant export presence. In fact, the analysis in the paper contributes by observing the lower energy intensity of India's exports. The sector-level analysis is useful to highlight potential of the less emissive manufacturing sectors through export expansion at lower environmental costs. This is in contrast to the key finding of Amador (2011) on the increasing content of India's manufacturing exports. The difference is attributed to the use of real flows in the present paper as compared with the approach of deviations in nominal flows used by Amador (2011). Within manufactured products, particularly important are other manufactures such as textiles and apparel, along with agriculture, processed food and mining, due to the export potential alongside improved energy intensity. At the same time, increasing intensity and export share of

[17] The low shares of agricultural exports in a specific year also reflect poor global demand due to high prices and domestic shortages due to sudden natural calamities.

basic metals and non-ferrous metal products draw attention for further efforts to improve energy efficiency.

5. Conclusions

This paper analyses the changes in sector-wise energy intensity along with the evolving export structure to assess the energy intensity of India's exports.

The changes in export structure highlight the significance of the relatively less energy intensity in services exports along with a growing contribution from petroleum products as energy intensive exports. Exports of manufactured goods and primary sectors, *viz.* agriculture and mining, lag behind in terms of contribution in the export basket. The predominance of services is not necessarily heartening in view of the relatively low employment potential when compared with the manufacturing sector. There is, however, a silver lining to the cloud when the export structure is viewed from the energy intensity perspective. Incidentally services with high export shares, including IT and ITES, have low energy intensity. This results in a high proportion of exports in the least demanding sectors in terms of energy. With the increase in service exports, energy intensity of GDP is expected to fall, as also recognised by Kalirajan et al. (2010) while measuring environmental impacts of trade. The manufacturing sectors, which are relatively energy intensive, exhibit low export performance. At the same time, two core manufacturing sectors which are also highly energy intensive have strengthened their export presence. The energy intensity of exports due to the growing significance of petroleum products can be discounted by considering strong import dependence. The findings reject the proposition that India's export basket is dominated by energy intensive sectors. However, this is not the consequence of a conscious attempt to lower the energy intensity of India's export basket, by encouraging services at the cost of manufacturing activity. This is an unintended implication of the regulations on the manufacturing and agricultural sectors which have prevented these sectors from unleashing the true export potential.

Given the relatively high energy intensity in core manufacturing sectors, it is important to point out that future policy for manufacturing growth could have a contrary effect on the related emissions from increased exports. Particularly, if the policy focus is on increasing exports of the core manufacturing without emphasising improvements in efficiency or technology. As the country endeavours to indulge in more value-added production and prepares to strengthen foothold in the world export markets, energy efficiency parameters attain greater importance. Efficient and low energy use not only increases cost competitiveness but also supports environmental compliance, both of which can be challenging for Indian manufacturing. This is particularly important in view of the increasing emphasis on regionalism through the proposed agreements, such as Trans-Pacific Partnership (TPP) and Trans-Atlantic Trade and Investment Partnership between the EU and the US (TTIP), which tend to restrict or discriminate access to the non-member countries.

Therefore a balanced approach is required which, on one hand, would expand the manufacturing industries benefiting from abundant domestically available resources, and on the other hand would encourage efficient production through continuous adoption of better technology and substitution to alternate fuels and raw materials.

The manufacturing sector includes an array of production activities that range across labour intensive industries - textiles, readymade garments and leather industries - to skill intensive sectors such as the gems & jewellery sector and transport equipment. Within these, the energy intensity of textiles is relatively low as compared with the manufacture of transport equipment. Encouragement to textiles exports will not only enhance India's low polluting exports but also generate income and employment to many unskilled labourers in the industry.

India is among the top global producers of fresh fruits, rice, wheat, fresh vegetables, sugarcane and cotton lint, among others. The existing strength in the agriculture sector, which has modest energy intensity, should be turned into an export opportunity that would make the farmer richer at the least cost to environment.

Although the mining sector has low energy intensity, the associated environmental impact in the form of deforestation, soil erosion, water and air pollution can be severe. At the same time, extraction of ores is crucial as a raw material input for both industry and the energy sector itself. Any policy recommendation for export promotion should be made after due diligence on the environmental impact along with resource requirements of the domestic industries.

To sum up, India's export structure is skewed with services which are comparatively less energy intensive. Predominance of low energy intensive sectors in the export basket perhaps refutes the pollution haven hypothesis for India. Textiles and agriculture are the visible opportunities for strengthening exports in the relatively less energy intensive sectors of the economy, which have also registered efficiency improvement in energy use. Exports from such sectors will help to balance India's foreign trade balance in the relatively less emissive sectors alongside their cost advantage, employment potential and domestic resource availability. However, a complete assessment including the import structure is suggested for evaluating the net energy liability of the country as an area for future work. Also, promotion of the core manufacturing sectors will have implications in terms of increasing energy intensity of the overall basket of exports. At the very least, technological improvement is a distinct option in such sectors which need to be balanced in export competitiveness *vis-a-vis* environmental competitiveness.

References

Anand, R.. Kochhar, K., & Mishra, S. (2015). *Make in India: Which exports can drive the next wave of growth?* IMF Working paper no. WP.15/119.

Amador, J. (2011). *Energy content in manufacturing exports: a cross-country analysis.* Working paper 10, Banco de Portugal, NOVA School of Business.

BAIN (2013). *Helping businesses become more energy efficient*. Bain and Company.

Banga, R. (2005). *Critical issues in India's service-led growth.* Working paper no. 171, Indian Council for Research on International Economic Relations.

Bhagat, R. P. (2002). *Coke making from coal: Scope for SSI.* Retrieved from *http://eprint.nmlindia.org/6641*

Bhatnagar, S. (2006). India's software industry. In V. Chandra (Ed.), *Technology, adaptation and exports: How some developing countries got it* (pp 95–124). World Bank.

Bhattacharjya, S., & Nanda, N. (2012). *Potential impact of carbon barriers to trade: The case of India's exports to the US under border tax adjustment.* TERI-NFA Working paper no. 3, The Energy and Resources Institute. Delhi.

Bhushan, C. (2010). Aluminium. In *Challenge of the new balance*, Chapter 3. Centre for Science and Environment, pp. 57–66.

Biswas, P. K., Banerjee, P., Kumari, R., Choudhury, A., & Kukreja, P. (2014). *Industry structure and the pattern of innovation: Basic metal industry of India. Council of Scientific and Industrial Research, National Institute of Science, Technology and Development Studies.* Delhi.

Celasun, M. (1984). *Sources of industrial growth and structural change: the case of Turkey.* Staff Working paper SWP614, World Bank.

Central Electricity Authority (2015). *Executive Summary*, *Power Sector*. Ministry of Power, Government of India.

Central Statistical Office (Various years). *Energy statistics.* Ministry of Statistics and Programme Implementation, Government of India.

Central Statistical Organization (Various years). *Input-output transactions table.* Ministry of Statistics and Programme Implementation, Government of India.

Copeland, B.R. (2000). Trade and environment: Policy linkages. *Environment and Development Economics, 5,* 405–432.

Cui, L. B., Peng, P., & Zhu, L. (2015). Embodied energy, export policy adjustment and China's sustainable development: A multi-regional input-output analysis. *Energy XXX*, 1–11.

Eurelectric (2003). *Efficiency in electricity generation. Union of the Electricity Industry* - Eurelectric, VGB. Brussels.

European Business and Technology Centre (2013). *Transports and energy in India.* Torino.

Frankel, J. (2010). *Environmental effects of international trade.* Expert report no. 31 to Sweden's Globalisation Council, Harvard Kennedy School, Harvard University.

Ganguly, S.K., Rao, B.S., & Guha, P.C. (1933). Indian coal tar. *Journal of Indian Institute of Science, 16*, 185–192.

Goldar, A., Bhanot, J., & Shimpo, K. (2011). Prioritizing towards a green export portfolio for India: An environmental input-output approach. *Energy Policy*, *39*, 7036–7048.

Goldar, B. (2010). *Energy intensity of Indian manufacturing firms: effect of energy prices, technology and firm characteristics.* Institute of Economic Growth. Delhi.

Helper, S., Krueger, T., & Wial, H. (2012). *Why does manufacturing matter? Which manufacturing matters? A policy framework.* Brookings, February. Washington D.C.

Heredeen, B.A. and Bullard, C.W. 1976 US Energy balance of trade. *Energy Systems and Policy,* 1(4),383–390.

Huichao, Y.U. & Wang, L. (2010). Carbon emission transfer by international trade: Taking the case of Sino-U.S. merchandise trade as an example. *Journal of Resource and Ecology*, *1*(2), 155–163.

India Brand Equity Foundation (2013a). *Cement.* Cement sector report. August. Delhi.

India Brand Equity Foundation (2013b). *Textiles and apparel.* August. Delhi.

India Brand Equity Foundation (n.d.). *Role of manufacturing in employment generation in India*. Retrieved from http://www.ibef.org/download/Role-of-Manufacturing-in-Employment-Generation-in-India.pdf.

IRADe (2007). *Natural gas demand by Indian fertiliser sector*. Delhi.

Isabel, M. B., Jacob, J., & Wang, L. (2015). Energy consumption and exports: An analysis of high-tech exporters in China. Paper presented at DRUID15, Rome, June 15-17.

Jayanthu S., Rammohan, P., & Chandramohan (2014). *Technological innovations in coal mining industry.* Conference paper at the 29th Indian Engineering Congress. December. Hydrabad.

Kachru, R. P. (2010). *Agro-processing industries in India- growth, status and prospects*, January. Retrieved from http:/*/www.panelamonitor.org/media/docrepo/document/files/agro processing-industries-in-india-growth-status-and-prospects.pdf*

Kalirajan, K., Anbumozhi, V., & Singh, K. (2010). *Measuring the environmental impacts of changing trade patterns on the poor*. Working paper No. 239, ADBI.

Kejun J., Cosbey, A., & Murphy, D. (2008). *Embodied carbon in traded goods*. Background paper, Energy Research Institute, China, Climate Change Seminar June 18–20, Copenhagen, Denmark.

Kellogg, R. (2007). *The pollution haven hypothesis: significance and insignificance.* Working paper, Berkley.

Khan, M. (2011). Petroleum Products Import & Export – Indian Option. Presentation accessed at *www.slideshare.net/MuzahidKhan/petroleum-products-import-export-indian-option,* Published online April 19.

Leontief, W. (1936). Quantitative input and output relations in the economic system of the United States. *The Review of Economic and Statistics*, *18*, 105–125.

Li, L. (2014). Empirical research on the relationship between China export and new energy consumption. *International Journal of Energy Economics and Policy*, *4*(2), 229–237.

Lin, B., & Sun, C. (2010). Evaluating carbon dioxide emissions in international trade of China. *Energy Policy*, *38*, 613–621.

Miller, R. E., & Blair, P. D. (2009). *Input–output analysis foundations and extensions*. 2nd ed. Cambridge: Cambridge University Press.

Ministry of Petroleum and Natural Gas (Various years). *Indian petroleum & natural gas statistics,* Government of India.

Mukherjee, S. (2012). Environmental costs of coal-based thermal power generation in India: Notion and estimation. In Mukherjee, S. & Chakraborty (Ed.), *Environmental Scenario in India* (pp. 100–118). Oxon: Routledge.

Mukherjee, S. & Mukherjee, S. (2012). *Overview of India's export performance: Trends and drivers.* Working paper no. 363, Bangalore: IIM.

Nnaji, C. E., Chukwu, J.O., & Nanji, M. (2013). Does domestic energy consumption contribute to exports? Empirical evidence from Nigeria. *International Journal of Energy Economics and Policy*, *3*(3), 297–306.

Neumayer, N. (2001). Pollution havens: An analysis of policy options for dealing with an elusive phenomenona. *Journal of Environment & Development, 10*(2), 147–177.

Pal, B. D., Ojha, V. P., Pohit, S., & Roy, J. (2015). *GHG emissions and economic growth, a computable general equilibrium model based analysis for India*. India: Springer.

Peters, G.P., Minx, J.C, Weber, C.L., & Edenhofer, O. (2011). *Proceedings of the National Academy of Sciences of the United States of America, Early Edition, 108 (21), 8903-8908,* Washington. doi: 10.1073/pnas.1006388108.

Planning Commission (Various years). *Five year plan,* Government of India.

Pradhan, B.K., Saluja, M.R., & Parida, Y. (2014). A social accounting matrix for India, 2005-06. *Research in Applied Economics*, *6*(1), 176–201.

Prasad H. A. C., Sathish, R., & Singh, S. S. (2014). *India's merchandise exports: Some important issues and policy suggestions.* Working paper no. 3/2014-DEA, Ministry of Finance, Government of India.

Rajput, N., Bhutani,S., & Kumar, R. (2014). Contribution of net exports to economic growth of India - An empirical study. *Research Journal of Economics & Business Studies*, 3(5),34–42.

Rao, G.S.C. (2014). *What is to be learned from the Indian sugar industry.* Presentation at the 3rd India Sugar Expo, Surabaya, Indonesia, May 21-22.

Ray, S. (2011). A causality analysis on the empirical nexus between export and economic growth: Evidence from India. *International Affairs and Global Strategy*, *1*, 24–38.

Sahu, S.K. & Narayanan, K. (2010). *Decomposition of industrial energy consumption in Indian manufacturing: The energy intensity approach.* MPRA paper no. 21719. Assessed online at https://mpra.ub.unimunchen.de/21719.

Sekhani. R. (2015). *Tackling India's trade deficit with China,* Associate paper, Future Directions International, 23 April. DAL Keyth, Australia.

SEPA (2006). *China's 11th five-year plan for environmental protection*. Retrieved from *www.sepa.gov.cn/plan/hjgh/sywgh/.*

Su, B., And, B.W., & Low, M. (2013). Input–output analysis of CO2 emissions embodied in trade and the driving forces: Processing and normal exports. *Ecological Economics*, *88*, 119–125.

Tandon, A., & Ahmed, S. (2015). Decomposition of energy consumption in India: A case of output leakage and technology improvement. *Review of Development and Change*, *XX* (1), 81–98.

The Hindu (2000). It's more than power…it's ash. Online edition, 15 January.

Trudeau, N., Tam, C., Graczyk, D., & Taylor, P. (2011). *Energy transition for industry: India and the global context*. Information paper, International Energy Agency. Paris.

Tsen, W. H. (2006). China exports and growth. *Review of Development Economics*, *14* (3), 625–639.

Wagner, G. (2010). Energy content of world trade. *Energy Policy, 38*, 7710–7721.

World Energy Council (2013). *World energy resources: Hydro.* Chapter 5. London.

Zheng, Y., Qi, J., & Chen, X. (2011).The effect of increasing exports on industrial energy intensity in China*. Energy Policy*, *39* (5), 2688–2698.