

Analyses of impacts of ETS on industries in Japan

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ABSTRACT

From 2013, EU-ETS entered its third phase, free allocation of emission permits for energy intensive industries will continue, and Border Adjustment will be adapted to mitigate carbon leakage and risk of losing competitive edge. Following with EU, Japan is planning to introduce Emission Trade Schemes. With a multi-region model, we analyzed the possible impacts of ETS on industries, especially energy intensive industries in Japan. Comparing with full auction scenario, grandfathering (GF), output-based (OB) and border adjustment (BD) scenarios are also considered for their effects of “anti-leakage” and mitigating risk of losing competitive edge. We found that the carbon leakage ratio in the case of full auctioning in the ETS of Japan is not very much different from the GF and OB scenarios. We can find that the “best” anti-leakage option depends on the policy objective and on the sector. Although the output-based allocation variants lead to a generally higher carbon leakage ratio than border adjustments, leakage remains very limited. The most efficient variant in this respect is the one with auctioning in the power sector and output-based allocation in the cement, iron and steel and petroleum chemical products sectors, covering both direct and indirect emissions.

Keywords: Carbon leakage, ETS, Amington Elasticity, Board adjustment

JEL classification: F18, F64, Q27, Q28

1. Introduction

Emissions from the production process is recognized as one important reason for global climate change (IPCC 2007). To control the behavior of firms, after the introduction of the Kyoto Protocol, an ETS (Emissions Trading Scheme) was suggested by some organizations such as the UNFCCC, and has been implemented by the EU since 2005.

As carbon intensity is quite different across various sectors in an economy and because there is a time-lag when introducing ETS across countries (carbon intensity also differs across countries), the impact on companies in different sectors is significantly different. Embodied carbon leakage in international trade does not only undermine the effect of climate policy but also weakens a country (or region)'s competitiveness (Weber and Matthews 2007, Peters 2008). Therefore, disputes over the unfairness of international trade complicated the process of adopting ETS in other countries, like Japan. The Japanese government intends to adopt ETS in Japan to meet its reduction target (25%, from 1990-2020) which was announced at the climate conference in Copenhagen in 2009. There is a need for governments to understand which industries will be severely impacted by the implementation of ETS. Based on the input-output (I-O) model, Asuka et al.(Asuka, Lu et al. 2010) contributed a preliminary analyses on carbon leakage and competition of Japanese industries. This report will summarize these studies and analyze policy scenarios (including border adjustment) with regard to ETS in Japan.

The use of the I-O model for environmental analyses was developed by Leontief (Leontief 1970).

The method is widely used to analyze ETS.

Stern (Stern 2007) carried out input-output studies on the distribution of mitigation costs among sectors in the UK and their international competition. He found that

The empirical evidence on trade and location decision, however, suggests that only a small number of worst-affected sectors have internationally mobile plant and process.

Stern 2007, pp282

He also concluded that, compared with other factors such as investment, labour force and technologies, environmental policies always have less effect on the location of firms.

Using a similar method to Stern 2007, Web and Peters (Weber and Peters 2009) analyzed industries in the US with carbon tax, and came to a conclusion that was not much different from that reached by Stern 2007. They also found that carbon tariffs can only cover a small part of embodied emissions in international trade and have limited effect on protecting industry competitiveness.

We use the same method to address the possible impact on sectors when ETS is adopted based on the input-output table of 2000 and 2005 respectively. The summary value of CO₂ emissions and macro-economy are listed in Table 1.

Table 1 CO₂ emission, macro-economy of 2000 and 2005

Year	GDP	Direct CO ₂ emission	Unit direct CO ₂ emission	Embodied CO ₂ emission intensity (including import)	Total CO ₂ emission (including import)	Embodied CO ₂ emission intensity (without import)	Total CO ₂ emission (without import)	Impact ratio of import
	JPY Billion	100 million t- CO ₂	t-CO ₂ /JPY million	t-CO ₂ /JPY million	100 million t- CO ₂	t-CO ₂ /JPY million	100 million t- CO ₂	%
2000	958.89	11.35	1.18	5.11	34.15	4.53	30.58	10.47
2005	972.01	11.63	1.65	5.04	36.50	4.23	30.98	15.11
Increase ratio	1.37%	2.48%	39.18%	-1.46%	6.88%	-6.67%	1.33%	44.40

In this table, we defined the impact ratio of imports as below:

$$\text{Impact ratio of import} = \frac{\text{total emission including import} - \text{total emission without import}}{\text{total emission including import}}$$

We found that GDP (real) increased by 1.37%, and direct CO₂ emissions increased by 2.48%. Domestic embodied CO₂ emissions intensity (without import) reduced greatly (6.67%) compared with the same value including import. Therefore, the impact ratio of import increased to 15.11% simultaneously.

Japan promised that it would reduce emissions by 25% by 2020 compared with 1990. To fulfill this target, the government will introduce ETS like has been done in the EU. But in fact, after the results of the last UNFCCC conference in Copenhagen and since the US is unlikely to implement a cap-and-trade system any time soon, industry groups in the EU will certainly continue to argue the threat imposed by the European Union Emissions Trading Scheme (EU ETS) on their international competitiveness. Fears of loss of competitiveness and of carbon leakage are the main arguments put forward by industry against stringent climate policies, and in favour of free allocation of allowances.

Competitiveness and leakage are also motivations for border adjustments proposals.

In the US, the Waxman-Markey bill, which was adopted by the House of Representatives in 2009, includes more concrete provisions. If no international agreement on climate change has been reached by 1 January 2018, the president of the United States is required to set up an “international reserve allowance program.” From 2020 onwards, imports in a covered sector would be prohibited unless the importer has obtained an “appropriate” amount of emission allowances from the international reserve allowance program.

Hence, the political debate on the competitive impact of the ETS, on the related carbon leakage and on the most appropriate policies for reducing this impact (if any) is not over. The debate is also still open from an academic point of view: there is disagreement among researchers both on the quantitative importance of leakage and on the effectiveness of the policy instruments proposed to limit leakage and competitive impacts. In the following section, we will analyze the detailed effect of the implementation of ETS on Japanese sectors and which sectors should be paid more attention. In section 3, based on the result of section 2, we established a model to analyze the possible policy scenarios.

Referring to the complex industry situation and the above debates, the objectives of this report are to find industries which will be most affected by ETS and focus on these industries to analyze possible policy options, such as comparing the performances of both alternatives – free allocation and border adjustment – to limit carbon leakage, as well as to mitigate production loss. We have developed a computational framework allowing representation of the industry at a disaggregated level (cement, petroleum chemical products, steel and electricity) and to analyze the design of the different “anti-leakage” options. We provide a quantitative assessment of the impact of these “anti-leakage” policies on the activities of the different industries included in the model, compared to a scenario without a climate policy, and to a scenario featuring auctioned allowances without any specific “anti-leakage” feature. The results show that the determination of the “best option” depends on the target, i.e. limitation of carbon leakage or mitigation of production loss, and differs depending on the sector considered as well. This last point emphasizes the importance of conducting this kind of analysis using a highly disaggregated model.

2. Addressing carbon leakage and international competitiveness

By introducing ETS to Japan, against the background of international trade, we must ask which sectors should be considered for protection. Carbon intensity and trade intensity should always be chosen as indices in studies addressing carbon leakage. Here, we introduce concepts which are suggested by Hourcade et al. (Hourcade, Demailly et al. 2007). The first one is Net Value Added at Stake (NVAS) which is defined as mastering the added cost of indirect emissions only. In Japan, indirect emissions mean that the government sells emission allowances only to the power industry (electricity). The second one is Maximum Value Added at Stake (MVAS) which calculates the carbon intensity of each sector including total emissions (direct and indirect). It is an added cost for a sector when it purchases emissions allowances from the government or market. Functions and are the definition of the above concepts:

$$NVAS_i = \frac{\varepsilon E_i}{v_i} \quad (1)$$

$$MVAS_i = NVAS_i + \frac{\tau D_i}{v_i} \quad (2)$$

where E_i is the electricity consumption (including in-site electricity) of sector i , ε is increase of electricity price when emissions allowance price is set as τ , v_i the Gross Value Added of sector i , D_i direct CO₂ emissions of sector i . We assume that the power sector will transfer all added costs

caused by purchasing emissions allowances to electricity price. Thus, the price change ε can be obtained like this:

$$\varepsilon = \tau e \quad (2)$$

where e is the unitary emission of electricity, which is set as $0.555kg - CO_2 / kWh$ in this report.

We define our concept of trade intensity t as follows:

$$t_i = \frac{e_i + m_i}{x_i + m_i} \quad (3)$$

where e , m , and x were export amount, import amount and domestic production amount, respectively. Thus $\partial t_i / \partial e_i > 0, \partial t_i / \partial m_i > 0$ means that both increase of imports and exports can increase trade intensity similarly.

For the convenience of comparing with other countries, we set the carbon price (emission allowance price) at JPY 3000/t-CO₂.

2.1. Sectors which should be focused on

All the sectors with MVAS greater than 2% are listed in Table 2.

Table 2 Sectors with MVAS>2%

No.	Sector	NVAS	MVAS	Trade Intensity
1	Cement	9.30%	129.62%	6.59%
2	Ocean transport	0.01%	37.48%	99.82%
3	Pulp	13.88%	37.14%	27.81%
4	Pig iron and crude steel	2.92%	27.02%	4.78%
5	Gas supply	0.77%	25.99%	0.03%
6	Electric power	0.89%	18.61%	0.20%
7	Industrial soda chemicals	14.70%	18.40%	5.81%
8	Synthetic rubber	4.25%	14.68%	28.63%
9	Aliphatic or cyclic intermediates	3.64%	11.89%	48.65%
10	Air transport	0.15%	9.93%	50.02%
11	Coal products	0.96%	9.60%	9.52%
12	Petrochemical basic products	2.65%	7.64%	12.12%
13	Other industrial inorganic chemicals	4.57%	7.61%	32.66%
14	Foreign paper and Japanese paper	4.73%	7.43%	8.23%
15	Coastal and inland water transport	0.08%	7.33%	5.04%
16	Chemical fiber	3.01%	7.32%	35.14%
17	Glass fiber and glass products	3.66%	6.60%	24.30%
18	Cast and forges materials(iron)	3.17%	6.38%	2.04%
19	Cold-finished steel and coated steel	2.99%	5.56%	20.06%
20	Other non-metal ores	2.27%	5.52%	105.23%
21	Steam and hot water supply	2.82%	5.34%	0.00%
22	Chemical fertilizer	1.57%	4.61%	24.83%
23	Other industrial organic chemicals	1.90%	4.60%	37.37%
24	Yarn and fabric dyeing and finishing	1.22%	4.27%	0.00%

25	Agricultural chemicals	1.57%	3.99%	13.26%
26	Non-ferrous metals	2.30%	3.98%	53.98%
27	Metallic ores	3.47%	3.85%	98.90%
28	Materials for ceramics	1.42%	3.46%	36.36%
29	Pottery, china and earthenware	0.87%	3.39%	25.30%
30	Miscellaneous ceramic, stone and clay products	1.07%	3.27%	23.94%
31	Marine fisheries	0.04%	3.10%	17.45%
32	Other sanitary services	0.51%	3.09%	0.09%
33	Railway freight transport	2.22%	2.62%	4.00%
34	Petroleum refinery products	0.37%	2.49%	19.08%
35	Minor forest products	0.70%	2.26%	18.03%
36	Photographic sensitive materials	1.14%	2.26%	68.80%
37	Other glass and glass products	0.60%	2.26%	38.91%
38	Resin	0.97%	2.12%	37.00%
39	Sheet glass and safety glass	0.33%	2.10%	18.39%
40	Spinnings	1.62%	2.06%	40.98%
41	Steel pipes and tubes	0.67%	2.04%	36.54%
42	Coal mining, crude petroleum and natural gas	1.94%	2.03%	99.10%

From the above table, we discover that, without considering the transport industry (like ocean transport) and energy industry, MVAS over 5.00%, with higher trade intensity sectors, are concentrated in industries like cement, iron and steel, petroleum chemical products, and pulp and paper. The cement sector takes the highest MVAS position with a trade intensity of 6.59%. Pulp takes the second highest MVAS (excluding the transport industry) of 37.14% (increased comparing with 13.27% of 2000) and its trade intensity is at 27.81%. Pig iron and crude steel sector, and Aliphatic or cyclic intermediates sector also have high MVAS and trade intensity. Some areas of the energy sector also have higher MVAS, but as they are not part of the international trade sector, they will be treated as having no direct carbon leakage effect in ETS analyses.

2.2. Incremental of product price with added cost of carbon allowance price

Beside the indices like NVAS, MVAS and trade intensity, economic impacts are always doubted by stockholders from industry. Like Stern (Stern 2007) and Web and Peters (Weber and Peters 2009), we assumed that the added cost caused by the price of emissions allowance would be perfectly transferred to the product price by companies, thus we can analyze the degree of price increase in each sector.

To match the 2.1 section, we set the carbon price at JPY 3000 /t-CO₂, so the incremental of output price can be derived from following function:

$$\Delta \mathbf{p} = \tau \mathbf{d}(\mathbf{I} - \mathbf{A})^{-1} \quad (4)$$

where $\Delta \mathbf{p}$ is the vector of price variation (incremental) , τ is price of carbon allowance (JPY3000/t-CO₂), $\mathbf{d}$ is the vector of embodied CO₂ emission intensity of production, and $(\mathbf{I} - \mathbf{A})^{-1}$ is Leontief inverse matrix. We use data which was upgraded in 2009 by the Center for Global Environmental Research (3EID) (Nansai, Moriguchi et al. 2002) to calculate the price variation, and the results are listed in Table 3 .

In the table, we list sectors whose price variation ratio is over 3.00%.

Without exception, the sectors with high MVAS also have a high price incremental ratio. As in section 2.3, we do not take the transport and energy industries in to consideration and we find that products from industries like cement, iron and steel, pulp and paper and petroleum chemical products have occupied a high price incremental ratio.

Table 3 Sectors with the price incremental ratio over 3.00%

No.	Sector	Price incremental ratio	Price incremental ratio (without import)	Share of GDP
1	Cement	40.25%	39.90%	0.04%
2	Pig iron	20.55%	19.53%	0.22%
3	On-site power generation	19.89%	19.48%	0.11%
4	Crude steel (converters)	12.82%	11.85%	0.39%
5	Electric power	8.20%	7.91%	1.52%
6	Ocean transport	8.18%	4.43%	0.28%
7	Ready mixed concrete	7.98%	7.73%	0.14%
8	Hot rolled steel	7.38%	6.72%	0.77%
9	Industrial soda chemicals	5.71%	5.39%	0.05%
10	Cold-finished steel	5.60%	4.97%	0.36%
11	Pulp	5.17%	4.81%	0.06%
12	Ferro alloys	5.08%	4.31%	0.03%
13	Synthetic rubber	5.07%	4.60%	0.05%
14	Steel pipes and tubes	4.92%	4.32%	0.13%
15	Cast and forged materials (iron)	4.78%	4.49%	0.14%
16	Rayon and acetate	4.75%	4.36%	0.01%
17	Steam and hot water supply	4.53%	4.35%	0.02%
18	Paper	4.45%	3.90%	0.22%
19	Coated steel	4.24%	3.68%	0.16%
20	Methane derivatives	4.18%	3.57%	0.01%
21	Waste management services (public)**	4.03%	3.94%	0.12%
22	Synthetic dyes	4.03%	3.34%	0.00%
23	Iron and steel shearing and slitting	4.01%	3.47%	0.18%
24	Paperboard	3.90%	3.33%	0.07%
25	Aliphatic intermediates	3.89%	3.17%	0.21%
26	Coal products	3.81%	2.87%	0.09%
27	Coastal and inland water transport	3.75%	3.57%	0.09%
28	Salt	3.65%	3.38%	0.01%
29	Cast iron pipes and tubes	3.61%	3.44%	0.01%
30	Synthetic fibers	3.28%	2.63%	0.04%
31	Air transport	3.25%	3.05%	0.29%
32	Self-transport by private cars (freight)	3.22%	2.86%	0.66%
33	Other industrial inorganic chemicals	3.21%	2.71%	0.08%
34	Compressed gas and liquefied gas	3.14%	2.95%	0.03%
35	Crude steel (electric furnaces)	3.13%	2.29%	0.15%

36	Self-transport by private cars (freight)	3.13%	2.80%	0.36%
37	Cast and forged steel	3.10%	2.71%	0.04%

As concluded by Asuka et al. (Asuka, Lu et al. 2010) (using data from 2000), we can also find that the GDP share of most of these sectors is low, for example, cement has a share of 0.04%, and pulp, a share of 0.06%. However the iron and steel industry has a relatively large share. This is one reason why we will analyze the implementation of ETS using different policy scenarios.

2.3. Effect coefficient of trade intensity

Policy-makers want to know about sectors which are high-carbon intensive but may be omitted due to their low trade intensity. These sectors may be the important intermediate inputs for other sectors with higher trade intensity. Therefore, they can impact international trade indirectly.

To uncover these sectors, we designed a new parameter named Effect Coefficient of Trade Intensity (ECTI), v :

$$v_j = \sum_i a_{ij} t_i \quad (5)$$

where v_j is Effect Coefficient of Trade Intensity of j sector, a_{ij} is input coefficient in j sector of output from i sector, t_i is trade intensity of sector i correspondently. With this definition, the sector with the higher input coefficient or higher trade intensity (or both) will receive a higher effect coefficient. The effect coefficient of the sectors with a high MVAS and a low trade intensity are listed in Table 4.

Table 4 Effect coefficient of relative sectors

Code	Sector	Effect Coefficient	Trade intensity	MVAS
252101	Cement	0.16	6.55%	139.69%
261101	Pig iron	0.40	1.71%	79.51%
202101	Industrial soda chemicals	0.06	5.67%	17.89%

We can find that the effect coefficient of pig iron is obviously larger than the other two sectors (2.57 times of cement, 6.31 times of industrial soda chemicals). This is because pig iron is an important intermediate input of other sectors which have higher trade intensity.

2.4. Employment

One of potential risks resulting from ETS which is often mentioned by policy-makers is employment. Based on the employment input table of Japan, 2005, we calculated labour that will be included in the sectors of eligible industries. We suggest that eligible industry must satisfy two conditions, i.e. MVAS is greater than 5% and trade intensity is over 15%. Figure 1 shows the labor in different categories.

We can find that even without considering triggering innovation, creating jobs of a well-designed ETS; the share of labor which will be impacted directly is very low, at 0.53%. Therefore, we can conclude that ETS in Japan will not adversely affect employment.

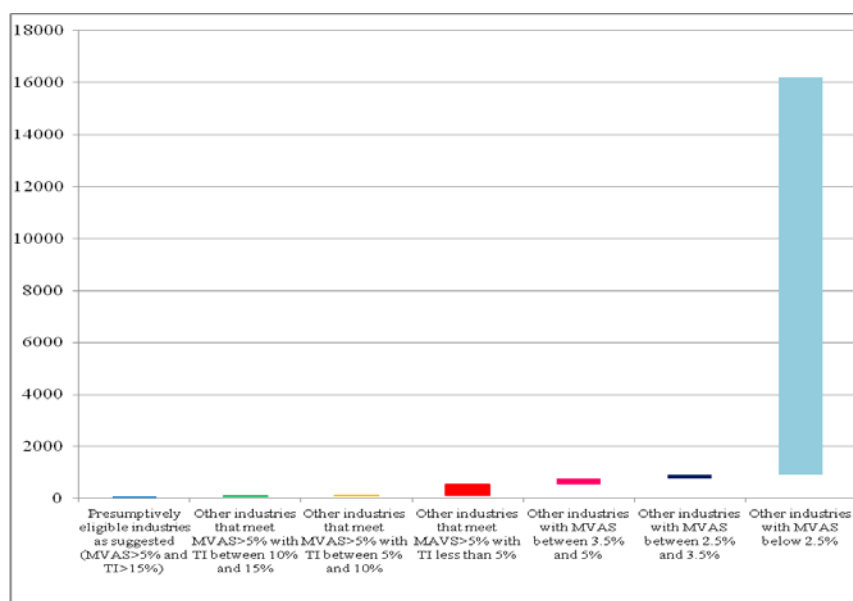


Figure 1 Employees in eligible industries and other categories.

From the above analyses, we can conclude that the impact or the risk of carbon leakage is limited to some sectors with high carbon intensive and trade intensity. In Japan, these sectors include cement, iron and steel, petroleum chemical products and pulp and paper. The situations of these four sectors are listed in Tables 5, 6, 7, and 8.

Table 5 Iron and steel industry

	GDP	Direct CO2 Emission	CO2 Emission Unit	Quantity	Price
Sector	JPY Million	t-CO2	t-CO2 /JPYMillion	t	JPY/t
Pig iron	2154291	131500605	65.09	83058130	25937
Ferro alloys	257770	2758871	14.35	963900	267424
Crude steel (converters)	3743816	9506395	39.49	83626875	44768
Crude steel	1426203	1571102	7.64	28844499	49445
Hot rolled steel	7476530	8577962	22.40	105213062	71061
Steel pipes and tubes	1282281	1210040	14.41	9636625	133063
Cold-finished steel	3470077	6538865	16.57	33431613	103796
Coated steel	1601221	1934623	12.28	17624885	90850
Cast and forged steel	386987	448176	9.03	983151	393619
Cast iron pipes and tubes	106631	639587	11.48	402757	264753
Cast and forged materials (iron)	1407208	7328378	14.96	12211473	115237
Iron and steel shearing and slitting	1724267	526547	11.57	0	
Other iron or steel products	276748	147056	8.05	0	

Table 6 Cement industry

	GDP	Direct CO2 Emission	CO2 Emission Unit	Quantity	Price
Sector	JPY Million	t-CO2	t-CO2/JPY Million	t	JPY/t
Cement	404,940	50,355,454	133.02	73,681,081	5,491

Table 7 Petroleum chemical products industry

	GDP	Direct CO2 Emission	CO2 Emission Unit	Quantity	Price
Sector	JPY Million	t-CO2	t-CO2 /JPY Million	t	JPY/t
Petrochemical basic products	1950273	3140899.3	5.00	23567579	82752
Petrochemical aromatic products (except synthetic resin)	975152	1510872.6	4.45	16663968	58519
Aliphatic intermediates	2042232	7815654.9	10.57	15488150	131858
Cyclic intermediates	1510690	3675949.9	6.59	8296005	182098
Synthetic rubber	523537	4992904.7	15.33	1626903	321800
Methane derivatives	138242	1012117.2	11.90	1549326	89227
Oil and fat industrial chemicals	89332	141523.1	3.72	458243	194945
Plasticizers	102161	277786.9	7.33	350264	291669
Synthetic dyes	38929	240184.3	11.13	31517569	1235
Other industrial organic chemicals	1017591	1921623.3	7.10	1568989	648565

Table 8 Pulp and paper industry

	GDP	Direct CO2 Emission	CO2 Emission Unit	Quantity	Price
Sector	JPY Million	t-CO ₂	t-CO ₂ /JPY Million	t	JPY/t
Pulp	562249	5434081	16.03	10833315	51900
Paper	2169860	7609707	13.00	18901072	114801
Paperboard	672056	1479419	11.09	12051254	55766
Corrugated cardboard	651017	116168.1	6.22	13728793	47420
Coated paper and building (construction) paper	519625	309411	4.55	0	
Corrugated card board boxes	1233577	168726.1	3.04	0	
Other paper containers	708475	158016.5	3.43	1470213	481886

Paper textile for medical use	480563	278797.6	3.77	0	
Other pulp, paper and processed paper products	906476	289484	3.54	113241590	8005

In the next section, we will use these four industries as examples to analyze policy scenarios of ETS in Japan

3. Analyses on ETS policy scenario of Japan with CASE II model

To address carbon leakage in ETS-EU, Monjon and Quirion (Monjon and Quirion 2009) established a static partial equilibrium model (CASE II). They used the three industry sectors that have high carbon intensive levels in EU (cement, aluminum, and iron and steel) as examples to analyze the policy scenarios and their impacts on carbon leakage. In our study, we will use CASE II model to analyze the policy scenarios of Japan.

3.1. The model

CASE II of Japan is a static and partial equilibrium model, which represents four sectors with international trade: cement, iron and steel, petroleum chemical products, pulp and paper, and one domestic energy industry: electricity. Although the general equilibrium effects have significant implications for climate policy, they mainly play a role in energy market leakage, but are less important for comparing anti-leakage policies (Fisher and Fox 2009).

The model aims to evaluate the impact of different designs of ETS for Japan's targets announced by the Japanese government in 2010 (25% emission reduction from 1990 to 2020). Based on this reduction level, we derived that the target for Japan from 2005 to 2020 is 17%, and set the production levels, the price levels and the trade flows of each industry as given. Thus, it is possible to calculate the leakage ratio of each sector in different ETS scenarios in Japan.

3.1.1. Consumption

There are two regions in this model: Japan (JP) and the rest of the world (RoW), i.e., $r = JP, RoW$. The representative consumer is assumed to have a two-tier utility function. The upper tier is a (logged) Cobb–Douglas function of the utility derived from consuming the goods produced by each industry, giving rise to fixed expenditures shares (α_r^i) out of income (Y_r):

$$U_r = \sum_{i=C,S,R,E} \alpha_r^i \ln(u_r^i) + \left(1 - \sum_{i=C,S,R,E} \alpha_r^i\right) \ln(Z_r) \quad (6)$$

where α_r^i is the expenditure share of the region r in industry i , u_r^i is the sub-utility from the consumption of the varieties produced in the industry i and Z_r represents the consumption level of the numéraire good. Indices C, A, S and E represent cement (C), iron and steel (S), petroleum chemical products (R) and electricity respectively (E)

Expenditures in region r for goods produced by industry i are then $\alpha_r^i Y_r$. We assume that the expenditure parameters stay constant between 2005 and 2020. GDP Y_r is set as exogenous and growing at constant ratio.

In turning to the lower-tier of the utility function, we examine expenditures allocation in the industries, each consisting of a domestic variety and a foreign variety. The sub-utility u_r^i is a constant elasticity substitution (CES) aggregate of the two varieties. The representative consumer has different preferences over varieties depending on their places of production, allowing in particular for home bias. This preference parameter in region r for the domestic variety is denoted $pref_{rr}^i$ while the preference parameter for the imported variety is denoted $pref_{rr'}^i$, where r and

$r'=\{JP,RoW\}$ and *rand*. The sub-utility function is then:

$$u_r^i = \left(\left(pref_{rr}^i \cdot Q_{rr}^i \right)^{(\sigma_i-1)/\sigma_i} + \left(pref_{rr'}^i \cdot Q_{rr'}^i \right)^{(\sigma_i-1)/\sigma_i} \right)^{\sigma_i/(\sigma_i-1)} \quad (7)$$

where Q_{rr}^i (resp. $Q_{rr'}^i$) is the consumption level in region r of the good produced by industry i in region r (resp. r') and σ_i represents the elasticity of substitution (Armington elasticity) between domestic and foreign varieties in industry i .

Maximising this sub-utility function subject to expenditures and the delivered prices from the two possible product origins, we obtain the demand curves:

$$Q_{rr}^i = \alpha_r^i \cdot Y_r \frac{\left(pref_{rr}^i \right)^{\sigma_i-1} \cdot \left(p_{rr}^i \right)^{-\sigma_i}}{\left(pref_{rr}^i \right)^{\sigma_i-1} \cdot \left(p_{rr}^i \right)^{1-\sigma_i} + \left(pref_{rr'}^i \right)^{\sigma_i-1} \cdot \left(p_{rr'}^i \right)^{1-\sigma_i}} \quad (8)$$

$$Q_{rr'}^i = \alpha_r^i \cdot Y_r \frac{\left(pref_{rr'}^i \right)^{\sigma_i-1} \cdot \left(p_{rr'}^i \right)^{-\sigma_i}}{\left(pref_{rr}^i \right)^{\sigma_i-1} \cdot \left(p_{rr}^i \right)^{1-\sigma_i} + \left(pref_{rr'}^i \right)^{\sigma_i-1} \cdot \left(p_{rr'}^i \right)^{1-\sigma_i}} \quad (9)$$

where p_{rr}^i and $p_{rr'}^i$ are the delivered prices respectively of the domestic and of the foreign variety of the industry i faced by the consumers of the region r .

The electricity demand in region r is then the sum of the demand of the selected sectors' firms located in region r and of a fixed expenditure share out of income $\alpha_r^E \cdot Y_r$ from the representative consumer.

3.1.2. Supply

The CES specification of the representative consumer's utility has mostly been used in monopolistic competition models following Dixit and Stiglitz (Dixit and Stiglitz 1977) and Krugman (Krugman 1980) where firms do not take into account the effect of their behaviour on other firms. Strategic interactions are therefore neglected, which is not very relevant for the industries analyzed in this paper since they feature a small number of large firms. Consequently we explore the case where firms compete in quantities, as in a standard Cournot oligopoly. Thus, our modelling framework encompasses both the standard Cournot oligopoly (the substitution elasticity between the imported and the domestic variety tends toward infinity) and the pure competition Armington framework (if the number of firms tends towards infinity).

In the cement, iron and steel, petroleum chemical products sectors, each firm sells in both regions. In each region, there are n_r^i domestic firms in competition. Firms are in competition regionally and, less intensively, internationally. Trade between the regions entails a constant per-unit transportation cost. Then the profit function of a firm localized in region r is:

$$\pi_r^i = \left(p_{rr}^i - mc_r^i \right) \cdot q_{rr}^i + \left(p_{rr'}^i - mc_r^i - tc_{r,r'}^i \right) \cdot q_{rr'}^i - FC_r^i \quad (10)$$

where p_{rr}^i and $p_{rr'}^i$ are the delivered prices of the good produced by a firm of industry i localized in region r and sold, respectively, in region r and in region r' , mc_r^i (resp. FC_r^i) the marginal (resp. fixed) production cost of firms localized in region r , q_{rr}^i (resp. $q_{rr'}^i$) the quantity sold in the domestic market (resp. in the foreign market) and $tc_{r,r'}^i$ the (unit) transportation cost from region r to region r' .

This framework allows firms to set different prices in each market. This contrasts with the Dixit-Helpman-Krugman model in which firms perceive the same elasticity of demand in each market and therefore set export prices (net of transport costs) equal to their domestic prices (Head

and Ries 2001).

Each firm sets its production for domestic and foreign markets to maximise its profit, under quantity competition with the firms of the same region and of the other region. To determine the number of firms in each region, we assume that free-entry sets profits equal to nil in both regions. At the equilibrium, all firms from the same region being symmetric, we have

$$Q_{rr}^i = n_r^i q_{rr}^i \quad (11)$$

Excluding expenditures related to the climate policy, production costs (variable and fixed) are assumed constant but differ across regions.

When a climate policy is carried out in Japan, Japanese firms incur three types of additional cost: abatement cost, purchase of allowances and increase in electricity price.

We assume a cost pass-through of 100% in the power sector, whatever the scenario. The electricity price rises by the sum of the abatement cost and of the purchase of allowances.

The risk of carbon leakage seems to be the highest for semi-finished products. Consequently, the model focuses on this stage of the production chain.

In the cement sector, we consider that in Japan, cement may be imported as a finished product, or in the form of clinker which must be milled and blended into cement at the point of arrival. We assume out clinker exports from the Japan to the RoW since they are already negligible absent climate policy. For the Japan, we take into account the substitution between clinker (the CO₂-intensive intermediate product) and CO₂-free substitutes (e.g. fly ashes or blast furnace slag) as well as the substitution between domestic and imported clinker. The proportion of clinker used to produce cement in the Japan, Sh^{CK} , and the market share of imported clinker in the Japan, $Sh_{Jap,RoW}^{CK}$, are modelled through nested logit functions:

$$Sh^{CK} = \frac{(TC_{Jap}^{CK})^{-\eta_1}}{(TC_{Jap}^{CK})^{-\eta_1} + (TC_{Jap}^{SUB})^{-\eta_1}} \quad Sh_{Jap,RoW}^{CK} = \frac{(TC_{Jap,RoW}^{CK})^{-\eta_2}}{(TC_{Jap,Jap}^{CK})^{-\eta_2} + (TC_{Jap,RoW}^{CK})^{-\eta_2}}$$

Where $TC_{Jap}^{CK} = Sh_{Jap,RoW}^{CK} \cdot TC_{Jap,RoW}^{CK} + (1 - Sh_{Jap,RoW}^{CK}) \cdot TC_{Jap,Jap}^{CK}$

TC_{Jap}^{CK} and TC_{Jap}^{SUB} represent, respectively, the total cost of using clinker and of using CO₂-free substitutes (flying ashes, blast furnace slag...) in Japan cement production, $TC_{Jap,Jap}^{CK}$ and $TC_{Jap,RoW}^{CK}$ represent, respectively, the cost of using domestic and imported clinker to produce cement in Japan, and η_1 and η_2 are positive parameters representing the responsiveness of Sh^{CK} and $Sh_{Jap,RoW}^{CK}$ to the changes in the relative costs.

3.1.3. Decomposition of (direct) emissions reduction

We use the following notations: E : emissions; Q : production; SE : specific emissions; C : consumption; X : exports; M : imports; Cc : cement consumption; Qc : cement production; Mc : cement imports; Xc : cement exports; Qck : clinker production; Mck : clinker imports; Rck : clinker ratio, i.e. share of clinker in cement production.

Electricity sector:

$$E = SE * Q \quad (12)$$

$$\Delta E = Q * \Delta SE + SE * \Delta Q \quad (13)$$

Δ indicates the difference between the value in a climate scenario and the value in the BAU scenario. Many decomposition methods exist; for a survey, cf. e.g. Liu and Ang (2007) (Liu and Ang 2007). In our case, the LMDI approach, which is often considered as the preferred method, gave unreliable

results with imports and exports. Instead we use the “trapezoid method” of decomposition (Muller 2006), which provides almost as good results as the LMDI approach (Ang, Zhang et al. 1998). That is to say, for instance, for the value of Q in $\Delta UE * Q$ in the equation above, we use the arithmetic average between its value in the BAU scenario and its value in the climate scenario.

Steel, Cement and petroleum products:

Here, the decomposition is more complex because of international trade.

$$Q = C + X - M \quad (14)$$

$$\Delta E = (C + X - M) \Delta SE + SE \Delta C + SE \Delta X - SE \Delta M \quad (15)$$

3.1.4. Model structure

This is a two-region model focus on Japan (Jap) and Rest of World (RoW), with all sectors connected by an international market.

In the domestic market, all sectors are linked through the CO₂. The CO₂ price clears the market; thanks to specific emissions abatement and production fall, the sum of the emissions from these sectors equals the total amount of allowances allocated for free or auctioned.

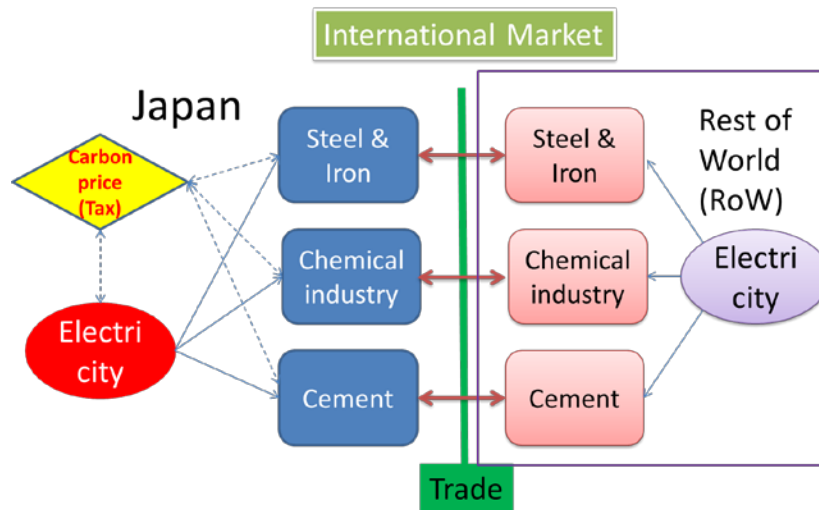


Figure 2 Framework of CASE II model of Japan

We do not model emissions in the rest of the Japan or emissions outside the ETS. These emissions could differ across our scenarios, due to some indirect effects (e.g. substitution between electricity and gas in building heating) but this effect is most likely to be negligible.

3.2. Policy scenarios

Our goal is to evaluate the efficiency of different instruments to mitigate the production loss and to limit carbon leakage due to the ETS of Japan. We consider two possible options: output-based allocation (OB) and border adjustment (BA). Each option can be applied in different ways, which, as we shall see, impacts its capacity to limit carbon leakage or to alleviate industrial production loss in Japan.

3.2.1. Output-based allocation (OB)

Since allocation in the ETS is linked to production capacity, not to actual output, it can reduce the incentive to relocate production capacity (investment leakage) but not the incentive to use existing

plants abroad rather than domestic plants (operational leakage). A suggested approach for tackling this problem is output-based allocation, in which, for example, a steel producer would receive a given amount of allowances per ton of steel actually produced. Practically, this requires an update of the allocation when production is known. In particular, an OB allocation, called “home rebate” by Fischer and Fox (Fisher and Fox 2009), keeps the playing field at home and abroad but at the expense of opportunities to reduce emissions by reducing consumption. With the experiment of EU, considering that actual production is partly linked to production capacity, the allocation method in the ETS of Japan can be seen as an intermediate one between pure lump-sum allocation and output-based allocation.

In the CASE II model of Japan, we model output-based allocation since it would tackle leakage more efficiently than the capacity-based allocation of the EU ETS. Several configurations of such OB allocation are then considered.

3.2.2. Border adjustment (BA)

A growing body of literature has come to the conclusion that BAs may effectively prevent climate policies from negatively impacting industry's competitiveness. For example, in US, in the Waxman-Markey bill adopted by the House of Representatives, a cap-and-trade scheme with a BA is planned for 2016 onwards.

When a BA is considered, we assume that allowances are auctioned. Indeed, a BA is much more difficult to justify under free allocation than under auctioning: with a BA the Japanese industry does not suffer from a competitive disadvantage (or much less so), there is thus little rationale for free allocation, which creates economic distortions.

Different elements require being defined, in order to implement a BA as a complement to the ETS of Japan: form of the BA (tax-based or allowances-based), coverage of the BA (imports or imports and exports; direct emissions or direct and indirect emissions) and adjustment base (JP or foreign average specific emissions, in particular). In the model of CASE II of Japan, the modelling of the BA is equivalent to a tax on imports and a subsidy on exports, equal to the allowance price. For the other elements, we compare several configurations.

We analyze seven climate policy scenarios and compare them to a no-policy (“business-as-usual”) scenario. The scenarios aim to compare contrasted policy options currently discussed among researchers and/or stakeholders.

1. Auction: 100% auctioning of allowances in every sector, without border adjustment.
2. Full Border Adjustment (Full BA): 100% auctioning, with border adjustment on both exports and imports. In every sector, the export adjustment is proportional to the average specific emissions of Japan for direct emissions and to the average specific electricity consumption for indirect emissions (i.e. emissions due to the production of electricity used in this sector) while the import adjustment is proportional to the Rest of the World (RoW) average specific emissions (direct emissions) and to the RoW average specific electricity consumption (indirect emissions). The next three scenarios represent various weaker forms of border adjustments, which are less efficient at preventing leakage but may be chosen nevertheless, in order to improve the likelihood of WTO acceptance or because they might be more easily accepted by other countries, thereby reducing the risk of the international negotiations on climate change
3. Border Adjustment Based on Average Value of Japan (JP_AV_BA): all auctioned permits in ETS, BA on imports and exports - average JP unitary emissions for imports and average JP unitary emissions for exports.
4. Border adjustment Based on Average Value of Japan (import) and RoW (export), IMPORT_DIRECT: all auctioned permits in ETS, BA on imports - average JP unitary emissions for imports and average RoW unitary emissions for exports.

5. Border Adjustment on Imp(JP_IMPORT_DIRECT): all auctioned permits in ETS, BA on imports - average JP unitary emissions for imports and average JP unitary emissions for exports
6. Grandfather scenario (GF): free allocation based on 2005 (direct and indirect) emission of each sector (-17% decrease for each sector)
7. Output-based scenarios: free allocation based on output (i.e. for each ton produced a firm receives x% of the JP average unitary emissions (x is produced endogenously)), allowances are distributed for free in proportion of current production. In every sector, the amount of allowances allocated per unit produced is calculated by applying a reduction ratio to the 2005 specific emissions. Note that since we apply the same reduction ratio to several sectors that differ by their abatement cost, the sectors with the cheapest abatement opportunities will typically sell some allowances to the sectors with the most costly abatement.

3.3. Assumption and simulation

The model has been calibrated on 2005 data (prices and quantities). The values of the preference coefficient and the unit transport costs are determined by the calibration and are supposed to be constant.

Concerning the values of the Armington elasticity, large differences exist across sectors and countries. Based on the estimation of Asuka et al. (Asuka, Lu et al. 2010), we set Armington elasticity as follows:

Cement: $\sigma_C = 2$;

Iron and Steel: $\sigma_S = 4.5$;

Petroleum chemical products: $\sigma_R = 3$;

Of course, Armington elasticity can be set at a lower level. The larger the Armington elasticity, the more easily imported commodities may substitute for domestic commodities.

The BAU scenario is simulated for 2020 without climate policy. This scenario is based on a growing GDP and changing technical coefficients (specific emissions, specific electricity consumption). Other exogenous variables stay constant (in particular production costs).

We then simulate different policy scenarios for the future which are then compared to a business-as-usual scenario. The output variables are: the prices in the domestic and the foreign markets, the production levels for the domestic and the foreign markets, the number of firms, the CO₂ price and the specific emissions.

For the carbon tax on electricity, we set the value at USD10/tonCO₂. ETS covers cement, steel and petroleum products (direct and indirect). Reduction for ETS is -17% between 2005 and 2020 (direct and indirect).

3.4. Simulation result and analyses

Results are reported for the year 2020; the year that the Japanese government is set to fulfill its mid-term target. We will focus on the carbon price, carbon leakage ratio on the different policy scenarios. The impacts of ETS on selected sectors will also be analyzed in this section.

3.4.1. Carbon price on difference policy scenarios

Figure 3 presents the main results of carbon price in different policy scenarios of this model. The CO₂ price is the lowest under *Auction* and the highest under *OB*. The explanation is the following. Free allowances under *OB full* constitute a subsidy to the production of CO₂-intensive goods, so production levels are higher than under the *Auction* and BA scenarios. Consequently, to get the same aggregate emissions under *OB full* as under the other scenarios, lower CO₂ emissions per unit produced are required, which implies a higher CO₂ price (Fischer 2001). The CO₂ price is at an

intermediate level under other policy scenarios, this is intuitive since these two scenarios are a combination of auctioning and output-based allocation. The CO₂ price is slightly higher under the BA scenarios than under *Auction*, because the border adjustment limits (completely or partially) the substitution of foreign production to domestic production, which is a way of reducing CO₂ emissions in Japan. Hence a higher CO₂ price is needed to get lower specific emissions.

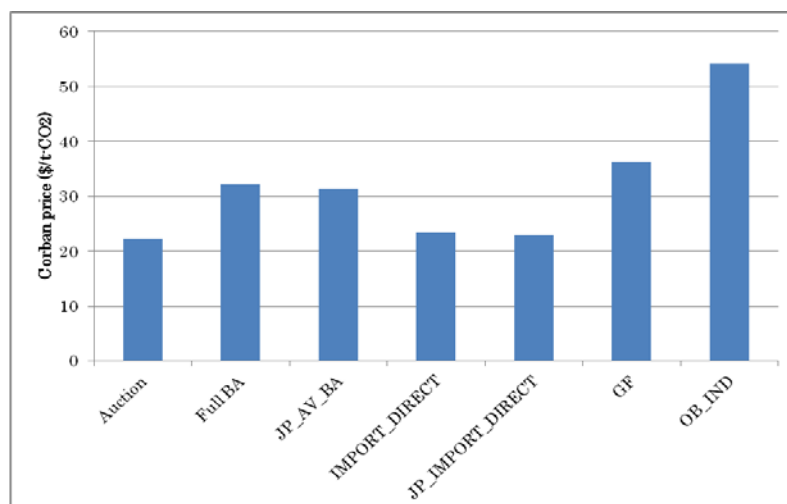


Figure 3 CO₂ price with different policy scenarios

CO₂ emissions in each scenario are shown in Figure 4 (for the definition of variables in the results, please refer to Appendix 2).

We can find that different sector's lowest emission (Japanese product for domestic consumption) values are different by policy scenarios. For example, under the ETS of Output-based scenario, the iron and steel sector gets its lowest emission value, in opposition to the cement sector's emission, which reaches its peak in the same scenario. The reasons are complicated; different carbon intensive ratios and differing Armington elasticity can impact on these processes.

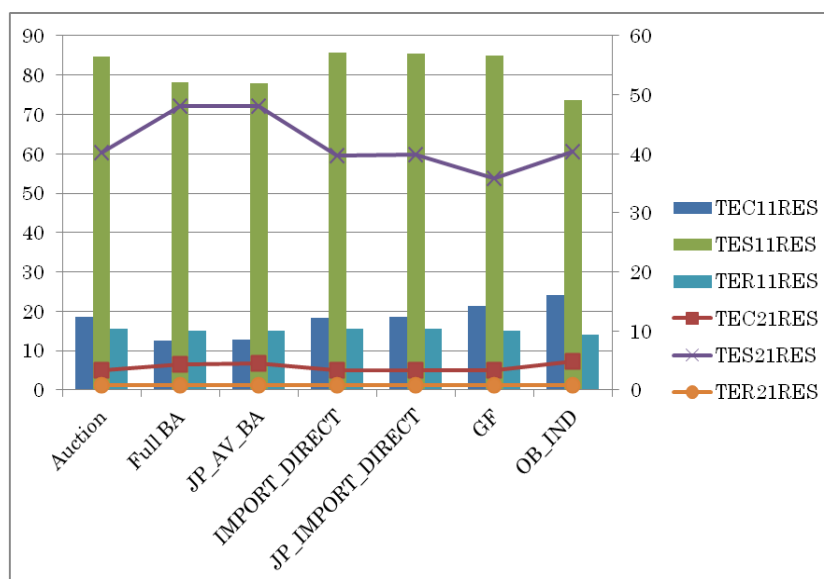


Figure 4 CO₂ emissions with different policy scenarios

3.4.2. Carbon leakage and policy scenarios

We then addressed sectors with the highest carbon leakage risk. Figure 5 gives the carbon leakage ratio of these sectors under different policy scenarios.

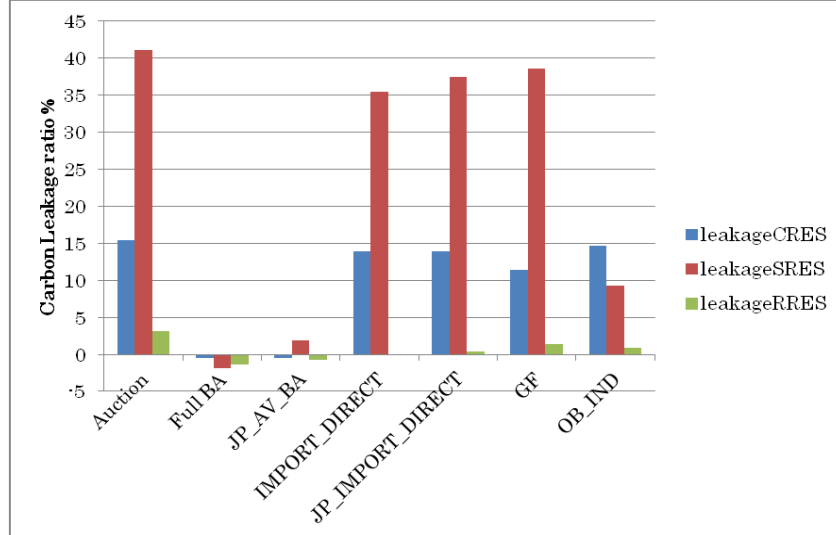


Figure 5 Carbon leakage and different policy scenarios

In the CASE II model of Japan, our definition of carbon leakage ratio is an increase in RoW emissions divided by the decreased emissions of Japan, that is:

$$CLR = - \frac{\Delta eCO2_{RoW}}{\Delta eCO2_{JP}} \quad (16)$$

Compared with the results of EU, the carbon leakage of selected sectors in Japan is at a higher level. This is partly because of the lower carbon intensity of Japanese products. Another reason to consider is in CASE II model of Japan, we used higher Armington elasticity settings than the EU model. Monjon and Quirion (Monjon and Quirion 2009) found that the carbon leakage ratio is very sensitive to Armington elasticity.

As expected, with all sectors, carbon leakage ratio is the highest under *Auction*. The OB scenarios bring this figure down greatly for iron and steel sector, other two sectors also decreased in the OB scenario.

Under Full BA scenario, the leakage-to-reduction ratio is negative, meaning that emissions in the RoW actually decrease.

4. Conclusion

Does leakage have to be addressed, and if so, how? The answers to these questions are not straightforward. Our simulations indicate that without any "anti-leakage" policy, the carbon leakage ratio in the case of full auctioning in the ETS of Japan is not very much different from the GF and OB scenarios.

Moreover, in our model as in others, the leakage ratio depends crucially on Armington elasticity, the estimates of which vary considerably across all available studies. Differences in the emission intensities between the regions also play a crucial role when BA is considered. Hence we cannot rule out that the "real" figure will be higher, in which case anti-leakage policies would be even more useful.

A first conclusion is that the "best" anti-leakage option depends on the policy objective –

mitigating carbon leakage or industrial production – and on the sector. Moreover, the design is crucial.

The "anti-leakage" policies (like Full BA and JP_AV_BA) were analyzed and found to be successful at significantly reducing the carbon leakage ratio. Among the two families of "anti-leakage" policies simulated, border-adjustments and output-based allocation, the former is more efficient in this respect. Moreover, most border adjustment policies entail a negative leakage-to-reduction ratio, meaning that emissions in the rest of the world decrease following the ETS climate policy of Japan. This spillover is mainly due to the reduction in Japan demand for CO₂-intensive goods, which entails a decrease in exports of these goods from the rest of the world to Japan, hence of the production of these goods in the rest of the world. Because of this mechanism, even if the border adjustment only covers imports, not exports, or if it only covers direct emissions, not indirect emissions, the leakage ratio is almost nil. This result gives room for maneuvers to design a border adjustment without threatening the goodwill in international negotiations on climate change. For example, a border adjustment covering only imports may be easier to negotiate because it generates public revenues, which may be redistributed to exporting countries. The latter would then probably be less likely to interpret the border adjustment as a protectionist policy.

Although the output-based allocation variants lead to a generally higher carbon leakage ratio than border adjustments, leakage remains very limited. The most efficient variant in this respect is the one with auctioning in the power sector and output-based allocation in the cement, iron and steel and petroleum chemical products sectors, covering both direct and indirect emissions. In this scenario, the CO₂ price is much higher than under auctioning because the incentive to decrease consumption of cement, steel and petroleum chemical products is much lower, and so it goes for the incentive to reduce the clinker ratio in cement since allocation is proportional to current clinker production. As a consequence of this higher CO₂ price, public revenues are almost equal to those of the scenario with full auctioning, in spite of the fact that a part of the allowances are allocated for free. Therefore, an attractive policy scenario is one that combines auctioning in the power sector and output-based allocation in the cement, steel and petroleum chemical products sectors, covering both direct and indirect emissions. Nevertheless, in the long term, stabilizing the climate system will require more stringent emission targets than those analyzed in this paper. This implies not only reducing specific emissions but also the consumption of CO₂-intensive products, which is prevented by output-based allocation. Thus, the latter should be seen as a transitory solution, to be replaced later by auctioning.

Reference

- Ang, B. W., et al. (1998). "Factorizing changes in energy and environmental indicators through decomposition." Energy **23**: 489-495.
- Asuka, J., et al. (2010). Emission Trading and International Competitiveness: Case Study for Japanese Industries, Institute for Global Environmental Strategies.
- Dixit, A. K. and J. E. Stiglitz (1977). "Monopolistic competition and optimum product diversity." The American Economic Review **67**(3): 297-308.
- Fischer, C. (2001). Rebating Environmental Policy Revenues: Output-Based Allocations and Tradable Performance Standards. Discussion Paper 01-22, Resources for the Future.
- Fisher, C. and A. K. Fox (2009). Comparing Policies to Combat Emissions Leakage: Border Tax Adjustments versus Rebates. Discussion paper of Resources for the Future.
- Head, K. and J. Ries (2001). "Increase returns versus national product differentiation as an explanation for the pattern of U.S.-Canada trade." The American Economic Review **91**(4): 108-122.
- Hourcade, J. C., et al. (2007). Differentiaion and Dynamics of EU ETS Competitiveness Impacts. Climate Strategies Report.
- IPCC (2007). Climate change 2007: Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.
- Krugman, P. (1980). "Scale Economies, product differentiation, and the pattern of trade." The American Economic Review **70**(5): 950-959.
- Leontief, W. (1970). "Environmental repercussions and the economic structure: An input-output approach." The Review of Economics and Statistics **52**: 262-271.
- Liu, N. and B. W. Ang (2007). "Factors shaping aggregate energy intensity trend for industry: Energy intensity versus product mix." Energy Economics **29**: 609-635.
- Monjon, S. and P. Quirion (2009). Addressing Leakage in the EU ETS: Results from the CASE II model. Climate Strategies Working Paper.
- Muller, A. (2006). Putting decomposition of energy use and pollution on a firm footing - clarifications on the residual, zero and negative values and strategies to assess the performance of decomposition methods. Göteborg University. School of Business, Economics and Law. Working Papers in Economics, nr 213.
- Nansai, K., et al. (2002). Embodied Energy and Emission Intensity Data for Japan Using Input-Output Tables (3EID). EGER-Report, Center for Global Environmental Research, National Institute for Environmental Studies, Japan.
- Peters, G. (2008). "From production-based to consumption-based national emission inventories." Ecological Economics **65**(1): 13-23.

16th Annual Conference on Global Economic Analysis, June, 2013

Stern, N. (2007). The Economics of Climate Change: the Stern Review, Cambridge University Press.

Weber, C. and G. Peters (2009). "Climate change policy and international trade: Policy considerations in the US." Energy Policy **37**(2): 432-440.

Weber, C. L. and H. S. Matthews (2007). "Embodied Environmental emissions in U.S. international trade, 1997-2004." Environmental Science and Technology **41**(14): 4875-4881.