Assessing the Likely Impact of Carbon Taxes on India's Exports, Domestic Production and Employment

Draft Report

Bishwanath Goldar and Meera Bhalla

Institute of Economic Growth
University Enclave, University of Delhi,
North Campus, Delhi – 110 007
Tel: 27667101, 288
Fax: +91-11-27667410

November 2011

Acknowledgements

Assessing the Likely Impact of Carbon Taxes on India's Exports, Domestic Production and Employment

1. Introduction

The concentration of carbon dioxide (CO_2) in the atmosphere has been increasing over the last two decades at the average rate of about 0.5 percent per year. Some recent studies have indicated that inconceivable catastrophic changes in the environment will take place if the global temperatures increase by more than 2° C. It is believed that such an increase in global temperatures threatens both the ecosystem and the survival of humanity. A warming of 2° C corresponds to a carbon dioxide (CO_2) concentration of about 450 ppm in the atmosphere. CO_2 concentration has already crossed 390 ppm (392 ppm by volume in July 2011)[1] and has been rising on average 2-3 ppm each year. Thus, if the present trend continues, the critical value will be reached in approximately 20 to 30 years from now, which makes it a major concern today.

If CO_2 emissions are halved by 2050 compared to the 1990 level, global warming can be stabilized below two degrees. This is shown by two studies published in the journal, *Nature* (Allen et al., 2009; Meinshausen et al., 2009). In contrast, between 1991 and 2008, CO_2 emissions have increased by about 46 percent. The annual growth rate of emissions at the global level in the 1990s was about one percent per year, while that in period 2000 to 2008 was more than 3 percent per year. All these make immediate containment of CO_2 emissions extremely important.

At the multilateral level, countries are currently engaged in intense negotiations for evolving appropriate responses to challenges posed by climate change, including measures to combat climate change. In this context, it may be mentioned that while the developed countries had undertaken greenhouse gas (GHG) reduction commitments under the Kyoto Protocol of 1997, the developing countries were not required to make any such commitments. This was based on the principle of "common but differentiated responsibility" (CBDR principle) which lies at the heart of the United Nations Framework Convention on Climate Change (UNFCCC) of 1992. The Kyoto Protocol was, however, not ratified by all developed countries. It was ratified late by Australia in 2007, and not ratified by the US. With the first commitment period ending in 2012, there have been a lot of activities in the last few years towards framing of a new commitment. A critical facet of recent discussions is the protest aired by the developed countries that they could not continue to shoulder the burden of mandatory obligations on their own, and the developing countries, which are major emitters of greenhouse gases, would need to undertake some commitments. The Copenhagen Accord of December 2009 reflects these ideas, and the Cancun Agreement of December 2010 further builds on these (Anuradha, 2011). It should be noted that neither the Copenhagen Accord nor the Cancun Agreement has the status of a legally binding treaty. The Copenhagen Accord is widely held as a political agreement between some parties but not all. The Cancun Agreement goes a step further in that it reflects the commitment of parties to

---

[1] As reported in Wikipedia (http://en.wikipedia.org/wiki/Carbon_dioxide accessed 21-10-2011).

work on the principles contained therein. The significance of the Cancun Agreement is that it reflects a move towards more concrete obligations for developing countries for greenhouse gas reduction.

The interface of international trade with the measures for combating climate change has been receiving increasing attention (Asselt and Zelli, 2011). One serious concern of the developing countries in this regard is the possibility of some developed countries adopting unilateral trade measures in the form of border tax adjustments (BTA) to restrict exports of the developing countries to the developed country markets. The developed countries may take such measures on the ground that if they adopt measures to reduce substantially their GHG emissions, they may lose competitiveness of the energy intensity industries vis-à-vis the countries that do not adopt similar measures. Another argument is that in the absence of border tax adjustments, there may be emission leakage since production of energy intensive products may shift to locations where it faces much less restrictions (i.e. China, India and other developing countries) with the consequence that at the global level, the emissions may not reduce in accordance with the efforts made by the developed countries. Legislative efforts are underway in the US and the EU to cap GHG emissions, which contain provisions that provide ability to impose unilateral trade measures on imports from countries that do not have comparable GHG reduction norms (Anuradha, 2011).

It should be pointed here out that Article 3.5 of the UNFCCC provides for the use of unilateral trade measures. At the same time, it guards against the possibility of such measures being discriminatory and trade restrictive. Article 3.5 of the UNFCCC states that "Measures to combat climate change, including unilateral ones, should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade." The article is, however, silent on the actual circumstances that might justify such measures. It appears that unilateral action under Article 3.5 is likely under two situations – one, if countries fail to arrive at greenhouse gas reduction commitments for the period beyond 2012 pursuant to the emission reduction regime agreed to in the Kyoto protocol, and two, if countries feel that any agreement concluded does not meet the negotiating objectives (Anuradha, 2011). Evidently, absence of a satisfactory agreement on GHG emissions reduction beyond 2012 will be a fertile ground for adoption of unilateral trade measures. But, even if a satisfactory agreement is reached, inadequate compliance could trigger such unilateral measures (Anuradha, 2011).

One major issue about the unilateral trade measure is whether these are compatible with the WTO rules. Many commentators on this subject feel that any unilateral action involving carbon border adjustment of imports would be challenged under the WTO rules. A developing country could argue that the measure targets products that can be considered 'like' and therefore the unilateral measure is unjustified (Sindco, 2009). Furthermore, if the measure contains a determination of 'comparable action' (as do the measures for which legal processes are underway in the US and the EU), it can be argued that it is not applied to all countries as required by the most-favoured nation principle (Sindco, 2009). There are other issues which the developing countries could raise about the implementation of the measure. In fine, there are legal uncertainties about the unilateral trade measure and the final word will be with the judicial bodies of the WTO (Asselt and Gupta, 2009).

Given the serious concerns that the developing countries have with the unilateral border measures that the developed countries, particularly the US, may adopt, this study deals with introduction of carbon tax in the US, and tries to ascertain what impact it will have on India in terms of exports, output and employment, if the carbon tax in the US is accompanied by unilateral trade measures that restrict India's exports to the US.

The Report is organized as follows. The next section, Section 2, discusses briefly some earlier studies that have been done on the impact of carbon tax on the US economy. A particular focus is on the impact that border tax adjustments will have on developing country exports to the US if such measures are adopted by the US. This is followed in Section 3 by a theoretical discussion on how developing countries would be impacted by the introduction of carbon tax in a developed country, if the tax is coupled with border adjustment. Section 4 takes up the case of India and makes an attempt to assess how India will be impacted by a carbon border tax in the US. Impact is assessed in terms of exports, domestic production and employment. Section 5 compares India and a few other developing countries with the US in terms of energy intensity and CO_2 emission intensity. This is obviously relevant in the context of the present study, especially for judging how a carbon border tax based on the carbon embodied in imports will impact different developing countries. Finally, the finding of the study and conclusions are given in Section 6.

2. Previous studies on the impact of Carbon Tax in the US

There have been a number of studies on the impact of carbon price policies on the US economy, especially on energy intensive industries in the US.[2] The computable general equilibrium (CGE) models have generally been used for assessing the impact of carbon tax (including cap-and-trade schemes).[3] Often, this has been done on the basis of the GTAP (Global Trade Analysis Project) database, which is a multi-sector (more than 50 sectors), multi-region database of output and trade flows and permits formulation of a general equilibrium model for the world economy. Some studies have used a national model. Others have used a global model in which the behavior of countries other than the US has been taken into account. To give an example of the former group of studies, the Inter-temporal General Equilibrium Model (IGEM) have been used by Jorgenson et al. (2007) who find that by 2020 the economic burden of greenhouse gas mitigation policy based on a revenue neutral carbon tax or a cap-and-trade system with emissions constrained to year 2000 level would be relatively small at about 0.5 to 0.7 percent of GDP. According to their analysis, substitution away from more costly inputs (energy) and towards cheaper materials, labour and capital, along with price induced technical change will help to reduce the adverse impact of carbon pricing policies. To give an example of the second group of studies, Adkins et al. (2011) apply a global CGE model based on GTAP-7 data. They consider eight countries/ regions, namely US, Canada, Mexico, China, India, Rest of Annex-I[4] countries,

---

[2] Such studies have been undertaken also for EU (for example, Bollen and Brink, 2011), Japan (for example, Yano, Kojima and Zhou, 2011; and Takeda, Horie and Arimura, 2011), and other countries such as Australia (Pezzey and Lambie, 2001), Indonesia (Yusuf and Resosudarmo, 2007) and Thailand (Malla, 2005). Some studies have covered both US and EU (for example, McKibbin and Wilcoxen, 2008). Some studies consider the impact of carbon price policies in respect of the entire block of industrialized countries (for example, Hübler, 2009).
[3] There have been studies on US climate policy without employing a CGE model, for example, Houser et al. (2008).
[4] Annex-I countries are parties to the UNFCCC and include industrialized countries and transition economies. These countries have ratified the protocol and have committed to reduce their emission level to targets that are mainly set below the 1990 level. (Wikipedia, accessed 28November 2011).

Oil Exporters and Rest of the World, and 29 industries. Another example is Dong and Whalley (2009a) who consider four regions: US, EU, China and the rest of the world.

To list here some of the other studies undertaken on the impact of carbon pricing policies on the US economy, these include Ho et al. (2008), Adkins et al. (2010) and Fischer and Fox (2007, 2009a, 2009b) using GTAP based model, the US Energy Information Administration (EIA, 2009) using its NEMS model, the US Environment Protection Agency (EPA, 2009a) using the ADAGE model and the inter-agency US government using an updated version of the Fischer-Fox model (EPA, 2009b).[5] A common finding of these studies is that output based rebates are effective in containing output decline in energy intensive trade exposed industries caused by the carbon pricing policies.

Particularly relevant to the present study are the modeling attempts made in the context of carbon tax in the US where the model designing was done in accordance with the Waxman-Markey bill (the American Clean Energy and Security Act which was passed the US House of Representatives in June 2009 but did not subsequently get approval in the Senate). But, there have been other modeling attempts which took into account provisions of other bills. Metcalf et al. (2008), for instance, consider Larson proposal (H.R. 3416; America's Energy Security Trust Fund Act of 2007) and Stark-McDermott proposal (H.R.2069; Save Our Climate Act of 2007). The provisions relating to border tax adjustment in various bills for the US have been discussed by Asselt et al. (2009) among others.

A common finding emerging from many of the studies undertaken on the impact of carbon tax in the US is that the extent of emission leakage at the aggregate level is relatively low. The estimated leakage rate in the study of Adkins et al. (2011), for instance, is 6.3 percent. Such estimate reported in Fischer and Fox (2009b) is about 14 percent. However, for specific industries, the leakages could be high. In the estimates made by Fischer and Fox (2009a) for energy intensive industries, the baseline leakage rates are: 20 percent for chemicals, 39 percent for non-metallic mineral products, 11 percent for pulp, paper and printing, and 60 percent for iron and steel industry. The estimates of leakage rate in Adkins et al. (2010), similarly, are 27 percent for chemicals, rubber and plastics, 15 percent for ferrous metals, 10 percent for non-metallic mineral products, and 13 percent for non-ferrous primary metals manufacturing.

Studies have recognized that there are two sources of leakage: (a) through trade channel, replacement by domestic production by imports, and (b) through fall in world energy price induced by cuts in energy use in countries following carbon pricing policy with the consequence that non-policy countries are encouraged to step up their energy consumption. Empirical research undertaken on this issue indicates that the second source accounts for a significant portion of the leakage. In the case of ferrous metal, for example, the estimates of Adkins et al. (2010) indicate that US emissions will decline by about 4.6 million tons of CO_2 as a result of carbon pricing policy (based on carbon price of US$ 15 per ton of CO_2 coupled with rebates for domestic producers). On the other hand, emissions in non-Annex I countries will go up by 0.96 million tons, of which only 0.2 million tons is due to increased exports to the US, whereas 0.7 million tons is due increased carbon intensity in the non-Annex I countries which is traceable to

a decline in global energy prices.   In this example, it can easily be seen that imposing border adjustment tax on imports from developing countries will not achieve much in reducing emission leakage. A similar conclusion may from the estimates of leakage presented in Fischer and Fox (2009a). In several products, only a small part of the leakage is due to production change, i.e. shift of production to another location. Evidently, in these cases too, border tax adjustment will not be able to curtail leakage substantially. By contrast, Elliott et al. (2010) find that increased CO_2 emissions in developing countries would undo over 20 percent of reductions made by the developed countries by virtue of imposing a carbon tax on producers of \$105 per ton C (\$29 per ton CO_2) and the leakage gets eliminated when full border tax adjustments are applied. This finding of Elliott and associates which is at variance with the findings of several other studies could be an outcome of particular features of their model. Thus, it seems reasonable to conclude that even after full border tax adjustment is applied, a significant portion of the leakage which is connected with a fall in global energy prices may remain unaffected.

Turing now to the impact of carbon pricing policy on the US economy, Table 2.1 presents estimates of the medium-run effects on the US manufacturing industries obtained in the study by Adkins et al. (2010). This is the estimated effect of carbon being priced at US\$ 15 per ton of CO_2 coupled with rebates for domestic producers in accordance with the provisions of the Waxman-Markey bill. It would be noticed that in most cases, the effect on output is less than one percent. The effect on imports is positive in almost all cases. The effect on imports is, however, small, barring a few cases.

According to the estimates of Adkins et al. (2010), the long- run effect of carbon price and domestic output subsidy will be to reduce GDP of US by 0.09 percent. Evidently, the expected effect is rather small. As for India, they expect Indian GDP to go up by 0.77 percent. In a subsequent paper of the same authors (Adkins et al., 2011), the estimate of fall in US GDP is 0.12 percent, while the increase in Indian GDP is estimated at 0.05 percent.[6] The estimated change in imports of manufactures is positive in almost all cases. It is small in magnitude, mostly one percent or less.

The estimates of the effect on output under unilateral and multilateral action reported in the study of Adkins et al. (2010) indicate that the adverse effect on the US economy emanating from the carbon price policy will be relatively lower if there is multilateral action by all Annex I countries. The estimated effect on output in the medium-term under unilateral and multilateral action is shown in Table 2.2 in respect of energy intensive industries. It is seen from the table that the effect is relatively lower in a situation of multilateral action. A somewhat similar finding emerges from the analysis of Dong and Whalley (2009a) who in their model consider four regions, US, EU, China and rest of the world. Carbon pricing by the US increases US imports of high emission goods by 1.6 percent. If both US and EU adopt carbon pricing (at US\$ 100 per ton C) the increase in US imports of high emission goods is 1.5 percent. If both US and EU adopt BTA against China along with carbon pricing, the increase in US imports of high emission goods is lower at 1.24 percent. If both US and EU adopt carbon pricing and only US adopts BTA against China, the increase in US imports of high emission goods is still lower at 0.63 percent.

---

[6] The model estimates of McKibbin and Wilcoxen (2008), the effect on India's GDP is expected to be 0.1 to 0.3 percent.

Table 2.1: Estimated Medium Term Effect on the US economy – A \$15/ton CO_2 tax with H.R. 2454 Allocations

Sr no.	Industry	% change in production	% change in use	% change in imports
1	Food	-0.10	0.01	0.43
2	Textiles	-0.37	-0.13	0.17
3	Apparel	-0.06	0.03	0.04
4	Wood and furniture	-0.31	-0.20	0.03
5	Pulp and Paper Mills	-0.16	-0.08	0.14
6	Refineries	-5.66	-4.85	-1.25
7	Petrochemical manufacturing	-1.28	-0.48	2.57
8	Basic Inorganic Chemical Manufacturing	-1.28	-0.50	1.16
9	Other basic organic chemicals Mfg	-1.28	-0.55	1.19
10	Plastic and Material Resins	-1.28	-0.53	1.51
11	Artificial & synthetic fibers, Filaments	-1.28	-0.51	2.13
12	Fertilizers	-1.28	-0.43	0.75
13	Other chemical and plastics	-1.28	-0.38	0.67
14	Glass Containers	-0.60	-0.30	0.48
15	Cement	-0.60	-0.31	0.66
16	Lime and Gypsum	-0.60	-0.37	6.87
17	Mineral Wool	-0.60	-0.37	1.40
18	Other Nonmetallic minerals	-0.60	-0.32	0.47
19	Iron, Steel and Ferroalloy	-0.17	-0.30	-0.44
20	Alumina refining, primary and secondary Aluminium	-0.81	-0.31	0.12
21	Ferrous Metal foundries	-0.36	-0.34	-0.16
22	Non-Ferrous Metal foundries	-0.36	-0.34	NC
23	other primary metals	-0.81	-0.29	0.11
24	fabricated metals	-0.36	-0.31	-0.05
25	Machinery	-0.31	-0.28	-0.10
26	Computer and electrical equipments	-0.39	-0.19	-0.02
27	Motor Vehicles	-0.23	-0.08	0.04
28	Other Transportation Equipment Manufacturing	-0.23	-0.17	0.13
29	Miscellaneous Manufacturing	-0.12	0.14	0.33

Source: Computed from Table 14a of Adkins et al. (2010).
NC= Not computed, as the value of imports is very small.

Table 2.2: Medium term effect on production of energy intensive manufacturing industries in the US, unilateral and multilateral action through carbon pricing policy

(percent change in production)

Industry	Unilateral action	Multilateral action
Paper and publishing	-0.16	-0.06
Petroleum and coal products	-5.66	-4.12
Chemicals, rubber, plastics	-1.28	-0.66
Non-metallic mineral products	-0.60	-0.47
Ferrous metals	-0.17	0.17
Non-ferrous primary metals	-0.81	-0.23

Source: based on Table 14a of Adkins et al. (2010).

From a perusal of the studies on the effect of carbon pricing policy on the US, it is found that the estimated fall in US GDP due to the carbon pricing policy is generally less than one percent. The studies by Adkins et al. (2010, 2011) and Jorgenson et al. (2007) mentioned above report estimates that indicate that the fall in GDP will be less one percent. This is true for several other studies. According to the estimates made by McKibbin and Wilcoxen (2008), the US carbon price policy will reduce US GDP by about 0.7 percent. According to the estimates of Fischer and Fox (2009b), the production fall due to carbon tax will be about 0.2 percent. Aldy and Pizer (2009) report a slightly bigger impact on manufacturing. According to their estimates, pricing of CO_2 at US$15 per ton, would lead to an average production decline of 1.3 percent across U.S. manufacturing.

The analysis of the American Clean Energy and Security Act of 2009 by the EPA (EPA, 2009a) reveals that by 2020 output of energy intensive industries will fall by about 0.8 percent in the absence of output-based rebates to domestic producers and by about 0.4 percent if such rebate is provided. The expected decline in GDP estimated by the ADAGE model is 0.26 percent for 2020. The estimate based on the IGEM model is 0.75 percent for that year. The EPA report notes that the allowance price obtained by various models shows an upward trend over time. The estimates indicate that the allowance price will increase from US$20-50 per ton of CO_2 in 2015 to US$ 160-200 per ton of CO_2 in 2050. As a result, the adverse effect on GDP goes up over time. Going by the estimates of the ADAGE model for the Lieberman-Warner proposal, the decline in GDP due to carbon price policy will be about 0.7 percent in 2020, which will increase to about 2.4 percent in 2050.

Before concluding this discussion on the findings of the studies undertaken on the effects of the US or EU carbon price policy, it should be pointed out that these studies present estimates of effects mainly for those economies, and do not provide information, or provide very little information on how India is going to be impacted. Even though some studies give an estimate of effect on Indian GDP, the sectoral break up of the effect is not provided. Also, the focus is often on GDP, welfare, carbon leakage, etc whereas from India's point of view, it is more important to get detailed information on how imports of US, EU etc from developing countries are going to be affected.

<u>Limitations of the CGE models</u>

Since most of the research on the impact of carbon pricing policies is based on a CGE model commonly using the GTAP database, it is important to call attention to certain limitations of such an analysis.

- First, the models rarely incorporate the carbon tax induced technological advance. There are exceptions such as Jorgenson et al. (2007). Thus, in most models, the focus is on the resource reallocation impact of the carbon pricing policies including the rebates and border tax adjustment. This must be contrasted with another body of literature that holds or tries to verify the belief that environmental regulations do not lead to any major loss of competitiveness (the Porter hypothesis; see Porter and van der Linde, 1995). There is empirical literature to suggest that the hypothesis of Porter is valid and firms do improve their productivity level on being subjected to stringent environmental regulations. The implication is that by disregarding the carbon tax induced technological advance, the CGE models tend to overstate the loss in competitiveness suffered by industrial firms in developed countries due to emission cuts and carbon tax.
- Secondly, the GTAP data based CGE models use the same set of elasticities of substitution for all countries. One may ask: will it be right to assume that the extent of substitution possibilities captured by the elasticity of substitution between imported goods obtained from two developed countries are the same as the extent of substitution possibilities between an imported good from a developing country and that from a developed country? It is not unreasonable to argue that the level of technology and hence the quality of product will differ between developed and developing countries, and hence the assumption of uniform elasticity of substitution across all country sources of imports is unrealistic. It appears that the GTAP database over-states the elasticity of substitution between imports obtained from a developed and a developing country.
- Third, the CGE models are like 'black boxes' and the reason why a particular type of result has been obtained is sometimes difficult to ascertain. At times, the results obtained may be counter-intuitive or hard to accept. This is illustrated by the findings of a CGE based study done on the carbon pricing policy in Japan (Yano et al., 2011). In one scenario, energy efficiency improvements in China and India according to the proposals made by these countries regarding reduction in CO_2 intensity have been taken into account. Interestingly, the model results indicate that energy efficiency improvements in China and India will cause an increase in the Global CO_2 emissions because of lowering of energy prices. Many may find this finding of the CGE analysis hard to accept since energy efficiency improvements are aimed at reducing global CO_2 emissions.[7] This brings out that the results of the CGE model depends crucially on the structure of the model and assumptions made about (values assigned to) the parameters.

---

[7] At the same time, it needs to be recognized that an attempt to reduce CO_2 emissions by a set of countries may not fully succeed because increases in emissions by others following the fall in global energy prices may substantially neutralize the effect. Dong and Whalley (2009b) consider the impact of a uniform carbon tax used by all non-OPEC countries. If the tax rate is set at 20 percent, the emissions in non-OPEC countries fall about 11 percent. But, emissions in OPEC countries increase by109 percent. Thus, at the global level, emissions fall by only three percent.

9

- Two other weaknesses of CGE models may be highlighted, which have been noted by Wing (2004) in the context of CGE models dealing with carbon pricing. First, there is often an assumption of inelastic supply of labour and full employment. The implication is that the fall in labour demand in fossil fuel and energy using sectors does not get translated into unemployment. Rather, the labour market adjusts by lowering wages so that the surplus labour gets re-absorbed elsewhere. This may not be realistic because of impediments on labour mobility. Secondly, there is need for taking into account the "putty-clay" nature of capital,[8] which is missing at least in some of the models if not in many of them.

Findings of a Paper by Mattoo and Associates

The findings of a paper by Mattoo and associates (2009) require a more detailed discussion in the Report, since this study unlike most others has found that the climate policies of industrialized countries will have a significant adverse effect on developing countries. Mattoo and associates report that if industrialized countries impose carbon tax with a view to cut down CO_2 emissions by about 20 percent and adopt border adjustment measures to take care of the concerns of competitiveness and carbon leakage using the emission intensity of the exporting countries, there will be an additional tariff on exports of manufactures from China and India at the rate of about 26 and 20 percent respectively (for energy intensive manufacturing, the additional tariff will be 43 percent for China and 29 percent for India), which will in turn lead to a fall in exports of manufactures from these countries by about 20 percent (21 percent for China and 16 percent for India). [9] For low and middle income countries, the corresponding figure is 15 percent. If domestic carbon content in industrialized countries is taken as the basis for imposing carbon tax on imports, the adverse effect on developing countries will be much smaller. The fall in manufactured exports will be 3.4 percent for China and 3.2 percent for India and for low and middle income countries. These findings may be contrasted with the findings of some other studies. The study undertaken by Takeda et al. (2011) for the Japanese economy indicates that carbon price policy coupled with border tax adjustment on the basis of emission intensity of the exporting countries will lead to a fall in Japanese imports of energy intensity trade exposed products by about 3.5 percent. In case, the Japanese emission levels are used, the fall in imports will be only one percent. In the scenario, when such policies are adopted by the US, EU and Japan, the fall in imports are by 4.4 percent when BTA is based on exporting country intensity, and 1.9 percent when based on Japanese intensity.

The high estimates of the adverse effect on developing countries in the paper by Mattoo and associates seem to be attributable in part to their assessed price of carbon. In the study by Ho et al. (2008) for the US, the carbon price was taken as US$ 10 per ton of CO_2. In the study by Adkins et al. (2010, 2011) for the US, the carbon price has been taken as US$ 15 per ton of CO_2.

---

[8] The "putty-clay" nature of capital means the possibilities of inter-sectoral shift of capital or of changing the proportion between capital and other inputs (say labor) gets severely restricted once the investment has been done. Thus, there is flexibility ex-ante, but not ex-post.

[9] The US imports of energy intensive manufactured products fall by about 10 percent, while that of EU falls by about 39 percent. It seems that it is the fall in manufactured products imports of the EU that mainly drives the fall in exports of manufactured products of China and India.

Fischer and Fox (2009b) have used a CGE model to simulate the effects of a US$50/ton C (about $14 per ton of CO_2) emission price implemented unilaterally in the US. The study undertaken by McKibbin and Wilcoxen (2008) take the carbon price as US$ 20 and US$ 40 per ton (less than $15 per ton of CO_2). Some studies have used a somewhat higher figure. But, overall, the price range used for carbon in various studies undertaken is US$ 10 to US$ 50 per ton of CO_2. The study by Mattoo and associates is very different, since they assess that the price of carbon per ton will be about US$ 300 in EU, US$ 250 in the US (i.e. about US$ 70 per ton of CO_2), US$ 240 in Japan and about US$220 in other Annex I countries. This is clearly quite high, and the use of such high price of carbon influences the estimated effects on developing countries. In support of this point that a carbon price of US$ 70 per ton of CO_2 is high, it may be added that recently Australia has imposed carbon tax on its local firms. According to a media report, the rate of tax has been specified as Australian dollar 23 per ton of carbon. This comes to about 24 US dollar per ton of carbon (about US$ 7 per ton of CO_2). Further, according to some media report, citing International Emissions Trading Association, about 3.6 billion tons of carbon dioxide equivalent was trade globally in the first half of 2011 valued at about US$ 71 billion. The price of carbon dioxide comes to about 20 US dollars per ton CO_2.

Another factor that influences the results of the Mattoo et al. (2009) study is that they based the tax on imports from developing countries on the level of carbon embodied in imports. In the study of Dong and Whalley (2009a), the increase in US imports of high emission goods is 1.6 percent if the carbon price is set at US$ 200 per ton C (comparable to the price used by Mattoo and associates) and there is no BTA. The use of BTA against China and EU caused the US imports of high emission goods to fall by 2.5 percent. Dong and Whalley (2009a) observe that their estimates of the effect of carbon pricing coupled with BTA is much smaller than that of Mattoo and associates (2009) because while they base the tax on imports on domestic emission intensity, Mattoo and associates use the emission intensity of the exporting country. Thus, whether the domestic emission intensity or the exporting country emission intensity is used for the BTA makes a lot of difference. But, one can raise the question whether the latter option is compatible with WTO rules. Also, how big is the difference between the domestic emission intensity and the exporting country emission intensity matters a lot. This aspect receives attention in Section 5 of this Report.

3. Impact on a Developing Country

How would the carbon price policy of a developed country, say the US, impact a developing country in terms of its exports and production. This is analyzed in this section using a theoretical framework which is an extended version of the theoretical framework employed by Fischer and Fox (2009a). Instead of considering the entire economy, a particular sector is considered. A two-good, two-country partial equilibrium model is used since the impacts and adjustments can more clearly be seen in such a model.

Consider two countries, Home and Foreign. The home country is a developed one and the foreign country is a developing one. Home produces good H at a per-unit cost $c_H(r_H)$ that rises with reductions r_H from the baseline emission rate e^0_H. For notational simplicity, c^0_H denotes

$c_H(0)$, i.e., when reductions from baseline are zero. Foreign country produces good F at a per-unit cost c_F which is assumed to be fixed. Producers are assumed to be perfectly competitive.

Each country has a representative consumer who demands some of each good. Let home and foreign consumption of good H be h and x(exports), and let home and foreign consumption of good F be m(imports) and f. Consumer demand for each good is a simple function of the prices of both competing good in the country of consumption. Let the prices be denoted by p_H, p_X, p_M and p_F. The price of home good exported is denoted by p_X, and the price of foreign good imported is denoted by p_M. The prices p_H, p_X, p_M and p_F are equal to the (constant) marginal costs of production inclusive of any taxes or rebates.

Assuming constant elasticity demand functions, the components of demand in the two countries can be expressed as:

$$h = \alpha_h p_H^{\beta_{hH}} p_M^{\beta_{hM}} \quad \dots(1)$$

$$m = \alpha_m p_H^{\beta_{mH}} p_M^{\beta_{mM}} \quad \dots(2)$$

$$x = \alpha_x p_X^{\beta_{xX}} p_F^{\beta_{xF}} \quad \dots(3)$$

$$f = \alpha_f p_X^{\beta_{fX}} p_F^{\beta_{fF}} \quad \dots(4)$$

The market equilibrium conditions are

$$H= h(p_H, p_M) + x(p_X, p_F) \quad \dots(5)$$
$$F= f(p_X, p_F) + m(p_H, p_M) \quad \dots(6)$$

From the above equations, and applying differentiation, the change in foreign country production (i.e. the production in the developing country) can be derived as:

$$dF = f \left[\beta_{fX} \frac{dp_X}{p_X} + \beta_{fF} \frac{dp_F}{p_F} \right] + m \left[\beta_{mH} \frac{dp_H}{p_H} + \beta_{mM} \frac{dp_M}{p_M} \right] \quad \dots(7)$$

Consider now an emission price of t per unit of emission imposed in the home country and no adjustment mechanism. The price of the home good and the exported good (of the developed country sold to the developing country) may then be derived as: $p_H = p_X = c_H(r_H) + \text{t}(e^0_H - r_H)$. The price of the foreign good and the imported good (produced in the developing country) is given by $p_F = p_M = c_F$. Taking into account this above mentioned change in the home good and the export good, and simplifying equation (7), the change in the production of foreign good F that results from the changes in prices may be written as:

$$dF = \frac{c_H - c_H^0 + te_H}{c_H^0}\left(\beta_{fX}f + \beta_{mH}m\right) \ ...(8)$$

where $e_H = e^0{}_H - r_H$.   And defining, γ as:

$$\gamma = \frac{c_H - c_H^0 + te_H}{c_H^0},$$

the following equation is obtained:

$$dF = \gamma\left(\beta_{fX}f + \beta_{mH}m\right) = \gamma(\beta_{fX}f) + \gamma(\beta_{mH}m) \ ...(9)$$

In the above equation, γ represents the increase that takes place in the price of home good because of the costs associated with the reduction in emission level and the carbon tax paid on the reduced level of emission. The term $\gamma(\beta_{fX}f)$ shows the additional local sales of the domestic industry in the foreign (developing) country because the exports from the developed country have become costlier due to emission control and carbon tax. This is positive. The term $\gamma(\beta_{mH}m)$ reflects loss of competitiveness of the home country producers. Since the price of the home good becomes costlier, imports from the developing country increases replacing the domestically produced good in the home country. This is also positive. Evidently, with the imposition of carbon tax in the developed country, and in the absence of any border adjustment, the developing country gains. If (1) the rate of carbon tax is high, (2) the control of emission is more costly, and (3) the price elasticity of demand is high, the gains to the developing country will be greater.

Consider next border adjustment for imports in order to level the playing field between the home good and the imported good. It is assumed now that there is a carbon tax on imports of foreign good into the home market. It is assumed further that the tax will be applied on the basis of a policy-defined emission intensity, $\hat{e}_F$. Accordingly, the price of imported good is p_M goes up; it becomes equal to $c_F + t\hat{e}_F$. The price of the foreign good sold in the foreign country's domestic market remains at the earlier level, i.e. $p_F = c_F$. There are several possibilities about $\hat{e}_F$. One possibility, the base case, is to take it as equal to the emission intensity of the foreign good, i.e. $\hat{e}_F = e_F$. Thus, the tax is based on emission embodied in the imported good. However, many of the proposed border adjustment policies that are thought to be WTO compliant involve a smaller border tax. Thus, one proposal is to base it on home country emission intensity (expected to be less than the embodied emission in imports of the good from a developing county), i.e. $\hat{e}_F = e_H$. Another proposal is to impose the tax on embodied emission above some baseline denoted by $e_F{}^*$, i.e. $\hat{e}_F = e_F - e_F{}^*$.

In the base case when the domestic industry is subject to carbon tax and the tax is imposed on emission embodied in the imported good, the change in production of foreign good, F, may be derived as:

$$dF = \frac{c_H - c_H^0 + te_H}{c_H^0}\left(\beta_{fX}f + \beta_{mH}m\right) + \frac{t\widehat{e_F}}{c_F^0}\left(\beta_{mM}m\right) \quad …(10)$$

The above expression may or may not be positive. Thus, carbon price policy in the home (developed) country will be beneficial to the foreign (developing) country for specific range of values of the parameters. If (1) β_{mH} is more or less equal to β_{mM} (i.e. the price elasticity of demand for imports with respect to price of the imported good is almost equal in absolute value to the price elasticity of demand for imports with respect to the price of domestic substitute) and (2) the carbon tax on imports does not exceed that on domestic production, then the carbon price policy of the developed country will be beneficial to the foreign country even when a tax is imposed on imports to level the playing field. Even if the above condition is not satisfied, the foreign country may still gain if there is a significant fall in exports from the home country to the foreign country because of the cost disadvantage created by carbon tax which permits larger sales of local firms in the foreign country to the local market. Evidently, a crucial factor is whether carbon tax on imports from the developing country will be based on emission embodied in imports or emission intensity of home (developed country) production. In the latter case, there is a greater probability that the foreign (developing) country will gain from the carbon policies of the home (developed) country.

The next policy measure to be considered is an export rebate. Since the domestic industry is put to a disadvantage by the carbon tax, a border rebate for exports may be provided to level the playing field abroad. Thus, there will be full emission pricing at home, but for exports, the value of emission in exports will be given a rebate. With this change, and maintaining carbon tax on imports, equation (10) gets transformed to:

$$dF = \frac{c_H - c_H^0}{c_H^0}\left(\beta_{fX}f\right) + \frac{c_H - c_H^0 + te_H}{c_H^0}\left(\beta_{mH}m\right) + \frac{t\widehat{e_F}}{c_F^0}\left(\beta_{mM}m\right) \quad …(11)$$

The above expression is lower in value than the expression in equation (10). The implication is that the gain to the developing country will be less, or the loss to the developing country will be greater, when the developed country producers subject to carbon tax get full rebate on exports. It should be pointed out that even after allowing for export rebate, the expression in equation (11) will be positive for certain parameter values. If the condition mentioned above regarding the price elasticities and carbon tax rates on domestic and imported goods hold true, the expression in equation (11) would be positive, i.e. the developing country will gain. Again, a crucial factor is whether the carbon tax on imports is based on emission embodied in imports or on the emission intensity of domestic production in developed countries.

An interesting extension of the above model is to allow for a third country. Let that be a developed country, which is hereafter referred to as country-X. Thus, imports of the home country are partly sourced from country-X and the remaining portion from the developing country. The effect of the carbon price policy of the home country now depends on the policy adopted by country-X. It is needless to say that the gains to the developing country from the carbon price policy of the home country will be relatively greater if country-X itself adopts as stringent a carbon price policy as done by the home country, than otherwise.

4. Empirical Analysis – Effect of US Carbon Price Policy on India and other Developing Countries

This section presents estimates of the impact of US carbon price polices on India, China and other developing countries. Section 4.1 outlines the methodology adopted. Section 4.2 describes the scenarios considered. Section 4.3 presents estimates of loss of exports of developing countries to the US market, and the consequent impact on manufacturing value added and employment in the developing countries. Section 4.4 carries the analysis further for India. It goes into the indirect effects on various sectors of the economy and thus estimates the total direct and indirect effect on employment and output.

4.1 Methodology

Unlike the studies that use CGE, the analysis presented here is based on a partial equilibrium approach. This has the advantage that the magnitude of impacts and their causes can more easily be understood.

For the purpose of the analysis, US manufacturing is divided into 29 industries. This follows the classification or industry grouping used by Adkins et al. (2010) since some basic data as well as the estimates of impacts of certain components of the carbon price policy are taken from that study. For the same reason, the analysis undertaken here is based on the data for 2006, which is the year for which Adkins et al. (2010) have undertaken their analysis.

For each industry, the demand structure is assumed to be nested, as commonly done in CGE studies. At the upper level, the demand for a commodity gets distributed between domestically sourced and imported. At the lower level, the demand for imports gets distributed between two groups of countries, those who are subject to carbon tax when their products are imported into US and those who are not subject to such tax.[10]

Let XA denote aggregate demand for the product of an industry in the US. Let XD and XM be respectively the domestic and imported components of the demand. The substitution elasticity at this level is given by σ^m. The demand functions may accordingly be specified as:

$$XD = \alpha^D \left(\frac{PA}{PD} \right)^{\sigma^m} XA \quad \ldots(12)$$

$$XMT = \alpha^M \left(\frac{PA}{PMT} \right)^{\sigma^m} XA \quad \ldots(13)$$

$$PA = \left[\alpha^D PD^{1-\sigma^m} + \alpha^M PMT^{1-\sigma^m} \right]^{1/(1-\sigma^m)} \quad \ldots(14)$$

---

[10] The demand structure assumed for the study follows Mensbrugghe (2009) who has used such a structure for studying the impact of agricultural trade reforms.

In these equations, PA is the aggregate price of the product, which is taken as a non-linear aggregation of two component prices: the price of domestically sourced product (PD) and the price of imported product (PMT).

In the second nest, aggregate imports, XMT, are broken up by two groups of countries: one group comprising of countries that are subject to carbon tax when their manufactured products are imported into US (hereafter, country group subject to carbon tax or country group m) and the other comprising of countries that are not subject to any such tax (hereafter, country group p). For these two country groups, subscripts m and p are used.[11] The demand functions for imports from regions m and p may be specified as:

$$XM_m = \alpha^m \left(\frac{PMT}{PM_m} \right)^{\sigma^w} XMT \quad \dots(15)$$

$$XM_p = \alpha^p \left(\frac{PMT}{PM_p} \right)^{\sigma^w} XMT \quad \dots(16)$$

$$PMT = \left[\alpha^p PM_p^{1-\sigma^w} + \alpha^m PM_m^{1-\sigma^w} \right]^{1/(1-\sigma^w)} \quad \dots(17)$$

In the above equations, the substitution elasticity between imports from the two groups of countries is denoted by σ^w. The prices of imports from the two groups of countries are given by PM_p and PM_m. Without loss of generality, it may be assumed that PM_p includes cost, insurance and freight, while PM_m is the CIF value plus carbon tax at the rate τ. It may be noted that the aggregate price of imports, PMT, is a non-linear combination of the prices of imports from the two regions.

For the country group m, the price elasticity of demand with respect to their tax inclusive price may be derived as:[12]

$$\varepsilon_{m,m} = -\sigma^w + s_m[\sigma^w - \sigma^m s_D] \quad \dots(18)$$

where
σ^m = elasticity of substitution between aggregate imports of a product and domestic supply of the product;
σ^w = elasticity of substitution between imports of a product from country group p verses country group m;
s_D = share of absorption met from domestic supply of the product; and
s_m = share of imports from country group m in aggregate imports of the product.

---

[11] In one scenario, China and India are included in group m, and the rest of the countries in group p. In another scenario, China, India and 12 other selected developing countries are included in group m, and the rest of the countries in group p.
[12] For derivation, see Mensbrugghe (2009).

For the country group p, i.e. the countries not subject to carbon tax, their exports to the US goes up when the other group is subjected to carbon tax (due to substitution among alternate sources of imports). The relevant elasticity is shown below:

$$\varepsilon_{p,m} = s_m[\sigma^w - \sigma^m \, s_D] \quad \ldots(19)$$

The elasticities of substitution σ^m and σ^w have been taken from GTAP database (see Annex-A). The estimates available for various manufacturing industries have been mapped into the 29 industries considered in this study. The share of absorption met from domestic supply of the product, s_D has been computed from data on domestic consumption and import reported in Adkins et al. (2010). The parameter, s_m, which is the share of imports from country group m in aggregate imports of the product, has been computed from country-wise detailed data on US imports for the year 2006. Data on US import at 4-digit level disaggregated by source country have been used to work out import data for the 29 industries under study with source country-wise disaggregation.

Fourteen countries/ regions have been considered for the analysis. These are China, India, 12 other selected developing countries (Brazil, Chile, Columbia, Indonesia, Malaysia, Mexico, Nigeria, Philippines, Thailand, South Africa, Venezuela, and Vietnam), OECD countries (except US) and the rest of the world. The 12 developing countries chosen for the study, other than China and India, have been selected on the criteria of GDP and emission level. China, India and the other 12 developing countries chosen for the study together account for a dominant portion of GDP of the developing world. The same applies to their share in the aggregate CO_2 emissions of the developing world.

It may be explained here that the impact of BTA is estimated in two steps. In the first step, the estimates of the medium-run effect on production, use and imports made by Adkins et al. (2010) (using a CGE model) for a tax rate of US\$ 15 per ton of CO_2 are applied to the actual data on production, use and imports in 2006, and then in the next step, the effect of BTA is superimposed using the elasticities described in equations (18) and (19).

4.2 Scenarios

Seven scenarios are considered for the analysis, which are described in Table 4.1. In three scenarios, it is assumed that the border tax adjustment will be done only for imports from China and India, and the carbon tax will not be imposed on imports on other countries including the OECD countries and the other developing countries. In the other four scenarios, it is assumed that besides China and India, the other 12 developing countries selected for the study will be subject to carbon tax on exports made to the US. In all the seven cases, it is assumed that the US adopts carbon price policy according to the American Clean Energy and Securities Act, 2009, with the output-based allowance allocations incorporated into the estimates. The effect that the carbon price policy with output based allowance will have different sectors of the economy has been estimated by Adkins et al. (2010) taking the carbon price of US\$ 15 per ton of CO_2. The

sector-wise production, use, exports and imports data are first altered taking into account the estimates of effect of carbon pricing in Adkins et al. (2010) and then the BTA is applied.

While the first two scenarios assume a carbon price of US$ 15 per ton of CO_2 as done by Adkins et al. (2010), in the other five scenarios, a much higher price of US$ 50 per ton of CO_2 has been assumed. The first four scenarios assume that the carbon tax will be based on the emission intensity in the US (industry-wise emission intensities have been taken from the study of Adkins et al. (2010)). The last three scenarios allow for the possibility that the tax may be based on emission embodied in imports. Thus, the emission intensity of the exporting country has been taken into account. The analysis presented in Section 5 below indicates that the emission intensity of China and India (at market exchange rate) far exceeds that of the US. The average of the estimated emission intensity (for 2006) for a number of developing countries including China and India is found to be about three times that of the US. Accordingly, the applicable carbon tax on imports from China, India and other 12 selected developing countries has been taken to be three times the tax that would have been applied if the US emission intensities were used. This is broadly in line with the paper by Mattoo et al. (2009).

Table 4.1: Scenarios Considered in the Study

Scenario	Countries covered by BTA	Carbon price assumed, US$ per ton of CO_2	Basis of carbon tax on imports
A	China and India	15	US emission intensity
B	China, India and other 12 selected developing countries	15	US emission intensity
C	China and India	50	US emission intensity
D	China, India and other 12 selected developing countries	50	US emission intensity
E	China and India	50	Exporting country emission intensity (developing country average: taken as three times the US intensity)
F	China, India and other 12 selected developing countries	50	Exporting country emission intensity (developing country average: taken as three times the US intensity)
G	China, India and other 12 selected developing countries	50	Exporting country emission intensity based on PPP (Assumption: Chinese emission intensity is 1.7 times the US intensity. For India, the figure is 1.5. For the group of the other 12 developing countries selected for the study, the figure is again taken as 1.5 on average).

The analysis in Section 5 later in the Report brings out that the gap between the US emission intensity of manufacturing and the average emission intensity of manufacturing of developing countries is relatively less when the comparison is made on the basis of PPP exchange rate. In the seventh scenario, therefore, this aspect has been incorporated. Also, a difference has been made between China and other developing countries. For China, a higher tax rate has been assumed.

It will be noticed from Table 4.1 that for several scenarios a carbon price of US$ 50 per ton of CO_2 has been assumed. This is much higher that used by Adkins et al. (2010) and Fischer and Fox (2009a, 2009b). But, it is not unreasonable. Under the Stark-McDormott proposal, the carbon price will start from US$ 10 per ton of CO_2 and then rise over time to about   US$ 70 per ton of CO_2 by 2050 (see Metcalfe et al., 2008). Elliott et al. (2010) in their model consider the carbon prices range from $15 to $175 per ton C ($4 to $48 per ton CO_2). In the model used by Wing (2004), the carbon price range considered is US$ 50 to US$ 200 per ton C. The price range considered in the study of Dong and Whalley (2009a) is from US$ 50 to US$ 200 per ton C. In both cases, the upper point of the range is about US$ 55 per ton of CO2. Tekeda et al. (2011) in their study of carbon pricing policy of Japan take the carbon price in the range of 90 to 100 US$ per ton of CO_2. Thus, the figure of US$ 50 per ton of CO_2 used in scenarios C through G is not unreasonable.

4.3 Estimates of Impact on India and other Developing Countries

The estimates of change in US imports of manufactured products from China, India and 12 over selected developing countries consequent upon the imposition of carbon tax on imports from such countries are presented in Tables 4.2 through 4.8. These correspond to the seven scenarios considered in the study. If the carbon tax rate is US$ 15 per ton of CO_2 or thereabout, which is the assumption made in several earlier studies on the impact of US climate policy, the effect on imports from developing countries is small. India's exports of manufactures to the US go down by about 2 percent. For the products of energy intensive trade exposed industries such as basic metals and chemicals, the impact is relatively greater. India's exports to the US go down by about 5 percent. The impact on China is slightly lower in relative magnitude when comparison is made with the existing level of exports made by China to the US. But, the absolute value of cut in Chinese exports to the US is much larger than that for India. The adverse effect on India and China are slightly lower when the other 12 selected developing countries are also subjected to the carbon tax than when they are not.

The adverse effect on India and other developing countries goes up substantially when the carbon price is set at US$ 50 per ton of CO_2 rather than US$ 15 per ton (as in scenarios A and B). Estimates presented in Tables 4.4 and 4.5 indicate that the imposition of carbon tax on imports based on a carbon price of US$ 50 per ton of CO_2 will reduce India's exports of manufactures to the US by about 6 to 7 percent. The exports of energy intensive manufactured products will go down by about 15 to 16 percent. A more or less similar effect will be there on China and the other 12 developing countries selected for the study.

The adverse effect on India and other developing countries gets accentuated if the carbon tax imposed by the US is based on the carbon embodied in the imports rather than basing it on domestic producers' carbon intensity. In this case, as Table 4.7 shows, the exports of manufactures fall by about 12 to 16 percent, while the exports of energy intensive manufactured products will fall by about 33 to 38 percent. The market lost by China, India and the 12 other selected developing countries will taken up by other countries. In particular, it may be noted that the OECD countries as a group will increase their exports to the US. Their exports of manufactures go up by 5 percent and that of energy intensive manufactured products go up by about 8 percent. The increase in exports from OECD countries is about half of the loss of exports suffered by China, India and the 12 selected developing countries. This implication is that the imposition of a high rate of carbon tax on imports from developing countries significantly benefits the US domestic manufacturing industry.

The estimates for scenario G is presented in Table 4.8. Here, the issue of using emission intensity using PPP exchange rate rather than market exchange rate is brought in. Ideally, sector-wise PPP should be used. Due to lack to data, the overall PPP has been used to estimate the emission intensity of manufacturing, and the average across a select set of developing countries has been taken as the basis for making the estimates. For China, the emission intensity (at PPP) is taken to be 1.7 times that of the US. For India, the relevant ratio is 1.5. The ratio could not be computed for each of the other 12 selected developing countries. For seven of them, the emission intensity has been computed. The average for the seven countries is not very different from that for India. Hence, for the groups of 12 selected developing countries, the average emission intensity (at PPP) has been taken as 1.5 times that of the US.

Comparing Tables 4.7 and 4.8, it is found that switching to PPP based emission intensities from market exchange rate based emission intensities will provide substantial benefit to the manufacturing industries of developing countries subject to US carbon tax with the rate of tax being determined on the basis of carbon embodied in imports. The fall in imports of manufactured products from the developing countries considered for the study (consequent upon the imposition of carbon tax) becomes lower: it comes down from about 12 to 16 percent to about 6 to 8 percent. In the case of India, the fall in India's exports of manufactured products to the US is about 15 percent when market exchange rate based emission intensity is used for ascertaining the rate of carbon tax, which gets lower to about 8 percent when PPP exchange rate based emission intensity is used.

Mattoo et al. (2009) estimate that the US imports of energy intensive manufactured products will fall by about 10 percent if industrialized countries impose carbon tax with a view to cut down CO_2 emissions by about 20 percent and adopt border adjustment measures in accordance with emission embodied in imports. The estimates obtained in this study are not comparable with those of Mattoo and associates because the estimates of this study reflect the outcome of unilateral action while Mattoo and associated consider multilateral action. Also, the estimates of this study are based on partial equilibrium framework, while the estimates of Mattoo and associates take into account the general equilibrium effects. Yet, it is worth noting that according to the estimates obtained in this study, US carbon pricing policy along with carbon tax on imports on the basis of carbon embodied in imports would make the US imports of energy intensive products from developing countries to go down by about 30 to 35 percent. Prima facie

it would appear that the estimates of effect of US carbon pricing policy on energy intensive manufactured import imports from developing countries obtained in this study are bigger than those obtained by Mattoo and associates. This is actually not true. The share of China, India and the other 12 selected developing countries in the US imports of energy intensive products is about 25 percent. Thus, if imports from other countries do not change, imports from these 14 developing countries will have to fall by about 40 percent if the aggregate US imports of energy intensive manufactured products have to fall by 10 percent. In effect, therefore, the results of Mattoo and associates indicate a larger fall in developing country manufactured exports to the US than what the results of this study do.

It may be mentioned in passing that Matoo et al. (2009) assess that due to the carbon pricing policy in industrialized countries coupled with BTA there will be an additional tariff of about 30 percent on imports of energy intensive manufactured products from India, and the corresponding figure will be about 40 percent for China. By comparison, the additional tariff in computed for this study for exports to the US market is less.

Table 4.2: Change in US Imports of Manufactured Products, by Source Country and Product Group, Scenario -A (US $ million)

Industry group	China	India	12 other selected developing countries	OECD	Rest of the world	All
Food products, textiles, leather products and apparel	-538.5	-137.6	124.3	153.9	182.5	-215.5
Wood, furniture, pulp, paper and printing	-870.7	-14.5	114.7	354.4	24.8	-391.3
Refinery products and petrochemical manufacturing	-8.7	-3.4	0.5	1.8	1.0	-8.7
Plastics, synthetic fiber etc	-133.4	-14.6	16.6	57.7	7.7	-66.0
Chemicals and products	-507.9	-82.5	31.4	304.6	43.7	-210.6
Cement and other non-metallic mineral products	-206.2	-9.8	32.4	68.9	18.5	-96.1
Basic Metals	-832.0	-162.5	124.5	383.8	132.6	-353.7
Fabricated Metals	-184.9	-8.2	43.2	42.2	12.1	-95.6
Machinery and transport equipment	-1128.3	-26.4	275.1	470.9	91.5	-317.2
Miscellaneous Manufacturing	-122.6	-10.7	15.3	57.2	10.9	-49.9
All industries	-4533.2	-470.2	778.0	1895.4	525.3	-1804.7
Energy intensive trade exposed industries	-2068.2	-279.4	231.6	1011.7	210.7	-893.6
All industries, change in imports as % of actual	-1.5	-2.1	0.2	0.2	0.3	-0.1
EITE, change in imports as % of actual	-5.0	-5.5	0.3	0.4	0.3	-0.2

Table 4.3: Change in US Imports of Manufactured Products, by Source Country and Product Group, Scenario –B (US $ million)

Industry group	China	India	12 other selected developing countries	OECD	Rest of the world	All
Food products, textiles, leather products and apparel	-438.3	-115.7	-500.8	318.8	301.9	-434.1
Wood, furniture, pulp, paper and printing	-761.5	-12.7	-502.8	591.3	39.8	-645.9
Refinery products and petrochemical manufacturing	-7.2	-3.1	-1018.4	29.1	16.7	-982.9
Plastics, synthetic fiber etc	-119.3	-13.0	-108.5	103.7	14.2	-122.9
Chemicals and products	-481.5	-78.6	-457.4	550.0	83.9	-383.7
Cement and other non-metallic mineral products	-179.7	-8.4	-182.0	136.3	35.0	-199.0
Basic Metals	-743.2	-142.3	-1339.3	994.0	346.6	-884.1
Fabricated Metals	-144.0	-6.4	-166.1	88.7	25.4	-202.3
Machinery and transport equipment	-861.2	-20.4	-1214.1	1207.6	180.7	-707.3
Miscellaneous Manufacturing	-108.6	-9.5	-36.4	74.8	14.3	-65.4
All industries	-3844.5	-410.1	-5525.8	4094.2	1058.5	-4627.7
Energy intensive trade exposed industries	-1886.8	-251.6	-3384.7	2158.0	509.0	-2856.1
All industries, change in imports as % of actual	-1.2	-1.9	-1.5	0.5	0.5	-0.3
EITE, change in imports as % of actual	-4.6	-5.0	-4.9	0.8	0.8	-0.6

Table 4.4: Change in US Imports of Manufactured Products, by Source Country and Product Group, Scenario -C (US $ million)

Industry group	China	India	12 other selected developing countries	OECD	Rest of the world	All
Food products, textiles, leather products and apparel	-1740.0	-442.0	414.2	512.8	608.2	-646.8
Wood, furniture, pulp, paper and printing	-2750.1	-45.7	382.3	1181.5	82.6	-1149.5
Refinery products and petrochemical manufacturing	-26.9	-10.1	1.8	6.0	3.5	-25.7
Plastics, synthetic fiber etc	-415.9	-45.5	55.5	192.3	25.7	-187.9
Chemicals and products	-1609.3	-259.4	104.7	1015.5	145.8	-602.7
Cement and other non-metallic mineral products	-573.0	-31.1	108.1	229.7	61.7	-204.6
Basic Metals	-2396.6	-462.5	414.9	1279.3	442.0	-723.0
Fabricated Metals	-605.2	-26.8	144.1	140.6	40.3	-307.1
Machinery and transport equipment	-3723.1	-87.1	916.9	1569.8	304.9	-1018.6
Miscellaneous Manufacturing	-406.5	-35.5	51.0	190.7	36.4	-164.0
All industries	-14246.5	-1445.8	2593.4	6318.1	1750.9	-5029.9
Energy intensive trade exposed industries	-6185.7	-828.9	771.9	3372.4	702.3	-2168.0
All industries, change in imports as % of actual	-4.6	-6.6	0.7	0.7	0.9	-0.3
EITE, change in imports as % of actual	-15.0	-16.4	1.1	1.2	1.1	-0.5

Table 4.5: Change in US Imports of Manufactured Products, by Source Country and Product Group, Scenario –D (US $ million)

Industry group	China	India	12 other selected developing countries	OECD	Rest of the world	All
Food products, textiles, leather products and apparel	-1418.4	-372.4	-1633.2	1062.5	1006.2	-1355.3
Wood, furniture, pulp, paper and printing	-2412.0	-40.2	-1585.3	1970.8	132.8	-1933.9
Refinery products and petrochemical manufacturing	-22.5	-9.3	-3198.6	97.0	55.8	-3077.5
Plastics, synthetic fiber etc	-374.4	-40.5	-339.1	345.6	47.2	-361.3
Chemicals and products	-1528.0	-247.7	-1446.2	1833.3	279.6	-1109.0
Cement and other non-metallic mineral products	-507.6	-26.9	-540.7	454.2	116.5	-504.5
Basic Metals	-2173.9	-412.7	-3818.1	3313.2	1155.4	-1936.0
Fabricated Metals	-473.1	-21.0	-545.5	295.8	84.7	-659.0
Machinery and transport equipment	-2846.9	-67.4	-4009.3	4025.3	602.4	-2296.0
Miscellaneous Manufacturing	-360.2	-31.5	-120.8	249.5	47.6	-215.5
All industries	-12117.0	-1269.7	-17236.8	13647.2	3528.3	-13448.0
Energy intensive trade exposed industries	-5701.9	-756.3	-10201.5	7193.5	1696.6	-7769.8
All industries, change in imports as % of actual	-3.9	-5.8	-4.8	1.6	1.8	-0.8
EITE, change in imports as % of actual	-13.8	-14.9	-14.6	2.6	2.6	-1.7

Table 4.6: Change in US Imports of Manufactured Products, by Source Country and Product Group, Scenario -E (US $ million)

Industry group	China	India	12 other selected developing countries	OECD	Rest of the world	All
Food products, textiles, leather products and apparel	-4804.0	-1200.1	1242.5	1538.5	1824.7	-1398.4
Wood, furniture, pulp, paper and printing	-7169.2	-118.8	1147.0	3544.4	247.7	-2348.9
Refinery products and petrochemical manufacturing	-65.6	-22.6	5.4	18.0	10.4	-54.5
Plastics, synthetic fiber etc	-1045.0	-113.2	166.4	576.9	77.1	-337.7
Chemicals and products	-4242.4	-671.6	314.2	3046.4	437.3	-1116.1
Cement and other non-metallic mineral products	-1224.1	-82.4	324.2	689.1	185.0	-108.1
Basic Metals	-5159.8	-958.4	1244.6	3837.8	1326.0	290.1
Fabricated Metals	-1725.6	-76.5	432.4	421.7	120.8	-827.2
Machinery and transport equipment	-10853.8	-253.7	2750.7	4709.5	914.8	-2732.6
Miscellaneous Manufacturing	-1200.9	-105.0	152.9	572.0	109.1	-471.8
All industries	-37490.4	-3602.3	7780.3	18954.3	5252.8	-9105.3
Energy intensive trade exposed industries	-14538.8	-1897.2	2315.7	10117.1	2106.9	-1896.2
All industries, change in imports as % of actual	-12.0	-16.3	2.2	2.2	2.7	-0.5
EITE, change in imports as % of actual	-35.2	-37.5	3.3	3.6	3.2	-0.4

Table 4.7: Change in US Imports of Manufactured Products, by Source Country and Product Group, Scenario –F (US $ million)

Industry group	China	India	12 other selected developing countries	OECD	Rest of the world	All
Food products, textiles, leather products and apparel	-3929.5	-1016.8	-4616.0	3187.6	3018.7	-3356.0
Wood, furniture, pulp, paper and printing	-6336.1	-105.3	-4115.3	5912.5	398.4	-4245.8
Refinery products and petrochemical manufacturing	-56.2	-21.3	-8197.5	291.0	167.5	-7816.6
Plastics, synthetic fiber etc	-956.3	-102.8	-857.6	1036.7	141.6	-738.4
Chemicals and products	-4045.0	-643.5	-3805.2	5500.0	838.8	-2155.0
Cement and other non-metallic mineral products	-1107.3	-72.4	-1295.4	1362.6	349.5	-762.9
Basic Metals	-4820.5	-888.5	-7923.7	9939.7	3466.3	-226.7
Fabricated Metals	-1361.9	-60.4	-1570.2	887.3	254.2	-1851.0
Machinery and transport equipment	-8343.4	-197.1	-11715.3	12075.8	1807.1	-6372.9
Miscellaneous Manufacturing	-1065.9	-93.2	-357.3	748.4	142.8	-625.2
All industries	-32022.1	-3201.4	-44453.4	40941.5	10584.9	-28150.4
Energy intensive trade exposed industries	-13651.7	-1775.3	-24169.5	21580.5	5089.7	-12926.3
All industries, change in imports as % of actual	-10.3	-14.5	-12.3	4.7	5.4	-1.6
EITE, change in imports as % of actual	-33.0	-35.1	-34.6	7.7	7.7	-2.8

Table 4.8: Change in US Imports of Manufactured Products, by Source Country and Product Group, Scenario –G (US $ million)

Industry group	China	India	12 other selected developing countries	OECD	Rest of the world	All
Food products, textiles, leather products and apparel	-2362.1	-545.2	-2412.7	1593.8	1509.3	-2216.9
Wood, furniture, pulp, paper and printing	-3959.8	-58.2	-2289.1	2956.3	199.2	-3151.7
Refinery products and petrochemical manufacturing	-36.5	-13.0	-4604.9	145.5	83.7	-4425.1
Plastics, synthetic fiber etc	-610.5	-58.2	-486.5	518.4	70.8	-566.1
Chemicals and products	-2512.7	-357.6	-2094.3	2750.0	419.4	-1795.3
Cement and other non-metallic mineral products	-783.2	-39.3	-758.0	681.3	174.8	-724.4
Basic Metals	-3396.7	-565.1	-5171.8	4969.8	1733.2	-2430.6
Fabricated Metals	-795.9	-31.1	-809.7	443.7	127.1	-1066.0
Machinery and transport equipment	-4811.4	-100.4	-5974.2	6037.9	903.6	-3944.6
Miscellaneous Manufacturing	-610.3	-47.1	-180.5	374.2	71.4	-392.3
All industries	-19879.2	-1815.2	-24781.8	20470.8	5292.4	-20713.0
Energy intensive trade exposed	-9102.8	-1060.4	-14335.0	10790.2	2544.8	-11163.1
All industries, change in imports as % of actual	-6.4	-8.2	-6.9	2.3	2.7	-1.2
EITE, change in imports as % of actual	-22.0	-21.0	-20.6	3.9	3.9	-2.4

Impact on the domestic manufacturing sector in developing countries

While the estimates of fall in exports by China, India etc to the US market are substantial in case the carbon price is set at US$ 50 per ton of CO_2, the impact on the domestic manufacturing industry in these countries is relatively much smaller. This may be seen from Tables 4.9 and 4.10. Considering the estimates obtained for India, it may be seen that even in the worst scenario, the fall in manufacturing value added due to reduced exports to the US is only about 1.4 percent. For employment, the corresponding figure is about 1.5 percent. These estimates have been made by applying for each industry the value added to output ratio to the estimates of fall in exports to the US and similarly by applying the employment-output ratios for various industries.[13] The analysis being based on partial equilibrium overstates somewhat the reduction in value added and employment. It seems reasonable to argue that in case a carbon tax on imports of the US leads to a fall in India's exports of manufactures to the US, the Indian producers may partly mitigate this adverse effect by exporting to other destinations. Thus, the actual impact on value added and employment in Indian manufacturing is likely to be less than 1.5 percent.

Table 4.9: Estimated Value Added Loss due to Reduced Manufactured Exports to the US

Country/ Scenario	A	B	C	D	E	F	G
Change in Value Added (US$ billion)							
China	-1.4	-1.2	-4.2	-3.6	-11.0	-9.5	-5.9
India	-0.2	-0.2	-0.6	-0.5	-1.4	-1.2	-0.7
12 other selected developing countries	0.3	-2.0	0.9	-6.1	2.8	-15.5	-8.7
All	-1.3	-3.3	-3.9	-10.2	-9.6	-26.2	-15.4
Change in Value Added % Actual manufacturing value added							
China	-0.14	-0.11	-0.42	-0.36	-1.09	-0.94	-0.59
India	-0.19	-0.16	-0.57	-0.50	-1.41	-1.25	-0.71
12 other selected developing countries	0.03	-0.22	0.10	-0.68	0.31	-1.73	-0.97
All	-0.06	-0.16	-0.19	-0.51	-0.48	-1.31	-0.77

Note: For description of Scenarios, see Table 4.1

---

[13] The employment to output ratio and value added to output ratio have been computed for different industries of different developing countries from the *Yearbook of Industrial Statistics*.

Table 4.10: Estimated Employment Loss due to Reduced Manufactured Exports to the US

Country/ Scenario	A	B	C	D	E	F	G
Change in Employment (000 nos.)							
China	-92	-78	-292	-248	-785	-670	-410
India	-13	-11	-40	-34	-106	-91	-49
12 other selected developing countries	22	-77	75	-250	224	-691	-366
All	-82	-166	-257	-532	-668	-1453	-825
Change in employment % Actual manufacturing employment							
China	-0.16	-0.13	-0.50	-0.43	-1.35	-1.15	-0.70
India	-0.17	-0.14	-0.54	-0.46	-1.45	-1.24	-0.67
12 other selected developing countries	0.06	-0.19	0.18	-0.62	0.55	-1.70	-0.90
All	-0.08	-0.16	-0.24	-0.50	-0.63	-1.37	-0.78

Note: For description of Scenarios, see Table 4.1

It has been explained above that the impact of BTA has been estimated in two steps. In the first step, the estimates of the medium-run effect on production, use and imports made by Adkins et al. (2010) for a tax rate of US$ 15 per ton of CO_2 are applied to the actual data on production, use and imports in 2006, and then in the next step, the effect of BTA is superimposed using the elasticities described in Section 4.1. In several scenarios, the carbon tax rate has been taken as US$ 50 per ton of CO_2. But, the estimates of Adkins et al. (2010) are for the tax rate of $15 per ton CO_2. They do not provide estimates for a higher level of tax. To take care of this point, an alternate estimate for scenario D has been made in which the estimates of Adkins et al. (2010) of the effects on production, use and imports has been proportionately raised to reflect the effect of a tax rate of US$ 50 per ton of CO_2 and then BTA has been applied. The difference is marginal. This may be seen from Table 4.11.

Table 4.11: Effects of BTA on China, India and other selected Developing Countries: Alternate specification of Scenario D

Country/scenario	All manufacturing industries, change in US imports as % of actual	Energy intensive trade exposed manufacturing industries, change in US imports as % of actual	Change in Value Added % Actual manufacturing value added	Change in employment % Actual manufacturing employment
China				
Scenario D	-3.9	-13.8	-0.36	-0.43
Scenario D modified	-3.9	-13.9	-0.36	-0.43
India				
Scenario D	-5.8	-14.9	-0.50	-0.46
Scenario D modified	-5.8	-15.0	-0.51	-0.46
Other 12 selected developing countries				
Scenario D	-4.8	-14.6	-0.68	-0.62
Scenario D modified	-4.8	-14.6	-0.68	-0.62

Note: Modification to Scenario D is explained in text.

4.4 Indirect Effects on the Indian Economy

An attempt has been made to assess for India the indirect effect of the loss of exports to the US on the rest of the Indian economy. This analysis is based on an input-output table for 2006-07 prepared by the Central Statistical Office (CSO), Government of India. The loss in exports to the US is converted into the change in the export vector of the input-output table. The change in the export vector is then multiplied by the Leontief inverse matrix to obtain changes in the output in different sectors of the economy. The changes in output of the different sectors of the economy are multiplied by the value added to output ratio computed for different input-output sector to derive the loss in aggregate value added in the economy. In a similar manner, the aggregate loss in employment is computed. This requires estimates of employment output ratio for different sectors of the economy. This has been done using employment estimates drawn from NSS (Nation Sample Survey) data[14] and value of output of different sectors of the economy as provided in the input-output table.

The estimates of direct and indirect loss in value added and in employment are reported in Table 4.12. This is shown for different scenarios. The estimates of direct loss are taken from Tables 4.10 and 4.11 above. The estimates of total loss, direct and indirect loss combined, have been made using the method explained above. In the worst scenario, the loss in GDP is about US$ 4.5

---

[14] The employment estimates are for 2004-05. These have been extrapolated to 2006-07.

billion. India's aggregate GDP in 2006-07 was about US$ 1016 billion. Thus, the loss in GDP in the worst scenario comes to about 0.4 percent. The loss in employment in the worst scenario is about two million. This comes to about 0.4 percent of the aggregate employment in the Indian economy in 2006 (about 480 million).

Table 4.12: Impact of Reduced Manufactured Exports to the US on GDP and Employment in the Indian Economy

Scenario	Impact on GDP (billion US$)		Impact on employment (000 persons)	
	Direct	Direct and indirect	Direct	Direct and indirect
A	-0.2	-0.4	-13	-183
B	-0.2	-0.4	-11	-156
C	-0.6	-1.3	-40	-579
D	-0.5	-1.1	-34	-496
E	-1.4	-3.2	-106	-1530
F	-1.2	-2.9	-91	-1319
G	-0.7	-1.6	-49	-720

Note: For description of Scenarios, see Table 4.1

While the US carbon price policy when accompanied with border tax adjustment is expected to have an adverse effect on the India economy because of the loss of exports to the US market, an indirect benefit is expected to be reaped by the Indian economy through the downward pressure that the US policy will have on the global oil prices. The studies on the US carbon price policy do not provide a clear indication of the likely fall in global oil prices that will take place due to these policies. Assessing the benefits that India will draw from the global oil prices is therefore difficult to ascertain. Nonetheless, the benefits could be large enough to compensate at least partly for the loss of output and employed caused by reduction in exports to the US.

5. Energy and carbon intensity of Different countries

The Waxman-Markey bill contains two kinds of provisions with potential trade impact. The first one is the grant of free emission allowances to certain energy intensive or trade intensive industries. But, whether these allowances will be given as subsidies or lump sum transfers has not been made clear yet. Another provision is about imposing border tax on the imports. The main questions which remain unanswered are:

1. Whether this tax will be imposed on all the products or only energy intensive products?

2. Whether this will be based on the carbon content of the imports or that of the comparable domestic products?

The impacts of these different scenarios would be different. Imposing tax on the basis of carbon content of imports will have greater impact on trade as it has already been shown in Section 3

that the impact depends on the magnitude of β_{mM} and β_{mH} and on the level of carbon taxes. This is brought out also by the estimates of impact of carbon tax presented in the previous section. While carbon tax based on the basis of comparable domestic production will benefit the foreign countries more, as it will give them an equal level playing field with domestic industries, it will also be able to address the problem of competitiveness and leakages effectively. One disadvantage of basing the carbon tax on emission intensity of domestic production is that it does not create sufficient incentive for foreign (developing country) producers to become more energy efficient and reduce their level of emission, as they will continue to pay the same tax even if they become more energy efficient.

The application of border tax has been advised by economists as an instrument to reduce the gap in the environmental related policies and measures among different countries, especially Annex I and II countries. It has been pointed out that developing counties like China, India, etc are highly energy intensive and their demand for energy intensive fuels are increasing rapidly. Between 1990-2005, china's manufacturing energy demand more than doubled, transport energy use almost tripled and the service sector increased its consumption by three and a half times. China's final energy use increased by 69% over this period. (WEO, 2007)

If the governments around the world continue with current policies, the world's energy needs would be well over 50 percent higher in 2030 than today. China and India would together account for about 45 percent of the increase in demand in this scenario. Globally, fossil fuels continue to dominate the fuel mix. These trends lead to continued growth in energy related emissions of carbon-dioxide (CO_2) and to increased reliance of consuming countries on imports of oil and gas – much of these from the Middle East and Russia. Both developments would heighten concerns about climate change and energy security. (WEO, 2007)

The global increase in energy demand amounts to 6 percent annually, making it all the more urgent for governments around the world to implement policies to curb the growth in fossil-energy demand and related emissions.

Rising CO_2 and other greenhouse-gas concentrations in the atmosphere, resulting largely from fossil-energy combustion, are contributing to higher global temperatures and to changes in climate. Growing fossil-fuel use will continue to drive up global energy-related CO_2 emissions in the years to come. The United States, China, Russia and India contribute about two-thirds of this increase. China is by far the biggest contributor to incremental emissions, overtaking the United States as the world's biggest emitter in 2007. India will become the third- largest emitter by around 2015. However, China's per-capita emissions in 2030 would be only 40% of those of the United States and about two thirds those of the OECD as a whole in the Reference Scenario. In India, per-capita emissions would remain far lower than those of the OECD, even though the growth rate of emission in India is higher than that in almost any other region.

This section deals with inter-country difference in energy intensity and emission intensity. How India compares with the US in this regard, is of particular interest. This analysis is important for understanding how big a gap is there between emission intensities of manufacturing industries of India and the US, and how large an impact will be there on the Indian exporters of manufactures

to the US if the carbon border tax in the US is imposed on the basis of carbon content of imports rather than carbon content of domestically produced goods.

5.1 Market exchange rate (MER) vs. Purchasing Power Parity (PPP)

To compute energy intensity or emission intensity for international comparison, it becomes necessary to express the value of output of different countries in some common currency, often in US $. The conversion of the value of output of a country from its local currency to US $ can be done at market exchange rate (MER) or at Purchasing Power Parity (PPP) exchange rate. Whether the market exchange rate is used for the purpose, or the PPP exchange rate is used, makes a lot of difference.

Both MER and PPP are the ways to convert the values expressed in the currencies of different countries into values expressed in a common currency, in practice in US $. Market exchange rates are influenced by short-term factors and are subject to substantial distortions from speculative movements and government interventions, and therefore comparisons based on exchange rates, even when averaged over a period of time such as a year, may yield unreliable and misleading results. By contrast, PPP conversions allow cross-country comparisons of economic aggregates on the basis of physical levels of output, free of price and exchange rate distortions. But PPP has its own limitations; a prominent one is that it does not include non tradable goods.

There is a large gap between market and PPP-based exchange rates in emerging market and developing countries, for most of which the ratio of the market to PPP U.S. dollar exchange rate is between 2 and 4. But, for advanced countries, the market and PPP rates tend to be much closer. As a result, developing countries get a much higher weight in aggregations that use PPP exchange rates than they do using market exchange rates. China's weight in the global economy is more than 15 percent using PPP exchange rates, but less than 5 percent with market-based exchange rate. For India, the corresponding figures are 6 percent and 1.5 percent, respectively.

A comparison of the energy intensity of US is made with a number of developing countries in Tables 5.1 and 5.2. The comparison in Table 5.1 is based on MER while that in Table 5.2 is based on PPP. When the comparison is made on the basis of market exchange rate, energy intensity of all the developing countries under study (in 2006) is found to be higher than the US. But, in PPP exchange rate, the relative position of different countries in energy intensity change. The relative position (vis-à-vis US) reverses for Brazil, Mexico and India, whereas for China and South Africa, the gap in energy intensity reduces significantly. Table 5.1 which is based on MER gives the impression that India is far less energy efficient than the US. But, a more correct comparison based on PPP presented in Table 5.2 which implicitly makes corrections for difference in price levels of commodities in the two countries indicates that the gap in energy efficiency level may not be large. One difficulty with the comparisons made in Tables 5.1 and 5.2 is that energy intensity at the aggregate economy may not correctly portray the difference in efficiency levels because the industry composition of the countries differs. Thus, a relatively higher share of services in an economy may reduce the energy intensity without the country actually being relatively more efficient in the use of energy as compared to others.

Table 5.1: Energy Intensity - Total Primary Energy Consumption per Dollar of GDP (Btu / Year 2005 U.S. Dollars (Market Exchange Rates))

Countries	2004	2005	2006
Mexico	7,890	8,014	8,267
United States	8,234	7,995	7,743
Brazil	10,524	10,601	10,567
South Africa	22,231	20,742	20,289
China	31,026	30,236	28,656
India	20,006	19,468	19,204

Source: EIA, available at

http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=90&pid=44&aid=8 (accessed on 10 November 2011)

Table 5.2: Energy Intensity - Total Primary Energy Consumption per Dollar of GDP (Btu/ Year 2005 U.S. Dollars (PPP))

Countries	2004	2005	2006
Mexico	4,965	5,043	5,203
United States	8,234	7,995	7,743
Brazil	6,050	6,094	6,075
South Africa	13,628	12,715	12,438
China	12,875	12,547	11,891
India	6,669	6,489	6,401

Source: EIA, available at http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=90&pid=44&aid=8 (accessed on 10 November 2011)

5.2 Sector wise energy intensity

The analysis of inter-country differences in energy intensity is taken a step further by making such a comparison at a disaggregated level. A comparison of energy intensity has been done for 10 broad industrial groups or sectors for Brazil, China, Mexico, India and US for the year 2006. The data on output have taken from the *Year Book of Industrial Statistics* 2010 and 2011 and the data on energy consumption from EIA.

Table 5.3 shows, for the ten sectors, the energy intensity of different countries at the market exchange rate and PPP exchange rate for the year 2006. The main findings from the comparison of energy intensity at Market exchange rate (MER) are:

1. China has relatively higher energy intensity in almost every product except paper and pulp.

2. Brazil has higher energy intensity than US for all the products, except Chemicals, Petroleum products and Textiles.

3. India has lesser energy intensity than the US in 4 products and higher energy intensity in 3 products. But, on average, energy intensity in India is higher than that in the US, which can be traced to a huge gap in energy intensity in Non metallic mineral products.

4. Mexico has by and large the same pattern as India (except for Food) and its average energy intensity is also higher than that of US. The relatively higher average energy intensity of Mexico compared to the US is because of the huge difference in energy intensity in transport.

5. South Africa is the only country showing lesser energy intensity than US.

When comparison of energy efficiency is made on the basis of PPP exchange rate, significant radical changes are observed. Some key points that may be noted are:

1. Except for Iron & Steel, the pattern has reversed for all the products under PPP. Under PPP, all the countries except Brazil, are showing lesser energy intensity than the US.

2. Only for Iron and Steel, the energy intensity of China is higher than US in both the cases. But, for other products, China's energy intensity has been become lesser under PPP. The average has also reduced under PPP.

3. Brazil is the only country which is showing higher average energy intensity than the US in both the cases, MER and PPP. In fact, except for chemical & petrochemical and Textile products, all the products are showing higher energy intensity in both the cases.

4. Indian energy intensity has also reduced under PPP. Under PPP all the products except non metallic mineral products are showing lesser energy intensity than the US.

The overall conclusion that one may draw on the basis of energy intensity comparison using PPP exchange rates is that the energy intensity of the studied developing countries (except Brazil) is lesser than the US. This is broadly in conformity with the pattern observed in Table 5.2.

Attention may be drawn here to the fact that while PPP exchange rates are meaningful when comparisons are made at the economy level, the PPP exchange rates may not show correctly the price differences for individual sectors. Ideally, for comparisons of energy intensity and emission intensity across countries at the industry or sector level, the sectoral PPP should be used. But as the data on sectoral PPP are not available, the country level PPP had to be used. This introduces a distortion in the comparison. But, it seems, the broad conclusion drawn from Table 5.3 will stand even if sectoral PPP exchange rates are used.

Table 5.3: Energy Intensity, 2006 (tones oil equivalent /million $ output)

ISCI code	description	Product code	Products	Mexico PPP	Mexico MER	Brazil PPP	Brazil MER	South Africa PPP	South Africa MER	China PPP	China MER	India PPP	India MER	US	PPP based average	MER based average
	Iron and steel			244.45	351.58	283.2	440.98	286.83	485.19	198.04	430.02	96.9	292.65	148.12	312.15	400.08
2710	basic iron and steel	19	Iron, Steel and Ferroalloy	65%a	137%a	91% a	198% a	94% a	228% a	34% a	190% a	-35% a	98% a		111% a	170% a
2731	casting of iron and steel	21	Ferrous Metal foundries		72%b		107% b		134% b		157% b		132% b			59% b
2413	chemical and petrochemical			47.02	67.62	66.89	104.16	57.12	96.62	98.99	214.94	28.24	85.28	122.12	88.23	113.72
2413	plastic in primary forms	7	Petrochemical manufacturing	-61% a	-45% a	-45% a	-15% a	-53% a	-21% a	-19% a	76% a	-77% a	-30% a		-28% a	-7% a
2411	basic chemicals	8	Basic Inorganic Chemical Manufacturing		17% b		31% b		32% b		95% b		47% b			21% b
2411	basic chemicals	9	Other basic organic chemicals Mfg													
2413	plastic in primary forms	10	Plastic and Material Resins													
2430	Man made fibers	11	Artificial & synthetic fibers, Filaments													
2412	Fertilizers	12	Fertilizers													
242	other chemicals	13	Other chemical and plastics													
	Non ferrous metals			8.02	11.53	247.01	384.64	124.58	210.74	78.27	169.96	7.85	23.72	133.47	136.42	160.112
2720	basic non ferrous metals	20	Alumina refining, primary and secondary Aluminum	-94% a	-91% a	85% a	188% a	-7% a	58% a	-41% a	27% a	-94% a	-82% a		2% a	20% a
2731	casting of iron and steel	21	Ferrous Metal foundries		3% b		103% b		65% b		69% b		12% b			18% b

Code	Category	No.	Subcategory													
	non metallic minerals			126.71	182.24	256.23	398.99	107.49	181.82	328.94	714.27	201.21	607.66	172.47	293.41	416.99
2610	glass and glass products	14	Glass Containers	-27% a	6% a	49% a	131% a	-38% a	5% a	91% a	314% a	17% a	252% a		70% a	142% a
2694	cement , lime n plaster	15	Cement		32% b		83% b		43% b		223% b		236% b			72% b
2694	cement , lime n plaster	16	Lime and Gypsum													
2699	non metallic mineral products	17	Mineral Wool													
2699	non metallic mineral products	18	Other Nonmetallic minerals													
	Transport equipments			294.64	423.77	--	--	3.92	6.63	57.46	124.77	--	--	50.37	118.67	185.06
331	medical measuring n all	28	Other Transportation Equipment Manufacturing	485% a	741% a			-92% a	-87% a	14% a	148% a				136% a	267% a
					256% b				5% b		134% b					132% b
	Machinery			0.73	1.05	--	--	4.49	7.6	32.63	70.85	7.8	23.55	45.68	11.41	25.76
291	Machinery	25	Machinery	-98% a	-98% a			-90% a	-83% a	-29% a	55% a	-83% a	-48% a		-75% a	-44% a
					1% b				7% b		84% b		34% b			31% b
	Food and tobacco			23.69	34.07	112.65	175.42	1.94	3.29	28.34	61.54	42.5	128.35	44.98	60.689	80.53
15	manufacturing of food products and beverages	1	Food	-47% a	-24% a	150% a	290% a	-96% a	-93% a	-37% a	37% a	-6% a	185% a	0% a	35% a	79% a
					23% b		140% b		3% b		74% b		191% b			44% b
	PAPER , PULP AND PRINTING			60.23	86.63	174.39	271.55	12.56	21.24	59.66	129.54	41.55	125.49	214.6	106.05	126.89
21	paper and pulp	5	Pulp and Paper Mills	-72% a	-60% a	-19% a	27% a	-94% a	-90% a	-72% a	-40% a	-81% a	-42% a		-51% a	-41% a
					12% b		45% b		4% b		33% b		39% b			10% b

20	Wood and wood products	4	Wood and furniture	--	--	--	--	4.73	8	27.83	60.43	--	--	57.2	16.28	34.21
	wood products							-92% a	-86% a	-51% a	6% a				-72% a	-40% a
3610	furniture								6% b		57% b					31% b
17	Textile and leather manufacturing of textile	2	Textile	--	--	34.28	53.38	7.21	12.19	44.81	97.3	10.61	32.04	76.02	39.84	48.73
						-55% a	-30% a	-91% a	-84% a	-41% a	28% a	-86% a	-58% a		-48% a	-36% a
							25% b		7% b		69% b		28% b			12% b
	Average			100.69	144.81	167.81	261.3	61.09	103.33	99.48	207.36	54.58	164.84	106.5	118.32	159.21

Industrial statistics 2010 and 2011 and EIA. a – percentage higher or lower than US   b- percentage difference between intensity computed on the basis of PPP and market exchange rate

5.3 carbon intensity

Two factors determine the carbon intensity of industrial production: the source of energy used to manufacture the good and the efficiency with which it is produced. These two factors can differ greatly between firms and between countries.

Figure 5.1: Total energy consumption by energy commodity in 2005
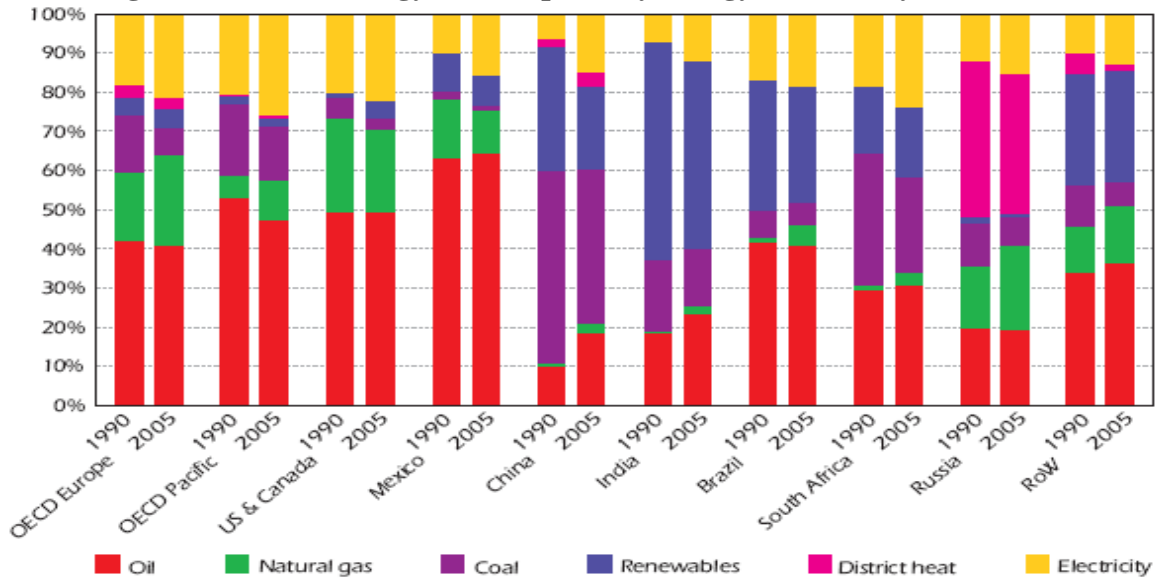
Sources: IEA, 2007 c; IEA, 2007 d; IEA estimates.
Note: Excludes fuel use in electricity and heat production.

Analysis of the energy mix of India (Figure 5.1) reveals that the type of energy with highest percentage is renewable energy, follwed by coal and oil, whereas China uses coal heavily to meet its energy requirments follwed by oil and renewables. But, US energy mix is heavily depends on Oil and natural gas, and the share of renewables is negligible.

Examination of the carbon intensity of different countries makes the picture more clear (Tables 5.4 and 5.5). Carbon intensity at market exchange rate shows relatively high intensity for China, India and South Africa, but at PPP, India's carbon intensity is almost equal to or less than the US.

Table 5.4: Carbon Intensity using Market Exchange Rates (Metric Tons of Carbon Dioxide per Thousand Year 2005 U.S. Dollars)

Countries	2005	2006	2007
Mexico	0.469	0.491	0.483
United States	0.474	0.456	0.455
Brazil	0.419	0.418	0.412
South Africa	1.751	1.705	1.684
China	2.442	2.287	2.154
India	1.408	1.395	1.357

Source: EIA, available on http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=90&pid=44&aid=8 (accessed on 10th November 2011)

Table 5.5: Carbon Intensity using Purchasing Power Parities (Metric Tons of Carbon Dioxide per Thousand Year 2005 U.S. Dollars)

Countries	2005	2006	2007
Mexico	0.2949	0.3088	0.3038
United States	0.4741	0.4557	0.4549
Brazil	0.2411	0.2403	0.2367
South Africa	1.0737	1.0451	1.0326
China	1.0135	0.9490	0.8938
India	0.4693	0.4648	0.4523

Source: EIA, available on http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=90&pid=44&aid=8 (accessed on 10th November 2011)

As we are dealing with the manufacturing sector in this study and we have taken 29 manufacturing industries, we should look at the carbon intensity of these industries as each country industry structure and energy mix are different. And, along with that we should look at the sectoral PPP to find out the exact energy and carbon intensity of different sectors. But as the data on sectoral PPP is not available, we have taken country level PPP to find out the carbon intensity of manufacturing sector.

It is seen from the Figure 5.2, that the CO_2 intensity of manufacturing sector of all the studied developing countries are higher than US. But, the gap reduces significantly when emission intensity is computed at PPP exchange rate. It is interesting to observe that the share of manufacturing in total CO_2 is lower in China than in India (Figure 5.3).

Figure 5.2: CO₂ emission ton/million US$ output for Manufacturing (2006)

CO2 intensity of manufacturing industries in 2006
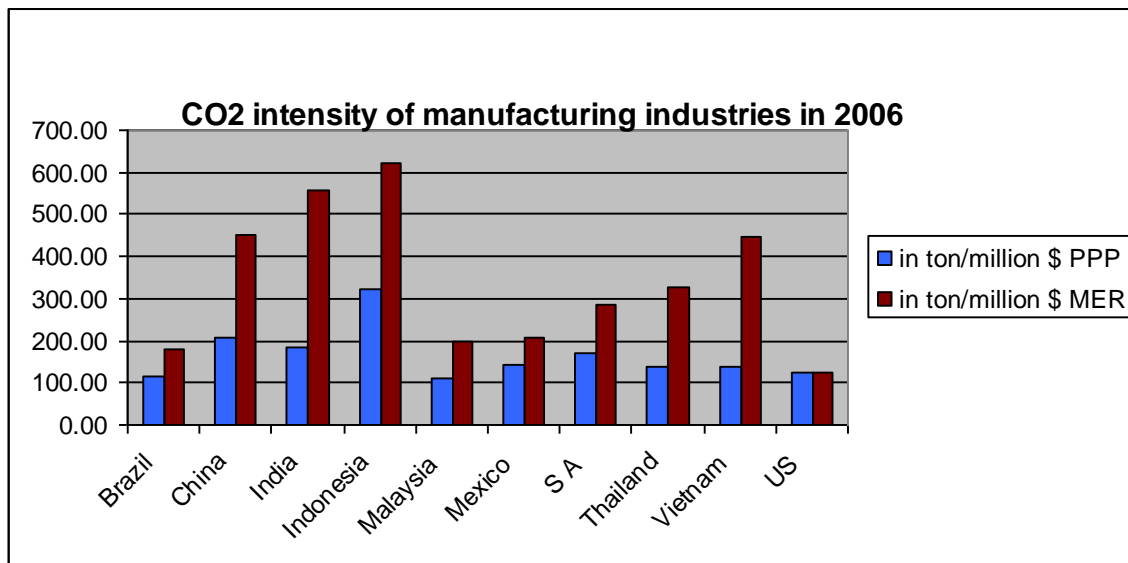
Source: CO_2 Emissions from Fuel Combustion 2008 and Value of output from Yearbook of industrial statistics 2010 and 2011. Intensity calculated by authors.

Figure 5.3: Manufacturing share of total CO₂ emission (percentage), 2005

Manufacturing share of total CO2 emission (percentage), 2005
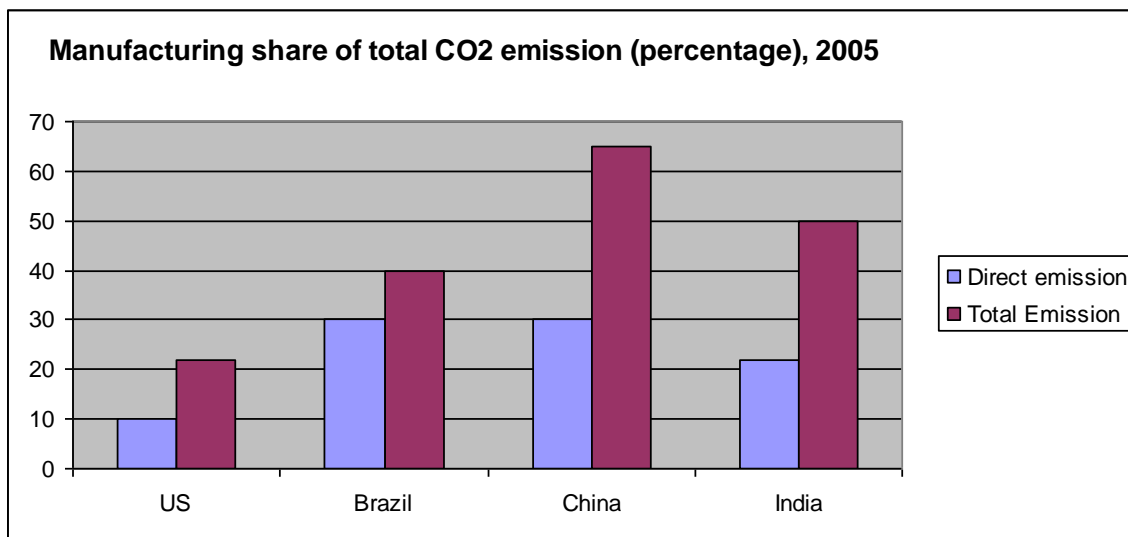
Source : IEA (International Energy Agency). 2007. *CO2 Emissions from Fuel Combustion.* Paris, given in Houser et al, "leveling the carbon playing field" 2008.

Comparison with Estimates in the Mattoo et al. paper

Aaditya Mattoo and associates have given estimates of direct and indirect emission intensity for the manufacturing sectors of US, China and India. If we look at the total (direct + indirect) emission, the India and China carbon intensity is very high as compared to US, 518 and 681tons per million US dollars respectively (226% and 328% higher than US) for 2004. But this gap reduces when we consider the direct emission level only, 208% and 253% respectively for India and China. Our data on emission intensity of manufacturing sector for direct emission also shows very high differences, 345% and 261%for India and China respectively for 2006. But a shortcoming of these figures is that these have been computed on market exchange rates.

If we compute the carbon intensity on PPP, the difference reduces drastically to 47% and 66% for India and China respectively (shown in figure 5.2) for manufacturing and construction sectors. As it has already been noted above, PPP is a better unit than MER. Therefore using MER data for carbon intensity would means exaggerating the carbon intensity of developing countries.

India-US comparison of carbon intensity

Figure 5.4 presents a comparison of Carbon intensity of a number of industries in India with their counterpart in the US. The estimates for India have been taken from Amrita Goldar et al. (2011) while those for the US are taken from Adkins et al. (2010; Table A8). These estimates represent total emissions of an industry, combining direct and indirect. There is probably some difference in the methodology adopted in the two studies on which the graph is based, and for this reason the estimates are not exactly comparable. Also, while the estimates for India are for 2003, those for the US are for 2006.

It is clearly seen from the graph that CO_2 emission intensity of Indian industries far exceeds that of the corresponding US industries. For the industries included in the figure, the average emission intensity for India is about four times that of the US. This is broadly consistent with the estimates of Mattoo and associated mentioned above as well as with the estimates shown in Figure 5.2. However, as noted earlier, the gap between the emission intensity of Indian industries and that of the US industries narrows when the output of Indian industries are converted into US$ using PPP exchange rate.

Figure 5.4: CO₂ Emission Intensity of Select Indian and US Industries
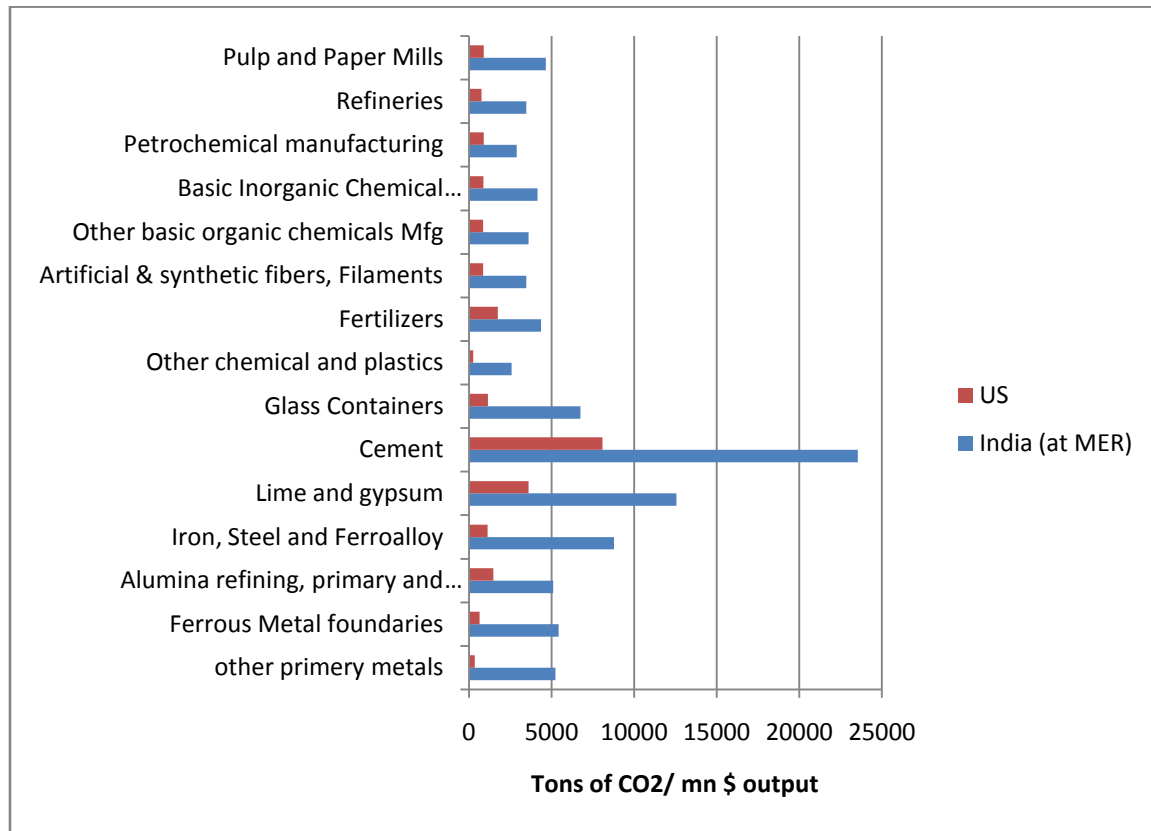
Note: The emission intensities show are total emission intensity combining direct and indirect emissions. The estimates for India are for 2003, and those for the US are for 2006.
Source: Estimates for India have been computed from Goldar et al. (2011), and those for the US have been taken from Adkins et al. (2010).

5.4 Sector wise Carbon Intensity

Steel

On average, US steel production is among the least carbon-intensive in the world. This is primarily the result of the type of production process the industry employs. The emission level of China and India is far higher than US and it is visible in the energy intensity data presented in Figure 5.5.

Figure 5.5: Carbon intensity of Steel 2005, tons of CO$_2$ per ton of steel
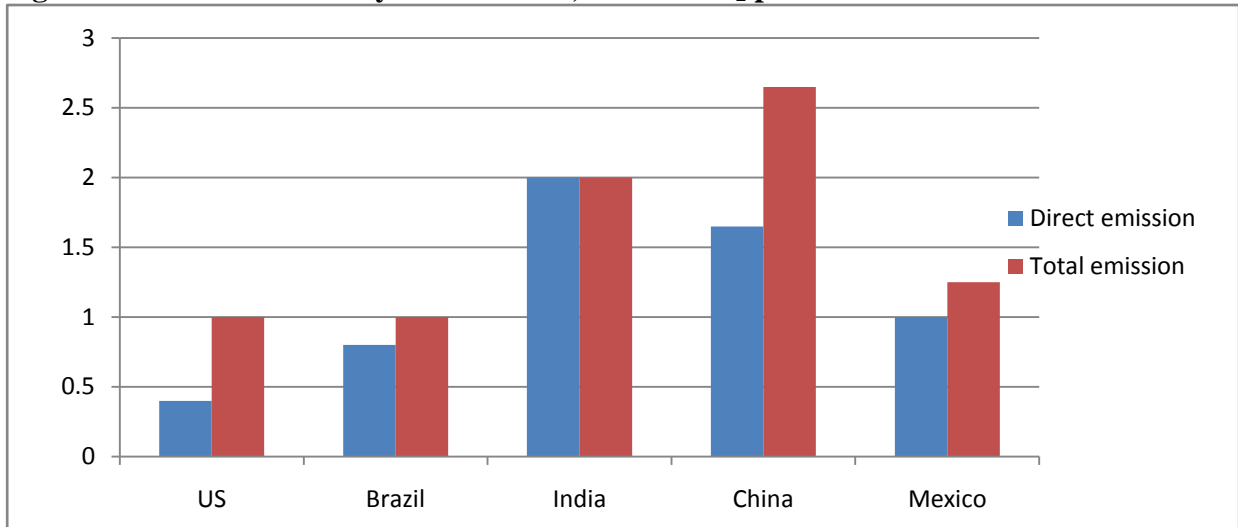
Source : Steel statistical year book 2007, given in Houser et al, "leveling the carbon playing field" 2008

Aluminum

The majority of the energy consumed in manufacturing primary aluminum is in the form of electricity. Thus, the carbon intensity of a ton of aluminum is largely determined by the source of electricity used to produce it. In the United States, roughly half of the electricity used in primarily aluminum production comes from hydropower, with the remainder coming from coal. That makes US smelters less carbon intensive than the average Asian or African smelter. Whereas, Indian electricity generation is dominated by inefficient Coal which constitute about 53% of the generation capacity.

Chemicals

The US chemical industry, with some of the oldest capital stock in the world, is fairly energy inefficient in the production of commodity chemicals. New ethylene crackers in China and the Middle East are all more energy efficient than the average facility in the United States. At the same time, the US chemical industry is more dependent on natural gas for feedstock than its competitors in Asia, which rely primarily on an oil-derived feedstock called naphtha, and as a result it is less carbon intensive than China and Taiwan (Figure 5.6).

Figure 5.6 : Energy and carbon intensity of different countries, Chemicals (2005)
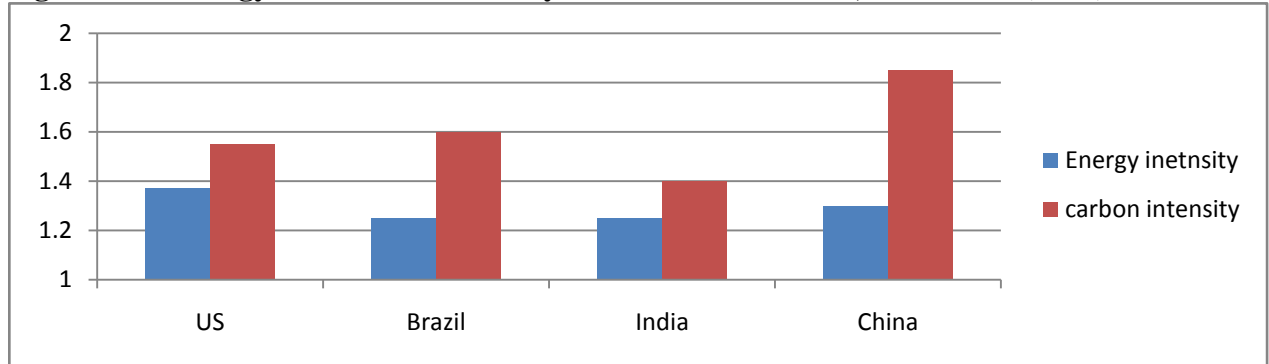
Source : IEA 2007, given in Houser et al, "leveling the carbon playing field" 2008. Note: An energy and carbon intensity index value of 1.00 equals best available technology and feedstock.

Cement

For cement production, the most important variable in determining carbon intensity is the type of kiln used. Coal accounts for less than two third of the furl used in kilns lesser than China and India , therefore on an average US cement industries are less carbon intensive than most Asian producers.

Paper and Pulp

US mainly use Chemical pulping for producing paper, which produces paper with a smaller carbon footprint, if one includes the CO_2 removed from the atmosphere during the life span of the trees (the kind of calculus used for biofuels). In fact, an integrated chemical pulping plant and paper mill can be configured to have zero emissions itself while also selling surplus low-carbon energy to other users (IEA 2007a). If US climate policy credited paper producers with the CO_2 absorbed when they replant trees, trade measures would likely give US mills a leg up on Asian and Canadian producers, though not those from Indonesia or Brazil.

6. Conclusion

The review of the literature and the analysis presented above show that carbon price policy of the US will not have much impact on exports, output and employment in India unless the US applies carbon tax on developing country imports into the US on grounds of competitiveness and carbon leakage. Even in this case, the seriousness of the impact will depend on the price place on carbon and the basis adopted for the imposition of carbon tax on imports. If the price of carbon is set at US$ 50 per ton of CO_2 and carbon tax on imports are based on the emission intensity of domestic producers, the loss manufacturing value added in India will be about 0.5 percent and loss of manufacturing employment will also be about 0.5 percent. This corresponds to reduction in India's exports of manufactured products to the US by about 5 percent (for products of energy intensive industries, about 15 percent). If the carbon tax on imports is imposed on the basis of carbon embodied in imports, India's losses will be greater. The loss in value

added in manufacturing will be about1.3 percent and that in manufacturing employment about 1.2 percent. In this case, India's exports of manufactured products to the US will go down by about 15 percent and energy intensive manufactured products by about 35 percent. This will be the expected loss if emission intensity is measured using the market exchange rate. There is good reason for basing the assessment of emission intensity on PPP exchange rates rather than market exchange rates. If the PPP based emission intensities are used for ascertaining the tax rates applicable to imports from different sources countries, the adverse effects on India will be much smaller since the emission rates in Indian manufacturing industries are relatively low in PPP exchange rates. The reduction in manufactured exports to the US will be about 8 percent. The value added loss to manufacturing will be about 0.7 percent and employment loss will also be about 0.7 percent.

There would also be indirect losses to other sectors of the Indian economy through inter-industry linkages. While in the scenario based on PPP exchange rate mentioned above, the direct loss in value added due to reduced exports to the US will be about 0.7 billion US dollars, the total impact (direct plus indirect) will be a loss of about 1.6 billion US dollars. Similarly, while the direct employment loss will be about 49 thousand persons, the total employment loss will be about 720 thousand persons.

Though not as large as the estimates of Mattoo et al. (2009), the estimated effects of US carbon price policy on exports, production and employment in Indian manufacturing obtained in this study are significant. If the use of unilateral measures by the developed countries cannot be prevented, India should strive for making the border tax based on the domestic emission intensity of developed countries rather than being based on carbon embodied in imports. If the latter form of carbon tax becomes inevitable, India's interest lies in ensuring that the tax should be based on emission intensity computed on the basis of PPP exchange rates rather than the market exchange rate. Emission intensity computed on the basis of PPP exchange rate has a stronger justification for being used in inter-country comparison of emission intensity than the estimates of emission intensity based on market exchange rate.

References

Adkins, Liwayway, Richard Garbaccio, Mun Ho, Eric Moore and Richard Morgenstern (2010), "The Impact on U.S. Industries of Carbon Prices with Output-Bases Rebates over Multiple Time Frames," Discussion paper no. REF 10-47, Resources for Future, Washington D.C., December.

Adkins, Liwayway, Richard Garbaccio, Mun Ho, Eric Moore and Richard Morgenstern (2011), "Trade Effects and Emission Leakage Associated with Carbon Pricing Policies," Draft Paper, April 2011, (available on line), Resources for Future, Washington D.C.

Aldy, Joseph, and William Pizer. 2009. *The Competitiveness Impacts of Climate Change Mitigation Policies*. Washington, DC: Pew Center on Global Climate Change.

Allen, Myles R., Allen, David J. Frame, Chris Huntingford, Chris D. Jones, Jason A. Lowe, Malte Meinshausen and Nicolai Meinshausen (2009), **"Warming caused by cumulative carbon emission: the trillionth tone,"** *Nature*, 458 (7242): 1163-1166.

Anuradha, R.V. (2011), "Unilateral Carbon Border Measures: Key Legal Issues," ICRIER Policy Series Paper no. 2, Indian Council for Research on International Economic Relations, New Delhi, July.

Asselt, Harro van and J. Gupta (2009), "Stretching Too Far: Developing Countries and the Role of Flexibility Mechanisms Beyond Kyoto," *Stanford Environmental Law Journal*, 28(2): 311-78.

Asselt, Harro van, Thomas Brewer and Michael Mehling (2009), "Addressing Leakage and Competitiveness in US Climate Policy," Working paper, Climate Strategies (www.climatestategies.org).

Asselt, Harro van and Faribarz Zelli (2011), "Interplay between Climate and Trade Policies," in Sunjoy Joshi and Marlies Linke (eds), *Sustainable Development and Climate Change*, New Delhi: Academic Foundation in association with the Observer Research Foundation.

Böhringer, Christoph, Carolyn Fischer, and Knut Einar Rosendahl, "Cost-Effective Unilateral Climate Policy Design: Size Matters," RFF Discussion Paper 11-34. Washington, DC: Resources for the Future

Bollen, Johannes and Cojan Brink (2011), "The Economic Impact of Air Pollution Policies in the EU," CPB Netherlands Bureau for Economic Policy Analysis.

Dong, Yan and John Whalley (2009a), 'How Large are the Impacts of Carbon Motivated Border Tax Adjustments?" Economic Policy Research Institute, EPRI Working Paper Series, Working paper no. 2009-3.

Dong, Yan and John Whalley (2009b), "A Third Benefit of Joint Non-OPEC Carbon Taxes: Transferring OPEC Monopoly Rent", CESIFO Working paper no. 2741 Category 8: Trade Policy, August.

EIA (2009), *Energy Market and Economic Impacts of H.R. 2454, the American Clean Energy and Security Act of 2009*, SR-OIAF/2005-05, Washington, DC: EIA.

Elliott, Joshua, Ian Foster, Samuel Kortum, Todd Munson, Fernando Pérez Cervantes, and David Weisbach (2010), "Trade and Carbon Taxes", *American Economic Review: Papers & Proceedings 100 (May 2010): 465–469*

EPA (2009a), *Analysis of the American Clean Energy and Security Act of 2009 H.R. 2454 in the 111th Congress*, Washington, DC: EPA.
http://www.epa.gov/climatechange/economics/pdfs/H.R.2454_Analysis.pdf.

EPA (2009b), *The Effects of H.R. 2454 on International Competitiveness and Emission Leakage in Energy-Intensive Trade-Exposed Industries: An Interagency Report Responding to a Request from Senators Bayh, Specter, Stabenow, McCaskill, and Brown*. Washington, DC: EPA.
http://www.epa.gov/climatechange/economics/pdfs/InteragencyReport_Competitiveness&EmissionLeakage.pdf.

Fischer, Carolyn, and Alan K. Fox (2007), "Output-Based Allocation of Emissions Permits for Mitigating Tax and Trade Interactions," *Land Economics*, 83: 575–599.

Fischer, Carolyn and Alan K. Fox (2009a), "Comparing Policies to Combat Emission Leakage: Border Tax Adjustment versus Rebates," Discussion Paper no. REF DP 09-02, Resources for the Future, Washington D.C., February.

Fischer, Carolyn and Alan K. Fox (2009b), "Combining Rebates with Carbon Taxes: Optimal Strategies for Coping with Emissions Leakage and Tax Interactions," Discussion Paper no. REF DP 09-12, Resources for the Future, Washington D.C., May.

Goldar, Amrita, Jaya Bhanot and Kazushige Shimpo (2011), "Prioritizing towards a green export portfolio for India: An environmental input–output approach," *Energy Policy*, 39:7036-7048.

Ho, Mun S., Richard Morgenstern and Jhih-Shyang Shih (2008), "Impact of Carbon Price Policies on U.S. Industry," Discussion paper no. REF 08-37, Resources for Future, Washington D.C. November.

Houser, Trevor, Rob Bradley, Britt Childs, Jacob Werksman, and Robert Heilmayr. 2008. *Leveling the Carbon Playing Field: International Competition and U.S. Climate Policy Design*. Washington, DC: Peterson Institute for International Economics and World Resources Institute.

Hübler, Michael (2009), "Can Carbon Based Import Tariffs Effectively Reduce Carbon Emissions?" Kiel Working Paper No. 1565, October 2009, Kiel Institute for the World Economy, Kiel, Germany.

International energy agency (2007), "World energy outlook 2007", Available at www.iea.org/textbase/npsum/weo**2007**sum.pdf (accessed on 10 November 2011)

IEA (International Energy Agency) (2008), *Worldwide trends in energy use and efficiency*, Available at www.**iea**.org/papers/2008/indicators_2008.pdf (accessed on 11 November 2011).

IEA (International Energy Agency) (2008), *CO2 Emissions from Fuel Combustion* 2008, Paris: Organization for Economic Cooperation and Development and International Energy Agency, given in Houser, T. et al (2008), "Leveling the carbon playing field", Peterson institute of international economics world resource institute, Washington, DC.

Jorgenson, Dale, Richard Goettle, Mun Ho, and Peter Wilcoxen (2007), "The Economic Costs of a Market-Based Climate Policy", White Paper, Arlington, VA: Pew Center on Global Climate Change.

Malla, Sunil (2005), "Implications of Carbon Tax and Energy Efficiency Improvement on Thai Economy: Application of AIM/CGE", School of Environment, Resources and Development, Asian Institute of Technology, Pathumthani, Thailand.

Mattoo, Aaditya, Arvind Subramanian, Dominique van der Mansbrugghe and Janwu He (2009), "Reconciling Climate Change and Trade Policy," Policy Research Working Paper no. 5123, Development Research Group, World Bank.

McKibbin, Warwick J. and Peter J. Wilcoxen (2008), "The Economic and Environmental Effects of Border Tax Adjustments for Climate Policy" Paper Prepared for the Brookings Conference on 'Climate Change, Trade and Competitiveness: Is a Collision Inevitable?' held in Washington June 9, 2008.

Mensbrugghe, Dominique van der (2009), "The Doha Development Agenda and Preference Erosion: Modeling the Impacts," in Bernard Hoekman, Will Martin, and Carlos A. Primo Braga (eds), *Trade Preference Erosion: Measurement and Policy Response*, Palgrave MacMillan, New York, and the World Bank, Washington D.C.

Metcalf, Gilbert, Sergey Paltsev, John Reilly, Henry Jacoby and Jennifer Holak (2008), Analysis of U.S. Greenhouse Gas Tax Proposals, Report no. 160, April 2008, MIT Joint Program on the Science and Policy of Global Change

Meinshausen, Malte, Nicolai Meinshausen, William Hare, Sarah C. B. Raper, Katja Frieler, Reto Knutti, David J. Frame and Myles R. Allen (2009), **"**Greenhouse-gas emission targets for limiting global warming to 2°C," *Nature*, 458 (7242): 1158-1162

Pezzy, J.C.V. and N.R. Lambie (2001), *Computable General Equilibrium Models for Evaluating Domestic Greenhouse Policies in Australia: A Comparative Analysis*, Report to the Productivity Commission, AusInfo, Canberra.

Porter, M.E., and van der Linde, C. (1995), "Green and Competitive: Ending the Stalemate" *Harvard Business Review*, September-October: 120-135.

Rao, Narasimha, Girish Sant, Sudhir Chella Rajan, Ashwin Gambir and Gayatri Gadag (2009), "An overview of Indian Energy Trends: Low Carbon Growth and Development Challenges," Prayas energy group, Pune, India.

Richardson, Y. Le Bouthillier, H. McLeod-Kilmurray and S. Wood (eds), *Climate Law and Developing Countries: Legal and Policy Challenges for the World Economy*, Cheltenham, UK: Edward Elgar.

Sindco, F. (2009), "Climate and Trade in a Divided World: Can Measures Adopted in the North End Up Shaping Climate Change Legislative Framework in the South?" in B.J.

Takeda, Shiro, Tetsuya Horie and Toshi H. Arimura (2011), A CGE Analysis of Border Adjustments Under the Cap-and-Trade System: A Case Study of the Japanese Economy, Available at SSRN.

UNIDO (2010, 2011), *Year Book of Industrial Statistics* 2010 and 2011.

Wing, Ian Sue (2004), "Computable General Equilibrium Models and Their Use in Economy-Wide Policy Analysis, MIT Joint Program on the Science and Policy of Global Change, Technical Note No. 6, September.

Yano, Takashi, Satoshi Kojima and Xin Zhou (2011), The Economic and Environmental Effects of Border Adjustment Measures: A multi-regional CGE analysis for Japan, Institute for Global Environmental Strategies, Kanagawan, Japan; presented at the 19th International Input-Output Conference, Alexandria, Virginia, USA, 13-17 June, 2011.

Yusuf, Arief Anshory and Budy P. Resosudarmo (2007), "On the Distributional Effect of Carbon Tax in Developing Countries: The case of Indonesia", Economics and Environment Network Working Paper #EEN0706, Australian National University.

Annex-A: Elasticity of substitution taken from GTAP database

Code	Description	ESUBD σ^m	ESUBM σ^w
19 cmt	Meat: cattle,sheep,goats,horse	3.9	7.7
20 omt	Meat products nec	4.4	8.8
21 vol	Vegetable oils and fats	3.3	6.6
22 mil	Dairy products	3.7	7.3
23 pcr	Processed rice	2.6	5.2
24 sgr	Sugar	2.7	5.4
25 ofd	Food products nec	2.0	4.0
26 b_t	Beverages and tobacco products	1.2	2.3
27 tex	Textiles	3.8	7.5
28 wap	Wearing apparel	3.7	7.4
29 lea	Leather products	4.1	8.1
30 lum	Wood products	3.4	6.8
31 ppp	Paper products, publishing	3.0	5.9
32 p_c	Petroleum, coal products	2.1	4.2
33 crp	Chemical, rubber, plastic prods	3.3	6.6
34 nmm	Mineral products nec	2.9	5.8
35 i_s	Ferrous metals	3.0	5.9
36 nfm	Metals nec	4.2	8.4
37 fmp	Metal products	3.8	7.5
38 mvh	Motor vehicles and parts	2.8	5.6
39 otn	Transport equipment nec	4.3	8.6
40 ele	Electronic equipment	4.4	8.8
41 ome	Machinery and equipment nec	4.1	8.1
42 omf	Manufactures nec	3.8	7.5