**Technology transfer, economic development and carbon emissions – an Input-Output analysis for India**

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Abstract

This paper attempts to answer the question what will be the implication of technology transfer in Indian economy, if the comparatively developed countries made their technology freely accessible by India? To find a suitable answer we have adopted input-output model and simulate it with various technologies for various selected sectors. Here technologies are sourcing from top 9 countries in terms of their GDP. Results of this study show that the technology from Japan for electricity, gas and water supply sector is most preferable as it results rise in GDP and employment along with substantial fall in GHG emissions, and acidification. Further this study has identified most efficient technologies for the emission intensive sectors keeping in view the issue of border carbon tax on carbon contents. Finally, we have shown the combined effects of technologies on Indian economy and pre requisite conditions for its successful outcome. In this context this study has argued that service sector led growth and creation of renewable energy infrastructure will be crucial to reap maximum possible benefit from technology transfer.

*Keywords: Technology Transfer, Carbon mitigation, Carbon tax, Input-output model, Economic development*

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1. **Introduction**

Controlling carbon emissions without restricting economic development is common but differentiated responsibility of all the countries across the world. In connection to this, the provision of technology transfer became central part of international climate change negotiation held in Bali in December 2007 (Barton, 2008). The Bali ‘Road Map’ agreed in December 2007 by the parties to the UNFCCC makes technology one of its pillars, and calls for enhanced action on technology development and transfer. But no such outcome has come even in the recent climate change negotiation held in Warsaw in 2013. The major cause of this disagreement is compensation demand by the late industrializing economies.

Given this background, question may arise here that, even if the developing countries get access of efficient technologies, will it be worthwhile for them to achieve their sustainable development agenda? Further which technology for which sector is also another crucial question in this context. These questions are relevant in the sense that the technology does not determine only the amount of energy use, it also determines the level of material input use; labour; and capita input use in the production process. Therefore, technology determines the type of linkages among various economic activities, which in turn determines the level of economic growth, employment generation and environmental pollution etc. Since, unemployment; poverty; and low economic growth are major policy challenges for Indian economy, the above mentioned questions are also relevant for the Indian economy.

However, the expert committee report prepared by IPCC in the year 2000 on technology transfer has highlighted only the GHG mitigation issue and the other socio economic consequences of this technology transfer is missing and needs a clear understanding. In this context, study by Nishimura (2003) has analyzed the welfare implication of technology transfer from Japan to Philippines to determine the optimum schedule of technology for Philippines. On the other hand, Pablo et.al (2012) have done an analysis on impact of technological change on GHG emissions and economic growth for the Mexican economy. In this study, authors have replaced highly emission intensive technology of Mexican economy with the low emission intensive technology of Canada. But, the scope of these above studies is limited to a single source of technology i.e. from Japan for the first study and Canada for the second. Whereas technology may be sourced from other countries and they may have different level of welfare implications.

Apart from the above studies the issue of technology transfer in policy research has been acknowledged by many other researchers across the world. For example, the study by Pachamuthu (2011) has analyzed the potentiality of technology transfer at industry level together for China, Korea, Japan, Singapore, Malaysia, UK, Germany, USA and Brazil. Another study by Damijan et.al (2003) has analyzed FDI as one of the route for technology transfer and further this study has also analyzed spillover effect of technology transfer. But these studies do not include environmental implications of technology transfer in their study.

On the other hand there is no such study available for India to understand the source of technologies and their implications on both socio-economic and environmental indicators for India. Therefore, our objective in this study is to bridge that knowledge gap and provide an analytical input to the policy makers for their future policy making process for India.

Following this introductory section rests of this paper is organized as follows. The section 2 describes methodology, assumption and method of data estimation for the IO model for Indian economy. Section 3 describes key findings from the model and section 4 describes conditions for successful implementation of the technology transfer. Finally section 6 describes major concluding remarks of this study.

1. **Methodology**

Since the Leontief Input-Output coefficients describe the technology pattern of an economy; this method is power full to understand inter industry relationship, technology pattern and associated input use. Again, the input output multiplier model helps to understand economy wide impact of any exogenous changes in the economy. Given these advantages of IO model, the above mentioned studies by Nishimura (2008) and Pablo (2012) have applied IO framework for their analysis. Therefore, in this study we have chosen IO model as the method of our analysis.

In this study, we have used latest Input-Output tables from some selected developed and developing countries and a cross country comparison has been performed to understand technological pattern and carbon emission for various economies. Finally, the sector specific input output coefficients have been used for simulating input output model to see the implication of technology transfer on key economic indicators of India.

Again as the input-output model is a demand driven model, the implication of technology on output supply and thereby on gross domestic product (GDP) of the economy will depend on level of final demand of the Indian economy. Therefore to understand the implication of technology transfer into Indian economy we have developed an input-output model for India by considering 2009 as base year and final demand as exogenous driving factor of the Indian economy. The detail structure and method of dynamic model are borrowed from the articles by (Leontief (1936); Pradhan et.al (2006); Manne & Rudra (1965)). Below we have given a brief description of the IO model as described by those authors.

**2.1 Input Output Model and its assumptions**

Since final demand changes over time and hence the level of investment of the economy, a dynamic IO model would be more suitable to understand implication of technology transfers on the economy. In this context, the dynamic Input-output Model DIMITRI (Dynamic Input-output Model to study the Impacts of Technology Related Innovation) prepared by Idenburg and Wilting in the year 2000 for Netherlands is more suitable. But not much data regarding capital stock, capacity utilization, investment and depreciation rates per sector are available for Indian economy to do such analysis. Therefore we have considered actual change in sector specific final demand and investment between 2009 and 2011 as exogenous to see the implication of technology transfer on Indian economy under different situation of the final demand and investment level of the economy. The detail description of the model is described below.

Let XM be the vector of composite output of n number of sectors, A be the n x n inter-industry coefficient matrix, I be the n x n identity matrix, and finally F be the n x 1 final consumption vector excluding import.

Then the IO model can be derived as,

XM = X + M, where X = domestic output vector and M = Import vector (1)

XM = (I – A) -1 F (2)

Where, ‘F’ vector consists of consumption, investment and export.

Now M = m \* XM (3)

Where, ‘m’ is n x n import coefficient matrix.

The model described by equations (1), (2) and (3) help us to estimate the level of output corresponding to the given level of final demand and capacity (investment level) of the economy corresponding the base year of this analysis i.e. year 2009 in this case. So if we simulate this model by changing technical coefficient in ‘A’ matrix, the solutions of will give the deviation in level of output due to technology transfer to India. However, to do the simulation using IO model we have to understand the underlying assumption of this model in this study and these are described below.

1. Every production process is operating under excess capacity and price has no role in the IO multiplier process
2. Due to this first assumption, we have assumed technologies are freely accessible by India, but the choice depends on their implication on the economy.
3. Technology transfer implies complete diffusion of technology and hence the IO coefficient will vary for different technology corresponding to different sectors.
4. Since technology transfer is not induced with the cost of technology, the findings of this model determine amount of loss/gain to the beneficiary rather than the amount of compensation to be claimed by the beneficiary.

Given these assumptions, this model can be solved to determine sector wise level of output under various technology scenarios. However, the model presented by equations (1), (2) and (3) do not say anything about the way to determine GDP level, employment, energy use and environmental emissions, endogenously under different technology scenarios. To do these analyses we need further extension of this model and this is described below.

**2.2 Extension of IO model**

In this study we have extended the above mentioned IO model in different ways to solve it for following impact analyses.

**2.2.1 Impact on GDP**

To estimate GDP, we have applied sector specific value added coefficients in this model in the following manner.

GDP = v \* X. (3)

Where ‘X’ can be obtained from equation (1) after estimating ‘XM’ and ‘M’ with the help of equation (2) and (3) respectively.

Parameter ‘v’ is 1xn value added coefficient vector.

Since technology determines amount of energy input use and most of the energy commodities are being imported from rests of the world, the technology transfer will determine the amount of import of energy commodities required in the Indian economy. On the other hand technology will also change the demand for intermediate input use in the industry, so the level of import of other non-energy material input will also change due to technology transfer. Again as this import is a part of GDP accounting, the level of GDP will change due to change in import. On the other hand, the change in value added coefficients due to technology transfer will also be reflected in the level of GDP obtained for the Indian economy corresponding to the different technology level.

**2.2.2 Impact on employment**

Labour is a crucial factor input for economic activities and its demand depends on technology pattern adopted by the economic activities. Since India is a second largest populated country in the world and problem of un-employment is like chronic diseases, it is essential to analyze the impact of technology transfer on employment level. In this study we have estimated number of employment corresponding to the different types of technology for different sectors. The method of estimation equation is given below:

 EMP = em \* X. (4)

Where ‘em’ is a 1 x n matrix of sector specific employment coefficient i.e. number of persons required to produce one monetary unit of output.

**2.2.3 Impact on Energy and emission**

Energy is a key input for production process as well as the major cause for environmental pollution and technology determines level of energy use in the production process. On the other hand the energy input available from renewable sources like solar, wind, water does not generate any pollutants in the atmosphere, but their application is limited in India till date. By contrast, energy inputs available from the combustion of fossil fuel like coal, petroleum and natural gas are causing environmental emission. But the level and volume of emissions are different for different types of fossil fuel. Therefore to analyze the impact of technology transfer on emission level we have to first understand its implication on sector specific volume and type of energy use. To do this we have used following equation ().

ENERTent x 1 = enent x n \* X. (4)

Where, ent = coal, petroleum, natural gas, and other renewable, ENERT is volume of different types of energy inputs, and ‘en’ is amount of different types of energy (in physical unit) required to produce one monetary unit of output in each sector.

The consumption of energy input thus obtained is used to estimate emission level of different types of pollutants. In this study we have taken into account two different types of pollutants like – global pollutants and domestic pollutants. Pollutants like Carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) are considered as global pollutants and they are together also called green house gases (GHGs). On the other hand, nitrogen di-oxide (NOx), sulpher dioxide (SO2), and ammonia (NH3) are considered for domestic pollutant and they together cause for acidification and determine the domestic air quality. Apart from that, carbon monoxide (CO) is also considered as domestic pollutant. Now to estimate emission of these pollutants we have to first estimate emission coefficients corresponding to energy use. For this, though there are methods available in IPCC guideline, it involves various complexities relating to emission factor, energy type and assumption involved in estimating emission factors. To avoid such complexities, we have estimated average emission coefficients for various pollutants by dividing sector specific emissions with their total energy use in calorific value (i.e. energy content in the fossil fuel). However, one may argue that the emission coefficients obtained in this way will give higher weight in terms of emission to the less emission intensive energy input. But this is not so in this case. Because, it is observed from the IPCC guideline that more the energy content in the fossil fuel less will be its emission intensity. For example the energy and carbon contents in natural gas are respectively 48.0 terajoule/gigagram and 15.3 kg/gigajoule as compared to 11.9 terajoule/gigagram and 27.6 kg/gigajoule for lignite (IPCC, 2006). Thus the emission coefficients estimated in the above mentioned way rule out the possibility of overweighting emission to the less emission intensive energy input. Therefore, with the help of following eq(5) we can analyze the impact on emission level for the Indian economy under both BAU and technology scenarios.

Emcof pol x n = EMIT pol x i \* (1/ sum (entf, ENER(entf, i)) (5)

where, entf = coal, petroleum, and natural gas ; pol = CO2, CH4, N2O, CO, NOx, NH3, SO2 ; Emcof = sector wise pollutants wise emission coefficients; EMIT = sector specific emission of pollutants.

EMISS pol x 1 = emcof pol x n \* enshare n x entf \* ENERG entf x 1 . (6)

Where, EMISS is aggregate emission of different pollutants. ENERG is aggregate energy consumption of the economy.

Thus we have estimated sector specific energy demand and its impact on emissions. As described in the above methodology, we have to estimate energy coefficients for different technology wherever it is originating from. Moreover, the information about the potential emission for every new technology is required to simulate equation (4), (5) and (6) for analyzing the impact of technology transfer on energy use and environmental pollution.

After preparing the conceptual and analytical framework of IO model and its integration with energy and environmental pollution, we have to solve these equations for Indian economy with the help of realistic data as available for this economy. In this regard, the detail description about data and implementation of this model is presented the following section.

* 1. **Data and Implementation of the Model**

The World Input-Output Data (WIOD) base is the primary source of data for this analysis. This data base provides monetary IO table for 40 different countries including India and other developed and developing countries along with the sector specific socio-economic indicators, energy consumption, and environment related data in physical unit for every country. Moreover, the WIOD gives time series of these data since the year 1995 to latest year 2009 with common sectoral classification and their energy, environment and socio-economic components for the different countries IO table. Since base year of this model is 2009, we have selected 2009 data base from WIOD for this analysis. This IO tables takes into account 35 sector of the economy with detail description of services and manufacturing sectors. But as our objective in the above mentioned IO model is to analyze the overall impact, we have aggregated the 35 sector IO table into 23 broad sectors to avoid analytical complexity. The aggregation scheme is mentioned in table 1 of the following section.

Again it can be easily observed that the IO coefficients corresponding to different countries are different, which implies different country have different technologies[[1]](#footnote-1). Here, it can also be argued that, all the countries may not have better energy efficiency than India. Therefore, selection of the country is crucial for this analysis. On the other hand different sector have different level of energy and emission intensities. So identification of sectors in India for which technology transfer is necessary is also an equally important factor for this analysis. In this regard the selection procedure is described below.

**2.4 Identifying sectors of the Indian economy**

The center point of debate for technology transfer is to control predictable rising trend of GHG emissions from developing countries. Therefore, being a developing economy, India has to identify its production sectors wisely to get maximum possible benefits for its nation from technology transfer. Keeping this view in our mind, we have considered sector specific contribution to GDP and GHG emissions as economic and environmental indicator for identification purpose. If a sector’s contribution to GDP is less than its contribution to overall GHG emissions in India, we have selected those sectors as key sectors for technology transfer. Again the amount of GHG emission per se may be higher for some sector which is also contributing more in GDP than in GHG. But due to technology related uncertainty, selection of such sector may not be smart choice. Since, technology involves risks, any loss in the comparatively high income generating sector would result severe crisis into that economy. However, researcher may choose economic indicators other than GDP. But globally the energy & emission intensities are measured in terms of GDP. Therefore, to make this study comparable across the world, the choice of GDP and GHG to select relevant sectors for this analysis is logical. The following Table 1 gives detail about the identified sectors for this study. The sectors marked with black shed in the table 1 are the selected sectors for this study.

**Table 1: Selection of sector for which technology transfer is necessary**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|   | Economic Activities | WIOD Sectors | Contribution to GDP (%) | Contribution to GHG (%) |
| 1 | Agriculture, Hunting, Forestry and Fishing | C1 | 16.90% | 18.82% |
| 2 | Mining and Quarrying | C2 | 2.49% | 7.25% |
| 3 | Food, Beverages and Tobacco | C3 | 1.49% | 3.11% |
| 4 | Textiles and Textile Products | C4 | 1.82% | 0.48% |
| 5 | Leather, Leather and Footwear | C5 | 0.19% | 0.02% |
| 6 | Pulp, Paper, Paper , Printing and Publishing | C7 | 0.39% | 0.40% |
| 7 | Coke, Refined Petroleum and Nuclear Fuel | C8 | 1.02% | 2.19% |
| 8 | Chemicals and Chemical Products | C9 | 1.89% | 2.16% |
| 9 | Rubber and Plastics | C10 | 0.35% | 0.15% |
| 10 | Other Non-Metallic Mineral | C11 | 0.96% | 4.04% |
| 11 | Basic Metals and Fabricated Metal | C12 | 2.64% | 5.58% |
| 12 | Machinery, Nec | C13 | 1.03% | 0.26% |
| 13 | Electrical and Optical Equipment | C14 | 1.25% | 0.18% |
| 14 | Transport Equipment | C15 | 1.40% | 0.50% |
| 15 | Manufacturing, Nec; Recycling | C6 & C16 | 1.10% | 0.58% |
| 16 | Electricity, Gas and Water Supply | C17 | 1.76% | 36.94% |
| 17 | Construction | C18 | 8.24% | 0.55% |
| 18 | Retail & Whole sale trade | C19, C20 & C21 | 15.02% | 0.26% |
| 19 | Hotels and Restaurants | C22 | 1.42% | 0.92% |
| 20 | Inland Transport | C23 | 5.59% | 1.53% |
| 21 | Water Transport | C24 | 0.16% | 0.27% |
| 22 | Air Transport | C25 | 0.12% | 0.13% |
| 23 | Other services sectors | C26 to C35 | 32.77% | 5.66% |

Note: For sectoral description of WIOD sectors, please visit [www.wiod.org](http://www.wiod.org)

**2.5 Indentifying source of countries for technology transfer**

In this study we have followed three stage sampling method. Since economic development is one of the key objectives of this analysis, in the first stage we have selected those countries which are experiencing more GDP level than India. As shown in the World Bank data base, only 9 countries have fallen in the above mentioned category[[2]](#footnote-2). In the next stage we have compared energy intensity of all the selected countries corresponding to the above mentioned sectors. Countries which have low energy intensity in any of the above selected sector (as shown in table 1) are selected as source of alternative technology for that sector. Finally, as we have assumed technology transfer as complete diffusion of technology, the issue of up-scaling that technology at macro level is important. To solve this issue one has to look at country which is self sufficient in production of the sectors we have selected in this study. Therefore, we have selected those countries where trade balance corresponding to the selected sector is positive even if their energy intensity is less than Indian technology. The list of selected countries corresponding to the selected sector is given in the following table 2.

 **Table 2: Sector wise selected country as source of Technology**

|  |  |  |  |
| --- | --- | --- | --- |
| **Food and beverages & Tobacco** | **Chemicals and Chemical Products** | **Basic Metals and Fabricated Metal** | **Electricity, Gas and Water Supply** |
| **India** | **India** | **India** | **India** |
| Brazil | Germany | Brazil | Itali |
| Germany | France | Itali | UK |
| China |   | Japan | USA |
| France |   | Russia | Brazil |
|   |   |   | China |
|   |   |   | France |
|   |   |   | Germany |
|   |   |   | Japan |
|   |   |   | Russia |

After selecting sectors and their source of technologies from different countries our next task is to estimate the relevant parameters and exogenous variables for the above mentioned dynamic model. In this case most of the parameters like – sector wise technical coefficients, energy use coefficients, emission coefficients, employment and value added coefficients are estimated directly from the IO table of the respective countries corresponding to the selected sectors. The data and relevant parameters thus obtained are applied in the model described in section 2 to analyze the implication of technology transfer on Indian economy. The results of this model are described in the following section.

1. **Results and analysis**

Since our goal in this study is to analyze the implication of technology transfer on GDP, Employment, GHG emissions, Acidification, and energy use, the following Table 3 describes it in detail. The Table 3 describes overall impact on the above mentioned indicators due to adoption of various technologies in the individual sectors. The name of the countries listed in Table 3 is representing the selected sources of technology corresponding to the selected sectors. It can be observed from this table that the GHG emission is significantly falling in India in almost every case even after meeting its current level of demand. Therefore it seems the technologies sourcing from these selected countries will be efficient enough to mitigate GHGs and other pollutants. Given this fact if the policy makers are restricting them only on emission mitigation, technologies resulting lowest possible emission levels will be preferred. But this restrictive approach to select technology for emission mitigation may not be sustainable in terms of income and livelihood generation in the economy. To understand this we have done detail sector specific analysis in the following paragraphs on the basis of results presented in Table 3.

In case of Food and beverages sector, the technology sourcing from Brazil shows highest impact on GHG emission mitigation (-2.37%), subsequently it results a fall in GDP (-0.35%) and employment (-1.26%) of the Indian economy. On the other hand, adoption of China’s technology for this same sector is showing positive impact on GDP (0.03%) but it’s potentiality to mitigate GHG emission (-1.93%) is less than that is observed in case of Brazil’s technology. Moreover, the fall in employment due to China’s technology (-3.57%) is higher than the Brazil’s technology. Again in case of technologies from Germany and France, the impacts on employment (-4.31% and -4.03% respectively) are higher than China and Brazil along with low potentiality of GHG emissions (-1.56% and -1.45% respectively). The lower impact on GHG emissions due to the technologies from China, Germany and France is mainly because of their dependency of coal energy. It is observed from the Table 3 that the over impact on coal energy use corresponding to these three source of technologies are positive (2.77% for China, 0.31% for Germany and 0.20% for France). By contrast Brazil’s technology has negative impact on the overall coal energy use (-1.24%) in the Indian economy. More interestingly, the overall all impacts on renewable energy use, which is termed as green energy, are significantly positive in case technology from Germany, China and France. Hence, we can easily argue that, each technology has its own features to generate energy and non-energy input demand and create different linkages effects into the economy.

**Table 3: Impact of technology transfer on key economic & environmental indicators**

|  |
| --- |
| **Food & Beverages** |
|   | GDP | EMP | GHG | Acidification | CO | Coal | Petroleum | Gas | Renewable energy |
| Brazil | -0.35% | -1.26% | -2.37% | -0.66% | -1.74% | -1.24% | -15.57% | -4.93% | 0.22% |
| Germany | -0.38% | -4.31% | -1.56% | -0.82% | -3.01% | 0.31% | -16.45% | 4.50% | 4.47% |
| China | 0.03% | -3.57% | -1.93% | -2.89% | -4.64% | 2.77% | -17.10% | -4.61% | 7.97% |
| France | -0.11% | -4.03% | -1.45% | -0.84% | -3.09% | 0.20% | -16.82% | 1.91% | 1.71% |
| **Chemical and Chemical Products Sector** |
|   | GDP | EMP | GWP | Acidification | CO | Coal | Petroleum | Gas | Renewable energy |
| Germany | -0.01% | -0.78% | -2.90% | -3.23% | -3.78% | -2.18% | -7.25% | 10.51% | 26.37% |
| France | 0.08% | -0.22% | -1.33% | 0.38% | -0.23% | -1.15% | -0.09% | -6.44% | -0.43% |
| **Electricity Sector** |
|   | GDP | EMP | GWP | Acidification | CO | Coal | Petroleum | Gas | Renewable energy |
| Itali | -0.29% | -0.17% | -24.26% | -20.12% | -2.00% | -59.03% | -0.68% | 46.31% | -14.89% |
| UK | -0.27% | -0.27% | -21.08% | -19.58% | -2.04% | -51.15% | -7.23% | 51.99% | 81.42% |
| USA | 0.22% | -0.64% | -38.09% | -24.40% | -36.89% | -57.27% | -8.89% | -19.92% | -13.85% |
| Brazil | 0.02% | -0.60% | -34.37% | -24.21% | -7.49% | -65.79% | -7.50% | -39.29% | 105.83% |
| China | -0.04% | 0.08% | -9.46% | 14.97% | -26.62% | 1.25% | -7.16% | -30.77% | 42.16% |
| France | -0.05% | -0.07% | -30.02% | -21.45% | -4.27% | -62.07% | -6.99% | -18.75% | 1345.78% |
| Germany | 0.14% | -0.41% | -19.82% | -21.90% | -8.48% | -45.20% | -6.20% | 26.64% | 189.53% |
| Japan | 0.14% | 0.05% | -24.68% | -20.73% | -12.97% | -53.68% | 1.11% | 52.05% | 278.67% |
| Russia | -0.14% | -0.10% | -3.73% | -24.25% | -10.00% | -55.14% | 1.86% | 245.71% | 221.85% |
| **Basic Metal** |
|   | GDP | EMP | GWP | Acidification | CO | Coal | Petroleum | Gas | Renewable energy |
| Brazil | 0.18% | -1.07% | -4.87% | 2.25% | -3.72% | -13.59% | 8.99% | 20.07% | -5.61% |
| Itali | 0.82% | -0.28% | -10.38% | -2.74% | -12.22% | -19.10% | 3.98% | 16.38% | -5.26% |
| Japan | 0.85% | -0.06% | -3.29% | -1.45% | -9.97% | -4.37% | 1.33% | 13.61% | -7.70% |
| Russia | 0.30% | -0.68% | 2.74% | -1.36% | -3.39% | -3.68% | -0.62% | 86.16% | 114.23% |

*Note: GDP-Gross Domestic Product, EMP-Employment, GHG – Greenhouse gas, CO- Carbon Monoxide*

In case of Chemical and chemical products sector, the technology from Germany shows negative impact on both environmental and economic indicators (See Table 3). On the other hand the technology from France shows positive impact on GDP (0.08%) but negative impact on employment (-0.22%) though it is lower than that is observed in case of Germany’s technology. Again in case of GHG emissions Germany’s technology (-2.90%) proves better than the technology from France (-1.33%) for this sector. This is because of difference in renewable energy use and gas based energy use in these two technologies. The overall renewable energy demand due to Germany’s technology stands at 26.37% higher than the India’s existing level of renewable energy demand. But this overall renewable energy demand will fall by 0.43% in case of France’s technology.

In case of combined electricity, gas and water supply sector, it is clear from the Table 3 that the adoption of Japan’s technology has positive impact on GDP (0.14%) and employment (0.05%) along with the significant impact on GHG emissions and other environmental indicators. Though this is not the only technology for which we can observe positive impact on GDP and employment, but this is the only technology for which the positive impacts are observed together for GDP and employment (See Table 3).

Finally, the impacts of all the selected technologies for basic metal sector on overall GDP are positive and this is highest corresponding to the Japan’s technology (0.85%) followed by the technology from Itali (0.82%), Russia (0.30%) and Brazil (0.18%). Again the negative impact on employment is lowest in case of Japan’s technology as compared to the others. But the impact on GHG emissions is almost 3 times higher in case of Itali’s technology than the Japan’s technology. This happens mainly due to significant fall in coal energy demand for Itali’s technology (-19.10%) as compared to Japan’s technology (-4.37%). Thus we have observed variations in implications of different technologies for different sectors. The reason behind such variations in results is due to difference in input use pattern of the technology. The technology wise intermediate input use, employment use, energy use, GHG emissions and factor-output ratio for the selected sectors are given in the tables A1.1, A1.2, A1.3 and A.14 in Appendix 1 at the end of this paper.

However, two scenarios are emerging from the above analysis. First, since technology from Japan for Electricity sectors results positive implication on India’s GDP, employment, and emission control, policy makers may be in favor of adopting Japan’s technology for India’s electricity sector without considering technology transfer in other sectors. Secondly, if the issue of border tax on carbon contents is taken into account for world trade, the emission intensive sectors of India will suffer from comparative disadvantages in the international market. Since this will lead export from India to fall, this will pose another threat to the policy makers to keep the trade deficit at lower level. In this case they may opt for energy efficient technology for the emission intensive sectors. Since the selected sectors in this study are highly emission intensive and selected technologies for these sectors are less energy intensive, identifying one particular technology for each sector is crucial. This will again lead another debate among the experts from various fields even though they have common objective of emission reduction.

In this context, environmentalist will prefer the technology which results highest possible emission mitigation, monetary economists will look at minimum possible loss in GDP; welfare economists and politicians may not compromise employment fall for Indian economy as employment generation is existing challenge for the economy. To address this debate, a balance approach has to be followed and the technologies will be identified based on the minimum possible threats to the economy and environment. Though from the Table 3, one can understand the implication of various technologies on various economic and environmental indicators, generalizing their implication is difficult due to different level of their impact on different indicators. To generalize their impact one has to understand about the trade-off between emission control and economic indicators (GDP and Employment are key indicators for this study). The following Table 4 describes such trade-offs corresponding the each technology for each sectors.

**Table 4: Trade-Off between GHG emission reduction and GDP and Employment**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **GDP/GHG (USD/Tons)** | **EMP/GHG (USD/Tons)** | **Total Opportunity cost (USD/Tons)** |
| **Food & Beverages** |
| Brazil | 185.057 | 79.610 | 264.67 |
| Germany | 304.510 | 414.713 | 719.22 |
| China | -20.151 | 276.441 | 256.29 |
| France | 93.977 | 417.264 | 511.24 |
| **Chemical & Chemical Products** |
| Germany | 5.31 | 40.072 | 45.38 |
| France | -79.42 | 24.799 | -54.63 |
| **Electricity, gas and water supply** |
| Itali | 14.87 | 1.07 | 15.94 |
| UK | 16.45 | 1.91 | 18.36 |
| USA | -7.18 | 2.52 | -4.66 |
| Brazil | -0.89 | 2.60 | 1.71 |
| China | 5.59 | -1.20 | 4.39 |
| France | 1.92 | 0.35 | 2.27 |
| Germany | -8.97 | 3.10 | -5.86 |
| Japan | -7.15 | -0.28 | -7.44 |
| Russia | 48.21 | 4.00 | 52.21 |
| **Basic metal Industry** |
| Brazil | -47.86 | 32.90 | -14.96 |
| Itali | -100.29 | 4.05 | -96.24 |
| Japan | -328.01 | 2.54 | -325.47 |

In the above table we have estimated amount of GDP and employment in terms of US dollar to be sacrificed to reduce 1 tons of GHG emissions corresponding to each technology. Though the employment is measured at physical unit (i.e. number of persons), we have taken average compensation rate for India to quantify them in terms of US dollar. Finally we have added this two and obtained total trade-off corresponding to each technology for the selected sectors. The point to be noted here that, we have estimated trade-off for those technologies which lead to fall in GHG emissions. Hence we have not considered technology from Russia for basic metal industry as it causes 2.74% increase in overall GHG emissions in India (See Table 3). Again it is to be noted here that, the positive signs in the above table implies losses and negative sign implies gains in terms of US dollar to reduce 1 tons of GHG. Trade-offs thus estimated in the above are used to identify technology corresponding to every selected sectors of the Indian economy.

As observed from the Table 4, the technology from China for food and beverages sector has low trade-off as compared to other sources of technologies for the same sector. This is because of the gain in GDP due to China’s technology even though there is loss in employment. On the other hand, technology from France results gain in Indian economy due to gain in GDP and less fall in employment. Again there is no exception in case of electricity sector, as the Japan’s technology leads gain in both GDP and employment. The Japan’s technology for basic metal industry is also resulting overall gain in the economy. Thus we have selected technologies for every selected sectors based on the estimated trade-off to minimize the loss pertaining to the economy due to technology transfer. Once we have all the selected technologies for the selected sectors, it will be interesting to see their combined impact on the economic as well as environmental indicators. The detail analysis about this is described below.

***Impact of Combined Technologies on Economy & Environment***

In this case, the technologies selected on the basis of their trade-off are applied to their corresponding sector to see their combined impact on the selected economic and environmental indicators. The following table 5 presents the results of such analysis.

 **Table 5: Impact of adopting combined technology (China-Food & beverages) + (France - Chemical & products) + (Japan-Electricity gas & water supply) + (Japan-Basic metal)**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Technology** | **GDP** | **EMP** | **GWP** | **Acidification** | **CO** | **Coal** | **Petroleum** | **Gas** | **Renewable energy** |
| Combined | 1.10% | -3.75% | -30.47% | -23.83% | -27.35% | -54.22% | -14.58% | 52.72% | 266.84% |

In this table 5 we have estimated the implication of technology transfer when advanced technologies are adopted for different sectors together. Here also we observe a fall in employment by 3.75% as compared to the existing level of employment in India. But there is significant increase in GDP (1.10%) and significant fall in GHG emissions, and Acidifications. Given these results, even if the policy makers are intended to adopt the above mentioned combination of technologies, the question may arise here whether the above results are stable under different level and structure of final demand in Indian economy. To answer this question we have done same analysis corresponding to the level of sector specific final demand for the year 2011 as available in WIOD and the results are given below.

**Table 6: Change in Domestic Final Demand (US Dollar at 2009 PPP)**

|  |  |  |  |
| --- | --- | --- | --- |
|   | **2009** | **2011** | **% Change** |
| Agriculture, Hunting, Forestry and Fishing | 462817 | 614623 | 32.80% |
| Mining and Quarrying | 34904 | 24267 | -30.47% |
| Food, Beverages and Tobacco | 275482 | 322356 | 17.02% |
| Textiles and Textile Products | 175017 | 171988 | -1.73% |
| Leather, Leather and Footwear | 15039 | 13016 | -13.45% |
| Pulp, Paper, Paper , Printing and Publishing | 15025 | 18714 | 24.56% |
| Coke, Refined Petroleum and Nuclear Fuel | 69100 | 72303 | 4.64% |
| Chemicals and Chemical Products | 90408 | 73196 | -19.04% |
| Rubber and Plastics | 26829 | 24057 | -10.33% |
| Other Non-Metallic Mineral | 6882 | 4348 | -36.81% |
| Basic Metals and Fabricated Metal | 106073 | 92262 | -13.02% |
| Machinery, Nec | 95027 | 113593 | 19.54% |
| Electrical and Optical Equipment | 130102 | 82432 | -36.64% |
| Transport Equipment | 136835 | 151598 | 10.79% |
| Manufacturing, Nec; Recycling | 183209 | 47426 | -74.11% |
| Electricity, Gas and Water Supply | 30574 | 42665 | 39.55% |
| Construction | 667856 | 925523 | 38.58% |
| Retail & wholesale Trade | 239387 | 365265 | 52.58% |
| Hotels and Restaurants | 107653 | 122650 | 13.93% |
| Inland Transport | 242378 | 343097 | 41.55% |
| Water Transport | 4178 | 6035 | 44.44% |
| Air Transport | 4428 | 7282 | 64.44% |
| Other services | 992570 | 1285544 | 29.52% |
| Total | 4111770 | 4924240 | 19.76% |

As this Table 6 shows, there is actual fall in demand for some sector and rise in demand for some sectors but the overall demand has increased by almost 20% between the period 2009 and 2011. Hence there is change in both structure and level of final demand in the Indian economy. Since IO model is a demand driven model, this change in demand will result change in economic and environmental indicators, as this is shown in following table 7.

**Table 7: Impact of adopting combined technology under different demand scenario**

|  |  |  |  |
| --- | --- | --- | --- |
|   | **With Indian Technology** | **With Combined technology** | **Combined technology** |
| GDP (Miilion US dollar in 2009 PPP) | 4791916 | 4834115 | 0.88% |
| EMP (Number) | 266997710 | 257918015 | -3.40% |
| GWP (Tons of CO2 Equivalent) | 3221588162 | 2232767595 | -30.69% |
| Acidification (Tons) | 176093541 | 132736192 | -24.62% |
| CO (Tons) | 32241309 | 25370880 | -21.31% |
| Coal (Terajoule) | 15397197 | 6205848 | -59.69% |
| Petroleum (Terajoule) | 4650163 | 3960800 | -14.82% |
| Gas (Terajoule) | 2154092 | 3638334 | 68.90% |
| Renewable energy (Terajoule) | 754563 | 738056 | 272.55% |

In the above table 7 we have shown a comparative result between the Indian technology and the combined selected technology for the above mentioned selected sectors. It is observed that, with the change in structure and level of demand in Indian economy, there is not much variation in the structure of results as compared to that obtained corresponding to the level and structure of demand of the year 2009. Therefore if the current change in pattern of final demand continues for the future years, there will not be much variation in the implications of technology transfer on the Indian economy. However, the point to be noted here that the combined technology fails to generate more employment even with the increase in final demand of the Indian economy.

Therefore if the issues like GHG mitigation and border tax on carbon contents emerge in the world economy, the energy efficient technology transfer in India would lead loss in Indian economy in terms of equity aspects though there is increase in GDP. Because, increase in GDP without increase in employment will increase more inequality and hence threats the overall welfare of the economy. Given this fact the demand for compensation against technology transfer by the developing country like India is logical. However, the estimation of amount of compensation is beyond the scope of this study as it requires investment to adopt the technologies. On the other hand, we have assumed in the study that technology transfer is priceless. Therefore if the compensations from the annex-1 countries or the countries having energy efficient technology are in the form of freely transfer of technologies, the question may arise what are the internal adjustments are required to stabilize the rise in inequality in the Indian economy. In this context, the following section describes the conditions for successful outcome from the technology transfer.

1. **Conditions for successful outcome from technology transfer**

In this section we have highlighted three key conditions to obtain successful outcome from the technology transfer. First, the domestic policy adjustments; secondly, the policies for adequate intermediate input supply and last but not the least the infrastructure in terms of energy supply. Each of these conditions are analyzed below.

**5.1 Internal demand management policy**

The results shown in the Table 3 and Table 5 reveal that there are technologies for which there is gain in GDP of the Indian economy as compared to the existing level of GDP. Therefore if any policy can help to circulate this additional GDP in the economy it may boost level of aggregate demand of the economy and hence a positive outcome can be observed through multiplier process. Now as the increase in employment is crucial in this case, the increase in demand to the high employment intensive sector would be beneficial and policies must focus on that. Therefore to see the impact of demand boosting policy, we have selected service sector as it has high employment multiplier effects and less energy multiplier effect as compared to other sectors of the Indian economy (see Appendix 2 for Multiplier). So if the policies like export promotion of services and formalizing employment for domestic services by providing income tax benefits to the employer households help to absorb additional GDP in the service sector, the aggregate demand in the service sector will increase as compared to the existing level of demand. As a result, there will be further increase in the economic growth. The result of this analysis is given in the following Table 8.

**Table 8: Implication of technology Transfer with demand push policy**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|   | GDP | EMP | GWP | Acidification | CO | Coal | Petroleum | Gas | Renewable energy |
| **Food & Beverages** |
| China | 0.06% | -3.11% | -1.93% | -2.89% | -4.64% | 2.77% | -17.10% | -4.61% | 7.98% |
| **Chemical & Chemical Products** |
| France | 0.16% | 1.01% | -1.32% | 0.39% | -0.22% | -1.14% | -0.08% | -6.43% | -0.42% |
| **Electricity, Gas and Water Supply** |
| Japan | 0.27% | 2.11% | -24.67% | -20.72% | -12.95% | -53.67% | 1.12% | 52.08% | 278.75% |
| **Basic Metal** |
| Japan | 1.66% | 12.53% | -3.19% | -1.36% | -9.89% | -4.26% | 1.41% | 13.73% | -7.58% |
| **(China-Food and Beverages + France -Chemical & Chemical Products + Japan - Electricity, Gas and Water Supply** |
| Combined technology | 2.15% | 12.49% | -30.37% | -23.73% | -27.26% | -54.15% | -14.48% | 52.95% | 267.41% |

It is observed from the above table that the technology transfer is leading to positive impact on both GDP and employment along with the reduction in GHG emissions except the China’s technology in food and beverages sector. On the other hand, the combined technology is showing significant growth in GDP and employment with substantial fall in GHG emissions. Interestingly, the level of acidification is also reducing significantly due to the combined effect of technology, whereas the individual effects sometimes are leading to rise in acidification. For example, the technology from France to the chemical and chemical products sector though reduces GHG emission but increases the acidification which is an indication of degradation of domestic air quality. Therefore, policies to strengthen services sector to boost employment will act as a supporting tool to reap higher possible benefit from technology transfer. Hence, given the level and structure of demand as in the year 2009 and 2011, the technology adoption in all the selected sectors may not be successful due to loss in employment and this will be successful only with the service sector led demand growth.

**5.2 Type of intermediate input supply**

Since the IO model in this study considers final demand as exogenous with Import and intermediate demand as endogenous variables to ensure equilibrium in the economy, the technology transfer has an impact on intermediate input demand as shown in table 9.

**Table 9: Change in Intermediate demand after technology adoption in combination**

|  |  |  |  |
| --- | --- | --- | --- |
|   | India | Combined | Change |
| Agriculture, Hunting, Forestry and Fishing | 313659 | 232642 | -25.83% |
| Mining and Quarrying | 227908 | 201839 | -11.44% |
| Food, Beverages and Tobacco | 102552 | 94007 | -8.33% |
| Textiles and Textile Products | 86095 | 81436 | -5.41% |
| Leather, Leather and Footwear | 14258 | 13280 | -6.86% |
| Pulp, Paper, Paper , Printing and Publishing | 57803 | 63438 | 9.75% |
| Coke, Refined Petroleum and Nuclear Fuel | 293926 | 239866 | -18.39% |
| Chemicals and Chemical Products | 266904 | 215219 | -19.36% |
| Rubber and Plastics | 85001 | 81297 | -4.36% |
| Other Non-Metallic Mineral | 114286 | 120875 | 5.76% |
| Basic Metals and Fabricated Metal | 544903 | 624933 | 14.69% |
| Machinery, Nec | 103120 | 94186 | -8.66% |
| Electrical and Optical Equipment | 117254 | 117551 | 0.25% |
| Transport Equipment | 91346 | 83089 | -9.04% |
| Manufacturing, Nec; Recycling | 348001 | 322375 | -7.36% |
| Electricity, Gas and Water Supply | 189644 | 146816 | -22.58% |
| Construction | 167995 | 168551 | 0.33% |
| Retail & wholesale Trade | 441949 | 462095 | 4.56% |
| Hotels and Restaurants | 28552 | 42435 | 48.62% |
| Inland Transport | 377277 | 298927 | -20.77% |
| Water Transport | 6480 | 14009 | 116.19% |
| Air Transport | 6866 | 6578 | -4.20% |
| Other services | 528086 | 641521 | 21.48% |

It is clear from the above Table 9 that there is significant increase in transport and service sector input as compared to non-service sectors inputs. This implies most of the selected technologies are more biased towards the service sector than the non-service sector. Therefore, the technology transfer in the above mentioned sectors does not only include the adoption of energy efficient machineries or energy conservation practices, it also includes strengthening the service sectors including trade, administration, and transport services. Now in the IO model we assume excess capacity of the every sector and as a result we can observe above type of results as shown in Table 9. But in reality every sector may not have excess capacity to meet its rising demand. Therefore, increase in capacity of the sectors especially to the service sectors can be a pre requisite condition for successful adoption of advance technologies sourcing from above mentioned countries for the above listed selected sectors.

**5.3 Energy infrastructure requirements**

The results obtained earlier of this study shows that, there is rise in demand for renewable energy and gas based energy due to the combined and even in the individual technology effects. For example, the overall renewable energy demand due to combined technology adoption has increased by 267.41% and the demand for gas based energy has increased by 52.95% (See Table 8). Therefore, increase in supply of renewable energy and gas based energy to replace coal and petroleum based energy are essential to adopt these technologies. Since energy consumption is crucial for environmental pollution, creation of green energy infrastructure will most crucial to successfully control environmental pollution.

1. **Conclusion**

Balancing economic growth and controlling environmental pollution is major policy challenge across the world. Between the developed and developing countries, it the later which is highly vulnerable due to the GHG emissions led climate change. On the other hand, due to lack of advance technology and too much dependency on coal based energy, the future development in developing economies like India will increase the GHG emission inventory at a faster rate than it was increased historically by he developed countries. In this context, various options for emissions control have been debated in cooperation of parties in UNFCCC since more than two decades. Among these options, technology transfer is considered as one of the crucial option and debates are going on about its implementation. In this context, the analyses we have carried out in this study will help policy makers to understand the implication of various technologies not only from the point of view of GHG mitigation, but also from the view of economic growth and welfare. Moreover, this analysis has described the method of selecting most efficient technology for Indian economy to balance the economic growth as well as emission mitigation.

If the issue is only to mitigate GHG emissions, the analysis in this study shows that, the technology from Japan for electricity, gas and water supply sector would be the most preferred technology for India. On the other hand if India wants to enjoy comparative advantages in international trade in a situation of border tax on carbon contents in the commodity, selection of technologies for other sectors is crucial. Here also this study has shown the implication of technologies when adopted together for the emission intensive sectors. Though this study has found negative implication of combined technologies on overall employment in India, it has also described possible income redistribution policy for effective demand creation to achieve the goal of balancing environmental control without restricting economic growth.

Again, the technology changes structure of the economy in one hand and structure of the economy determines success of a technology on the other hand. In his context, this study has given an idea about the structural changes in the form of more service sector biased economy is required for successful adoption of the advanced technologies. The point to be noted here that, the Indian economy is following service sector led growth since past decades with more than 50% contribution in its GDP. So there is a potentiality in adoption of the listed technologies for India.

On the other hand, India’s policy focus in the current 12th five year plan is pertaining mostly on energy efficiency improvement by strengthening renewable energy production. But this requires technology to maximize the use of available resources in an efficient manner. In this context not much study available about the source of technology. Hence this study is an important contribution to understand the implication and source of technologies for the Indian economy.

However, this study is not free from its criticism. The assumption of complete replacement of technology in a year is not realistic. But as this study has adopted IO model which assumes every production process has excess capacity, the above assumption is technically relevant. However, to make this assumption more realistic, one has to adopt intertemporal dynamic model in an IO framework and assumes different adoption rates of technologies over the years. But this requires relevant data about capital composition matrix, which is not available easily for the Indian economy. So it can be considered as future research agenda on this topic. Though this analysis can be better understood in a dynamic framework, it can be observed from this study that, there are technologies which cause threats in welfare of the Indian economy even at the extreme assumption of full replacement under excess capacity of the economy. Hence, despite having the inherent criticism of this analysis, the contribution on identifying source of technologies for various sectors will attract attention of the policy makers.

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**Appendix 1.**

**A1.1: Specification of Technologies for Food and Beverages Sector**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|   | **India** | **Brazil** | **Germany** | **China** | **France** |
| Agriculture, Hunting, Forestry and Fishing | 0.35 | 0.32 | 0.20 | 0.17 | 0.22 |
| Mining and Quarrying | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Food, Beverages and Tobacco | 0.15 | 0.14 | 0.10 | 0.14 | 0.14 |
| Textiles and Textile Products | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Leather, Leather and Footwear | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pulp, Paper, Paper , Printing and Publishing | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 |
| Coke, Refined Petroleum and Nuclear Fuel | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 |
| Chemicals and Chemical Products | 0.02 | 0.01 | 0.01 | 0.02 | 0.00 |
| Rubber and Plastics | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 |
| Other Non-Metallic Mineral | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 |
| Basic Metals and Fabricated Metal | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| Machinery, Nec | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 |
| Electrical and Optical Equipment | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Transport Equipment | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Manufacturing, Nec; Recycling | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Electricity, Gas and Water Supply | 0.01 | 0.01 | 0.02 | 0.03 | 0.02 |
| Construction | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 |
| Retail & wholesale Trade | 0.10 | 0.10 | 0.11 | 0.18 | 0.14 |
| Hotels and Restaurants | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 |
| Inland Transport | 0.08 | 0.02 | 0.01 | 0.05 | 0.02 |
| Water Transport | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air Transport | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Other services | 0.05 | 0.10 | 0.18 | 0.10 | 0.16 |
| **Employment coefficients (Person/Output in 10^6 USD in PPP)** | 9.06 | 9.48 | 5.38 | 10.79 | 3.21 |
| **Energy intensity (Terajourle /Output in 10^6 USD in PPP)** |
| Coal | 0.48 | 0.01 | 0.06 | 0.47 | 0.12 |
| Petroleum | 1.76 | 0.20 | 0.19 | 0.07 | 0.14 |
| Gas | 0.37 | 0.11 | 0.66 | 0.01 | 0.49 |
| Other Renewables | 2.49 | 3.74 | 0.44 | 0.18 | 0.58 |
| Others | 0.00 | 0.00 | 0.05 | 0.08 | 0.00 |
| **Emission Intensity (Tons/Output in 10^6 USD in PPP)** |
| CO2 | 196.69 | 21.67 | 56.15 | 50.51 | 99.36 |
| CH4 | 0.11 | 0.11 | 0.01 | 0.01 | 0.01 |
| N2O | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 |
| NOX | 0.87 | 0.54 | 0.06 | 0.13 | 0.25 |
| SOX | 0.40 | 0.12 | 0.03 | 0.09 | 0.11 |
| CO | 2.65 | 1.77 | 0.03 | 0.26 | 0.14 |
| NH3 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 |
| **Factor payment output raio** | 0.15 | 0.19 | 0.23 | 0.24 | 0.20 |

**A1.2: Specification of Technologies for Chemical & Chemical Products Sector**

|  |  |  |  |
| --- | --- | --- | --- |
|   | **India** | **Germany** | **France** |
| Agriculture, Hunting, Forestry and Fishing | 0.01 | 0.00 | 0.00 |
| Mining and Quarrying | 0.01 | 0.01 | 0.01 |
| Food, Beverages and Tobacco | 0.03 | 0.01 | 0.02 |
| Textiles and Textile Products | 0.01 | 0.00 | 0.00 |
| Leather, Leather and Footwear | 0.00 | 0.00 | 0.00 |
| Pulp, Paper, Paper , Printing and Publishing | 0.01 | 0.01 | 0.02 |
| Coke, Refined Petroleum and Nuclear Fuel | 0.05 | 0.03 | 0.05 |
| Chemicals and Chemical Products | 0.29 | 0.13 | 0.20 |
| Rubber and Plastics | 0.02 | 0.01 | 0.02 |
| Other Non-Metallic Mineral | 0.00 | 0.01 | 0.01 |
| Basic Metals and Fabricated Metal | 0.01 | 0.02 | 0.02 |
| Machinery, Nec | 0.01 | 0.01 | 0.01 |
| Electrical and Optical Equipment | 0.00 | 0.01 | 0.00 |
| Transport Equipment | 0.00 | 0.00 | 0.00 |
| Manufacturing, Nec; Recycling | 0.02 | 0.00 | 0.00 |
| Electricity, Gas and Water Supply | 0.03 | 0.02 | 0.03 |
| Construction | 0.01 | 0.01 | 0.00 |
| Retail & wholesale Trade | 0.08 | 0.08 | 0.13 |
| Hotels and Restaurants | 0.00 | 0.00 | 0.00 |
| Inland Transport | 0.07 | 0.01 | 0.02 |
| Water Transport | 0.00 | 0.00 | 0.00 |
| Air Transport | 0.00 | 0.00 | 0.00 |
| Other services | 0.04 | 0.22 | 0.21 |
| **Employment coefficients (Person/Output in 10^6 USD in PPP)** | 6.94 | 2.85 | 1.13 |
| **Energy intensity (Terajourle /Output in 10^6 USD in PPP)** |
| Coal | 0.31 | 0.18 | 0.09 |
| Petroleum | 0.81 | 0.23 | 1.05 |
| Gas | 0.70 | 1.82 | 0.40 |
| Other Renewables | 0.50 | 1.08 | 0.83 |
| Others | 0.00 | 0.80 | 0.01 |
| **Emission Intensity (Tons/Output in 10^6 USD in PPP)** |
| CO2 | 199.85 | 203.60 | 118.02 |
| CH4 | 0.11 | 0.04 | 0.04 |
| N2O | 0.15 | 0.21 | 0.10 |
| NOX | 0.30 | 0.33 | 0.18 |
| SOX | 0.45 | 0.26 | 0.21 |
| CO | 1.38 | 0.02 | 0.25 |
| NH3 | 0.07 | 0.06 | 0.03 |
| **Factor payment output raio** | 0.27 | 0.34 | 0.20 |

**A1.3: Specification of Technologies for Electricity, Gas and Water supply Sector**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|   | **India** | **Itali** | **UK** | **USA** | **Brazil** | **China** | **France** | **Germany** | **Japan** | **Russia** |
| Agriculture, Hunting, Forestry and Fishing | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mining and Quarrying | 0.07 | 0.27 | 0.26 | 0.16 | 0.04 | 0.14 | 0.05 | 0.04 | 0.13 | 0.11 |
| Food, Beverages and Tobacco | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Textiles and Textile Products | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Leather, Leather and Footwear | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pulp, Paper, Paper , Printing and Publishing | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Coke, Refined Petroleum and Nuclear Fuel | 0.09 | 0.01 | 0.01 | 0.01 | 0.02 | 0.03 | 0.04 | 0.01 | 0.04 | 0.15 |
| Chemicals and Chemical Products | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 |
| Rubber and Plastics | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Other Non-Metallic Mineral | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Basic Metals and Fabricated Metal | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 |
| Machinery, Nec | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.00 | 0.02 |
| Electrical and Optical Equipment | 0.02 | 0.01 | 0.00 | 0.00 | 0.02 | 0.07 | 0.01 | 0.03 | 0.00 | 0.01 |
| Transport Equipment | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Manufacturing, Nec; Recycling | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| Electricity, Gas and Water Supply | 0.21 | 0.11 | 0.24 | 0.00 | 0.20 | 0.30 | 0.24 | 0.16 | 0.06 | 0.06 |
| Construction | 0.03 | 0.02 | 0.01 | 0.02 | 0.00 | 0.00 | 0.04 | 0.01 | 0.06 | 0.01 |
| Retail & wholesale Trade | 0.04 | 0.05 | 0.02 | 0.01 | 0.01 | 0.01 | 0.03 | 0.03 | 0.06 | 0.13 |
| Hotels and Restaurants | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 |
| Inland Transport | 0.04 | 0.03 | 0.01 | 0.05 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.03 |
| Water Transport | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 |
| Air Transport | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Other services | 0.07 | 0.05 | 0.06 | 0.05 | 0.09 | 0.09 | 0.14 | 0.14 | 0.14 | 0.06 |
| **Employment coefficients (Person/Output in 10^6 USD in PPP)** | 6.72 | 0.85 | 1.00 | 0.21 | 9.48 | 4.63 | 1.75 | 1.79 | 2.08 | 7.17 |
| **Energy intensity (Terajourle /Output in 10^6 USD in PPP)** |  |  |  |  |  |
| Coal | 44.89 | 3.42 | 8.02 | 6.90 | 0.28 | 39.89 | 2.42 | 15.54 | 9.31 | 7.81 |
| Petroleum | 1.56 | 1.77 | 0.36 | 0.16 | 0.42 | 0.24 | 0.41 | 0.72 | 2.23 | 2.18 |
| Gas | 4.19 | 9.84 | 8.99 | 2.74 | 0.28 | 0.79 | 2.27 | 7.66 | 11.42 | 35.01 |
| Other Renewables | 2.08 | 1.05 | 1.48 | 0.37 | 0.50 | 1.80 | 2.86 | 2.12 | 0.98 | 1.02 |
| Others | 3.71 | 3.53 | 6.51 | 4.06 | 7.85 | 4.68 | 52.49 | 11.67 | 16.91 | 14.26 |
| **Emission Intensity (Tons/Output in 10^6 USD in PPP)** |  |  |  |  |  |
| CO2 | 4608.92 | 1007.03 | 1294.69 | 768.17 | 5.71 | 3836.07 | 381.10 | 2066.26 | 1526.00 | 2890.31 |
| CH4 | 0.50 | 1.78 | 1.65 | 0.53 | 0.00 | 0.27 | 0.74 | 1.41 | 0.01 | 24.39 |
| N2O | 0.10 | 0.01 | 0.03 | 0.01 | 0.00 | 0.09 | 0.02 | 0.07 | 0.03 | 0.02 |
| NOX | 6.84 | 0.55 | 2.34 | 1.07 | 0.02 | 5.60 | 0.64 | 1.65 | 2.29 | 4.65 |
| SOX | 14.43 | 0.53 | 1.75 | 2.18 | 0.00 | 19.29 | 0.79 | 1.39 | 2.98 | 1.29 |
| CO | 13.90 | 0.26 | 0.70 | 1.03 | 0.01 | 5.70 | 0.12 | 1.18 | 0.28 | 4.45 |
| NH3 | 2.19 | 0.25 | 0.32 | 0.11 | 0.02 | 0.59 | 0.13 | 0.05 | 0.15 | 0.36 |
| **Factor payment output raio** | 0.34 | 0.36 | 0.35 | 0.68 | 0.51 | 0.28 | 0.35 | 0.48 | 0.43 | 0.31 |

**A1.4: Specification of Technologies for Basic Metal Sector**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|   | **India** | **Brazil** | **Itali** | **Japan** | **Russia** |
| Agriculture, Hunting, Forestry and Fishing | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mining and Quarrying | 0.08 | 0.07 | 0.01 | 0.05 | 0.11 |
| Food, Beverages and Tobacco | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Textiles and Textile Products | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Leather, Leather and Footwear | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pulp, Paper, Paper , Printing and Publishing | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Coke, Refined Petroleum and Nuclear Fuel | 0.03 | 0.01 | 0.01 | 0.01 | 0.04 |
| Chemicals and Chemical Products | 0.01 | 0.04 | 0.01 | 0.01 | 0.01 |
| Rubber and Plastics | 0.00 | 0.01 | 0.01 | 0.01 | 0.00 |
| Other Non-Metallic Mineral | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| Basic Metals and Fabricated Metal | 0.34 | 0.22 | 0.27 | 0.42 | 0.24 |
| Machinery, Nec | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 |
| Electrical and Optical Equipment | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 |
| Transport Equipment | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 |
| Manufacturing, Nec; Recycling | 0.01 | 0.01 | 0.02 | 0.00 | 0.00 |
| Electricity, Gas and Water Supply | 0.05 | 0.04 | 0.03 | 0.03 | 0.05 |
| Construction | 0.01 | 0.00 | 0.01 | 0.01 | 0.00 |
| Retail & wholesale Trade | 0.07 | 0.06 | 0.11 | 0.06 | 0.13 |
| Hotels and Restaurants | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 |
| Inland Transport | 0.06 | 0.01 | 0.03 | 0.02 | 0.01 |
| Water Transport | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 |
| Air Transport | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Other services | 0.04 | 0.10 | 0.10 | 0.07 | 0.04 |
| **Employment coefficients (Person/Output in 10^6 USD in PPP)** | 6.12 | 8.55 | 1.11 | 2.99 | 4.56 |
| **Energy intensity (Terajourle /Output in 10^6 USD in PPP)** |
| Coal | 2.10 | 0.73 | 0.21 | 2.27 | 2.36 |
| Petroleum | 0.14 | 1.09 | 0.68 | 0.27 | 0.22 |
| Gas | 0.42 | 1.57 | 1.45 | 0.96 | 4.08 |
| Other Renewables | 0.80 | 3.69 | 0.63 | 0.93 | 2.72 |
| Others | 0.00 | 0.05 | 0.10 | 0.00 | 1.77 |
| **Emission Intensity (Tons/Output in 10^6 USD in PPP)** |
| CO2 | 281.50 | 268.54 | 97.96 | 269.36 | 892.53 |
| CH4 | 0.08 | 0.32 | 0.05 | 0.01 | 0.90 |
| N2O | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 |
| NOX | 0.39 | 0.52 | 0.15 | 0.36 | 0.68 |
| SOX | 0.40 | 0.34 | 0.11 | 0.40 | 0.11 |
| CO | 6.28 | 12.14 | 1.63 | 1.78 | 9.75 |
| NH3 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 |
| **Factor payment output raio** | 0.15 | 0.19 | 0.23 | 0.24 | 0.20 |

**Appendix 2 : Employment and emissions Multiplier for India**

|  |  |  |
| --- | --- | --- |
|   |   | Energy Multiplier |
|   | Employment Multiplier | Coal | Petroleum | Gas | Other Renewable |
| Agriculture, Hunting, Forestry and Fishing | 125.83 | 1.06 | 1.21 | 0.16 | 0.79 |
| Mining and Quarrying | 28.41 | 10.88 | 0.85 | 1.98 | 0.35 |
| Food, Beverages and Tobacco | 75.34 | 2.74 | 3.00 | 0.75 | 3.56 |
| Textiles and Textile Products | 69.96 | 4.15 | 1.21 | 0.76 | 1.88 |
| Leather, Leather and Footwear | 58.85 | 2.29 | 0.89 | 0.34 | 2.10 |
| Pulp, Paper, Paper , Printing and Publishing | 57.53 | 6.49 | 1.13 | 0.82 | 2.13 |
| Coke, Refined Petroleum and Nuclear Fuel | 23.78 | 6.53 | 2.74 | 1.12 | 0.42 |
| Chemicals and Chemical Products | 30.29 | 4.56 | 1.93 | 1.52 | 1.29 |
| Rubber and Plastics | 38.29 | 5.08 | 1.24 | 0.87 | 1.70 |
| Other Non-Metallic Mineral | 58.12 | 11.86 | 1.51 | 1.19 | 2.13 |
| Basic Metals and Fabricated Metal | 27.24 | 10.62 | 0.99 | 1.55 | 1.77 |
| Machinery, Nec | 29.86 | 5.32 | 0.71 | 0.74 | 1.09 |
| Electrical and Optical Equipment | 25.75 | 4.58 | 0.73 | 0.69 | 0.99 |
| Transport Equipment | 30.73 | 5.71 | 0.66 | 0.68 | 1.22 |
| Manufacturing, Nec; Recycling | 58.32 | 4.85 | 0.83 | 0.41 | 1.89 |
| Electricity, Gas and Water Supply | 25.01 | 59.49 | 2.64 | 5.76 | 2.96 |
| Construction | 56.96 | 4.97 | 0.92 | 0.64 | 1.13 |
| Retail & wholesale Trade | 33.58 | 0.40 | 0.25 | 0.05 | 0.13 |
| Hotels and Restaurants | 69.27 | 3.65 | 1.06 | 0.32 | 3.22 |
| Inland Transport | 37.98 | 3.58 | 1.66 | 0.66 | 0.58 |
| Water Transport | 28.39 | 2.53 | 9.08 | 0.40 | 0.44 |
| Air Transport | 24.36 | 2.33 | 4.91 | 0.38 | 0.49 |
| Other services | 110.28 | 1.30 | 0.44 | 0.16 | 0.48 |

1. See website [www.wiod.og](http://www.wiod.og) and one can estimate IO coefficients for verification purpose. Here we are presenting only those data relevant for this analysis. [↑](#footnote-ref-1)
2. See world economic indicator data from [www.worldbank.org](http://www.worldbank.org) [↑](#footnote-ref-2)