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Yan Dong

John Whalley

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Yan Dong and John Whalley

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Department of Economics
Department of Political Science
Social Science Centre
The University of Western Ontario
London, Ontario, N6A 5C2
Canada

How Large are the Impacts of Carbon Motivated Border Tax Adjustments? [1]

Yan Dong

Chinese Academy of Social Sciences

and University of Western Ontario

John Whalley

University of Western Ontario, Centre for

International Governance Innovation (CIGI),

and NBER

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ABSTRACT

This paper discusses the size of impact of carbon motivated border tax adjustments on world trade. We report numerical simulation results which suggest that impacts on welfare, trade, and emissions will likely be small. This is because proposed measures use carbon emissions in the importing country in producing goods similar to imports rather than carbon content in calculating the size of barriers. Moreover, because border adjustments involve both tariffs and export rebates, it is the differences in emissions intensity across sector rather than emissions level which matters. Where there is no difference in emissions intensities across sectors, Lerner symmetry holds for the border adjustment and no relative effects occur.

In our numerical simulation analyses border tax adjustments accompany carbon emission reduction commitments made either unilaterally , or as part of a global treaty and to be applied against non signatories. We use a four-region (US, EU, China, ROW) general equilibrium structure which captures energy trade and has endogenously determined energy supply so that global emissions can change with policy changes. We calibrate our model to 2006 data and analyze the potential impacts of both EU and US carbon pricing at various levels, either along with or without carbon motivated BTAs policies on welfare, emissions, trade flows and production. Results indicate only small impacts of these measures on global emissions, trade and welfare, but the signs of effects are as expected. BTAs alleviate leakage effects as expected. In trade impacts, compared with no BTAs, BTAs reduce imports of committing countries, and increase imports by other countries. EU and US BTAs against China reduce exports by China. With BTAs, the value of production in the country with carbon reduction measures are introduced increases, and other country's production decreases compared with the case of no BTAs. With the contraction of world trade flows caused by the financial crisis, carbon motivated BTAs offer a prospect of a compounding effect in a world which is going protectionist and decarbonized at the same time, but the added effects of BTAs seems small.

1. Introduction

Emerging policy proposals for carbon based tariffs or border tax adjustments by EU, US and other OECD countries against developing countries that do not participate in global emissions reduction agreements are a central issue for current climate change negotiations[1]. Although not formally part of the post Bali road map, de facto the threat of such measures is a central part of the negotiation process. Proposals for carbon motivated tax adjustments include both import tariffs (carbon tariffs) and export rebates by countries with emissions reduction commitments against those without commitments.

Such border adjustments by participating countries are driven by two related objectives. One is to provide competitiveness offsets for domestic producers since the added costs for domestic producers involved with domestic carbon pricing impose a competitive disadvantage on them. The other is leakage, i.e. that the reductions in emissions in participating countries such as the EU and the US generate increases in emissions elsewhere. For countries such as China, who are heavily export-oriented, and towards manufactures, the prospect is one of a world being decarbonized and going protectionist at the same time against a background of a continuing downturn in world trade for the financial crisis.

Border tax adjustments and both their rational and effects on trade is not a new topic. Earlier debate on border tax adjustments occurred following the adoption of the value added tax in the EU as a tax harmonization target in the early 1960's (see Dosser (1967), Shibata (1967), Krauss & Johnson (1972)). The academic literature at that time suggested that with BTAs, a change between origin and destination is simply that between a broadly based production and consumption rate both of which are neutral, with no direct effects on trade. Neutrality of trade, production, and consumption effects would thus prevail under a tax basis change (see Krauss & Johnson (1972), Whalley (1979), Grossman (1980), and Lockwood et al.(1994)). As recently noted by Lockwood & Whalley (2008), carbon motivated border tax adjustments differ by product and sector, and so unlike in the debate on the VAT one needs to distinguish between price level and relative price effects (Neumark (1963), Hufbauer(1996)). With product or sector specific BTAs, relative price effects will come into play, and neutrality only holds in special cases.

This paper presents numerical simulation results exploring the effects of carbon motivated border tax adjustments in large OECD economies on welfare, global and country emissions,

[1] See Brewer(2008), Dröge & Kemfert (2005),Weber & Peters(2009).

trade flows and production[1]. We use a multi-region general equilibrium structure covering the US, EU, China and a residual rest of the world. In this, countries produce commodities of varying emissions intensities using substitutable fossil fuel based oil and non-oil inputs. Unlike in conventional trade models in which there is a fixed endowment of factor inputs for each country, here we incorporate a supply function for energy exporting countries with increasing extraction costs. Since emissions are directly related to energy use in production, emissions levels globally are endogenously determined and can change with policy change.

In our numerical simulation analysis of BTA's we construct a benchmark global equilibrium data set based on data for 2006 using a number of data sources. This covers production, consumption , and trade between the four regions (China,EU,US, ROW) .We calibrate our model to this data set using literature based estimates of key elasticities.

Results show that BTAs effects generally are small, depending on the carbon pricing (or size of emissions mitigations) adopted by importing countries. This is because both using carbon emissions in production of comparable goods in importing countries produces small barriers compared to using direct carbon content of goods and what produces real side effects is the difference in emission intensity across goods not the level of emission. Carbon border adjustments are not neutral since border tax adjustments in the carbon case are sector specific and relative price effects occur. Carbon BTAs alleviate the leakage effects as expected, but counteract the global emissions reduction effect of carbon pricing. Compared with no BTAs, BTAs reduce imports of committing countries, and increase imports by other countries. With BTAs the value of production in countries with carbon taxes increases, and other country's production (in value terms) decreases compared with no BTAs.

[1] There are also legal issues as to the GATT compatibility of such schemes. There are not discussed here. See De Cendra(2006), Ismer & Neuhoff(2007).

2. The Model

We use a 4 country general equilibrium model covering the US and the EU as the significant potential users of border tax adjustments, China as the major possible target country, and a residual rest of the world. There are no explicit dynamics. We use a single period model based on 2006 data, which can be interpreted as a steady state. Region utility functions directly incorporate temperature change. We capture the incremental impacts of BTAs on emissions in 2006, and onto temperature change over 50 years, which in turn enters utility. We index the 4 countries in the model by i and we use k to denote double country terms (exports of country i product to country k).

In the model, there are two goods produced in each region, indexed by j ($j=1,2$). Good 1 has high energy (emissions) intensity, and good 2 has low energy (emissions) intensity. This restriction on dimensionality is a reflection of data availability. Goods across countries are assumed heterogeneous (the Armington assumption). The model specifies one fixed and one variable factor in production of each good; E is energy input and is mobile across both countries and sectors. We assume ROW is the energy exporter and for simplicity, ROW does not produce final goods. China, EU and US thus export final goods to ROW and import energy from ROW.

In China, the EU and the US production functions are:

$$Y_j^k = \varphi_j^k (E_j^k)^{\alpha_j^k} \quad k = \text{country}, j = \text{sector} \quad k = 1, \cdots 3, \ j = 1, 2 \tag{1}$$

where Y_j^k is the output of good j produced in country k , E_j^k is the energy input in country k 's production of good j , φ_j^k are units terms (scalar parameters), and $\alpha_j^k < 1$ are the production exponents.

We assume that the energy input receives its value marginal product, which in turn equals the energy price ,ie

$$p_E = P_j^k \frac{\partial Y_j^k}{\partial E_j^k} = P_j^k \varphi_j^k \alpha_j^k (E_j^k)^{\alpha_j^k - 1} \quad k = 1, \cdots 3 \ , \ j = 1, 2 \tag{2}$$

We assume the Rest of the World is the energy exporting country, but unlike in traditional general equilibrium models which use a fixed endowment of energy, here we introduce an extraction cost function for the energy exporting country into the model. As a result of the extraction cost functions in ROW, energy supply by ROW and with this global

emissions are now endogenously determined. To keep the model tractable, we model the US, the EU, and China as oil importing with an exogenous endowment of energy $\overline{E}_i$.

The extraction cost function we use implies an increasing marginal cost of extraction and is written as

$$K = F(Q) = B_1 + B_2 Q^{B_3} \quad (3)$$

where K is the extraction cost , and Q (oil) is energy extracted .

From the first-order conditions for the extraction cost function, we get

$$p_E = \frac{dK}{dQ} = \frac{dF(Q)}{dQ} = B_2 B_3 Q^{B_3 - 1} \quad (4)$$

and the implied energy supply elasticity is

$$EQ = \frac{dK/K}{dQ/Q} = B_3 - 1 \quad . \quad (5)$$

Dividing the extraction cost function by the energy price, we can calculate the resources that are used in energy extraction.

$$ER = \frac{K}{p_E} = \frac{B_1 + B_2 Q^{B_3}}{p_E} \quad . \quad (6)$$

On the demand side of the model, we assume a representative household in each country with a utility function defined over both goods and global temperature change (which we later relate to emissions). We write this as

$$U_i = U_i(RX_i, \Delta T) = [r_{Hi}^{1/\sigma_{di}} H_i^{\sigma_{di}-1/\sigma_{di}} + r_{Li}^{1/\sigma_{di}} L_i^{\sigma_{di}-1/\sigma_{di}}]^{\sigma_{di}/\sigma_{di}-1} (\frac{C - \Delta T}{C})^{\beta} \quad (7)$$

where following Cai, Riezman & Whalley (2009), RX_i is a composite of consumption of high and low energy intensive goods in all regions in country *i*, and ΔT is global temperature change. H_i is a composite of high emission goods consumption across country sources, and L_i is a composite of low emission goods consumption across country sources, σ_{di} is the substitution elasticity between high and low emission goods in country i , β is the utility weight placed on damage from temperature change.

In this formulation, we specify expected damage from emissions today as related to future induced incremental temperature change from today's emissions relative to some upper bound. *C* can thus be thought of as the global temperature change at which all economic activity ceases (say, 20℃). In this formulation, as ΔT approaches *C*, utility goes to zero; and as ΔT goes to zero, there is no welfare impact of temperature change. We interpret

ΔT as the temperature change that will accrue over 50 years out to 2056 as a result of incremental emissions (energy use) in 2006.

In the utility functions, RX_i is, in turn, a two level nested CES function. Each region is assumed to maximize utility by first choosing among high and low energy (emission) intensity goods, and each region then chooses among domestic and other country source of supply at a second level. RX_i can thus be written as

$$RX_i = f(X_{i1}^1, X_{i2}^1, X_{i1}^2, X_{i2}^2, X_{i1}^3, X_{i2}^3) \quad (8)$$

where X_{ij}^k is country i's consumption of good j produced in country k.

Each of the four regions maximizes a top level utility function subject to a budget constraint. If I_i is income in country i, this can be written as

$$\sum_k \sum_j P_{ij}^k X_{ij}^k = I_i \qquad i = 1, \cdots 4. \quad (9)$$

Income in China, EU and US is revenue from the sale of goods minus import payments to ROW for energy. It also includes revenues from the sale of $\overline{E_i}$, the energy endowment in country *i*. We include carbon pricing revenue in the budget constraint, in the form of added costs from an internal carbon price (reflected in emissions reduction targets) related to emissions from energy use. We discuss this in more detail below. We also incorporate border measures reflecting tariffs on imports and rebates on exports under border tax adjustments .If we assume an exogenously given trade imbalance, the income side of the budget constraint becomes

$$I_i = P_j^i Y_j^i - p_E(\sum_j E_j^i - \overline{E}_i) + RC_i + R_i + TR_i \qquad i = 1, \cdots 3. \quad (10)$$

where RC_i is carbon pricing revenue, R_i is import tariff revenue, and TR_i are exogenous transfers between countries (net goods import plus net energy import). These can be zero, but incorporating them allows calibration to unbalanced trade data.

Income in the ROW includes energy export revenues and adding transfers from or to abroad gives

$$I_4 = p_E Q - K + TR_4 \quad (11)$$

In the model we also incorporate a temperature change function specifying how temperature change varies with annual emissions levels, assumed to prevail over a number of years. For simplicity, we abstract from emissions growth in later years due to GDP growth, and any changes in emissions intensity per unit of GDP. This is a strong assumption given

both growth and emissions intensities change in China, but is adopted to keep the model simple and tractable.

Assuming emissions are related directly to the amount of energy consumption allows us to write the temperature change function directly as a function of energy consumption, i.e.

$$\Delta T = g(\sum_i \sum_j E_j^i)^b = a(\sum_i \sum_j E_j^i)^b + c \qquad (12)$$

In equilibrium, prices for final goods and energy are such that goods and factor markets clear. Goods market clearing implies:

$$\sum_i X_{ij}^k = Y_j^k \quad i = 1, \cdots 4, \ j = 1,2 \ , \ k = 1, \cdots 3 \qquad (13)$$

Since energy is mobile across countries, in equilibrium global energy consumption must equal global energy extraction. The energy clearing condition is thus:

$$\sum_i \sum_j E_j^i = \sum_i \overline{E}_i + (Q - ER) \qquad i = 1, \cdots 3 \qquad (14)$$

where $\sum_i \sum_j E_j^i$ is energy consumption, $\sum_i \overline{E}_i$ is the combined energy endowment in China, EU and US, and $(Q - ER)$ are the energy sales by the ROW (energy extraction minus resources used in extraction).

We complete the model by specifying possible policy interventions linked to country carbon pricing and use of border measures. For each good j produced in country k, we define the producer's price (net of carbon pricing and border measures) as P_j^k. The internal consumer prices in country i for good j imported from country k (gross of carbon pricing and border measures) are denoted by P_{ijk}, and are given by

$$P_{ijk} = P_j^k + \lambda_{jk} p_c \qquad (15)$$

where p_c is the exogenous price of carbon , λ_{jk} is the emissions intensity of good j produced in country k. This treatment involves applying a border adjustment based on the carbon priced emissions costs of production in the importing country. This differs from using direct carbon content of goods as in Mattoo et al.(2009), which produces sharply higher barriers. $\lambda_{jk} p_c$ is thus the carbon motivated consumer price adjustment for good j produced in country i imported by country k.

The adjustments we consider include different forms of carbon pricing, carbon motivated import tariffs and carbon motivated export rebates. If we consider country k as the country potentially adopting both carbon pricing and border adjustments. λ_{jk} is emission intensity of

good j produced in country k. The adjustment at the border for exports by country i to country k is $\lambda_{jk} p_c$, and this same adjustment is used for all domestic production if there is no export rebate.

If export rebates apply exports from country k can be sold abroad at P_j^k rather than P_{ijk} and producers domestically can still cover costs. These are no border tax adjustments faced by goods enhancing country k if k has no carbon pricing.

We finally also consider cases where the importing country k only uses carbon tariffs as the border measure when they adopt carbon pricing, and do not use export rebates.

3. Data and Model Calibration

To use this model to analyze the impacts of various border tax adjustments, we first build a model compatible benchmark general equilibrium data set, which we then use in model calibration. Our base case data includes 2006 trade, production, and consumption data (as well as data on energy use) for our good of 2 sector classificatgion (energy /non energy intensive), and 1 variable factor (energy) structure for 4 regions (China, US , EU, ROW).

Table 1 sets out the main features of the data set we have assembled in this form. In Table 1-1, GDP data is from the World Bank's WDI database. The high-emission sector in each country is taken to be the manufacturing industry. The low-emission sector in each country is taken to be service and agricultural sectors. For Table 1-2, trade data is taken from the UNCOMTRADE database, and F.o.b. export values as reported by exporting countries are used. This data as reported aggregates energy and goods trade data in value terms. In Table 1-3 , energy data for 2005 is from IEA energy statistics. The unit of account used in the IEA statistics data is thousand of tonnes of oil equivalent, which we convert to billion US dollars, (assuming 1 toe = 7.33 barrel of oil equivalent, oil price (2006 average)=$50.64/per barrel). The extraction cost data for ROW is calculated using the IEA energy balance table. We use all of this data along side 2006 trade production and consumption data.

Table 1-4 reports 2006 sector energy intensities calculated using GDP and energy consumption data by country. These intensities are 4 times higher in China than in the US and 8 times higher in China than in the EU for the energy intensity sector, and even larger for the non energy intensive sectors. Table 1-5 presents data on goods consumption by region, after adjustments are made to consumption so as to be compatible with GDP minus exports. Table 1-6 reports 2006 aggregate energy consumption data from IEA sources.

Table 1 Data Used in Model Calibration

Table 1-1 2006 GDP by Sector by Region (Billion $)

	China		EU-27		US		ROW	
	High	Low	High	Low	High	Low	High	Low
GDP by sector	1279.23	1378.64	3852.48	10694.22	3006.63	10157.27	5418.78	12839.45
GDP	2657.87		14546.7		13163.9		18258.23	

Source: World Bank's WDI database, OPEC Annual Statistics Bulletin 2007.

Table 1-2 2006 Bilateral Trade Data (Billion $)

Export by		**Import by**			
		China	**EU-27**	**US**	**ROW**
China	**High**	0	159.05	139.22	396.2
	Low	0	85.42	64.58	124.46
	Total	0	244.47	203.8	520.66
EU-27	**High**	64	0	268.93	790.11
	Low	15.29	0	65.82	255.31
	Total	79.29	0	334.75	1045.42
US	**High**	35.33	159.52	0	572.02
	Low	19.89	59.63	0	190.64
	Total	55.22	219.15	0	762.66

Source: UNCOMTRADE database

Table 1-3 2005 Adjusted Energy (Oil) Balance Data (Billion $)

billion $	**Energy Endowment**	**Net Import**	**Consumption**	**High emission sector input**	**Low Emission sector input**
China	375.79	37.16	412.96	219.00	193.96
Eu27	120.43	363.26	483.69	254.32	229.37
US	320.42	272.78	593.20	347.47	245.73
ROW	673.20	-673.2	0	0	0
World	1489.84	0	1489.85	820.79	669.06

ROW — extraction cost data(Billion $)

billion $	**Extraction**	**Extraction cost**	**Energy Endowment**
ROW	733.16	-59.96	673.20

Source: IEA oil statistics

Table 1-4 Emission Intensity Data

tonne / billion $	High Energy Intensity Sector	Low Energy Intensity Sector
China	0.001127	0.000998
Eu27	0.000144	0.000130
US	0.000253	0.000179

Table 1-5 Consumption of Domestic Goods (2006) (Billion $)

	Consumption of Domestic Goods	
	High oil intensity goods	Low oil intensity goods
China	584.76	1104.18
Eu27	2729.44	10357.80
US	2239.76	9887.11

Table 1-6 Energy Consumption by Region in 2006 (Billion US $)

Year	China	EU-27	US	ROW	World
2006	412.96	483.69	593.20	1446.90	2936.75

Source: International Energy Agency: *Key World Energy Statistics*, 2008.

We calibrate the model to this base case data set in which no border adjustments operate using the standard calibration methods set out in Shoven and Whalley (1984). Given the use of both CES functions and an energy extraction function in ROW, elasticity parameters play an important role in the analysis.

In the central case model analyses elasticity parameters are set as follows. The consumption elasticity that is the top level substitution elasticity between high and low emission goods in consumption in all regions is set equal to 0.5. The lower level trade elasticity, ie the substitution elasticities between domestic and imported commodities follow a "rule of two", that is the substitution elasticity between domestic and imported goods is set equal to 2, as discussed in Hertel al. (2009). This rule was first proposed by Jomini et al.(1991) and later tested by Liu, Arndt,and Hertel(2002) in a back-casting exercise with a simplified version of the GTAP model. The extraction / energy supply elasticity in ROW is 0.5.

For the temperature change function, we follow Cai, Riezman and Whalley(2009) who use projections of temperature change and emissions out to 2056 as Business as Usual scenarios (BAU).

We use a power function

$$\Delta T = g(\sum_i \sum_j E_{ij})^b = 0.001(\sum_i \sum_j E_{ij})^{0.6137} \qquad (17)$$

with g and b determined by calibration to emissions levels in the BAU scenario. We assume a temperature change ΔT of 5℃ between 2006 and 2056 (consistent with Stern(2002)).

Table 2 then reports the calibrated preference parameters in equation (7) under alternative damage assumptions from incremental temperature change out to 2056. As discussed in Cai et al.(2009), the calibrated share parameter β is a reflection of the assumed severity of damage from incremental temperature change. In our central case, we assume a BAU utility loss of 3% of GDP in welfare equivalent terms from a 5℃ temperature change out to 2050. This implies $\beta = 0.1059$. We use the same value of β for all regions.

Table 2-1 reports the parameter values in production, preferences and extraction cost functions generated by calibration. These are independent of the assumed utility damage due to temperature change.

Table 2-1

Model Parameterizations Generated by Calibration to the 2006 Benchmark Data

A. Parameters in C-D production functions

	China		EU-27		US	
	high emission goods	low emission goods	high emission goods	low emission goods	high emission goods	low emission goods
technology coefficient	508.478	657.043	2672.699	9517.442	1529.084	8890.901
shares on energy	0.171	0.141	0.066	0.021	0.116	0.024

B. Parameters in Nested CES Utility functions

Shares of high and low energy (emission) composite goods

China		EU-27		US		ROW	
high emission goods	low emission goods	high emission goods	low emission goods	high emission goods	low emission goods	high emission goods	low emission goods
0.205	0.795	0.054	0.946	0.041	0.959	0.905	0.095

Shares of consumption of high energy (emission) domestic and import goods

	China	EU-27	US	ROW
China-H	0.634	0.163	0.156	0.277
EU-H	0.210	0.674	0.217	0.391
US-H	0.156	0.163	0.627	0.333

Shares of consumption of low energy (emission) domestic and import goods

	China	EU-27	US	ROW
China-L	0.799	0.078	0.070	0.272
EU-L	0.094	0.857	0.070	0.390
US-L	0.107	0.065	0.860	0.337

C. Parameters in Extraction functions

	Constant Parameter	Coefficient parameter
Constant Parameter	-428.813	0.025

Table 2-2 shows the size of EU and US border measures associated with carbon pricing at different assumed levels. These are the border measures we use in our numerical simulation analyses. These follow directly from equations (15), $P_{ijk} = P_j^k + \lambda_{jk} p_c$, and use the data in Table 2-2. From these we calculated the price adjustment at the border as $\lambda_{jk} p_c / P_{ijk}$. As can be seen, the barriers are small. Even when carbon pricing is assumed at $200 /ton, EU's import barriers are still less than 3%. The US price adjustment rate is higher than the EU, but the level is still small.

Table 2-2

Levels of EU and US Carbon Taxing and Border Measures

		Carbon Pricing Assumed			
		$25 /ton	**$50 /ton**	**$100 /ton**	**$200 /ton**
EU	**High emission goods**	0.360%	0.720%	1.440%	2.879%
	Low emission goods	0.325%	0.649%	1.298%	2.597%
US	**High emission goods**	0.634%	1.267%	2.535%	5.070%
	Low emission goods	0.448%	0.896%	1.793%	3.585%

As we note above, these border measures contrast with significantly higher barriers if the carbon content of goods is used, as in Mattoo et al.(2009). These are also sharp differences if the emissions implied by production in exporting countries are used since emissions intensities in our data are sharply huger in China than in the US and the EU.

4. Numerical Analysis of the Effects of Different Carbon Motivated Border Measures

We have used the resulting calibrated model based on the date in section 3 above to simulate the impacts of carbon pricing and border tax adjustments on country welfare and global emissions, cross country trade flows and on production by country. The carbon motivated policies include domestic carbon pricing at various assumed prices without BTAs, similar carbon pricing with BTAs , and carbon pricing with only an import tariff (no export rebates). Results from comparing the base case data to model solutions generated for these border and domestic measures are presented in Tables 3-1 to 3-6.

The impacts generally on all countries from carbon motivated border measures are small. These reflect both the calculation of border measures discussed earlier and based on the emissions generated by comparable domestic production in the importing country, rather than the carbon contained in the imported good, and the role played by the difference in emission intensity across sectors rather than levels. We use carbon emissions by domestic production in the importing country measure as this correspond to proposed border measures in the US case.

The result also confirm that BTAs are not neutral in their impacts due to sector specificity, and hence relative price effects occurs. As for the effects of BTAs on emissions, BTAs alleviate leakage effects as expected[1], which counteract the emissions reduction effects of country carbon pricing. As for trade flows, compared with no BTAs, BTAs reduce the imports of countries implementing measures and increase the imports of other countries. With carbon pricing and BTAs the value of production in countries with carbon taxes increases, and other country production values decrease compared no BTAs.

In Table 3-1, we report the results of both carbon pricing and border tax adjustments (import tariff and export rebate) being used by the EU against the US and China as an example of a BTA policy change in the model. We make different assumptions on the levels of domestic carbon pricing which vary between \$25/ton and \$200/ton , and report results in each case. We first measure welfare impacts using Hicksian compensating variation measures across base case and new equilibria, applied to the country utility functions specified in the model description above. In these utility based welfare measures the welfare impacts of climate change appears directly, unlike other models. Compared with no carbon

[1] Also see the discuss of leakage in Demailly et al(2005), Demaret & Stewardson(1994) ,Fischer & Fox(2009).

pricing, all countries welfare increases despite the use of border measures against the US and China. This reflects the joint utility gain from reduced emissions due to EU carbon pricing. Global emissions fall and as expected EU emissions decrease, and US and China increase emissions. In terms of trade impacts, the EU reduces imports of non energy intensive goods while China and the US increase imports of non energy intensive goods. The value of domestic production in the EU, the US and China increases as prices rise due to carbon pricing and the use of border measures. Results in Table 3-1 show that sector specific BTAs are non neutral in impacts if carbon pricing occurs when energy intensities are different between sectors.

Table 3-1 Impacts of Carbon Pricing and Border Tax Adjustments by EU against US and China

		Carbon Pricing Assumed			
		$25 /ton	**$50 /ton**	**$100 /ton**	**$200 /ton**
1. Welfare Impacts of Hicksian EV as % of GDP	**EU**	0.0072%	0.0142%	0.0280%	0.0541%
	US	0.0017%	0.0033%	0.0066%	0.0132%
	China	0.0018%	0.0036%	0.0073%	0.0145%
2.Impacts on Emissions (% change)	**EU**	−0.063%	−0.125%	−0.251%	−0.502%
	US	0.027%	0.055%	0.109%	0.219%
	China	0.032%	0.064%	0.127%	0.255%
	Total	−0.001%	−0.001%	−0.003%	−0.005%
3.Impacts on Imports of non Energy goods by value at seller's prices (% change)	**EU**	−0.046%	−0.093%	−0.185%	−0.372%
	US	0.043%	0.086%	0.173%	0.345%
	China	0.043%	0.085%	0.168%	0.333%
4. Impacts on domestic production (% change) Energy Intensive	**EU**	0.1945%	0.3890%	0.7776%	1.5537%
	US	0.0022%	0.0044%	0.0085%	0.0163%
	China	0.0033%	0.0066%	0.0132%	0.0267%
Energy Non-Intensive	**EU**	0.3056%	0.6107%	1.2199%	2.4340%
	US	0.0246%	0.0491%	0.0977%	0.1929%
	China	0.0303%	0.0603%	0.1198%	0.2360%

In Tables 3-2 to 3-6, we use our central case model specification, to analyze three broad groupings of country carbon pricing arrangements and accompanying BTAs. These are only the EU has carbon pricing, only the US has carbon pricing and both the EU and US jointly have carbon pricing.

For the first group for which the EU has carbon pricing, we analyze the impacts of three sub forms, the EU has no BTAs, the EU has BTAs against China and US, and the EU have import tariffs against China and the US. In the second group, in which the US has carbon pricing, we again analyze three sub forms, US has no BTAs, US has BTAs against China and the EU, and US have import tariffs against China and the EU. In the third group, both the EU and US have carbon pricing and we analyze seven sub forms in this case. These are both EU and US have no BTAs, both the EU and the US have BTAs against China, both the EU and the US have import tariffs against China (with no export rebates), only EU has BTAs against China, only EU has import tariff against China, only US has BTAs against China, only US has tariff against China. We again make calculations for different carbon pricing assumptions of $25 /ton, $50/ton, $100 /ton, and $200 /ton.

We report Hicksian EVs as a percentage of income. Generally in these results carbon pricing without BTAs increases domestic welfare and also decreases or increases other country's welfare due to terms of trade effects. This is illustrated in case 2.1. Here, carbon pricing in the EU without BTAs increases EU's welfare, reduces China's welfare, and increases US's welfare. These results occur because China faces a higher consumer price for imported goods from the EU and reduce their consumption of EU goods. With carbon pricing assumed at $25 /ton, $50/ton, $100 /ton, $200 /ton, welfare changes are still small; for the EU 0.0035%, 0.0070%, 0.0139% and 0.0274% of income, for the US 0.0003%, 0.0006%, 0.0013% and 0.0026% of income, and China -0.0001%,-0.0001%,-0.0003% and -0.0005% of income.

Import tariffs increase the welfare of the country with carbon taxes, and reduce the welfare of other countries. In case 1.3, compared with case 1.1, EU's import tariffs increase EU welfare, but reduce US and China welfare, due to possible terms of trade effects. This in large part also reflects the small size of barriers, which given elasticities in the model are below optimal tariffs. BTAs increase the welfare of all countries, since export rebates by the carbon pricing country reduce the import prices in other countries, increasing other country consumption. In case 1.3, compared with case 1.1, EU's import tariffs increase the welfare of EU, US and China. Cases 2 and 3 show similar results .

Table 3-2 Impacts of Carbon Motivated Border Measures on Welfare (Hicksian EV as % of GDP)

		Carbon Pricing Assumed			
1. EU Carbon Pricing		**$25 /ton**	**$50 /ton**	**$100 /ton**	**$200 /ton**
1.1 No BTA	**EU**	0.0035%	0.0070%	0.0139%	0.0274%
	US	0.0003%	0.0006%	0.0013%	0.0026%
	China	−0.0001%	−0.0001%	−0.0003%	−0.0005%
1.2 EU BTA against China, US	**EU**	0.0072%	0.0142%	0.0280%	0.0541%
	US	0.0017%	0.0033%	0.0066%	0.0132%
	China	0.0018%	0.0036%	0.0073%	0.0145%
1.3 EU tariff against China, US	**EU**	0.0093%	0.0184%	0.0363%	0.0707%
	US	0.0000%	0.0000%	0.0000%	0.0000%
	China	−0.0014%	−0.0028%	−0.0057%	−0.0112%
2. US Carbon Pricing					
2.1 No BTA	**EU**	0.0022%	0.0044%	0.0089%	0.0179%
	US	0.0057%	0.0114%	0.0225%	0.0437%
	China	−0.0004%	−0.0007%	−0.0014%	−0.0026%
2.2 US BTA against China, EU	**EU**	0.0018%	0.0036%	0.0072%	0.0144%
	US	0.0110%	0.0216%	0.0420%	0.0794%
	China	0.0024%	0.0047%	0.0093%	0.0184%
2.3 US tariff against China, EU	**EU**	−0.0009%	−0.0018%	−0.0035%	−0.0066%
	US	0.0142%	0.0282%	0.0549%	0.1047%
	China	−0.0013%	−0.0025%	−0.0051%	−0.0101%
3 . EU and US Carbon Pricing					
3.1 No BTA	**EU**	0.0057%	0.0114%	0.0228%	0.0453%
	US	0.0061%	0.0120%	0.0238%	0.0465%
	China	−0.0004%	−0.0008%	−0.0015%	−0.0024%
3.2 EU and US BTA against China	**EU**	0.0121%	0.0241%	0.0475%	0.0922%
	US	0.0000%	0.0000%	0.0000%	0.0000%
	China	0.0041%	0.0082%	0.0163%	0.0325%
3.3 EU and US tariff against China	**EU**	0.0121%	0.0240%	0.0473%	0.0919%
	US	0.0102%	0.0201%	0.0394%	0.0754%
	China	−0.0031%	−0.0062%	−0.0123%	−0.0243%

3.4 Only EU BTA against China	**EU**	0.0094%	0.0186%	0.0368%	0.0719%
	US	0.0000%	0.0000%	0.0000%	0.0000%
	China	0.0016%	0.0032%	0.0066%	0.0135%
3.5 Only EU tariff against China	**EU**	0.0095%	0.0190%	0.0375%	0.0736%
	US	0.0066%	0.0131%	0.0259%	0.0504%
	China	−0.0019%	−0.0037%	−0.0073%	−0.0142%
3.6 Only US BTA against China	**EU**	0.0085%	0.0169%	0.0335%	0.0657%
	US	0.0090%	0.0178%	0.0348%	0.0666%
	China	0.0021%	0.0041%	0.0084%	0.0171%
3.7 Only US tariff against China	**EU**	0.0083%	0.0164%	0.0326%	0.0638%
	US	0.0096%	0.0190%	0.0373%	0.0715%
	China	−0.0017%	−0.0033%	−0.0065%	−0.0127%

Table 3-3 reports impacts on country emissions. Again, these are small, but in total the effects reduce global emissions. Carbon pricing without BTAs reduces the emissions of each countries using carbon pricing and increases other country's emissions. They reduce global emissions, but leakage effects arise. In case 1.1, EU carbon taxes without BTAs reduce the emissions of the EU and increase the emissions of China and the US. With carbon pricing assumed at $25 /ton, $50/ton, $100 /ton, or $200 /ton, the changes in EU emissions are -0.209%,-0.417%,-0.836% and -1.676% respectively. The changes in US emissions are 0.094%,0.187%,0.376% and 0.755% respectively, and changes in China's emissions are 0.098%,0.196%,0.394% and 0.791% respectively. Global emissions change by -0.003%,-0.006%,-0.013% and -0.024% respectively, with only small effects. In case 2.1, US carbon taxes reduce the emissions of the US and increase the emissions of China and EU. In case 3.1, both EU and US carbon pricing reduce EU and US emissions and increases China's emissions.

Although BTAs alleviate leakage effects as expected, they also counteract the emissions reduction effects of carbon pricing. In case 1.2, with carbon pricing assumed at $25 /ton, $50/ton, $100 /ton, or $200 /ton, global emissions change by -0.001%,-0.001%,-0.003%, and -0.005% respectively. Compared with case 1.1, BTAs make the global emissions reductions smaller. This is because China and EU emissions increases are smaller and the EU emissions increase rises due to border measures in the form of export rebates and import tariffs. Cases 2.2, 3.2,3.4, 3.6 show similar results.

Table 3-3 also reports the emissions effects of carbon pricing with carbon tariffs alone (no export rebates). Comparing case 1.3 with 1.2, the effects of carbon tariffs are similar to BTAs. They alleviate leakage effects as expected, and also counteract the emissions reduction effects of carbon pricing. The effects of carbon tariff are a little smaller than BTAs. 2.3, 3.3, 3.5, 3.7 show similar results to case 1.3 .

Table 3-3 Impacts of Carbon Motivated Border Measures on Emissions (Energy Use)
(% Change in Emissions)

		Carbon Pricing Assumed			
1. EU Carbon Pricing		**$25 /ton**	**$50 /ton**	**$100 /ton**	**$200 /ton**
1.1 No BTA	**EU**	-0.209%	-0.417%	-0.836%	-1.676%
	US	0.094%	0.187%	0.376%	0.755%
	China	0.098%	0.196%	0.394%	0.791%
	Total	**-0.003%**	**-0.006%**	**-0.013%**	**-0.024%**
1.2 EU BTA against China, US	**EU**	-0.063%	-0.125%	-0.251%	-0.502%
	US	0.027%	0.055%	0.109%	0.219%
	China	0.032%	0.064%	0.127%	0.255%
	Total	**-0.001%**	**-0.001%**	**-0.003%**	**-0.005%**
1.3 EU tariff against China, US	**EU**	-0.103%	-0.207%	-0.414%	-0.831%
	US	0.055%	0.109%	0.219%	0.440%
	China	0.039%	0.077%	0.155%	0.312%
	Total	**-0.001%**	**-0.002%**	**-0.004%**	**-0.008%**
2. US Carbon Pricing					
2.1 No BTA	**EU**	0.196%	0.393%	0.789%	1.590%
	US	-0.306%	-0.613%	-1.229%	-2.469%
	China	0.188%	0.377%	0.756%	1.526%
	Total	**-0.006%**	**-0.012%**	**-0.024%**	**-0.044%**
2.2 US BTA against China, EU	**EU**	0.053%	0.106%	0.212%	0.424%
	US	-0.088%	-0.175%	-0.351%	-0.702%
	China	0.060%	0.119%	0.239%	0.477%
	Total	**-0.001%**	**-0.002%**	**-0.005%**	**-0.009%**
2.3 US tariff against China, EU	**EU**	0.088%	0.177%	0.355%	0.714%
	US	-0.133%	-0.267%	-0.536%	-1.077%
	China	0.081%	0.162%	0.326%	0.654%
	Total	**-0.002%**	**-0.004%**	**-0.008%**	**-0.016%**
3 . EU and US Carbon Pricing					
3.1 No BTA	**EU**	-0.013%	-0.025%	-0.048%	-0.089%
	US	-0.213%	-0.213%	-0.853%	-1.714%
	China	0.286%	0.575%	1.158%	2.348%
	Total	**-0.009%**	**-0.018%**	**-0.035%**	**-0.061%**
3.2 EU and US BTA against China	**EU**	0.066%	0.132%	0.263%	0.528%
	US	-0.129%	-0.259%	-0.518%	-1.041%

	China	0.101%	0.202%	0.405%	0.816%
	Total	**-0.002%**	**-0.004%**	**-0.008%**	**-0.017%**
3.3 EU and US tariff against China	**EU**	0.058%	0.115%	0.231%	0.464%
	US	-0.139%	-0.278%	-0.557%	-1.119%
	China	0.120%	0.241%	0.484%	0.977%
	Total	**-0.003%**	**-0.006%**	**-0.012%**	**-0.024%**
3.4 Only EU BTA against China	**EU**	0.054%	0.109%	0.218%	0.442%
	US	-0.207%	-0.414%	-0.830%	-1.668%
	China	0.210%	0.422%	0.848%	1.713%
	Total	**-0.007%**	**-0.013%**	**-0.025%**	**-0.046%**
3.5 Only EU tariff against China	**EU**	0.046%	0.092%	0.185%	0.376%
	US	-0.207%	-0.414%	-0.830%	-1.667%
	China	0.218%	0.437%	0.880%	1.780%
	Total	**-0.007%**	**-0.014%**	**-0.027%**	**-0.049%**
3.6 Only US BTA against China	**EU**	-0.001%	-0.002%	-0.005%	-0.010%
	US	-0.135%	-0.270%	-0.543%	-1.093%
	China	0.177%	0.355%	0.715%	1.448%
	Total	**-0.005%**	**-0.010%**	**-0.019%**	**-0.037%**
3.7 Only US tariff against China	**EU**	-0.001%	-0.002%	-0.004%	-0.007%
	US	-0.145%	-0.290%	-0.581%	-1.172%
	China	0.189%	0.379%	0.763%	1.546%
	Total	**-0.006%**	**-0.011%**	**-0.021%**	**-0.040%**

Tables 3-4 and 3-5 show the impacts of carbon pricing and border measures on trade flows in the form of imports and exports. Table 3-4 compares the effects of carbon pricing without BTAs, with BTAs, and with only a tariff on imports. Carbon pricing generally increases imports of domestic countries and reduces imports of other countries. In case 1.1, the EU's carbon tax increases EU's import of high and low emission intensive goods, and reduces US and China's imports of high and low emission intensive goods. In case 2.1, US's carbon tax increases US's imports and reduces China's imports. In case 3.1 joint EU and US carbon pricing increases both EU and US's imports and reduces China's imports. With BTAs carbon pricing reduces country's import due to the import tariff, and other country's imports increase due to the export rebate of the carbon pricing country.

For the case of only an import tariff without an export rebate, imports of the country with a carbon tax decrease further and other country's imports increase less compared with full BTAs. In case 3.2, EU and US BTAs against China increase EU imports compared to the case without BTAs. This is because the energy intensity of EU production is lower than the US the EU's carbon motivated import tariff rate and export rebate rate is lower than that of the US.

Table 3-4 Impacts of Carbon Motivated Border Measures on Imports

		% Change of Imports of High Emissions Goods				% Change of Imports of Low Emissions Goods			
		Carbon Pricing Assumed				Carbon Pricing Assumed			
1. EU Carbon Pricing		**$25 /ton**	**$50 /ton**	**$100 /ton**	**$200 /ton**	**$25 /ton**	**$50 /ton**	**$100 /ton**	**$200 /ton**
1.1 No BTA	EU	0.105%	0.211%	0.422%	0.845%	0.163%	0.327%	0.654%	1.308%
	US	−0.015%	−0.030%	−0.061%	−0.121%	−0.025%	−0.050%	−0.099%	−0.197%
	China	−0.022%	−0.044%	−0.088%	−0.175%	−0.032%	−0.065%	−0.130%	−0.261%
1.2 EU BTA against China, US	EU	−0.185%	−0.369%	−0.733%	−1.445%	−0.046%	−0.093%	−0.185%	−0.372%
	US	0.076%	0.151%	0.302%	0.604%	0.043%	0.086%	0.173%	0.345%
	China	0.077%	0.154%	0.308%	0.617%	0.043%	0.085%	0.168%	0.333%
1.3 EU tariff against China, US	EU	−0.293%	−0.584%	−1.160%	−2.290%	−0.104%	−0.208%	−0.415%	−0.828%
	US	−0.047%	−0.094%	−0.187%	−0.372%	−0.085%	−0.170%	−0.338%	−0.667%
	China	−0.089%	−0.177%	−0.353%	−0.703%	−0.107%	−0.215%	−0.429%	−0.853%
2. US Carbon Pricing									
2.1 No BTA	EU	0.005%	0.011%	0.021%	0.042%	0.017%	0.034%	0.070%	0.144%
	US	0.201%	0.403%	0.806%	1.616%	0.277%	0.554%	1.106%	2.207%
	China	−0.040%	−0.079%	−0.158%	−0.317%	−0.095%	−0.190%	−0.380%	−0.757%
2.2 US BTA against China, EU	EU	0.114%	0.228%	0.456%	0.913%	0.035%	0.070%	0.140%	0.280%
	US	−0.320%	−0.636%	−1.256%	−2.449%	0.084%	0.167%	0.325%	0.617%
	China	0.082%	0.164%	0.328%	0.654%	0.043%	0.084%	0.165%	0.321%
2.3 US tariff against China, EU	EU	−0.094%	−0.188%	−0.373%	−0.736%	−0.111%	−0.221%	−0.436%	−0.850%
	US	−0.443%	−0.881%	−1.741%	−3.401%	0.015%	0.028%	0.048%	0.069%
	China	−0.091%	−0.181%	−0.361%	−0.716%	−0.201%	−0.402%	−0.799%	−1.579%
3 . EU and US									

Carbon Pricing									
3.1 No BTA	**EU**	0.111%	0.221%	0.443%	0.889%	0.181%	0.362%	0.725%	1.456%
	US	0.186%	0.373%	0.746%	1.495%	0.252%	0.504%	1.007%	2.009%
	China	−0.061%	−0.123%	−0.245%	−0.490%	−0.127%	−0.256%	−0.511%	−1.015%
3.2 EU and US BTA against China	**EU**	0.143%	0.284%	0.566%	1.124%	0.246%	0.491%	0.980%	1.951%
	US	0.150%	0.301%	0.609%	1.241%	0.223%	0.444%	0.883%	1.746%
	China	0.148%	0.295%	0.593%	1.194%	0.097%	0.192%	0.382%	0.759%
3.3 EU and US tariff against China	**EU**	0.096%	0.191%	0.379%	0.752%	0.205%	0.410%	0.818%	1.626%
	US	0.107%	0.215%	0.437%	0.899%	0.186%	0.372%	0.738%	1.457%
	China	−0.206%	−0.412%	−0.820%	−1.625%	−0.300%	−0.600%	−1.194%	−2.360%
3.4 Only EU BTA against China	**EU**	−0.008%	−0.014%	−0.026%	−0.041%	0.077%	0.155%	0.310%	0.622%
	US	0.264%	0.528%	1.056%	2.111%	0.333%	0.666%	1.330%	2.655%
	China	0.052%	0.104%	0.211%	0.430%	−0.062%	−0.125%	−0.250%	−0.491%
3.5 Only EU tariff against China	**EU**	−0.041%	−0.081%	−0.159%	−0.306%	0.054%	0.108%	0.216%	0.434%
	US	0.254%	0.507%	1.014%	2.027%	0.322%	0.644%	1.288%	2.570%
	China	−0.128%	−0.255%	−0.509%	−1.011%	−0.213%	−0.426%	−0.849%	−1.684%
3.6 Only US BTA against China	**EU**	0.261%	0.521%	1.039%	2.066%	0.349%	0.698%	1.394%	2.784%
	US	0.072%	0.147%	0.301%	0.634%	0.142%	0.282%	0.560%	1.102%
	China	0.035%	0.071%	0.147%	0.317%	0.032%	0.064%	0.130%	0.270%
3.7 Only US tariff against China	**EU**	0.247%	0.494%	0.984%	1.954%	0.332%	0.664%	1.326%	2.644%
	US	0.039%	0.081%	0.169%	0.370%	0.116%	0.231%	0.458%	0.899%
	China	−0.140%	−0.280%	−0.556%	−1.099%	−0.215%	−0.430%	−0.856%	−1.693%

Table 3-5 compares the effects of carbon pricing without BTAs, with BTAs, and with only a tariff on exports. Cases 1.1, 2.1 and 3.1 indicate that carbon pricing reduces the exports of the country or countries using carbon pricing, and increases the exports of other countries. Countries without carbon pricing thus have a competitive advantage. With BTAs, as shown in case 1.2, 2.2 , 3.2,3.4 and 3.6 ,with EU BTAs against China, US BTAs against China ,and both EU and US BTAs against China, China's exports fall in value terms compared with no BTAs. When there is only a carbon tariff and no export rebates in the carbon pricing country, carbon tariffs reduce all counties' exports compared to BTAs.

Table 3-5 Impacts of Carbon Motivated Border Measures on Exports (Value Term)

		% Change of Exports of High Emissions Goods				% Change of Exports of Low Emissions Goods			
		Carbon Pricing Assumed				Carbon Pricing Assumed			
1. EU Carbon Pricing		**$25 /ton**	**$50 /ton**	**$100 /ton**	**$200 /ton**	**$25 /ton**	**$50 /ton**	**$100 /ton**	**$200 /ton**
1.1 No BTA	**EU**	−0.046%	−0.093%	−0.185%	−0.371%	−0.062%	−0.124%	−0.248%	−0.495%
	US	0.015%	0.031%	0.061%	0.123%	0.045%	0.091%	0.181%	0.361%
	China	0.024%	0.047%	0.095%	0.191%	0.064%	0.129%	0.257%	0.514%
1.2 EU BTA against China, US	**EU**	−0.062%	−0.124%	−0.248%	−0.492%	−0.094%	−0.188%	−0.375%	−0.746%
	US	0.031%	0.063%	0.127%	0.256%	0.090%	0.179%	0.356%	0.704%
	China	0.010%	0.020%	0.040%	0.082%	0.054%	0.108%	0.214%	0.423%
1.3 EU tariff against China, US	**EU**	−0.105%	−0.209%	−0.417%	−0.829%	−0.150%	−0.299%	−0.597%	−1.184%
	US	−0.027%	−0.054%	−0.107%	−0.208%	0.058%	0.116%	0.230%	0.453%
	China	−0.013%	−0.026%	−0.051%	−0.099%	0.042%	0.083%	0.165%	0.325%
2. US Carbon Pricing									
2.1 No BTA	**EU**	0.025%	0.050%	0.101%	0.204%	0.038%	0.077%	0.152%	0.300%
	US	−0.099%	−0.198%	−0.396%	−0.791%	−0.113%	−0.225%	−0.449%	−0.891%
	China	0.051%	0.103%	0.206%	0.414%	0.104%	0.209%	0.418%	0.834%
2.2 US BTA against China, EU	**EU**	0.006%	0.013%	0.028%	0.065%	0.146%	0.291%	0.574%	1.119%
	US	−0.165%	−0.329%	−0.652%	−1.285%	−0.197%	−0.392%	−0.778%	−1.533%
	China	0.006%	0.012%	0.025%	0.056%	0.106%	0.212%	0.419%	0.819%
2.3 US tariff against China, EU	**EU**	−0.054%	−0.106%	−0.209%	−0.405%	0.114%	0.226%	0.445%	0.863%
	US	−0.250%	−0.498%	−0.990%	−1.959%	−0.297%	−0.592%	−1.175%	−2.317%
	China	−0.016%	−0.031%	−0.059%	−0.110%	0.096%	0.192%	0.379%	0.740%

3 . EU and US Carbon Pricing										
3.1 No BTA	**EU**	−0. 021%	−0. 042%	−0. 084%	−0. 165%		−0. 024%	−0. 048%	−0. 096%	−0. 193%
	US	−0. 084%	−0. 167%	−0. 334%	−0. 665%		−0. 068%	−0. 135%	−0. 268%	−0. 529%
	China	0. 075%	0. 150%	0. 302%	0. 609%		0. 169%	0. 338%	0. 677%	1. 355%
3.2 EU and US BTA against China	**EU**	0. 064%	0. 127%	0. 254%	0. 506%		0. 066%	0. 131%	0. 257%	0. 499%
	US	−0. 018%	−0. 035%	−0. 070%	−0. 135%		0. 048%	0. 095%	0. 191%	0. 382%
	China	0. 016%	0. 033%	0. 068%	0. 146%		0. 169%	0. 338%	0. 671%	1. 323%
3.3 EU and US tariff against China	**EU**	0. 041%	0. 082%	0. 163%	0. 323%		0. 040%	0. 080%	0. 156%	0. 297%
	US	−0. 047%	−0. 094%	−0. 188%	−0. 372%		0. 002%	0. 004%	0. 009%	0. 020%
	China	−0. 032%	−0. 062%	−0. 122%	−0. 231%		0. 137%	0. 273%	0. 541%	1. 065%
3.4 Only EU BTA against China	**EU**	−0. 014%	−0. 028%	−0. 056%	−0. 109%		−0. 028%	−0. 056%	−0. 113%	−0. 229%
	US	−0. 029%	−0. 058%	−0. 115%	−0. 230%		0. 020%	0. 039%	0. 078%	0. 154%
	China	0. 061%	0. 122%	0. 245%	0. 496%		0. 151%	0. 301%	0. 601%	1. 199%
3.5 Only EU tariff against China	**EU**	−0. 029%	−0. 058%	−0. 115%	−0. 227%		−0. 046%	−0. 092%	−0. 184%	−0. 370%
	US	−0. 037%	−0. 073%	−0. 146%	−0. 293%		0. 009%	0. 017%	0. 034%	0. 068%
	China	0. 037%	0. 074%	0. 149%	0. 305%		0. 137%	0. 274%	0. 547%	1. 090%
3.6 Only US BTA against China	**EU**	0. 057%	0. 113%	0. 225%	0. 446%		0. 070%	0. 139%	0. 274%	0. 531%
	US	−0. 073%	−0. 145%	−0. 289%	−0. 573%		−0. 040%	−0. 079%	−0. 157%	−0. 307%
	China	0. 031%	0. 062%	0. 128%	0. 271%		0. 188%	0. 374%	0. 745%	1. 477%
3.7 Only US tariff against China	**EU**	0. 049%	0. 097%	0. 192%	0. 380%		0. 062%	0. 124%	0. 243%	0. 469%
	US	−0. 095%	−0. 189%	−0. 377%	−0. 749%		−0. 074%	−0. 149%	−0. 296%	−0. 586%
	China	0. 007%	0. 015%	0. 033%	0. 080%		0. 169%	0. 337%	0. 670%	1. 328%

In Table 3-6, we analyze the impacts of carbon pricing and BTAs on production. As shown in cases 1.1, 2.1 and 3.1, carbon pricing without BTAs increases the value of production of all countries as prices rise with the added cost of carbon in the carbon pricing country. But with BTAs, the value of production in the country with carbon pricing increases, and other country's production value decreases compared to the case of no BTAs. A carbon tariff alone has similar effects to those of BTAs, though the effect is relatively smaller.

Table 3-6 Impacts of Carbon Motivated Border Measures on Production (Value Terms)

		% Change of High Emissions Goods Production				% Change of Low Emissions Goods Production			
		Carbon Pricing Assumed				Carbon Pricing Assumed			
1. EU Carbon Pricing		**$25 /ton**	**$50 /ton**	**$100 /ton**	**$200 /ton**	**$25 /ton**	**$50 /ton**	**$100 /ton**	**$200 /ton**
1.1 No BTA	**EU**	0.0294%	0.0588%	0.1176%	0.2349%	0.0804%	0.1607%	0.3211%	0.6413%
	US	0.0134%	0.0267%	0.0535%	0.1072%	0.0110%	0.0222%	0.0443%	0.0886%
	China	0.0168%	0.0336%	0.0672%	0.1349%	0.0170%	0.0340%	0.0680%	0.1360%
1.2 EU BTA against China, US	**EU**	0.1945%	0.3890%	0.7776%	1.5537%	0.3056%	0.6107%	1.2199%	2.4340%
	US	0.0022%	0.0044%	0.0085%	0.0163%	0.0246%	0.0491%	0.0977%	0.1929%
	China	0.0033%	0.0066%	0.0132%	0.0267%	0.0303%	0.0603%	0.1198%	0.2360%
1.3 EU tariff against China, US	**EU**	0.1579%	0.3157%	0.6304%	1.2571%	0.2754%	0.5503%	1.0986%	2.1896%
	US	0.0263%	0.0525%	0.1047%	0.2085%	0.0312%	0.0622%	0.1237%	0.2443%
	China	0.0055%	0.0109%	0.0220%	0.0446%	0.0200%	0.0398%	0.0786%	0.1533%
2. US Carbon Pricing									
2.1 No BTA	**EU**	0.0335%	0.0671%	0.1344%	0.2699%	0.0399%	0.0799%	0.1595%	0.3187%
	US	0.0566%	0.1130%	0.2255%	0.4490%	0.1416%	0.2829%	0.5643%	1.1226%
	China	0.0329%	0.0659%	0.1321%	0.2659%	0.0237%	0.0474%	0.0947%	0.1885%
2.2 US BTA against China, EU	**EU**	0.0043%	0.0085%	0.0171%	0.0341%	0.0448%	0.0891%	0.1765%	0.3464%
	US	0.3520%	0.7036%	1.4064%	2.8094%	0.5024%	1.0036%	2.0028%	3.9877%
	China	0.0061%	0.0122%	0.0245%	0.0499%	0.0581%	0.1154%	0.2278%	0.4440%
2.3 US tariff against China, EU	**EU**	0.0238%	0.0476%	0.0952%	0.1907%	0.0538%	0.1070%	0.2120%	0.4164%
	US	0.3056%	0.6107%	1.2194%	2.4311%	0.4686%	0.9361%	1.8667%	3.7124%
	China	0.0104%	0.0209%	0.0421%	0.0855%	0.0543%	0.1076%	0.2118%	0.4101%

3 . EU and US Carbon Pricing									
3.1 No BTA	**EU**	0. 0630%	0. 1261%	0. 2527%	0. 5073%	0. 1203%	0. 2407%	0. 4816%	0. 9640%
	US	0. 0700%	0. 1399%	0. 2797%	0. 5589%	0. 1527%	0. 3053%	0. 6095%	1. 2147%
	China	0. 0497%	0. 0997%	0. 2002%	0. 4042%	0. 0408%	0. 0817%	0. 1638%	0. 3287%
3.2 EU and US BTA against China	**EU**	0. 2889%	0. 5773%	1. 1531%	2. 3003%	0. 4228%	0. 8449%	1. 6873%	3. 3644%
	US	0. 3124%	0. 6242%	1. 2458%	2. 4815%	0. 4510%	0. 9007%	1. 7963%	3. 5727%
	China	0. 0110%	0. 0220%	0. 0446%	0. 0909%	0. 0892%	0. 1777%	0. 3525%	0. 6935%
3.3 EU and US tariff against China	**EU**	0. 2602%	0. 5200%	1. 0381%	2. 0688%	0. 3902%	0. 7797%	1. 5562%	3. 1005%
	US	0. 2826%	0. 5645%	1. 1260%	2. 2400%	0. 4196%	0. 8379%	1. 6704%	3. 3195%
	China	0. 0163%	0. 0328%	0. 0661%	0. 1345%	0. 0698%	0. 1387%	0. 2739%	0. 5343%
3.4 Only EU BTA against China	**EU**	0. 1782%	0. 3563%	0. 7120%	1. 4217%	0. 2818%	0. 5633%	1. 1250%	2. 2437%
	US	0. 1444%	0. 2886%	0. 5761%	1. 1478%	0. 2390%	0. 4775%	0. 9527%	1. 8964%
	China	0. 0345%	0. 0690%	0. 1386%	0. 2795%	0. 0537%	0. 1073%	0. 2138%	0. 4247%
3.5 Only EU tariff against China	**EU**	0. 1615%	0. 3229%	0. 6450%	1. 2872%	0. 2639%	0. 5272%	1. 0527%	2. 0989%
	US	0. 1327%	0. 2651%	0. 5290%	1. 0532%	0. 2259%	0. 4514%	0. 9004%	1. 7913%
	China	0. 0370%	0. 0742%	0. 1490%	0. 3008%	0. 0410%	0. 0818%	0. 1627%	0. 3222%
3.6 Only US BTA against China	**EU**	0. 1733%	0. 3460%	0. 6893%	1. 3683%	0. 2609%	0. 5207%	1. 0373%	2. 0584%
	US	0. 2377%	0. 4744%	0. 9449%	1. 8749%	0. 3644%	0. 7270%	1. 4472%	2. 8680%
	China	0. 0263%	0. 0528%	0. 1064%	0. 2162%	0. 0763%	0. 1519%	0. 3012%	0. 5923%
3.7 Only US tariff against China	**EU**	0. 1614%	0. 3220%	0. 6410%	1. 2705%	0. 2463%	0. 4915%	0. 9784%	1. 9393%
	US	0. 2196%	0. 4381%	0. 8720%	1. 7274%	0. 3461%	0. 6903%	1. 3737%	2. 7198%
	China	0. 0291%	0. 0583%	0. 1176%	0. 2393%	0. 0696%	0. 1383%	0. 2736%	0. 5355%

4. Conclusions

In this paper, we present models from a numerical multi country general equilibrium model with endogenous determined energy extraction which we use to analyze the potential impacts of carbon motivated border adjustments on welfare, trade, and emissions. We calibrate our model to 2006 benchmark data, and using the calibrated parameters analyze the impacts of EU and US's carbon motivated BTAs on welfare, emissions, trade flows and productions. We compare cases of no carbon pricing, carbon pricing with BTAs, carbon pricing with only a carbon tariff in a model with the US, the EU, China and a residual rest of the world.

The most striking feature of model results is that the impacts, while of the sign predicted, are generally very small. This, in turn, reflects the relatively small barriers involved if carbon emissions in production in the importing country are used. If BTAs are uniform across industries when the carbon content of the goods are same, price level effects result in neutral impact. Smallness of result thus also reflects the impact of differences in carbon emissions intensity across production rather than the level of emissions intensity. Carbon motivated BTAs are not neutral when border tax adjustments are sector specific and our results show this, but as we emphasize produce small welfare impacts. This is in contrast to larger impacts of measures based on carbon content of commodities as discussed in Mattoo et al (2009).

As for the effects of BTAs on emissions, though BTAs alleviate leakage effects as expected, they also counteract the emissions reduction effects of carbon pricing. For trade flows, compared with no BTAs, BTAs reduce imports of the domestic country, and increase the imports of other countries. EU or US BTAs against China reduce exports in value terms by China. With BTAs, the value of production in the implementing country increases with carbon pricing, and the value of production in other countries falls compared to the case with no BTAs.

The negotiation in Copenhagen in December 2009 and to follow is to set a new series of arrangements in place on climate change which will come to play after 2012 in Post-Kyoto world. Developing countries, such as China, Brazil, India who did not participate in the Kyoto negotiation face pressures from the developed world to participate in the new round of negotiation, and the prospect of border tax adjustments if they do not participate is a major consideration for them.

Our results suggest that though the sign of the effects might be as predicted, the size of effects might quite small. This reflects both small barriers when carbon emissions in importing countries are used as the basis of barriers, and also that it is the difference in emissions intensities across production sectors that matters rather than the level of emissions.

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