BORDER CARBON ADJUSTMENT: AN EMPIRICAL INVESTIGATION INTO THE POLITICS OF CLIMATE CHANGE

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(Views expressed in the paper are personal)

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ABSTRACT

Significant attention has been drawn by the United States Waxman Markey Bill of 2009.It proposes an attempt to tackle the competitiveness and carbon leakage concerns of the nation's energy intensive industries by prompting at a measure like Border Carbon Adjustment. Using the Input-Output approach this study tries to assess the impact of a border carbon tax applied by the United States on India's export sector and the change that takes place in the value of production. Further, it finds out the impact on the resulting carbon emissions in India after a border carbon tax is imposed. The study empirically estimates whether the domestic emission reduction of the United States is partially or wholly counterbalanced by increased emissions in India. The results predict that carbon leakage takes place from U.S. to India due to difference in the technology of production. Imposition of a border tax of $10 and $25 per ton of carbon emission embodied in the exports leads to significant fall in the export of basic and heavy industries from India which have high carbon emission intensity per unit of output. India also witnesses a fall in the value of production as a result of fall in the exports. The resultant fall in the carbon emissions embodied in the exports is positive but modest.

Key Words: carbon leakage, energy intensive industries, border carbon adjustment, input-output, carbon emissions

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LIST OF ABBREVIATIONS

ACESA: American Clean Energy and Security Act

BCA(s): Border Carbon Adjustment(s)

BEA: Bureau of Economic Analysis

CBDR: Common but Differentiated Responsibilities

CGE: Computable General Equilibrium

CO_2 : Carbon dioxide

DART: Dynamic Applied Regional Trade Model

EIA: U.S. Energy Information Administration

EU: European Union

GATT: General Agreement on Trade and Tariffs

HS Code: Harmonized System Code

IO: Input Output

NAICS Codes: North American Industrial Classification Codes

UN COMTRADE: United Nations Commodity Trade

UNEP: United Nations Environment Programme

UNFCCC: United Nations Framework Convention on Climate Change

U.S.: United States

WTO: World Trade Organization

1. INTRODUCTION

1.1 BACKGROUND

Climate change is the consequence of a market failure which not only has global causes but also global consequences (Stern 2006). This has called for an effective international collaboration. It is true that rich countries have dominated in releasing emissions but emissions from developing countries are rising more rapidly. It was the past decade, from 2004-05 onwards, that the world had started glaring at countries like China and India whose total carbon dioxide (CO_2) emissions were steadily rising with China overtaking United States (U.S.) emissions in 2005 (World Resource Institute)[1]. In the year 2010 about 60 percent of global greenhouse gas emissions were released by developing countries when seen in terms of the absolute emission levels (UNEP)[2]. While China is projected to be accountable for 56 percent of the world emissions during 2007-2035, India, which takes the second position, is projected to contribute around 7 percent to the world emissions during the same period (EIA)[3].

As developing countries were not a party to the emission cuts required by the Kyoto Protocol, which was an international agreement that covered 55 percent of global emissions, the global community in general and developed nations like the U.S. and EU in particular started raising objections in international forums to showcase the asymmetry in emission cuts required under such an international agreement.

An internationally applauded agreement on collective greenhouse gas reduction targets has bleak prospects. This has lead individual industrialized countries to make an attempt to institutionalize unilateral climate policies to address climate change issues (Bohringer et al. 2012). However, such unilateral policies are subject to free riding and carbon leakages in which strong domestic actions causes these countries to lose their market share to countries which have not undertaken such emission cuts. It even leads such firms to relocate to these

[1] Accessed at: <http://cait2.wri.org/wri/Country%20GHG%20Emissions?indicator[]=Total%20CO₂ %20Emissions%20Excluding%20Land-Use%20Change%20and%20Forestry&year[]=2005&chartType=geo>

[2] Accessed at:<http://www.unep.org/pdf/UNEPEmissionsGapReport2013.pdf>

[3] Accessed at:<http://www.eia.gov/environment/emissions/ghg_report/ghg_overview.cfm>

free riding countries (Kuik and Hofkes 2010). Thus even though emission reduction is achieved at home, it is offset partially or wholly by increased emissions elsewhere (Cosby 2008, Winchester et al. 2011). Another often stated reason for such an increase in emission abroad is the impact of such policies on global energy prices. Lower demand for energy fuels in regulated nations lowers the energy prices which in turn render the production in non regulated nations more energy intensive (Kuik and Hofkes 2010, Goldar and Bhalla 2011).

To deal with such challenges of competitiveness and carbon leakage, environmental policy interventions like Border Carbon Adjustments or BCAs have often been proposed. Border Carbon Adjustment as the name suggests is the adjustment done with respect to the carbon content or carbon embodiment[4] in the goods when the goods cross boundaries. BCAs are either applied in the form of import taxes or it requires the importers to surrender carbon permits (Condon and Ignaciuk 2013).

Border Carbon Adjustment received recent attention in the United States Waxman Markey Bill or the American Clean Energy and Security Act of 2009 (ACESA; H.R. 2454) under Title IV, section 786 on 'International Reserve Allowance Program'. European Parliament was the first to put forward the notion of imposing BCA mechanism in the form of a border tariff on imports from countries that are slow to reduce emissions, targeting them specifically at U.S. U.S. had opposed this move undertaken by Europe. But while drafting its own climate policy in 2009 it advocated such measures targeting them at China and India. The politics of Border Carbon Adjustment comes to the surface under Section 3 of the Waxman Markey Bill as it was stated that the administrator needs to be reported annually whether China and India have adopted atleast as stringent green house gas emission standards as under this bill.

The literature points to the notion that border adjustments are proposed to be imposed by the U.S. against developing countries like China and India if they do not participate in global emission reduction agreements. It's used as a threat instrument to get China and India to legally commit to the Post Kyoto Agreement which will be discussed in the Paris conference to be held in 2015 and which has to come in force in 2020 (HÜbler 2012, Dong and Whalley 2009, Weber and Peters 2008).

The other reason for which a border carbon adjustment is propagated is to make the domestic producers more competitive because domestic carbon pricing alone, without a corresponding

[4] Carbon embodiment is the total tons of carbon emitted during the entire production process.

tax on imports, imposes a disadvantage on them. It also prevents carbon leakages where a carbon leakage is defined as increase in emission abroad due a policy at home relative to decrease in emission at home.

Because of such reasons developed nations like the U.S. have intensely started discussing BCAs in their parliament. An interesting point to note here is the impact of such mechanisms on the fall in global emissions is not expected to be much (HÜbler 2012, Guo et.al 2009, Dong and Whalley 2009). Though the measure was proposed yet the effectiveness and efficacy of such a measure is still unclear. There are questions even on the legality of border carbon adjustments under the GATT and WTO regime (Tamiotti 2011, Bordoff 2009).

Does this mean that BCAs are merely used as a threat instrument to get China and India to join the Post Kyoto Agreement or it is a means to make the U.S. energy intensive industries internationally more competitive?

1.2 RESEARCH OBJECTIVE

This paper explores whether the border carbon adjustment mechanism has an effect on greenhouse gas emission reduction or it just addresses the competitiveness concerns of the U.S. energy intensive industries by passing the environmental and economic burden to developing countries like India.

Using the input-output approach the study tries to assess the carbon emission intensity per unit of output or export and the total carbon embodiment in India's manufacturing export basket. It analyses the impact of a border carbon tax applied by the United States on India's export sector and the change that takes place in the value of production. Further, it finds out the impact on the resulting carbon emissions in India after a border carbon tax is imposed. The study empirically estimates whether the domestic emission reduction of the United States is partially or wholly counterbalanced by increased emissions in India.

2. LITERATURE REVIEW

2.1 LEGAL AND INSTITUTIONAL PERSPECTIVES

The concern about 'tragedy of commons' nature of climate change has led intense parliamentary discussions in the EU and the U.S. to impose unilateral trade measures on imports from countries that do not have comparable environmental regulations. UNFCCC's principle on "common but differentiated responsibilities" and the mandatory requirements for developed nations which require emission reduction commitments with respect to green house gas emissions has increased the demand from the developed countries to include developing nations to undertake some such commitments. The Copenhagen Accord of December 2009 and Cancun Agreements of December 2010 tried to overcome these issues but they did not have a legally binding status (Anuradha 2011).

The possibility of unilateral measures like border taxes is not denied by UNFCCC[5] but it does fail to specify the grounds on which such measures are applicable. The lack of any overarching framework that encompasses all the possibilities of unilateral trade measures often leads to a trade dispute under the WTO.

The BCAs in the form of border taxes[6] usually come in conflict with the WTO law. Article II of GATT limits the tariff rates by a ceiling or a bound rate which is the maximum allowed tariff rate while Article XI has provisions against quantitative restrictions on imports. Border taxes can be accepted as a border enforced internal measure if and only if the domestic products face the same regulations as the imports. This is stated in Article III of GATT on "National Treatment" of products that are imported. Another fulfillment criterion in this regard is Article I's "Most Favoured Nation (MFN)" clause which is necessary for the applicability of border taxes. This article states that the nations should not discriminate against importing countries. When the border taxes are consistent with these two provisions they can be applied as a border enforced internal measure.

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[5] "Measures taken to combat climate change, including unilateral ones, should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade" (Article 3.5, UNFCCC)

[6] Another form of BCA mechanism is the importers purchasing carbon allowances from the market at market price.

In case the BCAs or border taxes violate Article I and/or Article III by taxing only some countries imports like India and China or taxing products based on the production process, for instance, taxing steel imports from India and not steel imports from Canada, in such cases border taxes can only be applied if it satisfies the Environment Exception clause in Article XX (g) of GATT.

Article XX (g) is on “conservation of exhaustible natural resource” which takes clean air as an exhaustible natural resource and allows for BCA if it reduces carbon leakages and lowers green house gas emissions. Under this clause if some nations have stringent environment conditions or have comparative environment regulations then they can be excluded from border taxes net (Tamiotti 2011, Bordoff 2009). Hence, violation of MFN clause is allowed under this article though on specific grounds.

United States can use the Environment Exception clause in Article XX (g) while promoting the objective of prevention of carbon leakages to India and China. It can charge tariffs higher than the maximum permissible tariffs or bound rates by invoking this clause. The problem that arises here is that the objective of “conservation of the exhaustible natural resource”, taken here as the clean air, does not come out explicitly in the Waxman Markey Bill of 2009. It is because of this that the developing countries like India who have come under the scanner for carbon emissions are arguing against invoking Article XX(g) exception by the United States (Anuradha 2011, Bordoff 2009).

2.2 EMPIRICAL

The survey of the empirical part of the literature is divided into two sections. The first deals with the research undertaken in the area of competitiveness and trade effects and the second in the area of carbon leakages and international trade in goods.

2.2.1 Competitiveness and Trade Effects

Using a reduced form of regression framework at a disaggregated 4 digit industry level Aldy and Pizer (2011) did a study where they imposed a unilateral carbon price of $15 per ton of carbon dioxide on only U.S. industries. They found that the production in those industries declined by 3 to 4 percent due to higher energy prices in the heavy industries like iron and steel, aluminium etc. Consumption[7] declined by 2 to 3 percent. A moderate adverse competitiveness impact of 1 percent was estimated that might shift production overseas. Hubler (2012) stated that in such a case developing countries tend to gain due to increased production and exports.

When a border carbon tax is imposed on the imports of a country based on carbon embodied in goods then Dong and Whalley (2009) in a study analyzing the U.S.-China trade found that the exports of the country on which the tax is imposed decreases which subsequently lead to a fall in their value of production. The results were an outcome of Computable General Equilibrium (CGE) modeling for the year 2006.The study also found that there is a fall in the imports of the country imposing the tax which in turn leads to an increase in their value of production because of the carbon pricing policy and substitution towards domestic production. Dong and Whalley noted that the impact on exports and value added depends on the size of tax. The study took tax rates as $25, $50, $100 and $200 per ton of carbon dioxide emitted and found that the impact on both exports and value added got exaggerated. The impact was even more for high emission goods than low emission.

Atkinson(2011) in his paper on 'virtual carbon' linked carbon prices or taxes with the price elasticity of exportable products. He stated that if the demand for the good is infinitely elastic then taxing 'virtual carbon' or embodied carbon in goods is equivalent to taxing emission at source. In case of perfectly inelastic demand curve, tax has no effect on the production or the level of emissions. Intermediate cases for demand elasticity will vary as steeper the demand schedule less effective is tax on carbon.

Interestingly, Hubler (2012) in his study on China, U.S. and other developing countries found that China would be worse off if it doesn't participate in an international climate regime and instead is faced with a tax on its export. This result could be predicted using an extended version of CGE model which is called as DART or dynamic applied regional trade model. This model is preferred to CGE model because it captured the spillover effects as a result of international trade along with the pure trade effects which are captured by the CGE.

There have been a limited number of India specific studies in this regard. Goldar and Bhalla (2011) used a $15 and $50 per ton of carbon dioxide tax rates and showed the negative impact on the exports of India, China and other developing countries. They showed that India

[7] Includes domestic and imports

is affected more if the carbon tax is based on emissions embodied in India's export rather than U.S. producer's emission intensity for those products. Bhattacharya and Nanda (2012) did a study on India using the 2006-07 input output matrix of India and showed that India's exports fall by 2.34 percent and 3.5 percent for tax rates €20 and €30 per ton of carbon dioxide when imposed by U.S. The taxes were average and peak prices of carbon that was traded in European market for 2006-07. EU prices were considered due to non availability of U.S. carbon price data.

When a border carbon tax is imposed on the goods, the result is the changed commodity price vector. This change in the commodity price vector and the resultant consumer demand was captured through price elasticity by Choi et. al (2010). The border tax adjustment which is the key to the BCA mechanism is computed by multiplying embodied carbon per unit of output with the specific carbon tax. This is then converted to the ad valorem tax rates as done by Mckibben and Wilcoxen (2008).

2.2.2 Carbon Leakages and International Trade in Goods

When a border tax is imposed it intends to reduce carbon leakage though reduction might vary depending on tax rate applied but as showed in the literature leakage will reduce. The impact on total emissions is uncertain.

Winchester et.al (2011) using a multiregion CGE model stated that carbon leakage is reduced by 30 percent if a tax of $15 per ton of carbon emitted is applied only by U.S. and the leakage reduces by 60 percent if applied by a coalition of countries. They found that though carbon leakage is significantly reduced but there is only a modest reduction in global emissions. Bohringer et.al (2012) using GTAB database and multiregion CGE also stated that border carbon adjustment can effectively reduce leakage through trade in energy intensive and trade exposed industries (EITE). Using a seven country seven region general equilibrium model Barker et.al (2007) did a study for the OECD countries. They found that carbon leakage ranges between 50 to 130 percent in which case a policy to limit emissions in OECD countries would lead to adverse effect of increasing global carbon emissions. This is because their study included the market structure of the industries in the general equilibrium model through cournot oligopoly with the assumption of free entry and exit. In another study done for six EU member states by Barker et.al (2007) it was found using the energy environment and economy wide model of 27 European countries that during 1995 to 2012 carbon leakage was very small and in some cases negative because of technological spillovers between the member states. The result becomes more acceptable as the study was done on six EU member states. This might not be the case when we consider a developed and a developing country.

Using the DART model Hubler (2012) found that carbon intensive commodities flow from China and developing countries to industrialized countries like U.S. Carbon intensive exports from the industrialized nations to developing countries and China is low. Also trade in carbon intensive commodities within the developing countries and China is low. They found that there is small emission reduction from introduction of a carbon tariff.   A similar result was found by Dong and Whalley (2012). They did a study for the year 2006 using the static CGE model for four regions China, U.S., EU and rest of the world (ROW) and found that when U.S. imposes a tariff on China there is fall in U.S. emissions and increase in China's emissions. The global emissions showed a slight fall.

In order to determine the carbon exporting or importing nature of the countries many individual country level studies have been undertaken using the Single Region Input Output table (SRIO). Mongelli et.al (2006) did a study for Italy and found it to be a net importer for four of its most carbon intensive goods. A similar study was done for Spain by Sanchez-Choliz and Duarte (2005) where a slight exporting behavior for carbon intensive goods was found.

A lot of research has been undertaken for the Chinese economy. Lin and Shun (2010) did a study for China and found it to be a net exporter of carbon dioxide emissions in 2005.The highlight of his study was that it separately dealt with the re-exported emissions. The imported intermediate inputs were transformed into output after domestic reprocessing. Though the total amount of embodied emissions in a commodity would not change, however, the embodied carbon has been relocated among different sectors. To adjust for such changes the direct coefficient matrix was decomposed between domestic and imported products in the study (Lin and Shun 2010).Shui and Harriss (2006) and Du et.al (2011) did a study on U.S.-China carbon trade using the environmental input output matrix of the U.S. and adjusting it for China. While Shui and Harriss (2006) used purchasing power parity to account for currency value of the commodities in their study, Du et.al (2011) used energy to dollar ratio to account for both currency and environmental value of the commodities. Their study found that U.S. emissions would be 3 to 6 percent higher had the goods being imported from China produced in U.S. China's emissions were 7 to 14 percent higher because of producing goods for the U.S. The overall emissions showed an increase in their study. Li and Hewitt (2008) followed the method of Shui and Harriss (2006) and did a similar study for UK and China. It came up with similar results.

Akerman et.al (2007) analyzed the Japan-U.S. trade using the Japan U.S. International Input Output table that was prepared by the Japanese government in 1995. They found that U.S. shifted a part of its carbon burden to Japan. But with rest of the world, U.S. and Japan were net importers of carbon. The overall emissions showed a decline.

Most of the literature showed that it was the developing countries or countries relatively less developed to other countries that were the net exporters of carbon intensive goods.

The Single Region Input Output matrix (SRIO) which has been used by most of the studies has a major shortcoming. For calculating the emissions embodied in the imports it uses the domestic technology only. This problem is overcome by Bilateral Trade Input Output Matrix (BTIO) or linked single region model where national tables are exogenously linked with bilateral trade data for different countries for calculating embodied emissions (Wiedmann et.al 2007). He and Su (2014) took sixteen manufacturing sectors and single country linked IO model to calculate the carbon emissions embodied in trade for China with its trading partners. Guo et. al (2010) exogenously linked the tables of China and U.S. and found that U.S. decreased its carbon emissions through consumption of goods made in China while China's carbon emission were found to be increased as a result of this. There was a net increase in total carbon emissions.

This study attempts to study the impact of a border carbon tax on the competitiveness of Indian exports and hence the resulting changes in the value of production. It further attempts to see the resultant changes in the carbon emissions after a border tax is imposed. The study quantifies the carbon emissions in U.S.-India trade using a sectoral approach. It estimates the amount of carbon leakages that take place in the U.S. India bilateral trade. The next section discusses the methodology to be followed for this paper and the relevant data sources.

3. METHODOLOGY

The study is based on Input Output Analysis (IOA) which captures the direct and indirect, economic and environmental impact following a change in the total output. It does so through a well established linear economic model as proposed by Leontief for the first time in 1936 based on the input output tables. The main feature of IO table is to describe the economic system in a steady state period of one year. Each column of the table represents a sector which describes the quantities of all the other inputs that go into that sector while the row studies the distribution of the output of that sector to all the other sectors.

Input Output system is based on a set of assumptions. First, it assumes a fixed input output ratio. This is because of the linearity of the model. IO analysis works only for constant returns to scale technology. Second, is the assumption of price homogeneity which is necessary for aggregation of the goods produced or exchanged. Third, it assumes that the economic structure remains unchanged during the period of study. There are no structural or technological changes in the economy. Lastly, it assumes import substitution which means that if an inter-country model is not used then the imports from a country are considered as produced with the home technology only (Mongelli et.al 2006).

Given these set of assumptions this study uses the input output approach and presents the quantitative analysis required in the study through two parts.

The first part calculates the competitiveness impact. It includes estimation of the carbon intensity and the total embodied emissions in the exported products. Then using the estimates of price elasticity of exports and scenario based tax rates it calculates the impact on the exports of the carbon intensive commodities from India. Along with the changed export vector and the ratio of gross value added to the total output for each sector we then calculate the change in the value of production. This method is in line with the approach adopted by Choi et. al (2010), Mckibben and Wilcoxen (2008), Lin and Sun (2010), Sánchez-Chóliz and Duarte (2005), Bhattacharya and Nanda (2012), Goldar and Bhalla (2011). Choi et. al (2010) captured the changes in commodity prices that result from an imposition of tax on industry sectors and changes in consumer demand through price elasticity. Mckibben and Wilcoxen (2008) computed the border tax adjustment by multiplying embodied carbon per unit of output by the carbon tax and then converting it to ad valorem tax. This method is closely followed in the present study.

The second part studies carbon leakages during international trade in goods. It quantitatively assesses the CO_2 emissions avoided in the U.S. by importing Indian goods and how much emissions are generated in India as a result of producing for the U.S. This will help us draw the conclusion about changes in the total carbon emissions due to U.S.-India bilateral trade. This method follows the approach taken by Guo et.al (2010) and He and Su (2014). He and Su (2014) took sixteen manufacturing sectors and single country linked IO model to calculate the carbon emissions embodied in trade for China with its trading partner. Our study has taken a high value manufacturing export basket of twenty four manufacturing goods for India during 2007-08 and has linked this basket with the exogenous input output tables of U.S. and India inorder to calculate the carbon emissions embodied in bilateral trade between U.S. and India. Guo et. al (2012) has followed the same procedure as He and Su (2014) and found that U.S. CO_2 emissions decreased through consumption of Chinese goods and China's emissions increased. Our study predicts a similar result for India.

3.1 Model

Our study uses the input output system to note how much of fuels are going directly and indirectly into each sector of the IO table and by multiplying the fuels with the carbon emission coefficients we find the estimated carbon emission intensity per unit of output.

3.2 Model Assumptions

The IO model and the results of this study are based on certain assumptions. They are:

1. Depreciation of the currency (Indian rupee) does not occur or even if it occurs it is not significant: A depreciation can nullify or affect the effect of a tax on India's export by encouraging exports from India. But because this study is in a partial equilibrium framework we assume that depreciation of the currency does not occur or it is not significant.
2. CO_2 removals are not being considered.

3. United State and India's technology is assumed to be different: This assumption is met by taking the respective input output transaction table or the technology matrix of US and India.
4. Fuel coefficients are taken to be constant from 2004-05 to 2007-08 for India.
5. Price elasticity of exports for all sectors in the study is taken to be constant for the period of study.
6. Exports for the year 2007 are taken to be exports for the year 2007-08.

3.3 Competitiveness and Trade Effects

The Leontief System in matrix form is written as:

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

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

where X is the column vector representing total output of the entire economy. AX represents the intermediate input demand and Y is the final demand. Y includes household consumption, government consumption, investment, changes in inventory and net export. A represents a direct requirement coefficient matrix or the technology matrix. Its element $A_{ij} = \frac{Xij}{Xj}$ represents the amount of input from industry i required directly to produce per unit output from industry j. I is the identity matrix and $(I- A)^{-1}$ is the Leontief inverse matrix or "total requirements" matrix. Its element αij represents amount of input from industry i required directly and indirectly to produce per unit final demand from industry j. So the amount of petroleum required to produce a unit of output j will be given in the petroleum sector row and output column j.

3.3.1 Direct and indirect emissions/Carbon embodiment in exports:

Using IO table the total emissions embodied in the exports of a country can be calculated as follows:

$$\mathbf{F} = \mathbf{c} *(I- A)^{-1} \qquad (3)$$

$$C = \mathbf{c} *(I- A)^{-1} * \mathbf{E} = \mathbf{F} * \mathbf{E} \qquad (4)$$

where **E** is the desired vector of export values and **c** is a row vector representing direct CO_2 emission intensity of fuel. (I-A) $^{-1}$ is the sub matrix of fuels taken from Leontief inverse. **F** is a vector representing domestic embodied emissions per unit of output where Fi is the carbon embodied in a unit of output in sector i. Studies have also taken Fi directly as the ratio of total carbon embodied in sector i to the total value added of production of sector i i.e. Fi = CO_2 i/ VAi. Here Fi represents direct and indirect emissions generated during the production of a good to meet per unit of final demand. FiEi represents embodied emissions in final demand Yi. The domestic direct and indirect emissions generated by all the sectors could be represented by C (Lin and Sun 2010; He and Su 2014).

3.3.2 Imposition of a border carbon tax

Now, when a border carbon tax, t, is imposed:

I. Total tax per unit output $t_o = Fi * t$, (5)

where t is the specific tax rate applied on the estimated emission intensity per unit of export.

The computed tax is converted into an ad valorem tax rate per unit of export using the equation below:

Ad-valorem tax $t_\alpha = (Fi * t) / e$, (6)

where e is the export value of a unit of export. Ad valorem tax gives us the proportional change in the original price that takes place as a result of a specific border tax.

As price elasticity of demand (or export) is given by the ratio of percentage change in quantity demanded to the percentage change in price, or

$$\varepsilon_P = (\Delta Q/Q) / (\Delta P/P) , \qquad (7)$$

the proportionate fall in export quantity demanded can be computed. From this computation procedure a new vector of export quantity demanded and the value of new export quantity can be calculated given the price hike due to ad valorem tax rate. We assume that there is one-to-one increase in the value per unit of export due to the tax imposition.

The new vector of export quantity demanded is given by,

$$\mathbf{Q'} = Q – (\Delta Q/Q)*Q \qquad (8)$$

Now, Q' with the increased price of per unit export will give the vector of value of the new exports, that is,

$$\mathbf{E'} = \mathbf{Q'} * \mathbf{P'}, \qquad (9)$$

where $P' = e + (t_\alpha * e)$ or $P' = e + t_o$ as we assume one-to-one increase in the price due to tax imposition.

The change (fall) in the exports in value terms is given by

$$\mathbf{\Delta E} = \mathbf{E} – \mathbf{E'}, \qquad (10)$$

where E is the original value of export and E' is the new value of export after specific tax t_o or corresponding ad-valorem tax rate t_α is imposed along with price elasticity estimates ε_P .

II. Percentage change in the value added of production is given by the ratio of value added to output computed for each sector multiplied by the percentage change in the export vector:

$$(\Delta VA/VA) = \mathbf{R} * (\mathbf{\Delta E/E}) , \qquad (11)$$

where ΔVA is the loss in aggregate value and R is a vector of value added to output (or production) ratio for each industry i. **ΔE** gives the change in the export basket when a tax is imposed.

III. The total emissions embodied in the exports vector, **E'**, is given by

$$C' = \mathbf{c} *(I- A)^{-1} * \mathbf{E'} = \mathbf{F} * \mathbf{E'} , \qquad (12)$$

where **E'** is the value of exports after a tax is imposed (eq. 9). As we assume that the technology has not changed over time, we take the same carbon emission embodied in a unit of output as in eq. 3.

Change in carbon emissions embodied in the exported product is given by,

$$\Delta C = C - C', \qquad (13)$$

where C is given in eq. 4 and C' in eq. 12. ΔC will hint about the approximate fall in the carbon emissions embodied in the exports that take place as a result of imposition of a border carbon tax.

3.4 Carbon leakages and international trade in goods

3.4.1 CO_2 emissions embodied in international trade[8]:

The total CO_2 emissions embodied in export products of each sector is given by:

$$EC_i = c_i^E * (I - A^E)^{-1} * EX_i * X = F_i^E * EX_i * X, \qquad (14)$$

where EC_i is the total (direct and indirect) CO_2 emissions embodied in export products of each sector. F_i^E is the CO_2 emission intensity of sector i of the exporting country. $(I - A^E)^{-1}$ represents the sub matrix of fuels drawn from the Leontief inverse matrix of the exporting country and EX_i is the value of exports of sector i. X is the average exchange rate between the exporting and importing country.

The total CO_2 emissions embodied in goods imported by the importing country is given by:

$$IC_i = c_i^I * (I - A^I)^{-1} * IM_i = F_i^I * IM_i \ , \qquad (15)$$

where IC_i is the CO_2 emissions embodied in imported goods. F_i^I is CO_2 emission intensity of sector i of the importing country. $(I - A^I)^{-1}$ is the sub matrix of the fuels of the importing country drawn from the Leontief inverse matrix of the importing country. IM_i represents the value of imported goods of sector i from the exporting country in the currency of the importing country. It is necessary to have the import value in the currency of the importing country because each country's technology matrix is defined in their own currency.

[8] For this study the exporting country is India and the importing country is U.S.

Domestic emission reduction of country k through the consumption of imported goods is given by:

$$CO_2^k = c_i^k * (I - A^k)^{-1} * IM_i \;, \qquad (16)$$

where CO_2^k is domestic emission reduction of country k through the consumption of imported goods. c_i^k is the emission intensity of factor i of country k and $(I - A^k)^{-1}$ is the sub matrix of fuels drawn from the Leontief inverse matrix of country k.

3.4.2 Impact of international trade on global CO_2 emission:

$$CO_{2K}^k = (c_i^E * (I - A^E)^{-1} * EX_i * X) - CO_2^k \;, \qquad (17)$$

where CO_{2K}^k represents the increase or decrease of total CO_2 emissions through the consumption of imported goods by country k . $(c_i^E * (I - A^E)^{-1} * EX_i * X)$ represents the increase in CO_2 emissions of exporting country caused by the import behaviour of country k. CO_2^k represents the amount of carbon emissions that take place if the imports were produced by the importing country themselves. If CO_{2K}^k is positive it represents carbon leakages and that the exporting country is emitting more carbon emissions by producing for the importing country.

4. KEY DATA AND SOURCES

The study uses 130 X 130 sector India's Leontief Inverse Matrix published by Ministry of Statistics and Programme Implementation (MoSPI) for the year 2007-08. This is used to draw the sub matrix of fuels to calculate the emission intensity per unit of output and in turn the total carbon embodiment in India's export. NIC codes (national industrial classification) which define the manufacturing sector within the 130 sector table are of interest in the study.

The United States 2007 benchmark input output table published in 2014 is used to calculate U.S. carbon emissions for the relevant commodity basket. The commodity X commodity use matrix, which is a 389 X 389 industries table, is used to draw the sub matrix of fuels to be used for estimation. Though 15 and 79 industries matrix is also available, the detailed 389 industries matrix has been used to get the most accurate results with respect to the carbon emissions.

The exports from India are taken from UN COMTRADE (United Nations Commodity Trade) Database at 4 digit HS 2002 (Harmonized System) codes. A high value export basket of 24 manufacturing sector goods were selected. They were concorded with the Ministry of Commerce Export-Import database at 4 digit HS 2002 codes. Exports for the year 2007 were considered in US thousand dollars. Except for a minor difference in the value of exports in both datasets, the results in terms of the highest exportable products in value were the same in both datasets. The value of exports is taken from UN COMTRADE dataset because the study involves using the United States Input Output matrix also and the UN COMTRADE statistics very well satisfy the U.S. standard codes. The drawback of the annual export data is that the input output matrix is for financial year 2007-08 but this shortcoming will not affect the results much. The export quantity has also been taken from UN COMTRADE database so as to find the per unit value of the exportable products and to find the change in the quantity exported due to a carbon tax by using the price elasticity estimates.

Average exchange rate of INR 40.241 per U.S. dollar has been used to convert the dollar value of exports in Indian rupee. The average exchange rate for 2007-08 has been taken from the Reserve Bank of India[9].

[9] Access at: <http://www.rbi.org.in/scripts/PublicationsView.aspx?id=14503>

Exports from India were crosschecked with the imports to U.S. for 2007 from United States International Trade Commission Interactive Trade Dataweb using data retrieved from U.S. Bureau of the Census, an agency within the U.S. Department of Commerce. The data gave similar high value import sectors at 4 digit HS 2002 codes and 4 digit NAICS codes (North American Industrial Classification System). The import data was checked with NAICS codes because the U.S. Input Output matrix is based on BEA codes (Bureau of Economic Analysis codes) and the concordance between BEA and NAICS were available with the Bureau of Economic Analysis. As export values were given by HS code classification and there wasn't a ready concordance between HS codes and BEA codes, hence a concordance was drawn between HS codes and NAICS codes and then NAICS codes were concorded with BEA codes. Thus, an indirect concordance between HS codes and BEA was established.

For carbon emissions, instead of taking direct sector-wise emission coefficients, the study takes emission coefficient by fuels. Three major fuels have been considered in the study – coal and lignite, natural gas and crude petroleum. By taking a sub matrix of fuels from the IO table we get the amount of fuels going in different sectors per unit of output. On multiplying the sub matrix of fuels with the fuel emission coefficient we get the emissions embodied per unit of output in different sectors of the IO. The fuel coefficients for India have been taken from Parikh et.al (2009). It is assumed that the fuel coefficients listed for 2003-04 in Parikh et.al study have remained the same till 2007-08. The fuel coefficients for U.S. have been taken from U.S. Environment Protection Agency[10]. Appendix A1 lists the fuel coefficients used for India and U.S. for the corresponding three fuels considered in the study.

Two scenarios for carbon taxes have been considered in the study- U.S. $ 10 per ton of carbon emission and U.S. $ 25 per ton of carbon emission. They have been reviewed from a report by the World Bank in 2014 'State and Trends of Carbon Pricing 2014'. The report gives an overview of the existing and emerging carbon taxes.

For price elasticity, the elasticity of exports to U.S are taken from Aggarwal (2004) for all the sectors except non ferrous basic metals which has been taken from Lucas (1988) and cement which has been taken from Chadha, Pohit et.al (1998). We assume that the price elasticity for all sectors taken from Aggarwal (2004), Lucas (1988), Chadha, Pohit et.al (1998) remain the same till 2007-08. The elasticity for non ferrous metals and cement have been taken from Lucas (1988) and Chadha, Pohit et.al (1998) because recent estimates of price elasticity were

[10] Access at:< http://www.epa.gov/cleanenergy/energy-resources/refs.html >

not available. Also, in GTAB elasticities and elasticities given by Lucas (1988) and Virmani (1991), textiles and clothing or textiles and manufactured apparel have different price elasticities but here they have been assumed same because of lack of recent data on the sectors price elasticity. Appendix A2 lists the price elasticity estimates considered in the study.

Relevant export sectors for study: On the basis of the 4 digit HS 2002 codes, NAICS codes and the value of exports from UN COMTRADE, Ministry of Commerce and United States Trade Commission, the study concentrates on the major 24 high value export sectors(in U.S. dollar) which are cotton textiles; woolen textiles; silk textiles; art silk, synthetic fibre textiles; jute, hemp, mesta textiles; carpet weaving; readymade garments; miscellaneous textiles; paper, paper products and newsprint; leather, rubber products; plastic products; inorganic heavy chemicals; organic heavy chemicals; fertilizers; other chemicals; cement; iron and steel; iron and steel foundries; non ferrous basic metals; other non electrical machinery; electrical machine and wires; motor vehicles and watches and clocks. Diamonds and jewellery though have a high value in exports but are excluded from the analysis because the value addition in India for this sector is very low. Rice, on the other hand, is though carbon equivalent intensive but the value of exports when compared to a manufacturing sector is very low. For similar reason we have excluded agricultural sectors from the export basket and services sector from the study.

India's IO Leontief matrix, which is a 130 X 130 matrix, is modified to 126 X 126 matrix according to the export sectors identified through HS codes 2002 classification and the sectoral definition of IO 2007-08 matrix. For combining the relevant sectors, HS codes at 2 digit level were also considered. IO sector 46 and 47 were averaged to form cotton textiles; IO sector 59 and 60 were averaged to form leather; IO sector 77 and 78 were averaged to form iron and steel and IO sector 88 and 89 were averaged to form electrical machine and wires. Appendix A3 shows how the sectoral definition of HS codes at 2 digit and 4 digit level (2002) were concorded with the sectoral definition of the IO 2007-08 matrix. Total values of exports were thus arrived at by combining the relevant sectors at 2 digit and 4 digit level. Appendix A4 lists the export sectors and the value of exports taken for estimation.

Similarly, United States Leontief matrix or total requirements use matrix, which is a 389 X 389 matrix, is modified to 332 X 332 matrix according to the sectoral definitions given by Bureau of Economic Analysis and the export basket of India or equivalently import basket of

U.S. given by HS code classification 2002. Appendix A5 shows the sector concordance which was in turn used to average the relevant sectors coefficients in a way similar to that adopted for India.

The price index of fuels of coal and lignite, petroleum and natural gas has been taken from Ministry of Coal and Ministry of Petroleum and Natural Gas for India. For United States it's taken from Annual Energy Outlook 2008. Appendix A6 lists the price index of fuels used for both the countries. The price index of fuels is required to get the tonnes (coal and petroleum) or 1000 cubic metre (natural gas) of carbon emitted from the value of fuels in rupees or dollars. It deflates the value of fuel to give the physical units of fuels which when multiplied with the emission coefficient gives the carbon emission embodied in export by fuel type.

5. EMPIRICAL ESTIMATION

5.1 Competitiveness and trade effects

5.1.1 To calculate the carbon emission intensity in per unit of export or output, we multiply the carbon emission coefficients of fuels given in Appendix A1 with the sub matrix of fuels drawn from the Leontief inverse matrix which has been adjusted to a 126 X 126 matrix as stated earlier. The transpose of the sub matrix of fuels is given in Appendix A7 and the calculated carbon emission intensity per unit of export is shown in Appendix A8. The fuels considered in this study are Coal and Lignite, Natural Gas and Petroleum. The total carbon embodiment (in tonnes) for a high value manufacturing export basket (Appendix A9) is estimated by multiplying the carbon emission intensity per unit of export (Appendix A8) with the export basket in INR (Appendix A4).

5.1.2 Inorder to estimate the percentage fall in the exports when a border carbon tax, t, is applied on the tonnes of carbon emitted per unit of export, we impose a $ 10 per ton of carbon emitted and $ 25 per ton of carbon emitted on the carbon emission intensity of per unit export calculated in tonnes. This is converted to an ad valorem price increase based on the per unit value of exports. The ad valorem price increase along with the price elasticity of export figures gives us the percentage fall in quantity of export when a tax of $ 10 and $ 25 per ton of carbon emission is imposed on the carbon intensity of per unit export. From the percentage fall in quantity of exports we get the after tax export quantity estimates. As the ad valorem rate along with the per unit value of export gives us the estimates of the price per unit export after a border tax is imposed, we multiply the new price vector with the new found quantity of exports to get the value of exports after tax. The new value of export vector, after a tax is imposed, along with the carbon emission intensity gives the carbon emission embodied in the new exports. The difference in the original and new carbon emission embodied in exports gives the resultant change in the emissions when a tax is imposed (For results see: Table 1 for US $ 10 per ton of carbon tax and Table 2 for US $ 25 per ton of carbon tax).

Table 1: Change in the exports and price when the tax of $10 per ton of emission is applied on the emissions embodied in a unit export

Sector	Emission intensity per unit of output	Price Elasticity of Exports	Tax	Export Value ($)	Export Value (INR)	Export Quantity	Export Value per unit output (INR)	Ad valorem rate (%)	New Price	Export Fall (%)
Iron and Steel	1.7598	3.005	17.5978	422365202	16996398094	3.18E+08	53.493	0.32898	71.09	0.98858
Fertilizers	1.5184	7.943	15.1844	240183	9665204	284186	34.01	0.44647	49.194	3.54628
Other non-electrical machinery	1.0429	4.01	10.4288	977324326	39328508203	55480936	708.87	0.01471	719.29	0.05899
Iron and steel foundries	0.8758	3.005	8.7583	1246372045	50155257463	8.65E+08	57.974	0.15107	66.733	0.45397
Motor vehicles	0.8366	1.922	8.3663	561687422	22602863549	81881547	276.04	0.03031	284.41	0.05825
Cement	0.8319	1	8.3192	198397	7983694	1735127	4.6012	1.80805	12.92	1.80805
Organic heavy chemicals	0.831	2.119	8.3099	735403690	29593379889	1.34E+08	220.21	0.03774	228.52	0.07996
Non-ferrous basic metals	0.822	5.427	8.2198	183290707	7375801340	38576018	191.2	0.04299	199.42	0.23331
Inorganic heavy chemicals	0.7451	2.119	7.4511	33070946	1330807938	33662208	39.534	0.18847	46.985	0.39937
Plastic products	0.6576	4.279	6.5756	237514082	9557804174	1.18E+08	81.336	0.08084	87.911	0.34593
Art silk, synthetic fibre textiles	0.4602	1.592	4.6022	88527057	3562417301	25399486	140.26	0.03281	144.86	0.05224
Readymade garments	0.4162	1.592	4.1623	2831914519	113959072159	5.94E+08	192.01	0.02168	196.17	0.03451
Other chemicals	0.3975	1.41	3.9751	152818235	6149558595	39011811	157.63	0.02522	161.61	0.03556
Miscellaneous textile products	0.3461	1.592	3.4608	1049775485	42244015292	1.51E+08	279.85	0.01237	283.31	0.01969
Paper, paper prods. & newsprint	0.302	6.11	3.0203	50869834	2047052990	29043404	70.483	0.04285	73.503	0.26183
Rubber products	0.2968	4.519	2.9676	104224421	4194094925	31356293	133.76	0.02219	136.72	0.10026

Sector	Emission intensity per unit of output	Price Elasticity of Exports	Tax	Export Value ($)	Export Value (INR)	Export Quantity	Export Value per unit output (INR)	Ad valorem rate (%)	New Price	Export Fall (%)
Cotton	0.2954	1.592	2.9543	83975115	3379242603	14107026	239.54	0.01233	242.5	0.01963
Electrical Machine and Wires	0.2607	4.01	2.6067	919632556	37006933686	47007790	787.25	0.00331	789.86	0.01328
Leather	0.0566	0.984	0.5662	205772880	8280506464	5562907	1488.5	0.00038	1489.1	0.00037
Woolen textiles	0.0403	1.592	0.4029	4188024	168530274	499821	337.18	0.00119	337.58	0.0019
Jute, hemp, mesta textiles	0.0371	1.592	0.3712	20423163	821848502	7975250	103.05	0.0036	103.42	0.00573
Silk textiles	0.0305	1.592	0.3048	83315879	3352714287	816488	4106.3	7.4E-05	4106.6	0.00012
Carpet weaving	0.0272	1.592	0.2720	483442285	19454200991	74147681	262.37	0.00104	262.64	0.00165
Watches and clocks	0.0117	1.666	0.1173	1296656	52178734	116926	446.25	0.00026	446.37	0.00044

Source: Author's Calculation, Price Elasticity from A2, Export Value from A4, Export Quantity from UN COMTRADE

Table 2: Change in the exports and price when the tax of $25 per ton of emission is applied on the emissions embodied in a unit export

Sector	Emission intensity per unit of	Price Elasticity of	Tax	Export Value ($)	Export value (INR)	Export Quantity	Export Value per unit output	Ad valorem rate (%)	New Price	Export Fall (%)
Iron and Steel	1.75978	3.005	43.995	422365202	16996398094	317734106	53.493	0.822	97.487	2.4714
Fertilizers	1.51844	7.943	37.961	240183	9665204.103	284186	34.01	1.116	71.971	8.8657
Other non-electrical machinery	1.04288	4.01	26.072	977324326	39328508203	55480936	708.87	0.037	734.94	0.1475
Iron and steel foundries	0.87583	3.005	21.896	1.246E+09	50155257463	865127940	57.974	0.378	79.87	1.1349
Motor vehicles	0.83663	1.922	20.916	561687422	22602863549	81881547	276.04	0.076	296.96	0.1456
Cement	0.83192	1	20.798	198397	7983693.677	1735127	4.6012	4.52	25.399	4.5201
Organic heavy chemicals	0.83099	2.119	20.775	735403690	29593379889	134386317	220.21	0.094	240.99	0.1999
Non-ferrous basic metals	0.82198	5.427	20.55	183290707	7375801340	38576018	191.2	0.107	211.75	0.5833
Inorganic heavy chemicals	0.74511	2.119	18.628	33070946	1330807938	33662208	39.534	0.471	58.162	0.9984
Plastic products	0.65756	4.279	16.439	237514082	9557804174	117510335	81.336	0.202	97.775	0.8648
Art silk, synthetic fibre textiles	0.46022	1.592	11.506	88527057	3562417301	25399486	140.26	0.082	151.76	0.1306
Readymade garments	0.41623	1.592	10.406	2.832E+09	1.13959E+11	593513418	192.01	0.054	202.41	0.0863
Other chemicals	0.39751	1.41	9.9379	152818235	6149558595	39011811	157.63	0.063	167.57	0.0889
Miscellaneous textile products	0.34608	1.592	8.6521	1.05E+09	42244015292	150952571	279.85	0.031	288.5	0.0492

Sector	Emission intensity per unit of output	Price Elasticity of Exports	Tax	Export Value ($)	Export value (INR)	Export Quantity	Export Value per unit output (INR)	Ad valorem rate (%)	New Price	Export Fall (%)
Paper, paper products & newsprint	0.30203	6.11	7.5509	50869834	2047052990	29043404	70.483	0.107	78.033	0.6546
Rubber products	0.29676	4.519	7.419	104224421	4194094925	31356293	133.76	0.055	141.18	0.2507
Cotton	0.29543	1.592	7.3858	83975115	3379242603	14107026	239.54	0.031	246.93	0.0491
Electrical Machine and Wires	0.26067	4.01	6.5166	919632556	37006933686	47007790	787.25	0.008	793.77	0.0332
Leather	0.05662	0.984	1.4155	205772880	8280506464	5562907	1488.5	1E-03	1489.9	0.0009
Woolen textiles	0.04029	1.592	1.0072	4188024	168530273.8	499821	337.18	0.003	338.19	0.0048
Jute, hemp, mesta textiles	0.03712	1.592	0.928	20423163	821848502.3	7975250	103.05	0.009	103.98	0.0143
Silk textiles	0.03048	1.592	0.762	83315879	3352714287	816488	4106.3	2E-04	4107	0.0003
Carpet weaving	0.0272	1.592	0.6799	483442285	19454200991	74147681	262.37	0.003	263.05	0.0041
Watches and clocks	0.01173	1.666	0.2932	1296656	52178734.1	116926	446.25	7E-04	446.55	0.0011

Source: Author's Calculation, Price Elasticity from A2, Export Value from A4, Export Quantity from UN COMTRADE

5.1.3 To further calculate the change in the value of production as a result of the fall in exports we have to calculate the ratio 'R' which is the ratio of gross value added for each sector to the total output. Gross value added and total output is taken from absorption matrix 2007-08. The vector of R is multiplied with vector of fall in export percentage to arrive at the percentage fall in value added of production. The percentage fall in value added of production will be for two tax slabs and their respective effect on the percentage change in exports. For tax slab of US $ 10 per ton of carbon emissions the fall in value of production is approximately by 0.93 percent and for US $ 25 per ton of carbon emission the fall is around 1.45 percent.

5.2 Carbon leakages and international trade in goods

5.2.1 To estimate carbon emissions in India's export by fuel: The sub matrix of fuels drawn from the Leontief inverse matrix is multiplied with the export vector to get the total value of fuels in rupees or dollars embodied in India's export or U.S. imports respectively if the imports are produced domestically by U.S. Inorder to get the tonnes or 1000 cubic metre of fuel used we deflate the rupee or dollar value of each fuel by an appropriate price index (Appendix A6). On multiplying the physical quantities by respective carbon emission coefficients (Appendix A1) we arrive at carbon emission by fuel type. On summing them across the three fuels we get the total carbon emissions emitted by India on exporting goods to the US or carbon emissions emitted by U.S. by producing the import basket itself. The total carbon emissions in India due to India's exports to the U.S. are approximately 50641 tonnes and the total carbon emissions in U.S. if it produced the import basket itself is 12235 tonnes approximately. By not producing itself, U.S. is reducing carbon emissions to the tune of 38405 tonnes per year approximately. Appendix A10 shows the value of the fuels for U.S. and India. Appendix A11 shows the total carbon emissions in India's exports and U.S. imports produced domestically (by fuels, in tonnes).

6. ANALYSIS AND RESULTS

On finding the carbon emission intensity per unit output or export (in tonnes) of each of the high value exporting sector (Appendix A8) we find that iron and steel is most carbon intensive per unit of output with an intensity of 1.76 tonnes per unit output followed by fertilizers (1.51), other non electrical machinery (1.04), iron and steel foundries (0.88), motor vehicles (0.84) amongst other sectors. Except art silk and synthetic fibre (0.46) and readymade garments (0.41) all other textile sector exports are the least carbon intensive. It is important to note that emission intensity per unit of output includes both the direct and the indirect emissions released to produce a unit of output which is captured in the study by taking the sub matrix of fuels from the Leontief Inverse.

However, because of high value of exports of textile sector to the U.S. especially of readymade garments, we note that the total embodied emissions (Appendix A9) is highest in readymade garments sector followed by iron and steel foundries, miscellaneous textile products , other non electrical machinery, electrical machine and wires, organic heavy chemicals amongst others. It is interesting to see that fertilizers and cement which have high emission intensity per unit of export releases the least total carbon emissions from their respective sectors. This is because the quantity and value of exports to United States is quite less. Only some form of cement - Portland cement, aluminous cement, slag cement (4-digit 2002 HS Code 2523) - is exported which forms a value of $198397 (INR 7983694). For fertilizer the value of export is $240183 (INR 9665204). Mostly, the dominant sectors having high emission intensity per unit of export are also the sectors that have high emissions embodied in total export.

As the impact of specific tax of US$ 10 and US$ 25 per ton of carbon emissions on unit export of manufacturing output is expected to increase with higher carbon intensity of the product, we would expect the impact to be felt the most in the iron and steel sector followed by fertilizers, other non electrical machinery and so on. However, when the tax in terms of CO_2 emissions is converted to ad valorem tax with the base value being the respective per unit export values we find that fertilizers and cement sector face the highest percentage price increase. This is because the export value and export quantity of both fertilizer and cement are quite low and tax in terms of CO_2 emissions is quite high relatively. This is true for even other products exported. The effect of a tax on high per unit value export is quite less. Intuitively, if the ratio of value and quantity of exports is less, the export sector faces a larger impact in terms of price increase and if the ratio of value of exports and the quantity exported is large the effect of a tax somewhat diminishes. Besides fertilizers and cement, ad valorem price increase percentage is also high for heavy and basic industries which have high carbon emission intensity like iron and steel industries, inorganic heavy chemicals, iron and steel foundries. Textile sector and manufacturing sector do not face a high ad valorem price increase percentage because the value per unit export is quite high as compared to the tax per unit export and as discussed earlier the emission intensity per unit output is quite low for the textiles sector. The fall in exports as a result of a carbon tax is not only affected by the ad valorem rate but also the price elasticity of exports. Because of very high price elasticity of export of fertilizer, the impact on the fall in the exports is huge for the year 2007 when a carbon tax of $ 10 and $ 25 per ton of carbon emission is applied. Next in line is cement, here the effect of ad valorem tax rate dominates the price elasticity of 1. Iron and steel, iron and steel foundries, inorganic heavy chemicals, plastic products, paper and paper products, non ferrous basic metals follow the fall in exports of fertilizer and cement. The high emission intensity along with the catalyzing effect of high price elasticity of these sectors is the reason for such a fall. Organic heavy chemicals, other non electrical machinery and motor vehicles have a very high value per unit export because of which the incidence of a tax does not affect the export sector like it affects iron and steel and iron and steel foundries. The value of exports of these products is quite high because of which a tax of $10 and $25 per ton of carbon emission is not large enough to stimulate a major fall in the exports of such carbon intensive products even though the sectors have high price elasticity of export. The textile sector is not much affected by the tax because of low emission intensity per unit output and hence lesser is the incidence of a carbon tax. The export value per unit output is also high. Because of which the export fall in most of the textiles sector is very less. Leather is the only product which is price inelastic. It has a price elasticity of 0.984. Therefore though the exports are falling but fall in exports are lesser than the percentage rise in price. Hence the value of export of leather is rising after a carbon tax.

The fall in exports of 24 manufacturing sector goods also has an effect on the fall in the value of production. When a tax of $ 10 per ton of carbon emission is imposed on 24 manufacturing sector exports, the fall in value of production is approximately 0.93 percent and for a $ 25 per ton of carbon emission tax the fall in value of production approximates 1.45 percent. Thus, India does have a major fall in the value in terms of value of production when a carbon tax is imposed on its export and it's more so in case of $ 25 carbon tax. However, this study is limited only to the bilateral trade between U.S. and India and if we take into account the fall in exports from India to U.S. going to countries other than U.S., India might not be affected to such an extent.

In terms of the change in carbon emissions when a border carbon tax is imposed, we note that, as expected, there is a fall in total carbon emissions. When a border tax of $10 per ton of carbon emission is imposed the fall in resultant carbon emissions is by 3565210048 tonnes and the corresponding figure for $ 25 per ton of carbon emission is 7514328748 tonnes. Before tax carbon emissions (as given in Appendix A9) is 31959065048 tonnes. The maximum fall in the emissions take place as a result of the fall in emissions in the iron and steel foundries and iron and steel sector which are quite carbon intensive. Mostly, it is the heavy and basic industries like the other non electrical machinery, non ferrous basic metals, organic heavy chemicals, motor vehicles, plastic products and readymade garments that are contributing the most to the fall in the total carbon emissions. Other textile sector exports are not much involved in the reduction of carbon emissions. In relative terms, fertilizer and cement are not contributing much to the total emission from exports (Appendix A9) or the total emission reduction because the volume of exports, value of exports and hence total carbon emissions by these sectors are not much though these sectors have high emission intensity per unit output. On observing these sectors independently, we have noted that these sectors face a large percentage fall in exports when a border tax is imposed because the incidence of tax is high on per unit export value, thus in absolute terms the fall in emissions is quite high.

As expected, the impact of US $ 25 per ton on carbon emissions far exceeds the impact of US$ 10 per ton on carbon emissions in terms of fall in exports, fall in embodied emissions, fall in value of production and fall in carbon emissions.

For estimating the carbon leakages (Appendix A10 and A11), the rupee value of fuels (Appendix A10) going in the exports to the U.S. is INR 107032790 in India and the rupee value of fuels going in the U.S. imports from India produced by U.S. themselves is INR 31558730 ($ 765227.07). Crude petroleum followed by natural gas and coal and lignite dominates the value of fuels embodied in India's exports in both the countries. When we look at fuel use (Appendix A11) in tonne (for coal and lignite and petroleum) and 1000 cubic metre (for natural gas), we note the high use of coal and lignite in both U.S. and India though the amount of fuel embodied in India's export far exceeds the amount embodied in U.S. imports if imports from India were produced domestically. In terms of carbon emissions embodied in India's exports, we find a peculiarity in results for India. CO_2 emissions resulting from natural gas exceed those from coal and lignite. A reason for this result is the quality of coal that is available in India. India has large reserve of anthracite coal or clean coal (also called hard coal). The heat value of this coal is very high because of which it releases lesser emissions than even natural gas. In U.S. CO_2 emissions from coal and lignite are more than natural gas. This is because of the abundance of bituminous coal in U.S. Total embodied CO_2 in India's export for U.S. is approximately 50641 tonne and total embodied CO_2 in U.S. imports from India produced domestically is 12235 tonne. Thus carbon leakages that take place as a result of bilateral trade between U.S. and India is as high as 38505 tonne approximately.

A carbon tax will definitely reduce carbon leakages taking place from one country to another, however, an important drawback to note here of a border adjustment mechanism is that there are a lot of complexities involved in computing carbon content for all traded goods and between all trading countries. Also, if a product like diamond is mined in some country, polished in another which in turn exports it to the destination country then on which country will the incidence of tax fall? The country which has mined the diamond or which has polished and exported the diamond!

7. CONCLUSION

The competitiveness and carbon leakage concerns in the U.S. India bilateral trade, where carbon leakages in this study is estimated to be approximately 38505 tonnes for the year 2007, led the U.S. government to discuss the suitability of a border carbon tax in the 2009 Waxman Markey Bill. From the viewpoint of India, if a border tax of $10 per ton and $25 per ton of carbon emission is imposed, the highest percentage fall in exports is seen in basic and heavy industries like the iron and steel, iron and steel foundries, inorganic heavy chemicals, non ferrous basic metals, plastic and paper industries. This is not only because of the large ad valorem price increase percentage which in turn is the result of high carbon intensity per unit export but also because of high price elasticity of export. Fertilizer and cement are the two sectors which have high emission intensity per unit output but the carbon emissions contributed to the total carbon embodiment in the exports is relatively less. Thus, though these sectors face a high ad valorem price increase percentage and large export fall but the relative contribution to the total reduction in carbon emissions is not much. Most of the reduction in the total carbon emissions takes place as a result of the fall in emissions in the iron and steel, iron and steel foundries, other non electrical machinery, non ferrous basic metals industry, organic heavy chemicals, motor vehicles and plastic products industry.

Textiles and readymade garments sector exports though high in value of export but are not much carbon intensive. The tax per unit of export is relatively less as compared to export value per unit of output. Ad valorem price increase percentage is not much and export fall is modest. Reduction in the emissions is also less as compared to other heavy and basic industry sectors.

Impact on India's value of production is about 0.93 percent when a carbon tax of $10 per ton of carbon emission is imposed and is 1.45 percent when tax is $25 per ton of emission. Thus, India does face the burden of a border carbon tax if U.S. imposes the same on carbon embodied in a unit of export. Though the impact will be lesser than that empirically found because India will mitigate the impact by exporting to other countries in which case the carbon emission reduction will not be much but it will still remain positive.

Another factor which will neutralize the resultant reduction in carbon emission after a border tax is imposed is the fall in the oil prices that will take place if U.S. reduces its energy demand. This aspect has not been accounted for in the present study but if taken into account through a modeling exercise one might expect the fall in India's emission to be lesser if oil prices fall as the demand for energy by India would increase.

The study shows that in practice the effect of a border carbon tax is modest in carbon reduction and falls more heavily on India's energy intensive export basket and value of production. If the export diversification to other countries and global oil prices are allowed to fall, as in real life scenario, the impact of carbon reduction would be lesser and so will the impact on India's value of production and export fall.

This study concludes that border tax can be seen only as a threat instrument to get countries like China and India to take significant steps in adopting greener technology and reducing its overall carbon emissions.

8. POLICY IMPLICATIONS

This is a study which takes into consideration only bilateral trade between U.S. and India and 24 high value manufacturing sector exports; however, in the real life scenario countries trade with more than one country. If a border carbon tax is imposed by the U.S. on India, the Indian government should promote export diversification to countries other than U.S. A shift from more carbon intensive exports to less carbon intensive exports which are not much affected by a border carbon tax is desirable. A significant move in this direction would be for developing countries like India to adopt more environmental friendly technology which is less carbon intensive. Such a step would reduce the impact on the fall in value of production which for now is 0.93 percent when a border tax of $10 is applied and 1. 45 percent when the tax is of $ 25 per ton of carbon emission. An initiative by countries imposing a border carbon tax can be undertaken wherein they transfer a part of the revenue earned though a border tax to the counties on whom such a tax is imposed. This will further stimulate carbon emission reduction if such a revenue transfer is specifically used to promote renewable energy[11].

From the international perspective, the advantage of a border carbon tax is not much. The effect on fall in carbon emissions is positive but very modest. This can have very damaging results for the global trade and international negotiations in climate change. In case, a border tax is made applicable in future, it should mostly be moderate. A higher carbon tax has more damaging effects than positive.

[11] Timilsina et. al (2011) made a similar suggestion in his paper on "When does a carbon tax on fossil fuels stimulate biofuels?".

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APPENDIX

A1: Emission Coefficient by Fuel Type

Fuel	Units	India Emission coefficient in desired units	U.S. Emission coefficient in desired units
Coal and lignite	Tons of CO_2 / ton fuel	1.69585	2.052505335
Natural gas	Tons of CO_2 / 1000 cubic metre	2.1	1.929887705
Crude petroleum	Tons of CO_2 / ton fuel	3.1024	2.82204068

Source: J.Parikh et al.(2009); U.S. Environment Protection Agency

A2: Price elasticity estimates of export sector

Sectors	Price elasticity	Source
Readymade garments	1.592	Aggarwal 2004
Iron and steel foundries	3.005	Aggarwal 2004
Miscellaneous textile products	1.592	Aggarwal 2004
Other non-electrical machinery	4.01	Aggarwal 2004
Electrical Machine and Wires	4.01	Aggarwal 2004
Organic heavy chemicals	2.119	Aggarwal 2004
Motor vehicles	1.922	Aggarwal 2004
Carpet weaving	1.592	Aggarwal 2004
Iron and Steel	3.005	Aggarwal 2004
Plastic products	4.279	Aggarwal 2004
Leather	0.984	Aggarwal 2004
Non-ferrous basic metals	5.427	Lucas 1988
Other chemicals	1.41	Aggarwal 2004
Rubber products	4.519	Aggarwal 2004
Art silk, synthetic fibre textiles	1.592	Aggarwal 2004
Cottontext	1.592	Aggarwal 2004
Silk textiles	1.592	Aggarwal 2004
Paper, paper prods. & newsprint	6.11	Aggarwal 2004
Inorganic heavy chemicals	2.119	Aggarwal 2004
Jute, hemp, mesta textiles	1.592	Aggarwal 2004
Woolen textiles	1.592	Aggarwal 2004
Watches and clocks	1.666	Aggarwal 2004
Fertilizers	7.943	Aggarwal 2004
Cement	1	Chadha, Pohit et.al 1998

Source: Compilation by the author

A3: Concordance of IO codes and HS codes at 2-digit and 4-digit level for a subset of selected manufacturing goods.

IO code	Sector	HS code	Sector
46	Khadi, cotton textiles(handlooms)	52	Cotton
47	Cotton textiles		
48	Woollen textiles	51	Wool, fine/coarse animal hair, horsehair yarn & fur
49	Silk textiles	50	Silk
50	Art silk, synthetic fibre textiles	54	Man-made filaments
		55	Man-made staple fibres
51	Jute, hemp, mesta textiles	53	Other vegetable textile fibres, paper yarn & woven fabric
52	Carpet weaving	57	Carpets and other textile floor coverings
53	Readymade garments	62	Art of apparel & clothing access, not knitted/crochet
		61	Art of apparel & clothing access, knitted or crochet
54	Miscellaneous textile products	63	Other made up textile articles, sets, worn clothing
		58	Special woven fabric, tufted textile fabric, lace, tapestry
		60	Knitted or crocheted fabrics
		59	Impregnated, coated, cover/laminated textile fabric
		56	Wadding, felt and nonwovens, special yarns, twine, cordage, ropes and cables and articles thereof
57	Paper, paper products & newsprint	48	Paper & paperboard, art of paper pulp, paper/paper products
59	Leather footwear	42	Articles of leather, saddlery/harness, travel goose
60	Leather and leather products	41	Raw hides and skins (other than furskins) and leather
61	Rubber products	40	Rubber and articles thereof
62	Plastic products	39	Plastics and articles thereof
65	Inorganic heavy chemicals	28	Inorganic chemicals, compounds of precious metal, radioactive element
66	Organic heavy chemicals	29	Organic chemicals
67	Fertilizers	31	Fertilizers
73	Other chemicals	38	Miscellaneous chemical products

75	Cement	2523	Portland cement, aluminous cement, slag cement, super sulphate cement and similar hydraulic cements, whether or not coloured or in the form of clinkers
77	Iron, steel and ferro alloys	72	Iron and steel
78	Iron and steel casting & forging		
79	Iron and steel foundries	73	Articles of iron or steel
80	Non-ferrous basic metals	74	Copper and articles thereof
		78	Lead and articles thereof
		79	Zinc and articles thereof
		80	Tin and articles thereof
		76	Aluminium and articles thereof
87	Other non-electrical machinery	84	Nuclear reactors, boilers, machinery & mechanical appliance
88	Electrical industrial Machinery	85	Electrical machinery equipment parts thereof, sound record
89	Electrical wires & cables		
97	Motor vehicles	87	Vehicles other than railway/tramway roll-stock, parts & access
101	Watches and clocks	91	Clocks and watches and parts thereof

Source: Author

A4: High Value Exports of manufacturing sector goods from India to U.S. for the year 2007at HS 2002 2-digit and 4-digit level.

IO code	Sector	Exports in '000 US $	Exports in INR (exchange rate=40.241/$)
46	Khadi, cotton textiles(handlooms)	83975.115	3379242.603
47	Cotton textiles		
48	Woolen textiles	4188.024	168530.2738
49	Silk textiles	83315.879	3352714.287
50	Art silk, synthetic fibre textiles	88527.057	3562417.301
51	Jute, hemp, mesta textiles	20423.163	821848.5023
52	Carpet weaving	483442.285	19454200.99
53	Readymade garments	2831914.519	113959072.2
54	Miscellaneous textile products	1049775.485	42244015.29
57	Paper, paper prods. & newsprint	50869.834	2047052.99
59	Leather footwear	205772.88	8280506.464
60	Leather and leather products		
61	Rubber products	104224.421	4194094.925
62	Plastic products	237514.082	9557804.174
65	Inorganic heavy chemicals	33070.946	1330807.938
66	Organic heavy chemicals	735403.69	29593379.89
67	Fertilizers	240.183	9665.204103
73	Other chemicals	152818.235	6149558.595
75	Cement	198.397	7983.693677
77	Iron, steel and ferro alloys	422365.202	16996398.09
78	Iron and steel casting & forging		
79	Iron and steel foundries	1246372.045	50155257.46

80	Non-ferrous basic metals	183290.707	7375801.34
87	Other non-electrical machinery	977324.326	39328508.2
88	Electrical industrial Machinery	919632.556	37006933.69
89	Electrical wires & cables		
97	Motor vehicles	561687.422	22602863.55
101	Watches and clocks	1296.656	52178.7341

Source: Author; UN COMTRADE.

A5: Concordance between HS Codes, NAICS codes and BEA codes for a subset of selected manufacturing goods.

S.No.	HS Code	Sector	NAICS Code	Sector	BEA Code	Sector
1	52	Cotton	3131	Fibres	313100	Fibre, yarn, and thread mills
	51	Wool, fine/coarse animal hair, horsehair yarn & fur	3132	Fabrics	313200	Fabric mills
	50	Silk	3141	Textile furnishing	314120	Curtain and linen mills
	54	Man-made filaments			314110	Carpet and rug mills
	55	Man-made staple fibres	3149	Other textile products	314900	Other textile product Mills
	53	Other vegetable textile fibres, paper yarn & woven fabric	3133	Finished and coated textile fabrics	313300	Textile and fabric finishing and fabric coating mills
	57	Carpets and other textile floor Coverings				
	63	Other made up textile articles, Sets, worn clothing				
	58	Special woven fabric, tufted text fabric, lace, tapestry				
	60	Knitted or crocheted fabrics				
	59	Impregnated, coated, cover/ laminated textile fabric				
2	62	Art of apparel & clothing access, not knitted/crocheted	3152	Apparel	315000	Apparel manufacturing
	61	Art of apparel & clothing access, knitted or crocheted	3151	Knitted Apparel		
3	48	Paper & paperboard, art of paper pulp, paper/paper products	3222	Converted paper products	322210	Paperboard container manufacturing
					322220	Paper bag and coated and treated paper manufacturing
					322230	Stationery product manufacturing
					322291	Sanitary paper product manufacturing

					322299	All other converted paper product manufacturing
			3221	Pulp, paper and paperboard mill products	322110	Pulp mills
					322120	Paper mills
					322130	Paperboard mills
4	42	Articles of leather, saddlery/ Harness, travel goose	3169	Other leather products	316000	Leather and allied product manufacturing
	41	Raw hides and skins (other than furskins) and leather	3161	Leather and hide tanning		
5	40	Rubber and articles thereof	3262	Rubber	326210	Tire manufacturing
					326220	Rubber and plastics hoses and belting manufacturing
					326290	Other rubber product manufacturing
			3252	Resin, synthetic rubber	325211	Plastics material and resin manufacturing
					3252A0	Synthetic rubber and artificial and synthetic fibres and filaments manufacturing
6	39	Plastics and articles thereof	3261	Plastic Products	326110	Plastics packaging materials and unlaminated film and sheet manufacturing
					326120	Plastics pipe, pipe fitting, unlaminated profile shape manufacturing
					326130	Laminated plastics plate, sheet (except packaging) shape manufacturing
					326140	Polystyrene foam product manufacturing
					326150	Urethane and other

						foam product (except polystyrene) manufacturing
					326160	Plastics bottle Manufacturing
					326190	Other plastics product manufacturing
7	28	Inorganic chemicals, compounds Of precious metal, radioactive Elements	3251	Basic chemicals	325110	Petrochemical Manufacturing
	29	Organic chemicals			325120	Industrial gas Manufacturing
					325130	Synthetic dye and pigment manufacturing
					325180	Other basic inorganic chemical manufacturing
					325190	Other basic organic chemical manufacturing
8	31	Fertilisers	3253	Pesticides, fertilizers and other agricultural products	325310	Fertilizer manufacturing
					325320	Pesticide and other agricultural chemical manufacturing
9	38	Miscellaneous chemical products	3259	Other chemica products and preparations	325910	Printing ink Manufacturing
					3259A0	All other chemical product and preparation manufacturing
			5256	Soaps	325610	Soap and cleaning compound manufacturing
			3255	Paints, coating	325510	Paint and coating manufacturing
10	2523	Portland cement, aluminous cement, slag cement,	3273	Cement	327310	Cement manufacturing

		supersulphate cement and similar hydraulic cements, whether or not coloured or in the form of clinker				
11	72	Iron and steel	3311	Iron and steel ferroalloy	331110	Iron and steel mills and ferroalloy manufacturing
12	73	Articles of iron or steel	3312	Steel Products	331200	Steel product manufacturing from purchased steel
			3315	Foundries	331510	Ferrous metal foundries
13	74	Copper and articles thereof	3314	Non ferrous metal (except aluminium)	331411	Primary smelting and refining of copper
	78	Lead and articles thereof			331420	Copper rolling, drawing, extruding and alloying
	79	Zinc and articles thereof			331419	Primary smelting and refining of nonferrous metal (except copper and aluminium)
	80	Tin and articles thereof			331490	Nonferrous metal (except copper and aluminium) rolling, drawing, extruding and alloying
			3315	Foundries	331520	Nonferrous metal Foundries
14	76	Aluminium and articles thereof	3313	Aluminium and aluminium processing	33131A	Alumina refining and primary aluminium production
					33131B	Aluminium product manufacturing from purchased aluminium
15	84	Nuclear reactors, boilers, machinery & mechanical appliances	3336	Engines, turbines and power transmission	333611	Turbine and turbine generator set units manufacturing
					333612	Speed changer, industrial high-speed drive, and gear manufacturing

					333613	Mechanical power transmission equipment manufacturing
					333618	Other engine equipment manufacturing
16	85	Electrical machinery equipment parts thereof, sound record	3353	Electrical equipment	335311	Power, distribution, and specialty transformer manufacturing
					335312	Motor and generator manufacturing
					335313	Switchgear and switchboard apparatus manufacturing
					335314	Relay and industrial control manufacturing
			3359	Electrical equipments and components, nesoi	335911	Storage battery Manufacturing
					335912	Primary battery Manufacturing
					335920	Communication and energy wire and cable manufacturing
					335930	Wiring device Manufacturing
					335991	Carbon and graphite product manufacturing
					335999	All other miscellaneous electrical equipment and component Manufacturing
17	87	Vehicles other than railway/ tramway roll-stock, parts & acce	3361	Motor vehicles	336111	Automobile Manufacturing
					336112	Light truck and utility vehicle manufacturing
					336120	Heavy duty truck manufacturing
					336310	Motor vehicle gasoline

						engine and engine parts manufacturing
			3363	Motor vehicle parts	336320	Motor vehicle electrical and electronic equipment manufacturing
					3363A0	Motor vehicle steering, suspension component (except spring), and brake systems manufacturing
					336350	Motor vehicle transmission and power train parts manufacturing
					336360	Motor vehicle seating and interior trim manufacturing
					336370	Motor vehicle metal Stamping
					336390	Other motor vehicle parts manufacturing
18	91	Clocks and watches and parts thereof	334518-9	Clock and watches	33451A	Watch, clock, and other measuring and controlling device manufacturing

Source: Author; BEA for NAICS and BEA codes; UN COMTRADE for HS Codes

A6: Price Index for fuels

a. India

Fuels	Unit of price	Price	Source
Coal and lignite	Rs/t	2898	Standing Committee on Coal and Steel 2013-14, Ministry of Coal
Natural gas	Rs/'000m3	3200	MoPNG (2013-14)
Crude petroleum	Rs/t	13932	MoPNG (2009)

b. United States

Fuels	Unit of price	Price	Price in dolla	Source for Price
Coal	2006 dollar/ short ton	36.03	36.03	Delivered prices; Table A15.
Natural gas	2006 dollar/ thousand cubic feet	6.42	6.42	Table A 13.
Petroleum	2006 cents/gallon	234.50	2.35	Refined petroleum average price; Table A 12.

Source for Price Index: Annual Energy Outlook 2008

A7: Transpose of Fuel Rows for India in a 126 x 126 matrix

Sectors\Fuels	Coal and lignite	Natural gas	Crude petroleum
Paddy	0.02858	0.115282	0.202223
Wheat	0.014371	0.060616	0.090984
Jowar	0.000757	0.004939	0.009388
Bajra	0.000651	0.003617	0.008037
Maize	0.001536	0.008991	0.014831
Gram	0.001033	0.005062	0.011441
Pulses	0.003264	0.017129	0.037617
Sugarcane	0.002902	0.017055	0.022231
Groundnut	0.001033	0.006679	0.012306
Coconut	0.000422	0.002474	0.004469
Other oilseeds	0.002871	0.020797	0.032518
Jute	9.91E-05	0.00089	0.001508
Cotton	0.003051	0.017259	0.026273
Tea	0.000101	0.0008	0.001491
Coffee	0.000158	0.000372	0.001109
Rubber	0.00038	0.002401	0.003222
Tobacco	0.000326	0.001967	0.002368
Fruits	0.00173	0.006946	0.014362
Vegetables	0.00248	0.010143	0.020791
Other crops	0.011033	0.052518	0.096241
Milk and milk products	0.003859	0.01309	0.032682
Animal services(agricultural)	0.003379	0.012081	0.030154
Poultry & Eggs	0.00115	0.004564	0.009487
Other livestock products	0.002993	0.010411	0.025833
Forestry and logging	0.003905	0.008945	0.043227
Fishing	0.001726	0.004226	0.015633
Coal and lignite	1.029195	0.013179	0.035775
Natural gas	0.001878	1.003403	0.005462
Crude petroleum	0.008038	0.01127	1.029525
Iron ore	0.002626	0.003707	0.012211
Manganese ore	9.01E-05	0.000108	0.000278
Bauxite	0.000119	0.000157	0.00042
Copper ore	4.71E-05	8.41E-05	0.000233

Other metallic minerals	0.000464	0.000661	0.001448
Lime stone	0.000422	0.000753	0.001897
Mica	1.94E-06	3.68E-06	1.38E-05
Other non metallic minerals	0.001329	0.003068	0.007409
Sugar	0.003554	0.012036	0.026248
Khandsari, boora	0.001363	0.004576	0.009368
Hydrogenated oil(vanaspati)	0.001655	0.004512	0.0096
Edible oils other than vanaspati	0.008139	0.026369	0.051401
Tea and coffee processing	0.002557	0.004612	0.017028
Miscellaneous food products	0.026439	0.059523	0.135469
Beverages	0.005778	0.011632	0.027261
Tobacco products	0.002436	0.004418	0.011625
Khadi, cotton textiles(handlooms)	0.001826	0.003242	0.008405
Cotton textiles	0.024729	0.052702	0.129665
Woollen textiles	0.002053	0.003569	0.009447
Silk textiles	0.001137	0.004343	0.006264
Art silk, synthetic fibre textiles	0.020473	0.051566	0.102248
Jute, hemp, mesta textiles	0.002996	0.004264	0.007441
Carpet weaving	0.001429	0.00401	0.00527
Readymade garments	0.018838	0.049773	0.090177
Miscellaneous textile products	0.014335	0.058292	0.06426
Furniture and fixtures-wooden	0.010508	0.011823	0.02933
Wood and wood products	0.006103	0.006183	0.019164
Paper, paper prods. & newsprint	0.03323	0.023924	0.062997
Printing and publishing	0.013355	0.016058	0.038815
Leather footwear	0.001367	0.003129	0.008594
Leather and leather products	0.003445	0.007097	0.018355
Rubber products	0.016737	0.039843	0.059536

Plastic products	0.028094	0.086556	0.138004
Petroleum products	0.069531	0.86419	6.84219
Coal tar products	0.037036	0.030649	0.102922
Inorganic heavy chemicals	0.030962	0.120022	0.142004
Organic heavy chemicals	0.018883	0.07824	0.204573
Fertilizers	0.02129	0.286554	0.283834
Pesticides	0.0052	0.016307	0.023005
Paints, varnishes and lacquers	0.009649	0.033406	0.044496
Drugs and medicines	0.016424	0.056985	0.109526
Soaps, cosmetics & glycerine	0.012831	0.039382	0.066887
Synthetic fibres, resin	0.010915	0.067363	0.096204
Other chemicals	0.013512	0.080633	0.066165
Structural clay products	0.019816	0.029758	0.073288
Cement	0.108266	0.153093	0.105346
Other non-metallic mineral prods.	0.043159	0.053271	0.122067
Iron, steel and ferro alloys	0.61413	0.514371	0.250233
Iron and steel casting & forging	0.134397	0.078493	0.07376
Iron and steel foundries	0.174888	0.139071	0.092574
Non-ferrous basic metals	0.247875	0.065321	0.08524
Hand tools, hardware	0.038031	0.025131	0.03098
Miscellaneous metal products	0.22505	0.124141	0.114136
Tractors and agri. Implements	0.025241	0.018841	0.019169
Industrial machinery(F & T)	0.021786	0.020221	0.016258
Industrial machinery(others)	0.016833	0.01567	0.013898
Machine tools	0.039464	0.032072	0.036908
Other non-electrical machinery	0.18073	0.14875	0.136671
Electrical industrial Machinery	0.063886	0.047912	0.055842

Electrical wires & cables	0.025194	0.014978	0.020936
Batteries	0.004771	0.00333	0.004921
Electrical appliances	0.015671	0.013058	0.01794
Communication equipments	0.024285	0.021083	0.027932
Other electrical Machinery	0.067737	0.034459	0.048789
Electronic equipments(incl.TV)	0.022766	0.017253	0.025952
Ships and boats	0.004195	0.00365	0.004472
Rail equipments	0.021263	0.017064	0.023508
Motor vehicles	0.130873	0.106932	0.125752
Motor cycles and scooters	0.023523	0.020169	0.028664
Bicycles, cycle-rickshaw	0.007295	0.005863	0.008115
Other transport equipments	0.001765	0.001433	0.002108
Watches and clocks	0.00083	0.000906	0.002714
Medical, precision &optical instruments	0.008008	0.009922	0.022156
Jems & jewellery	0.037068	0.033738	0.105231
Aircraft & spacecraft	0.00041	0.000393	0.000939
Miscellaneous manufacturing	0.036728	0.034395	0.054937
Construction	0.666868	0.696239	1.093766
Electricity	0.370599	0.347033	0.31311
Water supply	0.002495	0.00507	0.013309
Railway transport services	0.029013	0.027288	0.05097
Land transport including via pipeline	0.086764	0.354438	2.259049
Water transport	0.002367	0.004026	0.012109
Air transport	0.004098	0.010581	0.046723
Supporting and auxiliary transport activities	0.005894	0.009497	0.035564
Storage and warehousing	0.001823	0.002009	0.003104
Communication	0.014101	0.014994	0.036826
Trade	0.076839	0.11849	0.400833
Hotels and restaurants	0.027783	0.053277	0.143872

Banking	0.013932	0.016851	0.045876
Insurance	0.005646	0.007359	0.023839
Ownership of dwellings	0.005878	0.006154	0.009811
Education and research	0.003927	0.008031	0.033473
Medical and health	0.010445	0.026268	0.063302
Business services	0.011538	0.012062	0.022114
Computer & related activities	0.018373	0.019019	0.029726
Legal services	0.001916	0.001975	0.003176
Real estate activities	0.000423	0.000522	0.001095
Renting of machinery & equipment	0.000675	0.000817	0.001158
Other commercial, social & personal services	0.008242	0.00878	0.01863
Other services	0.003519	0.003802	0.00675
Public administration	0	0	0

Source: Author; CSO

Appendix A8: Estimated emission intensity in tonnes of CO_2 per unit of output.

Sectors	Emission intensity per unit of output
Iron and Steel	1.759781
Fertilizers	1.518436
Other non-electrical machinery	1.042875
Iron and steel foundries	0.875835
Motor vehicles	0.836631
Cement	0.831925
Organic heavy chemicals	0.830993
Non-ferrous basic metals	0.82198
Inorganic heavy chemicals	0.745107
Plastic products	0.657556
Art silk, synthetic fibre textiles	0.460222
Readymade garments	0.416234
Other chemicals	0.397514
Miscellaneous textile products	0.346085
Paper, paper prods. & newsprint	0.302035
Rubber products	0.296758
Cotton	0.295432
Electrical Machine and Wires	0.260665
Leather	0.056621
Woollen textiles	0.040286
Jute, hemp, mesta textiles	0.03712
Silk textiles	0.030481
Carpet weaving	0.027197
Watches and clocks	0.011729

Source: Author’s Calculation

Appendix A9: Total Emissions in the export basket of high value manufacturing goods / The total carbon embodiment in the exports (in tonnes)

Sectors	Total emissions in export (in tonnes)
Readymade garments	8638000000
Iron and steel foundries	3802000000
Miscellaneous textile products	3202000000
Other non-electrical machinery	2981000000
Electrical Machine and Wires	2805000000
Organic heavy chemicals	2243000000
Motor vehicles	1713000000
Carpet weaving	1475000000
Iron and Steel	1288000000
Plastic products	724500000
Leather	627700000
Non-ferrous basic metals	559100000
Other chemicals	466100000
Rubber products	317900000
Art silk, synthetic fibre textiles	270000000
Cotton	256200000
Silk textiles	254100000
Paper, paper products & newsprint	155200000
Inorganic heavy chemicals	100900000
Jute, hemp, mesta textiles	62297203
Woollen textiles	12774818
Watches and clocks	3955217.1
Fertilizers	732635.25
Cement	605174.55

Source: Author's Calculations

Appendix A10: Value of fuels in U.S. import basket produced domestically & India's high value manufacturing export basket

Fuels	Value of Fuels (INR)	Value of Fuels (Dollar)
Coal and lignite	32690697	146547.09
Natural gas	34496210	227538.64
Crude petroleum	39845883	391141.34
Total value of fuels	107032790	765227.07

Source: Author's Calculation

Appendix A11: Total carbon emissions in India's exports and U.S. imports produced domestically (by fuels, in tonnes)

a) India

Fuels	Physical Units of Fuel	Units of physical quantity	Carbon emission coefficient	Units of carbon emission coefficient	Carbon emission by fuel (tonnes)
Coal and lignite	11280.43375	Tonnes	1.69585	t CO_2 / ton of fuel	19129.91722
Natural gas	10780.06563	1000 cubic metre	2.1	t CO_2 / 1000 cubic metre	22638.14
Crude petroleum	2860.026055	Tonnes	3.1024	t CO_2 / ton of fuel	8872.945
				Total carbon emissions in India's exports (tonnes)	50641.00888

b) United States

Fuels	Physical Units of Fuel	Units of physical quantity	Carbon emission coefficient	Units of carbon emission coefficient	Carbon emission by fuel (tonnes)
Coal and lignite	2248	Tonnes	2.052505335	t CO_2 / ton of fuel	4614.031994
Natural gas	2032.307	1000 cubic metre	1.929887705	t CO_2 / 1000 cubic metre	3922.124292
Crude petroleum	1310.77	Tonnes	2.82204068	t CO_2 / ton of fuel	3699.046262
				Total carbon emissions in U.S. imports produced domestically (tonnes)	12235.20255

Source: Author's calculation; Carbon emission coefficient from A1.