Proposal for a national inventory adjustment for trade in the presence of border carbon adjustment: Assessing carbon tax policy in Japan

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Abstract

In this paper we pointed out a hidden inequality in accounting for trade-related emissions in the presence of border carbon adjustment. Under a domestic carbon pricing policy, producers pay for the carbon costs in exchange for the right to emit. Under border carbon adjustment, however, the exporting country pays for the carbon costs of their exports to the importing country but not be given any emission credits. As a result, export-related emissions will be remained in the national inventory of the exporting country based on the UNFCCC inventory approach. This hidden inequality is important to climate policy but has not yet been pointed out. To address this issue we propose a method of National Inventory Adjustment for Trade, by which export-related emissions will be deducted from the national inventory of the exporting country and added to the national inventory of the importing country which implements border carbon adjustment. To assess the policy impacts, we simulated a carbon tax policy with border tax adjustment for Japan using a multi-region computable general equilibrium model. The results indicate that with the National Inventory Adjustment for Trade, both Japan's national inventory and the carbon leakage effects of Japan's climate policy will be greatly different.

Keywords: border carbon adjustment; national inventory adjustment for trade; multi-region computable general equilibrium model; carbon tax policy in Japan

1. Introduction

Border carbon adjustment (BCA) measures have been discussed intensively in domestic climate policy debates in the EU, the US, Australia and Japan to address the protection of domestic industrial competitiveness and the prevention of carbon leakage (Houser, et al., 2008; Persson, 2010; Reinaud, 2005; van Asselt and Brewer, 2010). Depending on the nature of domestic carbon pricing policy, BCA measures can take two different forms. One is border tax adjustment (BTA), under which a carbon tariff will be levied on imported products. Another form is to require importers to surrender allowances under a cap-and-trade system.

Under BCA, imported commodities are required to pay for the carbon costs, usually at the same rate as domestically produced commodities. In essence, a BCA measure can be regarded as an extension of domestic climate policy to imports. Domestically, under a carbon tax system, emitters pay the carbon tax for their emissions. Under an emissions trading system, emitters pay to buy the emission permits. In both cases, emitters pay for the carbon costs in exchange for the right to emit (see the two-directional arrows within the boundary of Country A in Fig.1). If the same rationale is applied to BCA, the exporting country should pay for the carbon costs of their exports to the importing country and in return receive the emission credits issued by the importing country, similarly to the mechanism of CDM projects. By receiving the emission credits, the exporting country can deduct export-related emissions from its national inventory. The deducted emissions will then be added to the national inventory of the importing country. However, none of the existing BCA proposals provide such a mechanism.

Current national inventory approach of the Kyoto Protocol requires that countries report "emissions and removals taking place within national (including administered) territories and offshore areas over which the country has jurisdiction" (UNFCCC, 1998). Based on this territorial emissions approach, emissions corresponding to the exports are included in the national inventory of the exporting country. If the BCA-implementing country does not issue emission credits to the target countries, export-related emissions will remain in the national inventory of the exporting country though they paid for the carbon costs (see the one-directional arrow cross border of Country A and B in Fig.1). Since national inventories reported to the UNFCCC are used as reference for ranking national emissions, setting national binding targets and assessing historical and accumulated contributions to global climate change, they can be considered as intangible costs to countries. Following current national inventory approach and the policy arrangement under BCA, the exporting country has to bear two kinds of carbon costs. One is the tangible carbon costs that the producers of the exporting country pay for entering into the market of the BCA-implementing country. The other one is the intangible costs of national inventory which includes the emissions accountable for producing the exports to the BCA-implementing country (see Fig. 1).

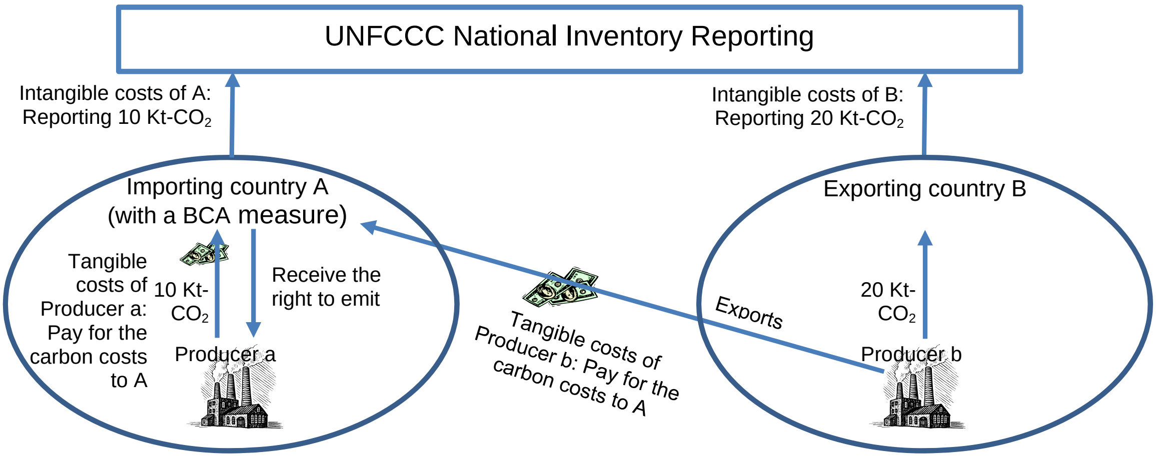

Fig.1 Current national inventory approach in the presence of border carbon adjustment

This is a hidden but real inequality between the exporting country and importing country. BCA on the one hand can level up the playing field for foreign producers to the same level of domestic producers; but on the other hand it will cause a new inequity for the exporting country because the BCA-implementing country charges on the carbon costs of imports but does not issue any emission credits to offset the emissions from the exporting country.

Two ways can help address this issue. First, if the exporting country also implements a comparable domestic climate policy, the exporting country should be exempted from BCA (see Fig.2). Therefore, the producers in both countries will pay for their carbon costs to their respective countries. The playing field for producers in Country A and B therefore can be considered equivalent. When Country B exports to A, B does not need to pay for the carbon costs to A. Given all countries implement a comparable domestic climate policy, there is no need for border adjustment. This argument has been addressed intensively by other literature (Droege, 2012; Muller and Sharma, 2005).

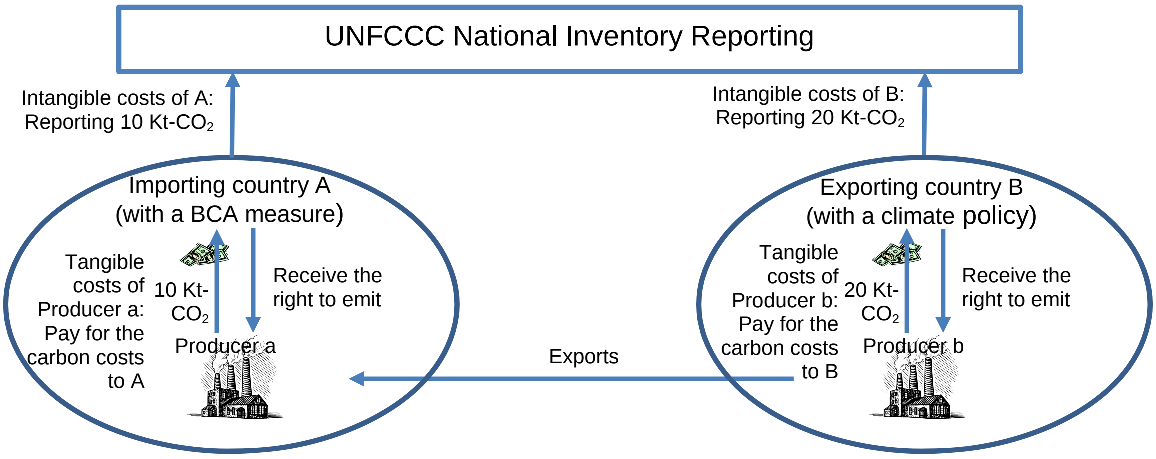

Fig. 2 Exemptions from border carbon adjustment

Second, if the exporting country does not implement a climate policy or a comparable climate policy, producers of Country B (an exporting country) shall pay for the carbon costs of their exports to A but at the same time Country B will receive the emission credits from A (see the two-directional arrows for cross-border transactions in Fig.3). As a result, the national GHG inventories of both countries should be adjusted based on the emissions related to bilateral trade. The emissions related to trade should be added to the national inventory of the importing country and deducted from the inventory of the exporting country, by which the global GHG emissions keep the same (see Fig.3). We call this National Inventory Adjustment for Trade (NIAfT). Following the NIAfT, producers from both countries are placed at the same-level play field on the one hand and on the other hand, both countries have an equitable transaction on trade-related emission credits.

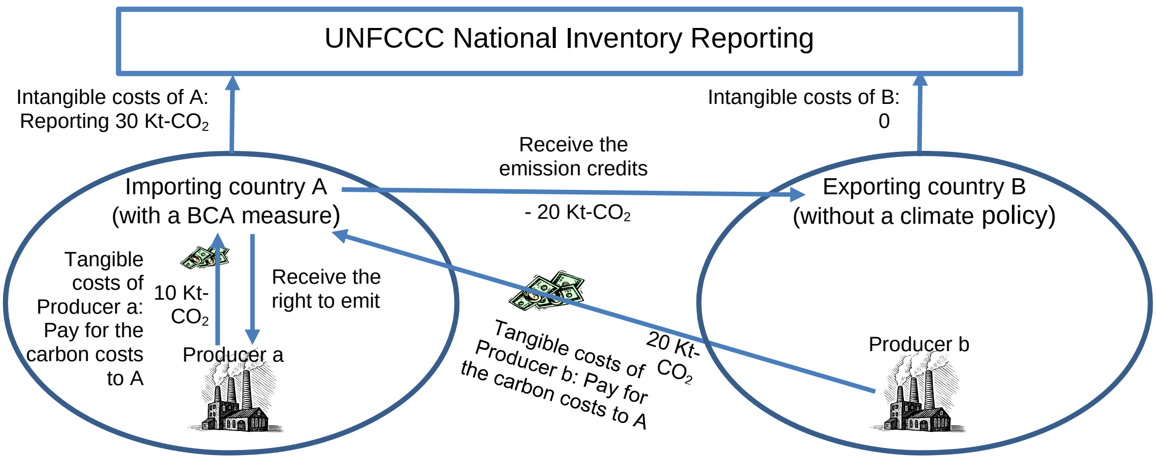

Fig. 3 National inventory adjustment for trade

Different from existing literature (for a review, please see Zhou, et al., 2010), the novelty and policy insights of this paper is to address the hidden inequality issue in accounting for trade-related emissions using current national inventory approach in the presence of border carbon adjustment. To address this issue, we propose to make corresponding adjustments to the national GHG inventories of both importing and exporting countries based on the emissions related to bilateral trade (Fig.3). To examine the differences between current situation and our proposal, we applied a multi-region general computable equilibrium (CGE) model to assess the competitiveness and carbon leakage effects of carbon tax policy and border tax adjustment (BTA).

Our focus country is Japan. To achieve her Kyoto target of 6% reductions in GHG emissions from the 1990 level, Japan promulgated the Law Concerning the Promotion of the Measures to Cope with Global Warming in 1998 (Ministry of the Environment of Japan, 1998). In 2005, the Kyoto Protocol Target Achievement Plan was formulated (Government of Japan, 2005). Recently in October 2012, Japan started a carbon tax on fossil fuels to help achieve its domestic targets of 25% reductions in GHGs from the 1990 level by 2020 and 80% percent reductions by 2050 (Ministry of the Environment of Japan, 2012). There have been great concerns on industrial competitiveness in Japan's domestic policy debates, in particular over energy-intensive and trade-exposed (EITE) industries, and BCA measures have been discussed in this regard (Council on the Global Warming Issue, 2008; Research Group on Environment and Tariff Policies, 2010).

The structure of this paper is as follows. Section 2 introduces the methodology. Section 3 presents the results. Discussions on policy implications and conclusions are provided in Section 4.

2. Methodology

2.1 Model description

In this study, a multi-region CGE model, GTAP6inGAMS (Rutherford, 2005), is applied to assess the economic and environmental impacts of a carbon tax on fossil fuels and BTA in Japan. A Leontief-constant elasticity of substitution (CES) nested function is employed as a production function. Intermediate goods and a composite of value added are defined by Leontief production function. Value added is aggregated by a CES function of production factors including unskilled labor, skilled labor, capital stock, land and natural resources. Allocation between domestic and imported intermediate goods follows the Armington (1969) approach.

A representative household maximizes her utility, expressed in a CES function of energy commodities and non-energy commodities. Energy and non-energy commodities are aggregated by the Cobb-Douglas function. Their allocations follow the Armington approach. Different from the GTAP6inGAMS model, household behavior is formulated by using per capita variables. Government behavior is presented by the Leontief function. Revenues from carbon tax and border carbon tariffs will become governmental revenue and are not transferred to households. Investment is treated as exogenous variable. Thus, the exogenous paths for production factors and population growth determine the dynamics of the model.

2.2 Data and assumptions

For the construction of the multi-region CGE model, GTAP Database Version 7 (base year of 2004) is employed (Badri and Wlmsley, 2008). GTAP Database Version 7 divides the world into 113 regions and each economy has 57 sectors. In this study, we re-categorized regions into 7 and sectors into 39 (see Appendix A and B). Except for Japan, Republic of Korea, China, India and ASEAN are considered as major trading partners of Japan in developing Asia. The US is also included because of its importance as a trading partner of Japan and as a counterpart which can be considered having a comparable domestic climate policy in place. Other countries are grouped into the rest of the world (ROW).

Of 39 sectors, there are 3 energy sectors (petroleum and coal products, electricity, and gas manufacture and distribution) and 36 non-energy sectors, of which 6 are defined as EITE sectors. Based on other studies (Houser, et al., 2008; Monjon and Quirion, 2010;

Reinaud, 2005; Takeda, et al., 2012), we define paper products and printing, chemical, rubber and plastic products, non-metallic minerals, iron and steel, non-ferrous metals and fabricated metal products as EITE sectors in Japan. Region and sector definitions are shown in Appendix A and Appendix B. For emissions data, we use the GTAP-E database which is included in the package of GTAP Database Version 7.

Key parameters of the multi-region CGE model such as elasticity of substitution are taken from GTAP Database Version 7. Following Rutherford and Paltsev (2000), the elasticity of substitution between energy goods and non-energy goods in household consumption is set as 0.5.

Similar to Lau, et al. (2000), a reference path is designed for future simulation. Using the World Bank's Global Economic Prospects (World Bank, 2012) as the reference, the growth rates of endogenous quantity and price variables are assumed as 3 percent. The future paths for other exogenous variables such as supply of production factors and population growth follow the forecast developed by the GTAP.

2.3 Simulation scenarios

The ultimate rate of Japan's carbon tax will be JPY289/t-CO_2 (USD2.67/t-CO_2, at the exchange rate of JPY108.2/USD in 2004), which will be reached by three steps: JPY95 from October 2012 to March 2014; JPY190 from April 2014 to March 2016; and JPY289 from April 2016 onwards. In this study, the carbon tax rate is added to the output prices and import prices of fossil fuels, which include coal (sector coal), gas (sector gas), and oil (sector oil and sector petroleum and coal products). Carbon tax is set to be introduced from 2012 onwards at fixed rate of JPY289/t-CO_2 for simplicity. The additional carbon costs on fossil fuels will influence the prices of downstream sectors in several ways: i) direct impacts through the consumption of fossil fuels; ii) indirect impacts through electricity consumption; and iii) indirect impacts through purchasing energy-intensive commodities as inputs to production. As a result, both EITE sectors and their downstream sectors will be impacted potentially either directly or indirectly. Non-fossil fuel sectors will assume the carbon costs of all emissions that are embodied in the upstream productions located in Japan.

For policy options, we set a business-as-usual (BAU) case under which Japan does not charge a carbon tax. Under the Japanese carbon tax (CTax_J) case, Japan unilaterally levies a carbon tax on fossil fuels. Under the Japanese border tax adjustment (BTA_J) case, Japan adopts a carbon tax system with a BTA measure under which imports of EITE sectors from other regions are subject to a carbon tariff at the same rate as Japan's domestic carbon tax, i.e. JPY289/t-CO_2. The carbon content of imports is determined by direct emissions from the production of imported products, calculated as total sectoral emissions divided by total sectoral outputs. Indirect carbon costs of imported products, which are embodied either in electricity consumption or in the use of energy-intensive commodities as inputs to the production, are not taken into account. To test the impacts of expanding participating parties, we assumed a scenario that the US introduces a same carbon tax policy (CTax_JU) and a scenario that both Japan and the US implement same carbon tax policies with BTA measures (BTA_JU). The reference year is 2004 with projections up to 2020.

To support our proposal on national inventory adjustment for trade, we designed a scenario in which the national inventories of both Japan as an importing country and other regions as exporting countries will be adjusted (NIAfT_J). Direct emissions in other regions from the production of the exported products to Japan will be added to Japan's national GHG inventory (see Eq.1) and deducted from the account of other regions (see Eq.2). When both Japan and the US implement the same border carbon adjustment measures, we designed a scenario under which the US is exempted from the BTA implemented in Japan and the vice versa, Japan is exempted from the BTA implemented in the US (NIAfT_JU). However, the national GHG inventories of Japan and the US as importing countries and other regions as exporting countries will be adjusted (see Eqs.3-5). In total, there are seven scenarios (see Table 1).

$$e^{J}_{NIAfT\_J} = e^{J}_{BTA\_J} + \sum_{R(-J)} \sum_{EITE} e(EITE)^{R(-J)J}_{BTA\_J} \tag{1}$$

$$e^{R(-J)}_{NIAfT\_J} = e^{R(-J)}_{BTA\_J} - \sum_{EITE} e(EITE)^{R(-J)J}_{BTA\_J} \tag{2}$$

where $e^{J}_{BTA\_J}$, $e^{R(-J)}_{BTA\_J}$, $e^{J}_{NIAfT\_J}$ and $e^{R(-J)}_{NIAfT\_J}$ represent the national inventories of Japan and other regions under the cases of BTA_J and NIAfT_J, respectively. $e(EITE)^{R(-J)J}_{BTA\_J}$ represents the emissions from the production of the exports of EITE sectors to Japan from other regions *R*(-*J*).

$$e^{J}_{NIAfT\_JU} = e^{J}_{BTA\_JU} + \sum_{R(-J-U)} \sum_{EITE} e(EITE)^{R(-J-U)J}_{BTA\_JU} \tag{3}$$

$$e^{U}_{NIAfT\_JU} = e^{U}_{BTA\_JU} + \sum_{R(-J-U)} \sum_{EITE} e(EITE)^{R(-J-U)U}_{BTA\_JU} \tag{4}$$

$$e^{R(-J-U)}_{NIAfT\_JU} = e^{R(-J-U)}_{BTA\_JU} - \sum_{EITE} e(EITE)^{R(-J-U)J}_{BTA\_JU} - \sum_{EITE} e(EITE)^{R(-J-U)U}_{BTA\_JU} \tag{5}$$

where $e^{J}_{BTA\_JU}$, $e^{U}_{BTA\_JU}$, $e^{R(-J-U)}_{BTA\_JU}$, $e^{J}_{NIAfT\_JU}$, $e^{U}_{NIAfT\_JU}$ and $e^{R(-J-U)}_{NIAfT\_JU}$ represent the national inventories of Japan, the US and other regions under the cases of BTA_JU and NIAfT_JU, respectively. $e(EITE)^{R(-J-U)J}_{BTA\_JU}$ and $e(EITE)^{R(-J-U)U}_{BTA\_JU}$ represent the emissions from the production of the exports of EITE sectors from other regions *R*(-*J*-*U*) to Japan and to the US, respectively.

Table 1

Simulation scenarios

	BAU	Japan Only		Japan & USA	
		CTax	BTA	CTax	BTA
No adjustment of national inventories	BAU	CTax_J	BTA_J	CTax_JU	BTA_JU
Adjustment of national inventories			NIAfT_J		NIAfT_JU

Note: BAU is the case of business as usual under which Japan and the US do not introduce carbon tax policies.

CTax is the carbon tax policy and BTA is border tax adjustment implemented with the carbon tax policy.

NIAfT is national inventory adjustment for trade.

3. Results

3.1 Description of EITE sectors

As mentioned before, the EITE sectors defined in our study include paper products and printing (ppp), chemical, rubber and plastic products (p_c), non-metallic minerals (nmm), iron and steel (i_s), non-ferrous metals (nfm) and fabricated metal products (fmp). These sectors are selected because their production is either carbon-intensive or electricity-intensive, such as aluminum production in the non-ferrous metals sector, which causes indirect carbon emissions in the upstream electricity generation. The description of EITE sectors in Japan and the US in 2004 are presented in Table 2.

Table 2

Descriptions of EITE sectors in Japan

EITE code	International trade		Carbon intensity (kg CO_2/USD)	Carbon costs		International transportation costs vs. total value of imports		Equivalent direct carbon costs vs. international transportation costs	
	Exports (million USD)	Imports (million USD)		Direct carbon costs (million USD)	Share in total outputs	International transportation costs (million USD)	Share in total value of imports (%)	Equivalent direct carbon costs (million USD)	Ratio to international transportation costs
ppp	3831.6 (18)	5373.5 (26)	0.076 (14)	3980.5	2.2%	489.40	6.3%	169.90	0.35
crp	69499.7 (4)	42234.9 (5)	0.171 (10)	19198.1	4.9%	2184.80	5.6%	1924.79	0.88
nmm	6255.7 (14)	4065.6 (29)	0.298 (6)	6523.8	8.6%	494.00	16.5%	257.47	0.52
i_s	20203.4 (5)	5204.9 (28)	0.253 (7)	12675.0	7.3%	331.00	4.2%	568.85	1.72
nfm	8611.7 (10)	15109.3 (12)	0.048 (15)	802.6	1.4%	342.60	2.8%	168.81	0.49
fmp	9630.9 (9)	6294.3 (24)	0.013 (25)	453.6	0.4%	475.80	10.7%	16.20	0.03

Note: 1. USD is the value in 2004. 2. Numbers in brackets are the rank among 39 sectors in each country. 3. Carbon costs are calculated based on Japan's carbon tax on fossil fuels, which is JPY289 /t-CO_2 (USD 2.67/t-CO_2). 4. Sector code: ppp (paper products and printing), p_c (chemical, rubber and plastic products), nmm (non-metallic minerals), i_s (iron and steel), nfm (non-ferrous metals) and fmp (fabricated metal products).

In Japan, chemical, rubber and plastic products, iron and steel, fabricated metal products, and non-ferrous metals are important exporting sectors, while chemical, rubber and plastic products, and non-ferrous metals are major export sectors but also dependent on imports. From environmental perspective, non-metallic minerals, iron and steel, and chemical, rubber and plastic products are major sources of direct emissions from production process, while iron and steel, non-ferrous metals, non-metallic minerals, chemical, rubber and plastic products, and fabricated metal products are more attributable to indirect upstream emissions. For the impacts of direct carbon costs in total outputs, non-metallic minerals will be influenced the most (8.6%), followed by iron and steel (7.3%). Fabricated metal products (0.4%) and non-ferrous metals (1.4%) will be influenced mildly. According to Reinaud (2005), international transportation costs can function as a trade barrier to protect domestic products. To check this mechanism, we examine the share of international transportation costs in the total value of imports (the higher the more protective from import competition) and the ratio of equivalent direct carbon costs of imports to the international transportation costs (the higher the more vulnerable to competitiveness loss). We found that non-metallic minerals and fabricated metal products, with the share of the international transportation costs as of 16.5% and 10.7%, respectively, are more protective from import competition, while iron and steel, with high ratio of the equivalent direct carbon costs of imports to international transportation costs (1.72), is more vulnerable to competitiveness loss.

3.2 Impacts on international competitiveness

International competitiveness of EITE sectors is measured by output change and change in global market share. Tables 3 presents the output change of EITE sectors in Japan under

CTax_J and BTA_J and Table 5 shows the output change of EITE sectors in Japan under CTax_JU and BTA_JU. Output change is evaluated in terms of both value change and percentage change. We compare the differences between i) CTax and BAU and ii) BTA and CTax.

Table 3

Output changes of EITE sectors under CTax_J and BTA_J

	ppp				crp			
	Change in value[1] (billion USD)		Change in percentage[2] (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_J	BTA_J	CTax_J	BTA_J	CTax_J	BTA_J	CTax_J	BTA_J
2012	-0.0002	0.0028	-0.0001	0.0014	-0.0023	0.0172	-0.0005	0.0039
2015	-0.0006	0.0052	-0.0003	0.0026	-0.0090	0.0344	-0.0019	0.0074
2020	-0.0023	0.0067	-0.0011	0.0032	-0.0304	0.0515	-0.0060	0.0102
	nmm				i_s			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_J	BTA_J	CTax_J	BTA_J	CTax_J	BTA_J	CTax_J	BTA_J
2012	-0.0003	0.0135	-0.0003	0.0164	-0.0015	0.0042	-0.0008	0.0022
2015	-0.0012	0.0170	-0.0013	0.0191	-0.0060	0.0075	-0.0029	0.0036
2020	-0.0048	0.0135	-0.0046	0.0129	-0.0220	0.0096	-0.0089	0.0039
	nfm				fmp			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_J	BTA_J	CTax_J	BTA_J	CTax_J	BTA_J	CTax_J	BTA_J
2012	-0.0007	0.0020	-0.0010	0.0029	-0.0005	-0.0018	-0.0004	-0.0014
2015	-0.0031	0.0019	-0.0039	0.0024	-0.0022	-0.0033	-0.0016	-0.0024
2020	-0.0141	-0.0021	-0.0124	-0.0019	-0.0082	-0.0053	-0.0056	-0.0036

Note: 1. For the output changes in value, CTax_J is calculated as Output (CTax_J) - Output (BAU); BTA_J is calculated as Output (BTA_J) - Output (CTax_J).

2. For the output changes in percentage, CTax_J is calculated as [Output (CTax_J) - Output (BAU)] / Output (BAU); BTA_J is calculated as [Output (BTA_J) - Output (CTax_J)] / Output (CTax_J).

Table 3 indicates that under CTax_J, the outputs of EITE sectors will be impacted negatively, however, the impacts are trivial, ranging from -0.03% (chemical, rubber and plastic products in 2020) to -0.0001% (paper products and printing sector in 2012). The sector of chemical, rubber and plastic products will be influenced the most and paper products and printing sector will be influenced the least in six EITE sectors. Except for fabricated metal products, the BTA measure in most cases is effective to help reduce competitiveness loss and in many cases, it can even help EITE sectors gain more competitiveness compared with BAU case. For fabricated metal products, the BTA measure will worsen the competitiveness of the sector in terms of outputs.

Table 4

Economy-wide output changes in all regions under CTax_J and BTA_J

	Japan				Korea			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_J	BTA_J	CTax_J	BTA_J	CTax_J	BTA_J	CTax_J	BTA_J
2012	-0.0112	-0.0217	-0.0001	-0.0002	0.0000	0.0007	0.0000	0.0000
2015	-0.0436	-0.0399	-0.0004	-0.0004	0.0001	0.0016	0.0000	0.0001
2020	-0.1532	-0.0606	-0.0015	-0.0006	0.0005	0.0034	0.0000	0.0001
	China				India			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_J	BTA_J	CTax_J	BTA_J	CTax_J	BTA_J	CTax_J	BTA_J
2012	0.0007	0.0173	0.0000	0.0003	0.0002	0.0007	0.0000	0.0000
2015	0.0030	0.0333	0.0000	0.0005	0.0006	0.0019	0.0000	0.0001
2020	0.0135	0.0347	0.0002	0.0004	0.0017	0.0019	0.0001	0.0001
	ASEAN				USA			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_J	BTA_J	CTax_J	BTA_J	CTax_J	BTA_J	CTax_J	BTA_J
2012	0.0003	0.0024	0.0000	0.0001	0.0010	0.0044	0.0000	0.0000
2015	0.0011	0.0039	0.0000	0.0002	0.0039	0.0094	0.0000	0.0000
2020	0.0044	0.0037	0.0002	0.0001	0.0137	0.0130	0.0000	0.0000
	ROW				World			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_J	BTA_J	CTax_J	BTA_J	CTax_J	BTA_J	CTax_J	BTA_J
2012	0.0073	0.0118	0.0000	0.0000	-0.0017	0.0155	0.0000	0.0000
2015	0.0269	0.0227	0.0001	0.0001	-0.0080	0.0329	0.0000	0.0000
2020	0.0902	0.0350	0.0002	0.0001	-0.0291	0.0311	0.0000	0.0000

When comparing the economy-wide impacts (Table 4), we can see that under both cases of CTax_J and BTA_J, Japan's total national outputs will be influenced adversely. Though the BTA measure can help Japan's EITE sectors to gain more international competitiveness, sectors other than EITE sectors will be influenced negatively. As a result, the total impacts of BTA_J case on Japan's economy-wide competitiveness will be worsened compared to the CTax_J case. In contrast, the national outputs in all other regions will be increased, in particular under the case of BTA_J. In particular, except for the ROW, which is a composite of many regions, the US will benefit the most in her national total outputs under CTax_J and China will benefit the most under BTA_J. From global perspective, the global outputs will be impacted negatively under CTax_J, however, under BTA_J, total global outputs will increase.

When the US joins Japan to implement a same carbon tax policy (see Tables 5), the negative impacts on the international competitiveness of EITE sectors in Japan can be even greater than in the case when Japan unilaterally implements a carbon tax policy. The mechanism of such effects cannot be unveiled without further analysis such as decomposition analysis, which is not included in current study. Under BTA_JU, most of Japan's EITE sectors (except for fabricated metal products) can gain back some competitiveness compared to the CTax_JU case, however, the positive impacts on Japan's EITE sectors are much less than the case when Japan alone implements a carbon tax policy with a BTA measure (Table 3).

Table 5

Output changes of EITE sectors under CTax_JU and BTA_JU

	ppp				crp			
	Change in value[1] (billion USD)		Change in percentage[2] (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_JU	BTA_JU	CTax_JU	BTA_JU	CTax_JU	BTA_JU	CTax_JU	BTA_JU
2012	0.0001	0.0023	0.0000	0.0012	-0.0516	0.0277	-0.0118	0.0063
2015	-0.0023	0.0043	-0.0011	0.0021	-0.2221	0.0568	-0.0478	0.0122
2020	-0.0465	0.0054	-0.0222	0.0026	-1.1435	0.0896	-0.2258	0.0177

	nmm				i_s			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_JU	BTA_JU	CTax_JU	BTA_JU	CTax_JU	BTA_JU	CTax_JU	BTA_JU
2012	-0.0160	0.0148	-0.0194	0.0180	-0.0526	0.0047	-0.0272	0.0025
2015	-0.0638	0.0191	-0.0718	0.0215	-0.1937	0.0092	-0.0919	0.0044
2020	-0.2388	0.0172	-0.2282	0.0164	-0.5102	0.0150	-0.2060	0.0061

	nfm				fmp			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_JU	BTA_JU	CTax_JU	BTA_JU	CTax_JU	BTA_JU	CTax_JU	BTA_JU
2012	-0.0419	0.0011	-0.0616	0.0016	-0.0125	-0.0018	-0.0095	-0.0014
2015	-0.1953	0.0003	-0.2427	0.0004	-0.0465	-0.0033	-0.0342	-0.0024
2020	-0.9374	-0.0016	-0.8280	-0.0014	-0.1435	-0.0049	-0.0982	-0.0033

Note: 1. For the output changes in value, CTax_JU is calculated as Output (CTax_JU) - Output (BAU); BTA_JU is calculated as Output (BTA_JU) - Output (CTax_JU).

2. For the output changes in percentage, CTax_JU is calculated as [Output (CTax_JU) - Output (BAU)] / Output (BAU); BTA_JU is calculated as [Output (BTA_JU) - Output (CTax_JU)] / Output (CTax_JU).

Table 6 shows the economy-wide impacts under CTax_JU and BTA_JU. On the one hand, similar to the case when only Japan implements climate policies, both cases of CTax_JU and BTA_JU can damage the economy-wide competitiveness in both Japan and the US. The negative impacts on US economy are much greater than on Japanese economy. Comparing Table 6 and Table 4 for Japan, CTax_JU case exerts more negative impacts on Japan’s total national outputs than in the case of CTax_J. On the other hand, other countries, except for Korea, will benefit in generating more national outputs under both cases, in particular under the case of CTax_JU. India will gain economy-wide competitiveness the most under CTax_JU case. In contrast to the two cases when only Japan implements climate policies (Table 4), Korea will lose economy-wide competitiveness under both cases of CTax_JU and BTA_JU. From global perspective, both the cases of CTax_JU and BTA_JU can increase global outputs, in particular the case of CTax_JU.

Table 6

Economy-wide output changes in all regions under CTax_JU and BTA_JU

	Japan				Korea			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_JU	BTA_JU	CTax_JU	BTA_JU	CTax_JU	BTA_JU	CTax_JU	BTA_JU
2012	-0.1810	-0.0216	-0.0019	-0.0002	-0.0504	-0.0068	-0.0025	-0.0003
2015	-0.7282	-0.0401	-0.0074	-0.0004	-0.2480	-0.0140	-0.0107	-0.0006
2020	-2.7148	-0.0605	-0.0266	-0.0006	-1.4486	-0.0168	-0.0514	-0.0006
	China				India			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_JU	BTA_JU	CTax_JU	BTA_JU	CTax_JU	BTA_JU	CTax_JU	BTA_JU
2012	0.3838	0.0514	0.0058	0.0008	5.2044	0.0182	0.0119	0.0000
2015	1.7864	0.1028	0.0245	0.0014	21.9914	0.0363	0.0487	0.0001
2020	13.0584	0.1299	0.1636	0.0016	79.9454	0.0588	0.1685	0.0001
	ASEAN				USA			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_JU	BTA_JU	CTax_JU	BTA_JU	CTax_JU	BTA_JU	CTax_JU	BTA_JU
2012	0.1139	0.0066	0.0050	0.0003	-5.2539	-0.0300	-0.0215	-0.0001
2015	0.4845	0.0115	0.0197	0.0005	-22.3378	-0.0501	-0.0863	-0.0002
2020	2.1506	0.0128	0.0762	0.0005	-78.6192	-0.0917	-0.2766	-0.0003
	ROW				World			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_JU	BTA_JU	CTax_JU	BTA_JU	CTax_JU	BTA_JU	CTax_JU	BTA_JU
2012	5.2044	0.0182	0.0119	0.0000	5.4212	0.0361	0.0041	0.0000
2015	5.2044	0.0182	0.0119	0.0000	6.1527	0.0645	0.0045	0.0000
2020	79.9454	0.0588	0.1685	0.0001	92.3172	0.0913	0.0627	0.0001

3.3 Carbon leakage effect

To test carbon leakage effects of different climate policies, we compared the changes in the national emissions of seven regions under the case when only Japan implements climate policies and the case when both Japan and the US implement same climate policies (Tables 7 and 8).

For the cases of BAU, CTax and BTA, national inventories are calculated based on the approach provided by the Kyoto Protocol. For the case of NIAfT_J, the national inventories of both Japan as an importing country and other six regions as exporting countries will be adjusted based on our proposed method (Eq. 1 and Eq. 2). Under the case of NIAfT_JU, the national inventories of Japan and the US as importing countries and other five regions as exporting countries will be adjusted based on Eqs. 3-5.

Table 7

National emissions changes under CTax_J, BTA_J and NIAfT_J

	Japan						Korea					
	Change in amount[1] (Mt CO_2)			Change in percentage[2] (%)			Change in amount (Mt CO_2)			Change in percentage (%)		
	CTax_J	BTA_J	NIAfT_J	CTax_J	BTA_J	NIAfT _J	CTax_J	BTA_J	NIAfT _J	CTax_J	BTA_J	NIAfT _J
2012	-0.0015	0.0107	26.4694	-0.0001	0.0010	2.5672	0.0000	0.0014	-0.7782	0.0000	0.0003	-0.1743
2015	-0.0056	0.0169	22.8445	-0.0005	0.0016	2.1214	0.0002	0.0023	-0.8133	0.0000	0.0005	-0.1688
2020	-0.0188	0.0186	20.0067	-0.0016	0.0016	1.7488	0.0008	0.0018	-0.8535	0.0001	0.0003	-0.1593
	China						India					
	Change in amount (Mt CO_2)			Change in percentage (%)			Change in amount (Mt CO_2)			Change in percentage (%)		
	Ctax_J	BTA_J	NIAfT _J	Ctax_J	BTA_J	NIAfT _J	Ctax_J	BTA_J	NIAfT _J	Ctax_J	BTA_J	NIAfT _J
2012	0.0013	-0.0451	-8.7628	0.0000	-0.0008	-0.1609	0.0003	0.0017	-0.3744	0.0000	0.0001	-0.0312
2015	0.0038	-0.0308	-4.8803	0.0001	-0.0006	-0.0882	0.0008	0.0035	-0.3009	0.0001	0.0003	-0.0246
2020	0.0116	-0.0090	-1.7713	0.0002	-0.0002	-0.0332	0.0015	0.0008	-0.1603	0.0001	0.0001	-0.0136
	ASEAN						USA					
	Change in amount (Mt CO_2)			Change in percentage (%)			Change in amount (Mt CO_2)			Change in percentage (%)		
	CTax_J	BTA_J	NIAfT _J	CTax_J	BTA_J	NIAfT _J	CTax_J	BTA_J	NIAfT _J	CTax_J	BTA_J	NIAfT _J
2012	0.0001	-0.0141	-4.4231	0.0000	-0.0014	-0.4297	0.0003	0.0071	-3.6203	0.0000	0.0001	-0.0625
2015	0.0003	-0.0199	-4.2516	0.0000	-0.0018	-0.3851	0.0007	0.0103	-3.8777	0.0000	0.0002	-0.0649
2020	0.0013	-0.0202	-4.4352	0.0001	-0.0017	-0.3632	0.0018	0.0013	-3.9340	0.0000	0.0000	-0.0633
	ROW						Total of Regions Other than Japan					
	Change in amount (Mt CO_2)			Change in percentage (%)			Change in amount (Mt CO_2)			Change in percentage (%)		

	CTax_J	BTA_J	NIAfT _J	CTax_J	BTA_J	NIAfT _J	CTax_J	BTA_J	NIAfT _J	CTax_J	BTA_J	NIAfT _J
2012	0.0007	-0.0017	-8.5507	0.0000	0.0000	-0.0771	0.0026	-0.0507	-26.5095	0.0000	-0.0002	-0.1060
2015	0.0032	-0.0023	-8.7407	0.0000	0.0000	-0.0762	0.0089	-0.0368	-22.8644	0.0000	-0.0001	-0.0887
2020	0.0125	-0.0085	-8.8676	0.0001	-0.0001	-0.0746	0.0294	-0.0338	-20.0219	0.0001	-0.0001	-0.0759

Note: 1. For the changes in amount, CTax_J is calculated as National Emissions (CTax_J) - National Emissions (BAU); BTA_J is calculated as National Emissions (BTA) - National Emissions (CTax_J); NIAfT_J is calculated as National Emissions (NIAfT_J) - National Emissions (CTax_J).

2. For the changes in percentage, CTax_J is calculated as [National Emissions (CTax_J) - National Emissions (BAU)] / National Emissions (BAU); BTA_J is calculated as [National Emissions (BTA_J) - National Emissions (CTax_J)] / National Emissions (CTax); NIAfT_J is calculated as [National Emissions (NIAfT_J) - National Emissions (CTax_J)] / National Emissions (CTax_J).

Comparing the cases of CTax_J and BAU_J (Table 7) we can find that the case of CTax_J can reduce domestic emissions in Japan, however, at the same time triggers the mechanisms of carbon leakage in other regions. Domestic reduction effects are very small, less than 0.002% decrease compared with BAU case. Though the carbon leakage rate is as high as 1.8 (calculated as the amount of total increase of emissions in other regions divided by the amount of emissions reductions in Japan), the scale of carbon leakage is very small, less than 0.0001% increase of the total emissions in other regions compared with BAU case. Carbon will leak mainly to China and the rest of the world (ROW), however, the levels are very low, around 0.0002% increase in China's total emissions compared with BAU case. This indicates that the carbon tax policy implemented in Japan has little effects on either domestic reductions or carbon leakage.

BTA_J case can generate negative carbon leakage at the global level. In most cases in China, ASEAN and the ROW, negative leakage will occur. However, similar to the negative effects of the carbon tax policy on carbon leakage, the positive effects of the BTA measure on preventing global carbon leakage are also very small. Unexpectedly, a carbon tax policy with a BTA measure cannot achieve any reductions in Japan but oppositely increase domestic emissions compared with BAU case. In addition, emissions from Korea, India and the US will also increase though very lightly.

Based on our proposal of NIAfT_J, in most cases, the carbon intensities of EITE sectors in other countries, in particular in China, India and ASEAN, are much higher than in Japan, usually from several times to dozens of times (Table 9). When the emissions related to the imports of EITE sectors from other regions to Japan are added to Japan's national inventory, Japan's total national emissions will increase dramatically, around 2% increase. Compared with Japan's Kyoto target, which is 6% reductions from the 1990 level, the effects of the NIAfT is significant. In contrast to Japan, the national emissions in all other regions will decrease, in particular in China and the ROW, indicating negative carbon leakage.

Table 8

National emissions changes under CTax_JU, BTA_JU and NIAfT_JU

	Japan						Korea					
	Change in amount[1] (Mt CO_2)			Change in percentage[2] (%)			Change in amount (Mt CO_2)			Change in percentage (%)		
	CTax_JU	BTA_JU	NIAfT _JU	CTax _JU	BTA_JU	NIAfT _JU	CTax _JU	BTA_JU	NIAfT _JU	CTax _JU	BTA_JU	NIAfT _JU
2012	-0.0721	0.0126	20.7368	-0.0070	0.0012	2.0114	0.0257	0.0020	-4.2965	0.0058	0.0005	-0.9620
2015	-0.2490	0.0222	17.2307	-0.0231	0.0021	1.6005	0.0869	0.0042	-4.6687	0.0180	0.0009	-0.9688
2020	-0.7435	0.0307	15.1203	-0.0650	0.0027	1.3225	0.3231	0.0040	-5.2497	0.0603	0.0007	-0.9786
	China						India					
	Change in amount (Mt CO_2)			Change in percentage (%)			Change in amount (Mt CO_2)			Change in percentage (%)		
	CTax _JU	BTA_JU	NIAfT _JU	CTax _JU	BTA_JU	NIAfT _JU	CTax _JU	BTA_JU	NIAfT _JU	CTax _JU	BTA_JU	NIAfT _JU
2012	0.9547	-0.1384	-9.2280	0.0175	-0.0025	-0.1695	0.2562	-0.0241	-19.4066	0.0214	-0.0020	-1.6177
2015	2.6289	-0.0969	-5.9140	0.0475	-0.0018	-0.1068	0.8422	-0.0345	-11.6055	0.0689	-0.0028	-0.9489
2020	8.2007	-0.0328	-3.5649	0.1534	-0.0006	-0.0666	1.6711	-0.0314	-4.7076	0.1414	-0.0027	-0.3977
	ASEAN						USA					
	Change in amount (Mt CO_2)			Change in percentage (%)			Change in amount (Mt CO_2)			Change in percentage (%)		
	CTax _JU	BTA_JU	NIAfT _JU	CTax _JU	BTA_JU	NIAfT _JU	CTax _JU	BTA_JU	NIAfT _JU	CTax _JU	BTA_JU	NIAfT _JU
2012	0.0582	-0.0379	-7.9559	0.0057	-0.0037	-0.7728	-1.3925	0.0875	84.3542	-0.0241	0.0015	1.4576
2015	0.1833	-0.0536	-6.8451	0.0166	-0.0049	-0.6197	-6.8970	0.1560	78.6592	-0.1155	0.0026	1.3187
2020	0.6971	-0.0552	-5.4134	0.0570	-0.0045	-0.4426	-22.1424	0.1716	75.4546	-0.3571	0.0028	1.2213

	ROW						Total of Regions Other than Japan and the US					
	Change in amount (Mt CO_2)			Change in percentage (%)			Change in amount (Mt CO_2)			Change in percentage (%)		
	CTax _JU	BTA_JU	NIAfT _JU	CTax _JU	BTA_JU	NIAfT _JU	CTax _JU	BTA_JU	NIAfT _JU	CTax _JU	BTA_JU	NIAfT _JU
2012	0.7683	-0.0435	-64.3457	0.0069	-0.0004	-0.5799	2.0631	-0.2419	-105.23	0.0107	-0.0013	-0.5476
2015	3.1650	-0.0954	-66.9546	0.0276	-0.0008	-0.5836	6.9063	-0.2763	-95.99	0.0349	-0.0014	-0.4843
2020	10.7186	-0.1888	-71.7412	0.0901	-0.0016	-0.6024	21.6107	-0.3042	-90.68	0.1071	-0.0015	-0.4488

Note: 1. For the changes in amount, CTax_JU is calculated as National Emissions (CTax_JU) - National Emissions (BAU); BTA_JU is calculated as National Emissions (BTA) - National Emissions (CTax_JU); NIAfT_JU is calculated as National Emissions (NIAfT_JU) - National Emissions (CTax_JU).

2. For the changes in percentage, CTax_JU is calculated as [National Emissions (CTax_JU) - National Emissions (BAU)] / National Emissions (BAU); BTA_J is calculated as [National Emissions (BTA_JU) - National Emissions (CTax_JU)] / National Emissions (CTax); NIAfT_JU is calculated as [National Emissions (NIAfT_JU) - National Emissions (CTax_JU)] / National Emissions (CTax_JU).

When the US implements a same carbon tax policy as in Japan (Table 10), the positive effects of Japan's carbon tax policy on domestic reductions will be strengthened. Comparing the two countries, the same carbon tax policy implemented in the US is more effective in reducing domestic emissions than in Japan, in terms of both quantity of reductions and percentage change in national emissions compared with BAU case. However, similar to the case of CTax_J, the effects are very small. In addition, with the two countries implement same carbon tax policies, carbon leakage will happen and the scale of the effects is much greater than in the case when only Japan implements a carbon tax policy, though the levels of the effects are still very small. Carbon leakage rate is up to 1.4.

When the US introduces a same BTA measure as in Japan, the effectiveness of the carbon tax policy in reducing domestic emissions in the two countries will be weakened. However, compared with BTA_J case, under BTA_JU case, Japan can still achieve certain domestic reductions from BAU levels. When both Japan and the US implement same carbon tax policy with a BTA measure, except for Korea, negative carbon leakage will happen in China, India, ASEAN and the ROW. At the global level, total emissions can be reduced compared with BAU case. Compared with BTA_J case, the positive effects of the BTA measure in preventing carbon leakage are strengthened under the case when both Japan and the US implement same BTA measures.

According to our proposal, the national inventories of both Japan and the US as importing countries and other regions as exporting countries should be adjusted in the presence of BTA. Under NIAfT_JU case, on the one hand the total national emissions of Japan and the US will increase dramatically and on the other hand the total national emissions in all other regions will decrease. Compared with NIAfT_J case, much more reductions in the national inventories of India and the ROW can be achieved, indicating the importance of bilateral trade of US-India and US-ROW in assessing carbon leakage effects under the scheme of NIAfT.

Table 9

Direct carbon intensity of EITE sectors (in kg CO_2/USD of 2004 value)

Code	Japan	Korea	China	India	ASEAN	USA	ROW
ppp	0.076	0.149	0.504	0.933	0.389	0.189	0.110
crp	0.171	0.073	0.656	0.598	0.374	0.237	0.257
nmm	0.298	0.825	3.965	3.581	3.150	0.656	0.621
i_s	0.253	0.236	1.193	1.279	0.860	0.402	0.592
nfm	0.048	0.050	0.538	0.281	0.196	0.189	0.207
fmp	0.013	0.020	0.103	0.085	0.124	0.040	0.052

3.5 Sensitivity analysis

Current carbon tax policy implemented in Japan is based on a low tax rate of JPY289/t-CO_2 (approximately USD2.67/t-CO_2) when compare with the tax rate in Australia (AUD23) (BBC, 2011) or the allowance price of the EU-ETS (predicted as an average of EUR22/t-CO_2 in Phase III) (Thomson Reuters Point Carbon, 2011). As shown in previous results, with such low tax rate, the impacts on domestic reductions, as well as the competitiveness effects and carbon leakage effects are trivial. In order to examine whether a carbon tax policy implemented in Japan can deliver substantial impacts on domestic reductions or generate real concerns on competitiveness and carbon leakage, we multiply the current tax rate by ten times and use the new rate (JPY2, 890/t-CO_2, approximately USD26.7/t-CO_2) to re-simulate the policy impacts. The results for the scenarios that only Japan implements stricter climate policies are presented in Tables 10-12.

Table 10

Output changes of EITE sectors in Japan when Japan implements stricter climate policies

	ppp				crp			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_J	BTA_J	CTax_J	BTA_J	CTax_J	BTA_J	CTax_J	BTA_J
2012	-0.0015	0.0276	-0.0008	0.0140	-0.0219	0.1767	-0.0050	0.0406
2015	-0.0069	0.0530	-0.0034	0.0264	-0.0984	0.3673	-0.0219	0.0816
2020	-0.0280	0.0706	-0.0137	0.0345	-0.3627	0.5907	-0.0787	0.1283
	nmm				i_s			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_J	BTA _J	CTax_J	BTA _J	CTax_J	BTA _J	CTax_J	BTA _J
2012	-0.0026	0.1305	-0.0031	0.1593	-0.0140	0.0443	-0.0073	0.0232
2015	-0.0127	0.1642	-0.0146	0.1888	-0.0656	0.0869	-0.0325	0.0431
2020	-0.0570	0.1416	-0.0596	0.1483	-0.2644	0.1209	-0.1242	0.0569
	nfm				fmp			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_J	BTA _J	CTax_J	BTA _J	CTax_J	BTA _J	CTax_J	BTA _J
2012	-0.0066	0.0208	-0.0098	0.0307	-0.0051	-0.0175	-0.0039	-0.0134
2015	-0.0346	0.0229	-0.0444	0.0295	-0.0245	-0.0329	-0.0182	-0.0244
2020	-0.1704	-0.0141	-0.1742	-0.0144	-0.1052	-0.0581	-0.0753	-0.0416

Table 11

Economy-wide output changes in all regions when Japan implements stricter climate policies

	Japan				Korea			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_J	BTA _J	CTax_J	BTA _J	CTax_J	BTA _J	CTax_J	BTA _J
2012	-0.1045	-0.2097	-0.0011	-0.0022	0.0001	0.0072	0.0000	0.0004
2015	-0.4819	-0.3825	-0.0050	-0.0039	0.0005	0.0160	0.0000	0.0007
2020	-1.9395	-0.6336	-0.0193	-0.0063	0.0039	0.0319	0.0001	0.0011
	China				India			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_J	BTA _J	CTax_J	BTA _J	CTax_J	BTA _J	CTax_J	BTA _J
2012	0.0061	0.1663	0.0001	0.0025	0.0014	0.0065	0.0001	0.0004
2015	0.0308	0.3196	0.0004	0.0044	0.0060	0.0177	0.0004	0.0010
2020	0.1661	0.3750	0.0021	0.0047	0.0202	0.0198	0.0011	0.0010
	ASEAN				USA			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_J	BTA _J	CTax_J	BTA _J	CTax_J	BTA _J	CTax_J	BTA _J
2012	0.0025	0.0236	0.0001	0.0010	0.0096	0.0437	0.0000	0.0002
2015	0.0119	0.0385	0.0005	0.0016	0.0426	0.0933	0.0002	0.0004
2020	0.0578	0.0417	0.0020	0.0015	0.1773	0.1383	0.0006	0.0005
	ROW				World			
	Change in value (billion USD)		Change in percentage (%)		Change in value (billion USD)		Change in percentage (%)	
	CTax_J	BTA _J	CTax_J	BTA _J	CTax_J	BTA _J	CTax_J	BTA _J
2012	0.0689	0.1149	0.0002	0.0003	-0.0160	0.1525	0.0000	0.0002
2015	0.3023	0.2223	0.0007	0.0005	-0.0878	0.3250	-0.0001	0.0003
2020	1.1959	0.3717	0.0025	0.0008	-0.3183	0.3449	-0.0003	0.0003

Table 12

National emissions changes when Japan implements stricter climate policies

	Japan						Korea					
	Change in amount (Mt CO_2)			Change in percentage (%)			Change in amount (Mt CO_2)			Change in percentage (%)		
	Ctax_J	BTA_J	NIAfT_J	Ctax_J	BTA_J	NIAfT _J	Ctax_J	BTA_J	NIAfT _J	Ctax_J	BTA_J	NIAfT _J
2012	-0.0132	0.1077	27.2369	-0.0013	0.0105	2.6471	0.0003	0.0132	-0.7893	0.0001	0.0030	-0.1767
2015	-0.0567	0.1801	24.2918	-0.0053	0.0169	2.2835	0.0012	0.0214	-0.8524	0.0003	0.0044	-0.1767
2020	-0.2022	0.2237	22.5905	-0.0185	0.0205	2.0718	0.0074	0.0170	-0.9628	0.0014	0.0031	-0.1786
	China						India					
	Change in amount (Mt CO_2)			Change in percentage (%)			Change in amount (Mt CO_2)			Change in percentage (%)		
	Ctax_J	BTA_J	NIAfT _J	Ctax_J	BTA_J	NIAfT _J	Ctax_J	BTA_J	NIAfT _J	Ctax_J	BTA_J	NIAfT _J

2012	0.0099	-0.4371	-9.4390	0.0002	-0.0080	-0.1733	0.0021	0.0161	-0.3713	0.0002	0.0013	-0.0310
2015	0.0353	-0.2953	-5.4892	0.0006	-0.0053	-0.0990	0.0077	0.0321	-0.2967	0.0006	0.0026	-0.0243
2020	0.1272	-0.0879	-2.1197	0.0024	-0.0016	-0.0395	0.0161	0.0070	-0.1853	0.0014	0.0006	-0.0156
	ASEAN						USA					
	Change in amount (Mt CO_2)			Change in percentage (%)			Change in amount (Mt CO_2)			Change in percentage (%)		
	Ctax_J	BTA_J	NIAfT_J	Ctax_J	BTA_J	NIAfT_J	Ctax_J	BTA_J	NIAfT_J	Ctax_J	BTA_J	NIAfT_J
2012	0.0005	-0.1377	-4.6515	0.0000	-0.0134	-0.4517	0.0016	0.0670	-3.6311	0.0000	0.0012	-0.0627
2015	0.0019	-0.1952	-4.6295	0.0002	-0.0176	-0.4186	0.0043	0.0932	-3.9878	0.0001	0.0016	-0.0667
2020	0.0118	-0.2101	-5.0239	0.0010	-0.0171	-0.4093	0.0143	0.0039	-4.3890	0.0002	0.0001	-0.0705
	ROW						Total of Regions Other than Japan					
	Change in amount (Mt CO_2)			Change in percentage (%)			Change in amount (Mt CO_2)			Change in percentage (%)		
	Ctax_J	BTA_J	NIAfT_J	Ctax_J	BTA_J	NIAfT_J	Ctax_J	BTA_J	NIAfT_J	Ctax_J	BTA_J	NIAfT_J
2012	0.0066	-0.0210	-8.7465	0.0001	-0.0002	-0.0788	0.0209	-0.4995	-27.6287	0.0001	-0.0020	-0.1105
2015	0.0326	-0.0415	-9.2413	0.0003	-0.0004	-0.0805	0.0831	-0.3852	-24.4969	0.0003	-0.0015	-0.0949
2020	0.1420	-0.1246	-10.0808	0.0012	-0.0010	-0.0846	0.3187	-0.3946	-22.7615	0.0012	-0.0015	-0.0860

When Japan implements a stricter carbon tax policy, the positive impacts on domestic mitigation are strengthened and the negative effects on Japan's industrial competitiveness and carbon leakage are aggravated from several times to a dozen of times. However, the impacts are still very small. A BTA adopted a tariff rate the same level as increased carbon tax rate will aggravate the negative impacts on domestic mitigation in Japan and strengthen the positive impacts on emission reductions in other regions. However, all the impacts are still very small. There are several other studies on the international competitiveness and carbon leakage effects of Japan's climate policy (e.g. Asuka, et al., 2010; Takeda, et al. 2012). However, most of the studies simulated an emissions trading system and different BCA measures and focused on the economic and environmental effectiveness of the climate policy and different BCA measures at sectoral and national levels.

4. Discussions and conclusions

In this paper we present the inequality issue in accounting for the emissions related to bilateral trade when border carbon adjustment is introduced as part of national climate policies. To address this inequality, we proposed two ways. One is to exempt the exporting country from the BCA list when a comparable climate policy is in place in the exporting country. Another is the National Inventory Adjustment for Trade, by which the exporting country pays for the carbon costs of their exports and receives emission credits in return. As a result, the national inventory of both of exporting and importing countries should be adjusted accordingly.

Three issues are worth further discussions. i) How to implement NIAfT when B implements a domestic climate policy which is not comparable with the one implemented in A? ii) How to implement NIAfT if the BCA implemented in A charges the carbon costs of imported products based on the emissions embodied in the products? iii) Will a BCA measure with NIAfT be compatible with WTO rules?

4.1 Comparability issue

If B implements a domestic climate policy which is considered incomparable with the one implemented in A, for example, B implements a carbon tax with the tax rate much lower than the tax levied in A, the carbon prices in the two countries, pc_A and pc_B, will be different and $pc_A > pc_B$. Given other conditions equal, the carbon costs of the same products produced in B will then be lower than the carbon costs in A. Even though both countries implement domestic climate policies, due to the differences in the strictness of climate policies, producers facing different carbon costs in different countries will be placed on an unequal playing field of international trade. The competitiveness and carbon leakage concerns still remain unsolved under this situation. How to define the comparability of domestic climate policies among participation countries is a practical challenge in designing a BCA and discussed by many BCA proposals (van Asselt and Brewer, 2010). Currently, the post-Kyoto arrangement for global mitigation is under negotiations under the UNFCCC. Expanding the coverage of participation to include all major emitters can be expected, however, allowing long-term differences in the strictness of setting national mitigation targets might be a compromised outcome of international negotiations. Against this background, how to address the compatibility issue will be very relevant to the design of BCA.

To address this situation, we discuss several options. We use the case of a BTA measure as an example to explain. First, use the carbon price in A as the criteria to determine the level of border adjustment. To equalise the carbon prices, it is rational to use the difference of the carbon prices in the two countries, i.e. $pc_A - pc_B$, as a criteria to determine the carbon tariff rate of BTA. Based on our proposal, as B pays for the additional carbon costs to A, B should be given emissions credits from A and therefore the national inventories of both countries should be adjusted accordingly. It is then rational to use the ratio $(pc_A - pc_B)/pc_A$ to determine the emissions credits that A gives to B, i.e. $[(pc_A - pc_B)/pc_A] \times e(EITE)^{BA}$ amount of emissions will be added to the national inventory of A and deducted from that of B. However, in practice it may be a big challenge to determine pc_B and therefore $pc_A - pc_B$ if the climate police implemented in B does not provide a definite price on carbon emissions, such as under a regulatory measure. As an alternative way, if pc_B is much lower than pc_A, we can consider B the same as a party which does not implement domestic carbon pricing policy. In such a case, pc_A can be used to determine the carbon tariff rate for the exports from B to A and the national inventories of both A and B will be adjusted based on our NIAfT proposal. If $pc_A - pc_B$ is very small, we can consider B the same as a party which implements a comparable domestic climate policy. In such a case, B will be exempted from the list of country coverage of the BTA implemented in A.

Second, use a universal reference carbon price, pc_u, as the criteria to determine the level of border adjustment. The reference carbon price can be determined based on the global average marginal abatement costs or through international negotiations under the UNFCCC. There are two cases. i) When $pc_A > pc_u > pc_B$, $pc_u - pc_B$ can be used as the criteria to determine the level of border adjustment. However, different from the discussions in the case of using pc_A as the criteria to determine the level of border adjustment, the price difference, $pc_A - pc_u$, cannot be properly addressed. If $pc_A - pc_u$ is large, the competitiveness concern and carbon leakage concern will remain. ii) When $pc_A > pc_B > pc_u$, based on our proposal, B should be exempted from the BTA implemented in A. However, similarly to the previous case, the price difference, $pc_A - pc_B$, cannot be properly addressed. If $pc_A - pc_B$ is large, the competitiveness concern and carbon leakage concern will remain. In addition, using the universal reference carbon price as criteria can address fairness and respect national diversity, however, it cannot encourage countries to adopt stricter climate policies.

4.2 Direct vs. embodied emissions

How to define the carbon content of imported products subject to the carbon adjustment at the border is a practical issue discussed intensively in both literature and policy proposals (European Commission, 2010; Houser, et al., 2008; McKibbin and Wilcoxen, 2009; Persson, 2010; Reinaud, 2008; van Asselt and Brewer, 2010; Zhou, et. al., 2012). There are two broad ways. One is to use the direct emissions from the production of the products and the other is to use both direct and indirect emissions associated with the production of the products. In the latter case, a partial way to include indirect emissions is to include the emissions from the generation of electricity which is used in the production of the products. A complete way to account for the total emissions embodied in the products is to include emissions directly or indirectly from all upstream productions in the supply chain of the products. A complete accounting of the emissions embodied in the products is particular difficult when the supply chain is built upon international collaborations among different countries, some of which may lack proper reporting and monitoring of GHG emissions at the firm level.

Placing this issue under the discussions of NIAfT, using direct emissions as criteria to determine the carbon content of imports subject to BCA is more straightforward. Direct emissions from the production of the imports will be used to determine both the carbon adjustment at the border and the national inventory adjustment based on NIAfT. When embodied emissions, either partially or completely, is used as criteria to determine the carbon content of imports, it becomes complex. There are several cases. i) If all upstream productions are located in the same country B, national inventory adjustment for the importing and exporting countries can use the same way as using direct emissions as criteria to determine the carbon content of imports. ii) If upstream productions in providing the exports from B to A are located in different countries, e.g. one production is in country C and another production is in country D, national inventory adjustment for the importing country A will be based on the total emissions embodied in the imports from B to A. However, adjustment of the national inventory of B is different from case i). Emissions related to the upstream productions in C and D will be deducted from the national inventories of C and D, respectively. The rest of the total emissions embodied in the production of the exports from B to A will be deducted from the national emissions account of B.

However, a supply chain is usually not a linear chain but a network of productions, such as coal is used to generate electricity which will be used in both coal extraction and iron and steel making. Iron and steel products are then be used in coal extraction and electricity generation. Consider coal extraction is located in C and electricity generation and iron and steel making are located in B and iron and steel products are exported from B to A. In this three-product simple example of a supply network, we can see it is very difficult to make the proper adjustment for national inventories. At aggregated sectoral levels, a multi-region input-output (MRIO) model can help make proper allocations among nations in determining the responsibilities for the emissions related to international trade (Lenzen, et al., 2012; Wiedmann, 2009; Zhou, et al., 2012; Zhou and Kojima, 2009).

4.3 WTO compatibility

In the presence of BCA, an exporting country are subject to pay for the carbon costs of their exports to the importing country and at the same time assume the responsibilities for the emissions related to the exports when they report their emissions in the national inventory submitted to the UNFCCC. Aiming to address the unequal playing field, however, a BCA measure can create another type of unequal playing field in favour of domestic producers. In the international trade regime, a trade measure needs to be justified by the non-discrimination principle, i.e. national treatment and the most-favoured-nation treatment, provided under GATT (Articles I, II and III). A BCA measure which can create an unequal playing field in favour of domestic producers cannot pass the national treatment clause of GTAA, in particular Article III.

NIAfT can address the unequal play field caused by the mismatched calculations for trade-related emissions based on current national inventory approach and the BCA measure. On the one hand, levelling the playing field by NIAfT can help a BTA measure to be justified by the non-discrimination principle of national treatment. However, on the other hand, based on GATT Article XX, a trade measure must prove substantial link between the trade measure and the stated climate change policy objective. The objective of a national carbon tax policy is to achieve domestic mitigation targets. Based on our assessment, the implementation of the BTA measure in Japan will increase domestic emissions, which is contradict to achieve domestic reduction. By NIAfT, the negative effects of BTA on domestic mitigation will be strengthened. The aggravated contradiction between the BTA measure with NIAfT and the stated objective of domestic climate policy will make the BTA measure even harder to pass WTO examination based on GATT Acticle XX.

4.4 Conclusions

By using a multi-region CGE model, we simulated the carbon tax policy introduced in Japan in 2012 and the scenarios of BTA with and without NIAfT. We also assumed that same climate policies are implemented in the US to test the impacts of expanding the coverage of participating countries in global mitigation efforts. Several findings are drawn up as follows.

(i) The carbon tax policy implemented unilaterally in Japan can reduce domestic emissions but at the same time trigger the carbon leakage mechanisms which result in an increase in global emissions. However, both domestic mitigation effects and the carbon leakage effects are very small. Current carbon tax rate adopted in Japan is low (less than USD 3), which might be the reason accountable for small impacts generated by the policy. By increasing the carbon tax rate by ten times through a sensitivity analysis, we found that the impacts are still very small. Based on our assessment, we concluded that the carbon tax policy in Japan cannot be considered as effective to address domestic mitigation nor be considered as a real risk of carbon leakage.

(ii) The carbon tax policy in Japan will impact the competitiveness of domestic industries adversely, including both EITE sectors and the economy as a whole. However, the impacts are trivial. Though by increasing the carbon tax rate by ten times, the impacts are still very small. Therefore the carbon tax policy implemented in Japan cannot be considered as a real threat to the competitiveness of domestic industries.

(iii) By introducing a BTA measure, competitiveness loss of the EITE sectors can be prevented, however, economy-wide competitiveness impacts cannot be addressed effectively. Since the competitiveness effects of the carbon tax policy are very small, the effects of the BTA measure to protect industrial competitiveness are also very small, even by a higher tax rate.

(iv) Unexpectedly, imposing a carbon tariff at the border will increase Japan's domestic emissions, contradicting to the carbon tax policy which aims to address domestic mitigation. The emissions from the rest of the world will decrease, indicating a phenomenon of negative carbon leakage. Based on our assessment, the BTA measure, as an accompanier of the carbon tax policy in Japan, can be considered effective to address the mitigation out of the border but not inside the border.

(v) To pass WTO examination, the proponent of a BCA measure, based on GATT Article XX[1], must prove the necessity of the trade measure in achieving the environmental objective related to Article XX (b) and (g), and substantial link between the trade measure and the stated climate change policy objective. The carbon tax policy in Japan, which can generate only trivial impacts on domestic mitigation, global carbon leakage and industrial competitiveness, cannot be justified as necessary to require a trade measure in achieving its stated mitigation objectives. Moreover, the negative effects of the BTA measure on achieving domestic mitigation can hardly prove the substantial link between the BTA measure and the stated climate policy objectives.

(vi) To address the inequality issue, we proposed NIAfT. Based on the NIAfT, the assessment results indicate that the effects of the BTA measure to address mitigation out of the territory rather than within the territory can be greatly strengthened, indicating a strong negative carbon leakage phenomenon.

[1] GATT Article XX General Exceptions: Subject to the requirement that such measures are not applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination between countries where the same conditions prevail, or a disguised restriction on international trade, nothing in this Agreement shall be construed to prevent the adoption or enforcement by any contracting party of measures:…(b) necessary to protect human, animal or plant life or health; … (g) relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption…

Acknowledgements

The authors would like to thank the Ministry of the Environment of Japan for its financial support to the project on the Sustainable Resource Use under the Second Phase of the Policy Study on Environmental Economics (PSEE Phase II). Our sincere thanks are also given to Hideyuki Mori for initiating and supporting this research topic at the Institute for Global Environmental Strategies (IGES).

Appendix A Region classification

Region	Code	Description
Japan	JPN	
South Korea	KOR	
China	CHN	
India	IND	
ASEAN	ASA	Including Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam
United States	USA	
Rest of the world	ROW	Including other regions than the nine countries/regions of the 113 regions in the GTAP Database Version 7

Appendix B Sector Classification

No.	Sector Code		Corresponding GTAP Sector	
	Code	Description	Code	Description
1	pdr	Paddy rice	pdr	Paddy rice
2	ocrp	Other crops	wht	Wheat
			gro	Other cereal grains
			v_f	Vegetables, fruit, nuts
			osd	Oil seeds
			c_b	Sugar cane, sugar beet
			pfb	Plant-based fibers
			ocr	Other crops
3	lvst	Livestock	ctl	Cattle, sheep, goats, horses
			oap	Other animal products
			rmk	Raw milk
			wol	Wool, silk-worm cocoons
4	frs	Forestry	frs	Forestry
5	fsh	Fishing	fsh	Fishing
6	coa	Coal	coa	Coal
7	oil	Oil	oil	Oil
8	gas	Gas	gas	Gas
9	omn	Other minerals (metal ores, uranium, gems, etc.)	omn	Other minerals (metal ores, uranium, gems, etc.)
10	fdpro	Food products	cmt	Meat: cattle, sheep, goats, horse
			omt	Other meat products
			vol	Vegetable oils and fats
			mil	Dairy products
			pcr	Processed rice
			sgr	Sugar
			ofd	Other food products
			b_t	Beverages and tobacco products
11	clo	Textile and leather products	tex	Textiles
			wap	Wearing apparel
			lea	Leather products
12	lum	Wood products	lum	Wood products
13	ppp	Paper products, publishing	ppp	Paper products, publishing
14	p_c	Petroleum, coal products	p_c	Petroleum, coal products
15	crp	Chemical, rubber, plastic products	crp	Chemical, rubber, plastic products
16	nmm	Non-metallic minerals (cement, lime, concrete, etc.)	nmm	Non-metallic minerals (cement, lime, concrete, etc.)
17	i_s	Ferrous metals (iron and steel)	i_s	Ferrous metals (iron and steel)
18	nfm	Non-ferrous metals (copper, aluminum, zinc, lead,	nfm	Non-ferrous metals (copper, aluminum, zinc, lead,
19	fmp	Fabricated metal products	fmp	Fabricated metal products
20	mvh	Motor vehicles and parts	mvh	Motor vehicles and parts
21	otn	Other transport equipment	otn	Other transport equipment
22	ele	Electronic equipment	ele	Electronic equipment
23	ome	Other machinery and equipment	ome	Other machinery and equipment
24	omf	Other manufactures	omf	Other manufactures
25	ely	Electricity	ely	Electricity
26	gdt	Gas manufacture, distribution	gdt	Gas manufacture, distribution
27	wtr	Water	wtr	Water
28	cns	Construction	cns	Construction
29	trd	Trade	trd	Trade
30	otp	Other transport (road, rail, pipelines, etc.)	otp	Other transport (road, rail, pipelines, etc.)
31	wtp	Sea transport	wtp	Sea transport
32	atp	Air transport	atp	Air transport
33	cmn	Communication	cmn	Communication
34	ofi	Other financial services	ofi	Other financial services
35	isr	Insurance	isr	Insurance
36	obs	Other business services	obs	Other business services
37	ros	Recreation and other services	ros	Recreation and other services
38	osg	Public administration, defense, health care and	osg	Public administration, defense, health care and
39	dwe	Dwellings	dwe	Dwellings

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