The Economic and Environmental Effects of Border Adjustment Measures: A Multi-Regional CGE Analysis for Japan

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Abstract

This paper aims at analyzing the economic and environmental effects of border adjustment measures by a global CGE model. Specifically, we quantify the impacts of Japan's proposed carbon tax, its export-rebate-based border adjustments and energy efficiency improvements in China and India. As a result, we find that carbon tax generates carbon leakage and border adjustments have impacts to lessen it. Energy efficiency improvement in China and India causes an increase in global CO_2 emissions through lower energy price; however, it enhances welfare in the two countries. In order to reduce CO_2 emissions globally, it is important to focus on the fall in carbon dependency rather than energy efficiency.

1. Introduction

Border adjustment as a measure to tackle carbon leakage and to level the playing field for international trade is one of the hot issues in domestic policy-making to mitigate GHG emissions. Recently, the Government of Japan revealed a plan to implement carbon tax from 2011. This plan will increase domestic production costs inevitably and put Japanese industries at a disadvantageous position in terms of their international competitiveness.

Although there is litter empirical analysis to date, many economic analyses focusing on the economic and environmental effectiveness of different border measures and applying general equilibrium analysis or partial equilibrium analysis have been conducted since last decade (e.g., Babiker, et al., 2000; Babiker and Rutherford, 2005; Peterson and Schleich, 2007; Manders and Veenendaal, 2008; Fischer and Fox, 2009; McKibbin and Wilcoxen, 2009; Monjon and Quirion, 2010; Takeda, et al., 2010, 2011; Winchester et al., 2010). By conducting a comprehensive literature review, we found that there is disagreement among researchers on both the quantitative importance of leakage and the effectiveness of policy instruments proposed to limit leakage and competitiveness

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impacts. Many studies indicated that how effective the various options will be in reducing competitiveness and leakage impacts depends, among others, on the differences in GHG emissions among like products from different sources. However, few of them address the emissions embodied in imports subject to adjustment at the border or take account of the nationally appropriate mitigation actions (NAMAs) to be implemented in developing countries. The implementation of NAMAs in developing countries in terms of either absolute mitigation or carbon intensity reduction will shorten the gap in the production costs between Japanese carbon-intensive industries and corresponding industries in developing countries. This will in turn influence the environmental and economic benefits of BAMs which are originally expected to correct such a cost differential.

In this paper, we assess domestic and international impacts of the BAMs together with a carbon tax policy to be implemented in Japan by using a recursive dynamic global computable general equilibrium model. We put particular emphasis on the emissions embodied in international trade and NAMAs in developing countries, in particular in China.

The rest of the paper is composed of three sections. Section 2 explains the model and data employed in this analysis. Section 3 presents simulation results. Finally, section 4 provides conclusion.

2. The Model and Data

2.1 The model

The model employed in this chapter is a multi-region CGE model which is based on the GTAP6inGAMS (Rutherford, 2005). In the model, a representative firm produces goods by using intermediate goods and production factors (skilled labor, unskilled labor, capital stock, land, natural resources). Inputs of intermediate goods and nested factors are described by the Leontief formulation while nested factors are aggregated by the constant-elasticity-of-substitution (CES) function. Household behavior is modeled by employing the Cobb-Douglas utility maximization. Allocation of demands (for both firms and household) between domestic goods and imported goods is formulated by the Armington approach (Armington, 1969). Sectoral investment is treated as an exogenous variable: hence, savings are not formulated in this model.

In order to do post-sample simulation, a recursive dynamics is introduced. Specifically, given the growth rates of population, skilled labor input, unskilled labor input and capital stock, we derive the future paths (from the year 2004 to 2020) of these three inputs.

Moreover, we add an embodied emission module to the original GTAP6inGAMS model by using the emission coefficients computed in Zhou et al. (2010).

2.2 Data

The main dataset of this analysis is GTAP Database version 7 (base year is 2004). Since the embodied emission coefficients in Zhou et al. (2010) are obtained by using the Asian International

Input-Output (AIIO) Table 2000 (Institute of Developing Economies, 2006), the sector aggregation of our dataset basically follows the 24-sector-classification in the AIIO Table. Sector classification and matching between the AIIO Table and GTAP Database are presented in Table 1. Also, the world economy is divided into thirteen regions in this model. The regional classification is described in Table 2.

As shown in Table 1, the chemical products and rubber products sectors are separated in the AIIO Table whereas they are aggregated in the GTAP Database. In this analysis, we disaggregate the chemical and rubber products sector in the GTAP Database by using sectoral output shares in India's 2004 input-output table (for India), EU KLEMS gross output data (for EU) and the AIIO Table 2000 (for the other ten economies) with the program SplitCom[1].

For constructing their future paths until 2020, the growth rates of population, skilled labor input, unskilled labor input and capital stock are taken from Dimaranan et al. (2007).

3. Simulations

Applying the model, we analyze the economic and environmental effects of BAM. Particularly, we focus on changes in international carbon leakage, global embodied emissions, output in energy-intensive sectors and GDP towards the year 2020. All results from 2011 are presented in this section since Japan's carbon tax will be put in practice from the year 2011.

3.1 Simulation Scenarios

In order to quantify the effects of BAMs and NAMAs, we prepare the baseline and the following three simulation scenarios: P1, P2 and P3.

P1: Carbon tax scenario

Carbon tax is levied on energy imports of Japan. The carbon tax rate is US$2.671 per ton-$CO_2$. This rate is implemented from 2011[2].

P2: Carbon tax plus export-rebate-based border adjustment

In addition to carbon tax in Japan, the P2 scenario includes rebates for all exports of Japan to the other economies[3]. This border adjustment rate is computed by embodied emission coefficient (carbon content) of exporting countries. The formulation of the tariff rate basically follows that in Winchester et al. (2010).

P3: P2 plus NAMAs

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[1] Regarding SplitCom, see http://www.monash.edu.au/policy/splitcom.htm

[2] For the details on the carbon tax rate, see the following web site: http://www.env.go.jp/en/policy/tax/tax-reform.html.

[3] Since Japan will levy carbon tax on energy imports, it might be better to apply border adjustment to embodied emissions of energy .in the other countries. However, Japan's carbon tax will be implemented in the upstream stage. Thus, we assume that border adjustment is applied to all exports of Japan.

The P3 scenario consists of the P2 scenario and NAMAs for China and India. Based on the Copenhagen Accord, China and India proposed to decrease CO_2 emissions per GDP in the year 2020 by 40-45 percent and 20-25 percent from the 2005 level, respectively. In this paper, NAMAs are introduced as efficiency improvement of energy input[4].

3.2 CO_2 Emissions

Table 3 illustrates the rates of changes in global CO_2 emissions from the baseline. We find the positive rates for the P1 scenario. Thus, Japan's carbon tax increases release of CO_2 emissions at the global level. In contrast, the introduction of border adjustments (export rebates) in Japan reduces the emissions. For the P3 scenario, CO_2 emission reduction can be seen until the year 2013 and the emissions start to increase from 2014. Energy efficiency improvement is expected to reduce energy demand and CO_2 emissions; however, energy efficiency also lets energy price go down. As a consequence of energy price decline, energy demand and CO_2 emissions rise.

3.3 Carbon Leakage

Percent deviations of CO_2 emissions in Japan and the other countries are shown in Table 4. Regarding Japan, CO2 emissions decrease by carbon tax while they increase by carbon tax plus border adjustments. By contrast, the opposite occurs for the other countries. From these results, it is concluded that international carbon leakage happens by the introduction of carbon tax. Moreover, border adjustments can have an impact to cancel out the effects of carbon tax. In exception to a case of the other countries during 2011-2013, CO_2 emissions increase for both Japan and the other countries. As explained in the previous section, one of the reasons for these results is a decline in energy price.

3.4 Sectoral Output

In this paper, changes in output are examined for the following energy-intensive sectors: the pulp, paper and printing, chemical products and metal products sectors (Tables 5 to 7). Overall, Japan's output in the selected sectors decline for the P1 scenario (the introduction of carbon tax in Japan) throughout the simulation period. From the results for output changes in the P2 scenario (carbon tax plus border adjustments), it is found that export-rebate-based border adjustments improve output in the energy-intensive sectors. In addition, energy efficiency improvement greatly benefits India's output in the chemical products and metal products sectors while it is detrimental to China's output. Its effects on Japan depend on sector (i.e., output in the pulp, paper and printing plus chemical products sectors increases whereas that in the metal products sector decreases).

3.5 Welfare

[4] This assumption implies that energy use for unit production decreases while the share of fossil fuels in energy supply remains in China and India.

Table 8 presents the rates of changes in welfare for Japan, China and India. Surprisingly, Japan's welfare improves by carbon tax. As one of the reasons, it is expected that positive effects resulted from government purchase (due to an increase of tax revenue) is greater than the negative effects of carbon tax. In addition, export-rebate-based border adjustments are also beneficial to Japan's welfare. China also faces the improvement of welfare while India's welfare is deteriorated by carbon tax and border adjustments. By contrast, energy efficiency improvement yields welfare gains to China and India. Japan's welfare declines until 2017; however, it increases from the year 2018.

4. Conclusion

This paper assesses the effects of carbon tax and border adjustments (export rebates) in Japan on global economy and environment by employing a global CGE model. Differed from most of the existing studies, we use embodied emissions to evaluate the impacts of border adjustments. Major findings can be summarized as follows:

- Introduction of carbon tax yields international carbon leakage and slightly increases global CO_2 emissions.
- Border adjustments help to alleviate international carbon leakage and to maintain output/competitiveness in energy-intensive sectors.
- Energy efficiency improvement does not necessarily contribute to global CO_2 emission reduction. However, it greatly improves welfare in countries which achieve the efficiency improvement.

From the last observation, we can conclude that the drop in carbon dependency is quite important to reduce CO_2 emissions rather than energy efficiency improvement.

For more concrete analysis, it is imperative to analyze the relations between energy efficiency improvement and embodied emission coefficients and to include the resultant mechanism into the CGE model.

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Table 1: Sector Classification

		AIIO 24 sector classification	GTAP 57 sector classification
	Symbol	Description	Code
1	PDR	Paddy	pdr
2	XAG	Other agricultural products	wht, gro, v_f, osd, c_b, pfb, ocr
3	LSP	Livestock and poultry	ctl, oap, rmk, wol
4	FRS	Forestry	frs
5	FSH	Fishery	fsh
6	CPG	Crude petroleum and natural gas	oil, gas
7	XMN	Other mining	coa, omn
8	FBT	Food, beverage and tobacco	cmt, omt, vol, mil, pcr, sgr, ofd, b_t
9	TEX	Textile, leather and the their products	tex, wap, lea
10	WDP	Timber and wooden products	lum
11	PPP	Pulp, paper and printing	ppp
12	CHM	Chemical products	crp
13	PTR	Petroleum and petro products	p_c
14	RBP	Rubber products	crp
15	NMM	Non-metallic mineral products	nmm
16	XMP	Metal products	i_s, nfm, fmp
17	MCN	Machinery	ele, ome
18	TRE	Transport equipment	mvh, otn
19	XMF	Other manufacturing products	omf
20	EGW	Electricity, gas, and water supply	ely, gdt, wtr
21	CNS	Construction	cns
22	TRT	Trade and transport	trd, otp, wtp, atp
23	SRV	Services	cmn, ofi, isr, obs, ros, dwe
24	PBA	Public administration	osg

Table 2: Regional Classification

1	Indonesia (IDN)
2	Malaysia (MYS)
3	Philippines (PHL)
4	Singapore (SGP)
5	Thailand (THA)
6	China (CHN)
7	Taiwan (TWN)
8	South Korea (KOR)
9	Japan (JPN)
10	United States (USA)
11	India (IND)
12	European Union (EU)
13	Rest of the world (ROW)

Table 3: Percent Deviation of Global CO_2 Emissions from the Baseline

	P1	P2	P3
2011	0.00000	-0.00020	-1.33283
2012	0.00000	-0.00019	-0.76484
2013	0.00001	-0.00038	-0.14615
2014	0.00001	-0.00036	0.52933
2015	0.00003	-0.00053	1.26730
2016	0.00003	-0.00050	2.07412
2017	0.00004	-0.00046	2.95573
2018	0.00004	-0.00043	3.91811
2019	0.00004	-0.00039	4.96701
2020	0.00005	-0.00035	6.10784

Table 4: Percent Deviation of CO_2 Emissions from the Baseline

	Japan			Other countries		
	P1	P2	P3	P1	P2	P3
2011	-0.00007	0.00215	0.50140	0.00001	-0.00027	-1.39112
2012	-0.00007	0.00221	0.47109	0.00001	-0.00027	-0.80336
2013	-0.00014	0.00456	0.44083	0.00002	-0.00053	-0.16409
2014	-0.00015	0.00470	0.40336	0.00002	-0.00051	0.53310
2015	-0.00024	0.00741	0.36505	0.00003	-0.00076	1.29377
2016	-0.00025	0.00768	0.31793	0.00004	-0.00074	2.12457
2017	-0.00026	0.00799	0.26498	0.00004	-0.00071	3.03138
2018	-0.00028	0.00832	0.20561	0.00005	-0.00068	4.02022
2019	-0.00030	0.00868	0.13938	0.00005	-0.00065	5.09685
2020	-0.00032	0.00908	0.06604	0.00006	-0.00061	6.26666

Table 5: Percent Deviation of Output in the Pulp, Paper and Printing Sector from the Baseline

	Scenario	2011	2015	2016	2017	2018	2019	2020
JPN	P1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	P2	0.001	0.003	0.004	0.004	0.004	0.004	0.004
	P3	1.723	2.087	2.197	2.317	2.448	2.591	2.746
CHN	P2	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	P2	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	P3	-72.085	-72.493	-72.560	-72.609	-72.638	-72.642	-72.616
IND	P1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	P2	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	P3	7.168	7.774	8.212	8.806	9.585	10.584	11.840
The rest	P1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	P2	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	P3	0.789	1.246	1.391	1.553	1.732	1.931	2.150

Table 6: Percent Deviation of Output in the Chemical Products Sector from the Baseline

	Scenario	2011	2015	2016	2017	2018	2019	2020
JPN	P1	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	P2	0.001	0.005	0.005	0.006	0.006	0.007	0.008
	P3	8.360	7.705	7.462	7.179	6.848	6.466	6.026
CHN	P2	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	P2	0.000	0.000	0.000	0.000	0.001	0.001	0.001
	P3	-12.219	-2.578	0.174	3.149	6.399	9.983	13.968
IND	P1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	P2	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	P3	81.555	147.587	166.760	187.262	209.269	232.958	258.500
The rest	P1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	P2	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	P3	-11.861	-13.963	-14.521	-15.091	-15.675	-16.274	-16.888

Table 7: Percent Deviation of Output in the Metal Products Sector from the Baseline

	Scenario	2011	2015	2016	2017	2018	2019	2020
JPN	P1	-0.001	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003
	P2	0.020	0.067	0.070	0.072	0.075	0.078	0.081
	P3	-4.897	-9.173	-10.502	-11.950	-13.525	-15.229	-17.062
CHN	P2	0.000	0.000	0.001	0.001	0.001	0.001	0.001
	P2	-0.003	-0.009	-0.009	-0.009	-0.008	-0.008	-0.008
	P3	-41.626	-31.660	-28.874	-25.883	-22.627	-19.035	-15.019
IND	P1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	P2	-0.002	-0.008	-0.008	-0.008	-0.009	-0.009	-0.010
	P3	75.144	85.351	87.911	90.668	93.769	97.388	101.735
The rest	P1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	P2	-0.002	-0.008	-0.008	-0.009	-0.009	-0.009	-0.010
	P3	-25.513	-29.164	-30.165	-31.210	-32.303	-33.448	-34.652

Table 8: Percent Deviation of Welfare from the Baseline

	Scenario	2011	2015	2016	2017	2018	2019	2020
	P1	0.000	0.001	0.001	0.001	0.002	0.002	0.002
JPN	P2	0.004	0.011	0.011	0.011	0.012	0.012	0.012
	P3	-2.194	-1.162	-0.818	-0.427	0.014	0.512	1.070
	P2	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CHN	P2	0.001	0.002	0.002	0.002	0.002	0.003	0.003
	P3	179.001	179.500	182.089	185.873	191.029	197.796	206.491
	P1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IND	P2	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	P3	77.109	85.060	87.839	91.030	94.696	98.910	103.758