Title of the Paper: Border vis-à-vis Domestic Carbon Adjustment: Implications of Alternative System Boundary for India to Reduce Carbon Emissions

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Border vis-à-vis Domestic Carbon Adjustment: Implications of Alternative System Boundary for India to Reduce Carbon Emissions

Abstract

Besides the spirit of WTO, the market-based instrument of Border Carbon Adjustment (BCA) violates the UNFCCC's present system boundary approach on territorial production-based emission reduction responsibility. Due to the contradiction in the implementation of the BCA under presently operational system boundary, this study investigates the implications of BCA imposition on India's exports under an alternative system boundary, based on the territorial consumption-based framework. The study is methodologically based on a computable general equilibrium (CGE) model and assumes India to implement a set of Domestic Carbon Adjustment (DCA) measures, including a Retaliatory Border Carbon Adjustment (RBCA). The results from this study indicate that the narrower the rates of BCA and the DCA the more effective the carbon adjustment schemes are to reduce the emission intensity of energy use in India. The stricter carbon adjustment measures also found changing the energy consumption pattern of Indian sectors by inducing the emission-intensive sectors to switch towards low-emission intensive natural gas, while the emission-non-intensive sectors to increase their uses of high-emission intensive coal and coal products. This study recommends the implementation of DCA measures as stricter as compared to the foreign standards in a consumption-based system boundary and emission accounting framework to make the carbon adjustment initiatives more effective. This study also recommends recycling the additional government revenue generated from the DCA to the household sector to control the distortions due to the DCA implementation.

Key-words

Border Carbon Adjustment, Domestic Carbon Adjustment, Consumption-based System Boundary, India, Computable General Equilibrium Model

1. Introduction

The agreements under the Kyoto Protocol (signed in December 1997, and came into force since 2005) required binding commitments from only the developed countries that were members of the Organisation for Economic Co-operation and Development (OECD) in 1992, and few countries with economies in transition, like the Russian Federation, the Baltic States, and several Central and Eastern European States, however, for the developing countries this agreement took only a softer stand by acknowledging their insignificant historical contribution to the global greenhouse gas generation during the post-industrial revolution era and the immense priorities for their economic development (UNFCCC, 1997). This uneven distribution of emission reduction responsibility among the different countries resulted in wider gaps in the stringency on emission regulations and governance which gives rise to the possibility of 'carbon leakage'[1] (Paltsev, 2001; Babiker, 2005; Kallbekken et al., 2007; Kuik and Hofkes, 2010; Aichele and Felbermayr, 2015). Besides this incidence of 'carbon leakage', the lack of uniformity in the emission reduction responsibility and the policy gaps among the countries, maybe placed firms with stricter climate policy from the developed countries at a competitive disadvantage as against those firms with softer climate policy from the developing world (Cosbey and Tarasofsky, 2007; Frankel and Aldy, 2009; Reinaud, 2009; Kee et al., 2010). Border Carbon Adjustment (hereafter mentioned as the BCA) as an economic instrument captured intensive discussions both academically and politically to address both these issues of 'carbon leakage' and 'competitiveness loss' (Babiker and Rutherford, 2005; Dong and Whalley, 2009; Weber and Peters, 2009; Kuik and Hofkes, 2010; Monjon and Quirion, 2011). Countries with binding emission reduction commitments may undertake these BCA measures

[1] 'Carbon leakage' is said to happen when the mitigation efforts from the developed countries due to their stricter unilateral environmental regulations are offset by the excessive emissions generated from the non-binding developing countries due to their relative weaknesses in carbon regulation policies (Bohringer et al., 2017).

either through imposing an import tax on the foreign goods which is produced without incurring the equivalent proportions of carbon costs in its homeland compared to the proportions if those goods have had produced rather in the committed countries, or by compelling the exporters to surrender their carbon allowances under a cap-and-trade system (van Asselt and Brewer, 2010; Cosbey et al., 2012; Condon and Ignaciuk, 2013).

The compatibility of BCA both in terms of its design and applicability under the existing provisions of 'national treatment' or 'most favoured nation treatment' by the WTO is extremely difficult and full of controversy (Biermann and Brohm, 2005; De Cendra, 2006; Ismer and Neuhoff, 2007; Pauwelyn, 2007; Sindico, 2008; Bordoff, 2009; Monjon and Quirion, 2014; Condon and Ignaciuk, 2013; Trachtman, 2016; Balistreri et al., 2019). However, one more inconsistency and contradiction are hidden in this arrangement of BCA to internalize the carbon costs to restrict the developing countries from 'free-riding' the benefits from global emission reductions which is almost untold in the previous literature is about the violation of 'system boundary' of emission reduction responsibility. The accounting framework for the 'National Responsibility for CO_2 Emissions (NRCE)' under the Kyoto-Protocol is based on territorial production-oriented system boundary. Even for the recently negotiated Paris Agreement in 2015 (21st meeting of the Conference of the Parties) which motivated almost all the countries to put forward their instruments of 'Nationally Determined Contributions (NDCs)', these NDCs are calculated as the amount of GHG emissions and mitigations which is taking place due to the production activities within the national boundaries (including administered territories) and offshore areas over which the country has jurisdiction (IPCC, 1996). Although the criticism against this present system boundary for calculating the national inventory of GHG emissions is frequently analyzed from its equity and efficiency perspective in many important studies (Rodrigues et al., 2006; Lenzen et al., 2007; Marques et al., 2012; Chang, 2013; Zhang, 2013), however, the inconsistency of BCA under this present framework has not yet been addressed so far. The contribution of this paper lies in questioning the applicability of the imposition of BCA by the highly regulated developed countries over the non-committed developing countries in a framework where the national emission inventory is calculated using a production-based approach. Moreover, this study examines the implications of imposing the BCA under an alternative system boundary approach which is based on a consumption-oriented accounting framework. To the best of literature review, this research may be regarded as the first attempt where the applicability BCA as a market based instrument is investigated in the presence of a set of Domestic Carbon Adjustment (hereafter mentioned as the DCA) measures in a setting of consumption-based system boundary framework.

The paper is structured as follows. Section 2 is giving a little more backdrop on the concept of carbon adjustment under a consumption-based accounting framework. Section 3 is elaborating the model and Section 4 explaining the data used in this study. Section 5 is interpreting the obtained results and discussing the implications. Finally, in Section 6 this paper concludes with remarks for future researches.

2. Carbon Adjustment under Consumption-based System Boundary

The relevance of BCA lies in internalizing the carbon costs universally to combat the carbon leakage problem and achieving a huge reduction in global emissions, either by incentivizing through cap-and-trade or by threatening through carbon motivated import tariffs, to the countries outside the ambit of Kyoto commitments by joining into the international march for combatting against the problem of global warming (Zhou et al., 2010; Condon and Ignaciuk, 2013). The European Union launched the EU Emission Trading Scheme (EU-ETS) in 2005. Until 2013 this programme covered various installations in 31 countries including all the members from the EU. The EU-ETS will be extended to 2030 with more stringent emission caps in Phase IV (2021 - 2030) with a hope to link up the ETS by a compatible system around the world to form a global carbon market. Similar to this scheme the famous Waxman-Markey

Bill proposed in May 2009 before the US House of Representatives where provisions of both a Federal cap-and-trade system through the years until 2050 as well as elements of Carbon Border Tax Adjustments were included. This bill was passed in the form of American Clean Energy and Security Act in June 2009. Japan formulated the Kyoto Protocol Target Achievement Plan in 2005 and for this the concerns for 'carbon leakage' and the loss of domestic competitiveness of the emission-intensive and trade exposed (EITE) sectors were seriously expressed (Government of Japan, 2005). The proposal of the Council on Global Warming Issues noted the usefulness of BCA measures in order for Japan to realize this dual target as a low carbon economy (Council on Global Warming Issues, 2008).

One common understanding implied in all the provisions so far either designed, proposed or implemented regarding the carbon adjustment measures are based on production-oriented emission inventory. Zhou et al. (2013) in their paper raised an important question about a hidden but real inequality in this production-based national inventory approach, since the imposition of BCA by the importing countries in this present setting imply that the exporting country has to bear two kinds of carbon costs. The first one is the tangible part which the producer of the exporting country pays for entering into the BCA implementing countries, the other one is the intangible cost due to the production-based emission inventory which makes the exporting country accountable for the production of the exportable even when the exporters already bore the BCA at a similar rate as compared to the importing country. Zhou et al. (2013) suggested for an inventory adjustment for the calculation of national emissions, where an equal amount of emission credits would be transferred to the exporting country if the exporters already charged with BCA for the production of exportable commodities according to the emission reduction standards set by their BCA implementing import partner countries. However, their study did not mention the clear violation of the 'system boundary' on emission reduction responsibility with this inventory adjustment. Because this adjusted amounts of emission inventory would be reported to the UNFCCC as a reference for ranking of the countries in terms of national emissions, the setting of national targets and for assessing the historical, accumulated and per capita contribution to global warming, this violation could be translated into a huge disadvantage for developing countries.

Because the *production-based system boundary* cannot distinguish between the domestic consumption and the foreign consumption of the domestically produced commodities as contributors to the NRCE (Munksgaard and Pedersen, 2001, Ferng, 2003, Peters and Hertwich, 2008), the implementation of BCA, only on foreign consumption part by the importers leads to violation of production-based accounting of emission responsibility. When the exporters pay for the BCAs to the governments of importing countries, this necessarily implies that the exporting countries are actually bearing the burden of emissions generated due to foreign consumption according to the standards set by the importers, while according to the UNFCCC they should only be held accountable for the emissions generated due to the productive activities occurred within their geographical space. Applying the tool of BCA the importing countries may shift their burden of responsibility outside the jurisdiction of their national territory by importing from non-committed developing countries as well as earn additional tariff revenues from the exporters in the name of higher reduction standards. Alternatively the 'consumption-based system boundary' for accounting the emission responsibility is frequently talked about counterfactual analysis in the economic literature which may replaces the production-based accounting by deducting the carbon emissions embodied in a country's exports from the emissions due to total domestic production, and then by adding it to the emissions embodied in imports manufacturing from foreign countries (Proops et al., 1993; Kondo et al., 1998; Bastianoni, 2004; Munksgaard et al, 2007; Rodrigues and Domingos, 2008). This paper uses this idea of comparing the impacts and implications of BCA under the alternative system boundary of consumption-based accounting framework where the exporting country is introducing a set of DCAs for its responsibility with consumption-oriented emission inventory. In this paper a single-country case is considered with India which would be one of the biggest affected countries if BCA is implemented by its importers. With DCA, India is introducing a *production carbon adjustment* (*pca*) which is to be imposed on Indian production of commodities, a *retaliatory border carbon adjustment* (*rbca*) which is to be imposed on Indian imports and a *compensated carbon adjustment* (*cca*) in the form of an exemption from paying the *pca* for the production Indian exports.

3. The Model

The study constructs a single-country multi-sector static computable general equilibrium (CGE) model to evaluate the implications of the BCA vis-à-vis the DCA under a consumption-oriented emission accounting framework. The CGE model is regarded as the most appropriate modelling tool for the ex-ante analysis of the energy and environmental policies for its ability to reveal the comprehensive relationships in the entire economy and conduct policy simulations under the assumption of general equilibrium (Xu & Masui, 2009; Ross et al., 2009; Böhringer et al., 2010; Burniaux, Chateau, & Duval, 2011; Hübler, 2011; Bao et al., 2013; Li and Su, 2017; Siriwardana et al., 2017; Zhao et al., 2018). In this study, the CGE analysis principally follows a modified version of the standard static model proposed by the 'Partnership in Economic Policy (PEP 1-1)' by Decaluwe et al. (2009), however significantly deviating with one respect. This study assumes that India is a big importer and has some influence on the pricing decision of its imported items. This assumption of 'big country' importer enriches the model with more realistic scenarios since India is a country of more than 1 billion population and that consists of a huge number of middle-class people which contributes to a bigger market for foreign products. This realistic assumption is modelled according to Hosoe-Gasawa-Hashimoto's (2010) extended applications on the standard CGE analysis. This study does not forecast about either the economy-wide or the sector-wise long-run performance of the BCA vis-à-vis the DCA policies, therefore avoids the complexities and additional data requirements for the dynamic modelling. The details of the model are explained as follows.

3.1. Production

This model is consisting of 6 non-energy activities (namely – Agriculture, Minerals other than Fuels, Light Weight Manufacturing, Heavy Weight Manufacturing, Construction and Services including Transportation) and 4 energy sectors (namely – coal and coal products, petroleum oil and oil products, natural gas and electricity). The manufacturing of both types of commodities follows a nested production-structure consisting of seven layers of processing stages as shown in the Figure 1 below. Mostly these processing are captured in terms of CES production technology except for the final output stage and the intermediate aggregate stage where a Leontief type production technology is assumed. The CES production functions are assumed to consider an opportunity to substitute between the inputs, especially to incorporate the idea of clean energy substitution and capital-labor substitution as a response to carbon taxation. On the other hand, the Leontief production function is assumed when the inputs are assumed to be used in fixed proportions, which is regarded as an engineering decisions, beyond the scope of economic policies. This specific production structure mostly followed the DART97 model (Klepper et al., 2003)[2] to represent the outputs from the energy and non-energy sectors in a better way, with few exceptions. For instance, the value added composite is represented in the DART97 as a Cobb-Douglas production function, however, in this static model only a limited substitution possibility among the two factors is considered for the short-run analysis.

[2] Appendix A explains this production structure with equations (A.1) to (A.8).

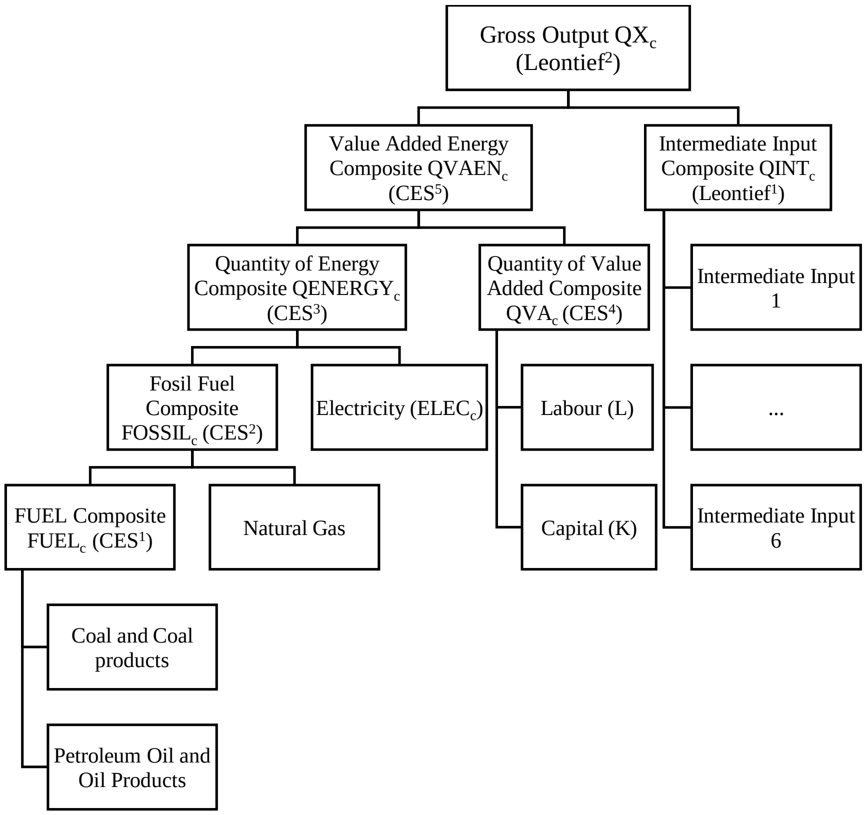

Figure 1. Commodity Production Structure consists of Seven Tiers of Processing

3.2. Trade

Imperfect substitution between domestic and foreign goods is allowed in the model based on Armington assumption (Armington, 1969), where producers and consumers differentiate goods from different markets according to their relative prices. The total domestic demand Q_c for any commodity c is composed of the domestically produced DOM_c and imports IM_c using a CES function as shown in equation (1) below. This CES function is also called the Armington function which derives the domestic demand for domestically produced commodities ($QDOM$) and imported commodities (QIM) based on the ratio of domestic demand prices (PDD) and import demand prices (PIM) as shown in equation (2).

$$QQ_c = \alpha_c^q \left\{ \delta_c^q QDOM_c^{-\rho_c^q} + \left(1 - \delta_c^q\right) QIM_c^{-\rho_c^q} \right\}^{-\frac{1}{\rho_c^q}} \quad (1)$$

$$\left(\frac{QDOM_c}{QIM_c}\right) = \left(\frac{PIM_c}{PDD_c} \cdot \frac{\delta_c^q}{\left(1 - \delta_c^q\right)}\right)^{\frac{1}{1+\rho_c^q}} \quad (2)$$

On the other hand, the Constant Elasticity of Substitution (CET) function is also assumed in the model to allow the substitution possibilities between the sales of domestic goods for domestic and foreign markets. The total domestic output X_c for any commodity c is composed of the domestically consumed DOM_c and exports EX_c using a CET function as shown in equation (3) below. This function determines the relative supply of exports based on the ratio of export prices (PEX_c) and domestic supply prices (PDS_c) as shown in equation (4) below.

$$QX_c = \alpha_c^t \left\{ \delta_c^t QDOM_c^{\rho_c^t} + (1 - \delta_c^t) QEX_c^{\rho_c^t} \right\}^{\frac{1}{\rho_c^t}} \qquad (3)$$

$$\left(\frac{QDOM_c}{QEX_c} \right) = \left(\frac{PDS_c}{PEX_c} . \frac{(1-\delta_c^t)}{\delta_c^t} \right)^{\frac{1}{\rho_{c-1}^t}} \qquad (4)$$

3.3. Institution

This study assumes a single representative household who earns factor incomes by selling labour and capital endowments and transfer incomes from the government and the rest of the world. After paying income tax and transfer payments to the government, household spends the disposable income (EH) for purchasing commodities and to save. Household consumption of commodities (QH) is modelled here in terms of a Linear Expenditure System (LES) derived from the Stone-Geary Utility Function[3] as shown in equation (5) below.

$$QH_c PQ_c = PQ_c \gamma_c + \beta_c \left(EH - \sum_{cp} PQ_{cp} \gamma_{cp} \right) \qquad (5)$$

Here PQ_c is the price of the commodity c and γ_c, β_c are regarded as the subsistence level of consumption of commodity c, and the marginal share of household consumption of commodity c respectively.

Enterprises earn income (YN) from factor incomes of capital and transfer incomes from the government. After paying the direct taxes ($dtax_{EN}$), Enterprises save the entire income

[3] The Stone-Geary Utility Function first represented by Roy C. Geary (1950) which introduces the element of subsistence level of consumption to the standard Cobb-Douglas Utility Function.

($ENSAV$), because this institution is not consuming commodities as shown in equation (6) below.

$$ENSAV = (1 - dtax_{EN}).YN \quad (6)$$

Income of the government (YG) composed of revenues from the direct taxes on households and enterprises, indirect taxes[4] on commodities and transfer incomes from households and from rest of the world. Besides government is assumed to earn through factor incomes from invested capital because to consider the huge operations of public sector in the industrial activities in India. Government expenditure (EG) is distributed for consumption of goods and services and transfer of income to households and enterprises. Government expenditure over and above the revenue is modelled as government savings ($GSAV$) which is residually determined and should be considered as a deficit that turns out negative.

$$GSAV = YG - EG \quad (7)$$

Foreign countries earn their income from their exports to India (or India's payment for imports), from their capital investments in India and through India's outflow of remittances. On the other hand, India earns from foreign countries through India's export, the inflow of remittances and Government's transfer incomes from abroad. Meanwhile, the net earnings of the foreign countries from India is represented as the savings of foreign countries. These foreign savings is considered as the current account deficit of India's balance of payments (BOP). The proceeds from the BCA is added to the foreign earning.

3.4. Closure

[4] Indirect taxes, as reported in the SAM, are net of subsidies and inclusive of all types of indirect taxes for domestic goods production, consumption and foreign goods import and export.

This model follows a Walrasian general equilibrium[5] where markets for all commodities and factors return to its equilibrium through the adjustment in prices. Therefore, the consumer price index (CPI) is considered as the model numeraire to exhibit all the prices as relative prices, hence CPI is assumed to be fixed. In addition to the market clear conditions for the commodity and factor market equilibriums, several other equilibrium conditions are assumed to close model for the macroeconomic balance.

Firstly, balance in Government account is assumed in such a way that the government consumption of commodities and all other rates (direct and indirect taxes, public debt, transfer income inflows and outflows) are considered to be fixed while government savings are calculated as a flexible residual of the current government revenues over current government expenditure. Secondly, for the external balance the real exchange rate is assumed flexible while the foreign savings (the current account balance) is fixed. Thirdly, in terms of saving-investment balance, this model is assumed an investment-driven closure, where savings is assumed flexible to balance with exogenous investment. Fourthly, two primary factors are assumed – labor and capital, both of them are fixed in supply, mobile, homogeneous and fully employed, where rents and wages are perfectly flexible for adjustments.

4. Data and Calibration

The main source of data for this model is a 'social accounting matrix (SAM)' which provides a detailed structure of the entire economy consisting of production and consumption activities and interactions between different sectors, factors of production and institutions. This study uses the latest SAM of India, the base year of which is 2007-2008. This original 78 sector SAM developed by Pradhan et al. (2013) is aggregated into a 10 sector SAM with two factors

[5] The Walrasian model assumes that if all the (n-1) number of markets are in equilibrium then the n-th market will also be in equilibrium, so the model would contain only (n-1) number of independent equations to show the equilibrium conditions for all 'n' markets.

of production, namely, capital and labour, a single representative household and other institutions, namely, private enterprises, government and the rest of the world.

As a convention for the CGE modelling, this study mostly adopted the calibration procedure for benchmark data of all the variables and for the CES and Leontief parameters, transfer and tax rates, etc. However, for the values of some elasticity and emission intensities of energy commodities, the information is collected from outside the SAM. The values of various elasticity are mostly taken from the DART97 (Klepper et al., 2003) and the EMPAX-CGE model (RTI International, 2008) model as shown in Table 1 below.

Table 1. Elasticity Values Collected from Outside the SAM

Substitution Elasticity	Non-Energy Sectors	Energy Sectors
CES^1 (FUEL)	1.5	0.75
CES^2 (FOSSIL)	1.5	0.75
CES^3 (ENERGY)	0.75	0.75
CES^4 (Value Added)	0.5	0.5
CES^5 (VAEN)	0.5	0.5
CES^q (Armington Function)	4.0	4.0
CET^t (Transformation Function)	2.0	2.0

For the calculation of emission intensities, this study followed the directions and accounting principles of the Intergovernmental Panel on Climate Change under Stationary Combustion (IPCC, 2006) based on Tier-II approach with country-specific intensity factors for coal and coal products, petroleum oil and oil products and natural gas. The Tier-II approach is mentioned in IPCC (2006) as more applicable since the uncertainty range associated with a country-specific value will be smaller than the uncertainty range of the Tier-I recommended default emission factors. These country-specific factors are calculated based on India's energy-commodity balance table following Banerjee (2020) from the 4th Issue of United Nations Energy Balances (Department of Economic and Social Affairs, UN Statistics Division, 2017a) for the year 2015. The energy information from this source is found in the form of *overall energy balance (OEB)* where energy flows from all types of energy is shown in terms of a common accounting unit (in terajoules) which avoids all the unnecessary complexities for using suitable conversion factors and aggregation of energy flows. To calculate the intensity factor for Electricity, this study used data from the UN Electricity Profile (Department of Economic and Social Affairs, UN Statistics Division, 2017b). According to the direction of IPCC (2006), the carbon emissions are calculated using the following formula as shown in Eq. (8) below.

$$EMINT_c = \frac{\sum_{Energy=1}^{n}(Energy\ Use\ _{Energy}).(Emission\ Factor_{Energy})}{Total\ Output_c} \qquad (8)$$

Where n = 3 when considering only the direct energy uses from primary sources, however, n = 4 when electricity is also included in the calculation.

5. Simulation Scenarios and Results

Table 2 summarizes the scenarios experimented[6] and analysed in the study. The foreign countries are assumed to impose a BCA on Indian export at a softer rate in Scenario 1 and at a stricter rate in Scenario 3 and Scenario 4. Because the SAM used in this study is not distinguishing the rest of the world institution between the developed countries and the developing countries, two different carbon adjustment policies have experimented assuming that the foreign countries are either following a weak climate policy or strong climate policy. On the other hand, India is assumed to implement the DCA measures at a softer rate in Scenario 1 and Scenario 2 and at a semi-stricter rate in Scenario 3 to counter and complement the BCA impositions by the rest of the world under a consumption-based system-boundary approach. Here the softer and the stricter rates are assumed as INR 420 and INR 840 per tonne of CO_2

[6] See Appendix B for the equations depicting the Scenario experiments.

emissions which is roughly equivalent to USD 10 and USD 20 respectively[7]. For the semi-stricter rate, INR 630 per tonne of CO_2 emission is assumed. Besides the rates for carbon adjustment, sub-scenarios under each of the Scenarios are evaluated considering either the proceeds from the DCA measures is to be added in Indian government revenue, or these proceeds are recycled to the household income in the form of additional transfer earnings from the Government.

Table 2. Scenario Experiments

Scenarios	Instruments	Feature
1-(a)	Softer BCA and Softer DCA	Proceeds from the DCA added as additional Government revenue of India.
1-(b)	Softer BCA and Softer DCA	Proceeds from the DCA recycled to Households as additional transfer incomes from the Government.
2-(a)	Stricter BCA And Softer DCA	Proceeds from the DCA added as additional Government revenue of India.
2-(a)	Stricter BCA And Softer DCA	Proceeds from the DCA added as additional Government revenue of India.
3-(a)	Stricter BCA And Semi-Strict DCA	Proceeds from the DCA added as additional Government revenue of India.
3-(b)	Stricter BCA And Semi-Strict DCA	Proceeds from the DCA recycled to Households as additional transfer incomes from the Government.

[7] So far there is no consensus in the literature for the choice of any particular rate on carbon price. The carbon adjustment rates in this study are based on the argument of Li and Su (2017). The carbon adjustment rates are converted into local currency equivalent based on the average exchange-rate in 2007-08 which was USD 1 = INR 41.26 (Reserve Bank of India).

5.1. Environmental Impacts

Table 3 showing the results on the impact of carbon adjustment based on consumption-based system boundary framework. This table is showing that the imposition of carbon adjustment measures bringing a reduction in total emissions, both with direct emission intensity and total emission intensity-based carbon adjustment instruments. With an increase in the rate of BCA from INR 420 to INR 840, this study found that the total emission is also reducing at a higher percentage. However, according to Scenario 3, implementing a semi-stricter DCA measure by India ensures even higher reductions in total emissions. This is because, while in Scenario 1, the BCA and the DCA rates are the same, the BCA rates are doubled in Scenario 2 with its base only on India's exports and in Scenario 3, the DCA measure is also increased by 1.5 times which has a higher tax-base on India's total consumption. So the impact on carbon-emission under Scenario 3 is becoming more effective. This study also measured the abatement cost as the ratio of the declining real GDP and the reduced emissions following Li and Su (2017) which is found highest in the case of Scenario 3, followed by Scenario 1 and Scenario 2. Under the sub-scenarios, when the DCA-revenue is recycled to households in the form of additional transfer income the increase in abatement cost is moderated may be because the relative fall in real GDP becoming smaller. Another interesting finding from this analysis is found from the measure of *emission-intensity of energy use* which is reduced in case of Scenario 1 and Scenario 3 but slightly increasing under Scenario 2. This implies when Indian producers have to bear substantially more burden due to the carbon adjustment in foreign countries as compared to India, the energy consumption pattern in productive activities become more emission-intensive. To better understand this aspect more detailed and sector-wise emission generation and energy-demand analysis is done next.

Figure 2 is depicting the complete result on the sector-wise change in emissions due to various forms of carbon adjustment measures. Among the energy-sectors, the emission reduction as a result of carbon adjustment found highest in the case of Coal. In the case of petroleum oil also the emission reduction found significantly high. However, for natural gas and electricity, the emission as a result of carbon adjustment found positive. This clearly indicates a gross transformation in the energy-consumption pattern of the country from high-emission intensity towards a low-emission intensity. Among the non-energy intensive sectors, carbon emissions are reduced from the Other-Mineral Products (OMIN), the Light-weight Manufacturing (LMAN) and the Heavy-weight Manufacturing (HMAN) sectors as per the sector-wise emission intensities. However, this study found that the carbon adjustment inducing more emissions from Agriculture and Allied Activities (AGRI) and Construction (CONS). The sector of Services including Transportation (SERV) also found generating more emissions under Scenario 2. This result implies that carbon adjustment decreased the emission-intensity of the high-emission intensive sectors, however, increased the emission-intensity of the low-emission intensive sectors. To investigate on this issue of why for some sectors the carbon emission is reduced and for some others this is increasing, this study portrays the findings on the sector-wise energy demands of the non-energy sectors due to the scenario-based carbon adjustment measures, in the form of Figure 3.

Figure 3 shows that the three high-emission intensive sectors, OMIN, LMAN and HMAN drastically reduced their energy demands, principally in coal, followed by electricity and petroleum oil, however, showed an increase in their demand for natural gas. In contrast to that, for the low-emission intensive sectors, like AGRI and CONS, demand for coal, petroleum oil and electricity found increased as a result of carbon adjustment, whereas the use of natural gas is reduced. The pattern of demand for the SERV sector found very peculiar, in that its response found similar to the high-emission intensive other sectors under carbon adjustments based on Scenario 1 and Scenario 3, maybe because this sector includes the highly emission-intensive transportation activities. However, under Scenario 2 when the rate of BCA is doubled, emission-switching behaviour completely changed for SERV and its demand for electricity substantially increased which increased the sectoral total emissions from this sector.

Table 3. Impact of Carbon Adjustment on Emission and Energy (Percentage Change)

Scenarios		Total Emissions (t-CO2)	Emission Intensity of Energy (t-CO2 per TJ)	Average Abatement Cost (INR Cores per t-CO2)
1-(a)	DIRECTCO2	-0.069	-0.553	1.059
	TOTALCO2	-0.062	-0.545	1.062
1-(b)	DIRECTCO2	-0.069	-0.553	0.962
	TOTALCO2	-0.062	-0.545	0.965
2-(a)	DIRECTCO2	-0.084	0.075	0.845
	TOTALCO2	-0.083	0.068	0.849
2-(b)	DIRECTCO2	-0.084	0.075	0.820
	TOTALCO2	-0.083	0.068	0.824
3-(a)	DIRECTCO2	-0.112	-0.207	1.339
	TOTALCO2	-0.123	-0.158	1.344
3-(b)	DIRECTCO2	-0.112	-0.207	1.276
	TOTALCO2	-0.123	-0.158	1.280

Author's Calculation

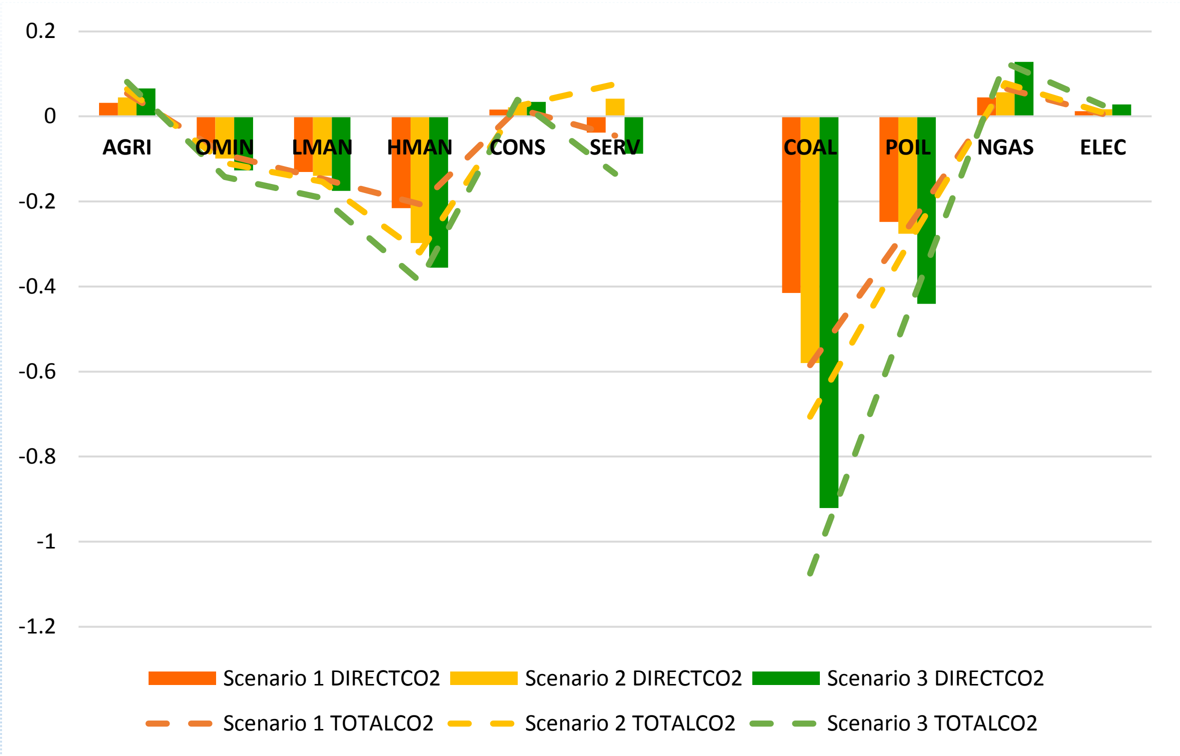

Figure 2. Impact of Carbon Adjustment on Sectoral Emissions

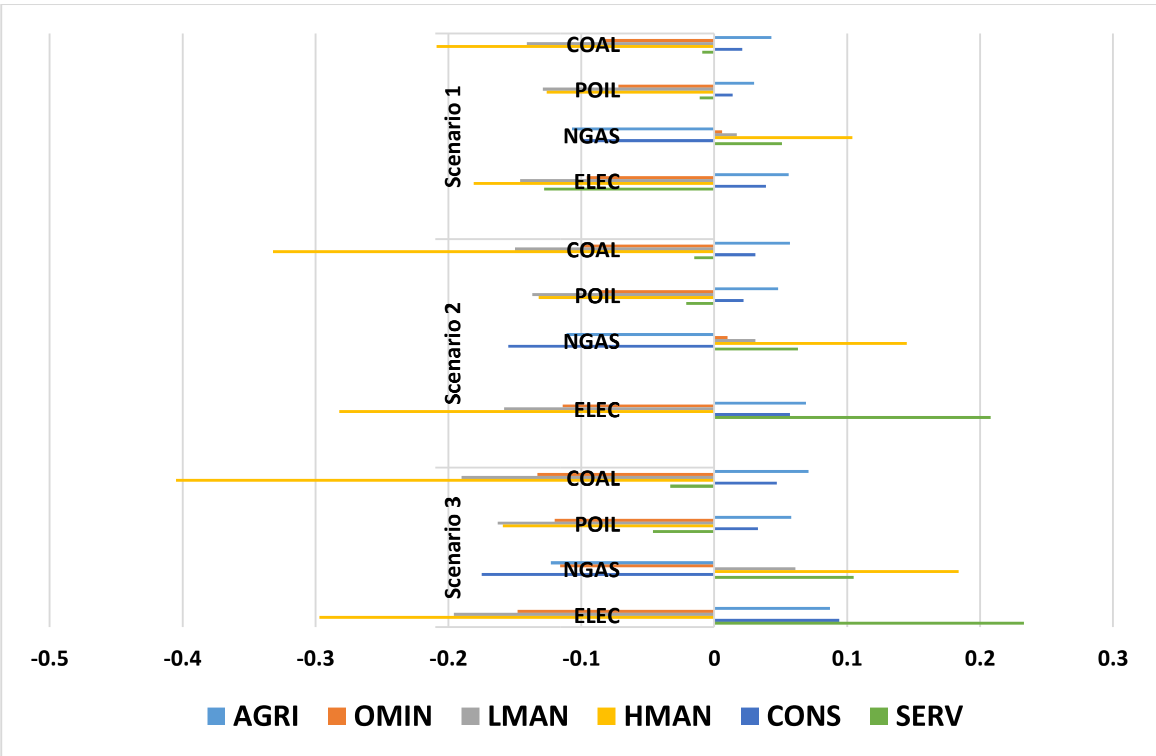

Figure 3. Impact of Carbon Adjustment on Sectoral Energy Demands

5.2. Macroeconomic Impacts

Carbon adjustment creates a widespread impact on the economy as well. The first impact of this external shock falls on the commodity prices of different sectors. In the face of inelastic foreign demand for Indian export products, an imposition of BCA reduces the supply prices of Indian exports received by Indian exporters. Similarly, all the measures under DCA impacts on commodity prices. Imposition of PCA reduces the price of output of Indian producers, however, is exempted from this burden, if export this production in the world market, for in that case the Indian producers have to bear the BCA to access the foreign markets. Under the consumption-based system boundary, India imposing carbon adjustment at the same of PCA on its imports. This study assumes India as a big importer with an elastic demand for its imports such that the imposition of RBCA on import products increase the price of import only less than proportionately and the foreign importers bearing the rest of the burden.

The entire macroeconomic impacts due to carbon adjustment measures under the consumption-based framework are shown in Table 4 below. According to this result, all types of carbon adjustments bringing reductions in the real GDP, however, when the proceeds of DCA measures are recycled under the sub-scenarios 1-(b), 2-(b) and 3-(b), this reduction found smaller. Carbon adjustments also decreasing the volume of international trade, and significantly the fall in import found higher than the fall in export under Scenario 1 and Scenario 3. Under Scenario 2, this feature is changing and export decreased more than the import. As far as the exchange rate is concerned, the depreciation rate is found highest under Scenario 2, followed by Scenario 1 and Scenario 3. Since the imposition of BCA reduces the domestic price of export, while the world price of export is constant, the exchange rate depreciation brings back the equilibrium in the international commodity trade. With increasing BCA from Scenario 1 to Scenario 2, this depreciation also found increased. When India is imposing the RBCA, demand for foreign commodities in the Indian markets may reduce if the international prices of the import commodities remain unchanged. Therefore, a semi-stricter RBCA measure found moderating the depreciation of the exchange rate due to the stricter BCA imposition by the foreign countries. Household consumption levels also found deteriorated due to imposition of carbon adjustment measures both in case of BCA and DCA measures. Revenue recycling from the DCA programme found in this study revived this deterioration to a large extent. Therefore the simulation results from the three sub-scenarios showing that the distortions caused by the imposition of additional taxes can be reduced if a recycling scheme can be designed to transfer the purchasing power to the household sector. Last but not the least, the tax-GDP ratio for India increased as a result of DCA implementation which is important from the perspective of welfare implications, especially when these additional tax-proceeds are channelled to the households. This ratio found almost doubled when India increasing its DCA rates to 1.5 times under Scenario 3, from its softer levels.

Table 4. Macro Impacts of Carbon Adjustment (Percentage Change)

Scenarios	Real GDP at Market Price	Total Exports	Total Imports	Household Consumption	Exchange Rate	Tax-GDP Ratio
1-(a)	-0.142	-0.342	-0.483	-0.404	0.300	3.925
1-(b)	-0.118	-0.329	-0.472	-0.203	0.300	0.000
2-(a)	-0.266	-0.551	-0.512	-0.824	0.700	3.925
2-(b)	-0.248	-0.522	-0.503	-0.580	0.700	0.000
3-(a)	-0.337	-0.575	-0.683	-1.111	0.200	7.605
3-(b)	-0.313	-0.539	-0.672	-0.280	0.200	0.000

Author's Calculation

6. Conclusion

Addressing the enormity of the issue of global warming the international community gathered for the Earth Summit in Rio de Janeiro in June 1992 to sign the United Nations Framework Convention on Climate Change (UNFCCC) and pledged to reduce the emissions of greenhouse gases at a level which would protect Earth's climate from the harmful interference of anthropogenic activities. This paved the way of signing a historic treaty called the Kyoto Protocol in December 1997 which is the first agreement of its kind that ultimately negotiated onto binding and targeted emission reduction commitments from some of the big emitter countries of this planet. However, the framework of accounting of the emission reduction responsibility did not put enough attention for the adjustments needed with international trade playing a vital role in shifting the burden of responsibility from the importing country to the exporting country. When the exporting country is accused of its weaker carbon regulations the importing country with its BCA instruments may be compelling the exporters to abide a stricter regulatory regime in order to cross the border to trade, this fundamentally means that the importing country is holding its responsibility for the emissions due to its consumption. The exporting country on the other hand both held accountable for the emissions due to foreign consumption and also bear the burden of higher costs due to BCA imposition with higher emission standards. Therefore the concept of BCA bringing a clear violation of the system boundary for emission accounting framework and spins around the age-old North-South debate over 'trade and environment'.

This study undertook a simple analysis to evaluate the implications of BCA under consumption-based system boundary approach and found that this instrument able to address the problem of 'carbon leakage' more effectively when a stricter DCA scheme is already in operation. In fact, this study found that when the regulatory gap between the home country and the foreign countries is converged under Scenario 1, the emission intensity of energy use in India is reduced to a minimum and when this is eventually diverging, the decrease in emission intensity of energy use found not so much under Scenario 3 and even this increased under Scenario 2. As far as the objective of emission reduction is concerned, the difference in the sector-wise response due to carbon adjustment creates another scope to rethink about the effectiveness of the carbon adjustment policies. The results from the simulation exercises found that carbon adjustment decreased the emission-intensity of the high-emission intensive sectors by inducing them to switch towards low-emission intensive natural gas option, however, increased the emission-intensity of the low-emission intensive sectors by inducing them to use more high-emission intensive fuels due to their reduced prices. However, this study has the limitation due to its static and a fairly aggregated analytical framework which restricts its ability to conclude the exact price dynamics involved in the changing energy demands of different sectors. Therefore, this study provokes a far-reaching research agenda on the implication of BCA under the consumption-based system boundary framework with sector-disaggregated dynamic equilibrium analysis.

The macroeconomic features also found deteriorated with higher rates of BCA under the consumption-based framework however recovered to some extent due to other complementary policies, like carbon revenue recycling and the flexible foreign exchange rate. In an economic perspective as well, as the regulatory gap is narrowing down in terms of carbon adjustment rates imposed by India and the rest of the world, the impact on the economy due to fall in export is compensated with the reduction in import such that the exchange rate depreciation is controlled. This study also recommends a carbon revenue recycling scheme to enable the household sector to absorb the increased tax-distortions caused due to a semi-stricter domestic carbon adjustment. Finally, since BCA under presently practised system boundary is inconsistent, either a ‘consumption-based accounting’ is recommended, to be made fully operational or resistance should be built among the developing countries to oppose the BCA from its implementation under production-based system boundary framework.

Appendix A. Production Functions

Tier I Processing: Coal and Oil Composite ($FUELi$)

$$QFUEL_c = \alpha_c^1 \left\{\delta_c^1 QCOAL_c^{-\rho_c^1} + (1-\delta_c^1) QPOIL_c^{-\rho_c^1}\right\}^{-\frac{1}{\rho_c^1}} \quad \text{(A.1)}$$

Where

$QFUEL$ = Quantity of 'coal-oil composite' commodity

$QCOAL,$ = Quantities of 'coal and coal products'

$QPOIL$ = Quantity of 'oil and oil products'

$\alpha_c^1,\ \delta_c^1, \rho_c^1$ = CES function (1) scale and share parameter and the exponent respectively.

Tier II Processing: Fossil Fuel Composite ($FOSSILi$)

$$QFOSSIL_c = \alpha_c^2 \left\{\delta_c^2 QFUEL_c^{-\rho_c^2} + (1-\delta_c^2) QNGAS_c^{-\rho_c^2}\right\}^{-\frac{1}{\rho_c^2}} \quad \text{(A.2)}$$

Where

$QFOSSIL$ = Quantity of 'fossil fuel aggregate' commodity

$QNGAS$ = Quantities of natural gas.

$\alpha_c^2,\ \delta_c^2, \rho_c^2$ = CES function (2) scale and share parameter and the exponent respectively.

Tier III Processing: Energy Composite ($ENERGYi$)

$$QENERGY_c = \alpha_c^3 \left\{\delta_c^3 QFOSSIL_c^{-\rho_c^3} + (1-\delta_c^3).(\lambda_{ELEC} QELEC_c)^{-\rho_c^3}\right\}^{-\frac{1}{\rho_c^3}} \quad \text{(A.3)}$$

Where

$QENERGY$ = Quantity of 'energy composite' commodity

$QELEC$ = Quantities of 'electricity'

$\alpha_c^3, \delta_c^3, \rho_c^3$ = CES function (3) scale and share parameter and the exponent respectively.

Tier IV Processing: Value Added Composite (VAi)

$$QVA_c = \alpha_c^4 \left\{\delta_c^4 LD_c^{-\rho_c^4} + (1-\delta_c^4) KD_c^{-\rho_c^4}\right\}^{-\frac{1}{\rho_c^4}} \quad \text{(A.4)}$$

Where

QVA = Production of 'value added composite' commodity

LD, KD = Input demands for 'labor' and 'capital' respectively

$\alpha_c^4, \delta_c^4, \rho_c^4$ = CES function (4) scale and share parameter and the exponent respectively.

Tier V Processing: Value Added and Energy Composite ($QVAENi$)

$$QVAEN_c = \alpha_c^5 \left\{\delta_c^5 (QVA_C)^{-\rho_c^5} + (1-\delta_c^5) QENERGY_c^{-\rho_c^5}\right\}^{-\frac{1}{\rho_c^5}} \quad \text{(A.5)}$$

Where

$QVAEN$ = Quantity of 'value added energy composite' commodity

$\alpha_c^5, \delta_c^5, \rho_c^5$ = CES function (5) scale and share parameter and the exponent respectively.

Tier VI Processing: Intermediate Input Aggregate ($INTi$)

Input Demand Functions

$$QINT_{CINT}^c = int_{CINT}^c QINTA_C \quad \text{(A.6)}$$

Where

$QINTA$ = Quantity of intermediate aggregate

$QINT$ = Quantity of intermediate inputs

int_{CINT}^c = Leontief coefficients (input CINT per unit of aggregate intermediate)

Tier VII Processing: Final Output (Xi)

Input Demand Functions

$$QVAEN_c = ivaen_c QX_C \tag{A.7}$$

$$QINTA_c = inta_c QX_c \tag{A.8}$$

Where

QX = Quantity of final output

$ivaen$ = Leontief coefficients for the $QVAEN$ in the final output production.

$inta$ = Leontief coefficients for the $QINTA$ in the final output production.

Appendix B. Simulations

Foreign countries imposing the BCA on Indian export. With BCA imposition Indian exporters receiving lower prices for their commodities.

$$PEX_c\left(1 + \frac{(bca_c EMINT_c)}{PX_c}\right) = \overline{PWEX}_c . EXR \tag{B.1}$$

Where

PEX = Supply price of Indian export

$\overline{PWEX}$ = Exogenous world price of Indian export

EXR = Exchange rate

bca = Border Carbon Adjustment

India imposing the RBCA on its import. With RBCA imposition the tax-burden is shared between Indian consumers and the foreign importers.

$$PIM_c\left(1 - \frac{(rbca_c emm_c)}{PWIM_c}\right) = PWIM_c . EXR \tag{B.2}$$

Where

PIM = Domestic price of Indian import

$PWIM$ = Endogenous world price of Indian import

$rbca$ = Retaliatory Border Carbon Adjustment

Under DCA measure, India imposing a PCA on Indian production of final output. With PCA imposition the cost function for the final output processing will change.

$$PX_c\left(1-\frac{(pca_c EMINT_c)}{PX_c}\right)=\frac{QVAEN_c PVAEN_c+QINTA_c PINTA_c}{QX_c} \qquad \text{(B.3)}$$

Where

QX, PX	= Quantity and Price of final output
$QVAEN$	= Quantity of 'value added and energy composite' commodity
$PVAEN$	= Price of 'value added and energy composite' commodity
$QINTA$	= Quantity of intermediate aggregate
$PINTA$	= Price of intermediate input aggregate
pca	= Production Carbon Adjustment

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