The costs of green house gas emission reductions in the Japanese economy – An investigation using the GTAP-E model

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Abstract

GHGs (greenhouse effect gases) emission reduction target for Japan was set at 6% below the 1990's level at COP3 held in Kyoto, Japan in 1997. This is a very ambitious target to meet during the first phase, 2008-2012, because the Japanese economy is now one of the most energy efficient in the world. This paper looks at the costs of reducing CO2 gas emissions to achieve this target for Japan by looking at a range of options from the traditional command and control method, to the alternative and more efficient method of emission trading (domestic and/or international). The welfare gains/losses from these different methods will be estimated and compared to give policy makers an estimate of the various degrees of desirability of using these methods for achieving the Kyoto target. This study uses the GTAP-E model, a multi-sectoral and multi-regional trade and energy model, which is well suited for the study of emission control and trading among various sectors of an economy, as well as between different regions of the world.

Keywords: emission trading, CGE, Japan

1. Introduction

At COP3, held in Kyoto, Japan in 1997, Japan's GHGs emission reduction target was set at 6% below the 1990 level. However, Japan already has one of the most energy efficient economic system in the world and energy conservation measures have been introduced since the first two oil price shocks during the 1970s, especially in the industrial sector. As the result of this fact, to meet Kyoto GHGs target will bring about serious negative

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impacts on industrial competitiveness of the Japanese economy.

To minimise these impacts, the Japanese government has made GHGs reduction plan, but most of GHGs reduction depends heavily on carbon sequestration by forest. However, judging from the discussion at COP6, it seems quite unlikely that estimation of GHGs reductions proposed by Japan and the USA is accepted by COP. It is clear that the Japanese government needs to reconsider GHGs emission reduction plan to meet the target which will depend, not so much on the traditional command-control method, or on uncertain future technology development, or voluntary GHGs emission reductions, but also from market mechanisms such as emission trading. From an economic point of view, because the marginal cost of carbon abatement in Japan is high, it is anticipated that it will be quite difficult to control emission reduction to meet the target by these traditional non-market measures alone. To minimise the overall costs of emission control, more comprehensive measures such carbon tax and emission trading should also be introduced and Japan will have to make the most use of Kyoto mechanisms, such as international emission trading, joint implementation and clean development mechanism.

This research aims to evaluate the potential impacts of emission trading from two points of view, one is the domestic GHGs emission reduction plan as currently envisaged by the Japanese government, and the other is the use of the Kyoto mechanism. To evaluate above impacts, we use GTAP-E model.

2. Design of the experiments

2.1. Trading categorisation of regions and sectors

We use the GTAP-E model for this investigation[1] The standard GTAP-E model, however, cannot deal with inter-sectoral emission trading or inter-national emission trading within a specific group of countries/regions. As a result, some modification of the model is necessary.

First, we make a distinction between ‘emission trading’ (ET) and ‘non-trading’ (NT) regions/countries. The former is indexed by ‘reg_ET’, and the latter by ‘reg_NT’. This is

[1] For more information on this model, see Truong (1999)

emission trading at the inter-regional or inter-national level. Next, within each ET region/country, we then allow for a distinction to be made between 'emission trading sectors' (sec_ET) and non-trading sectors (sec_NT). This is trading at the intra-regional (or intra-national) level. The categorisation of regions and sectors is summarised in Figure 1.

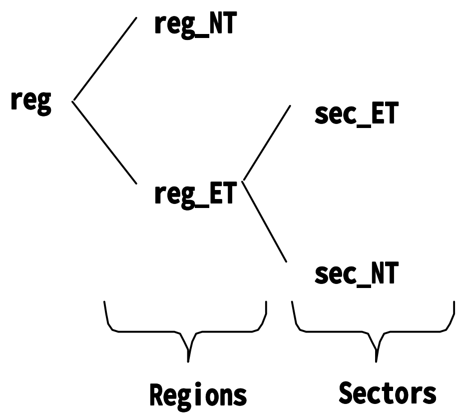

Figure 1: Categorisation of Regions/Countries and Sectors

2.2. Regional and sectoral specification

For this research, we use a 10 sectors by 8 countries/regions aggregation, based on the GTAP 4E data base[2]. The categorisation of these sectors and regions are as given in Tables 1 and 2.

[2] see Malcolm and Truong (1999)

Table 1: Categorisation of Sectors

Sector	with domestic trading	without domestic trading	Description
COL	sec_NT	sec_NT	Coal
OIL	sec_NT	sec_NT	Crude oil
GAS	sec_NT	sec_NT	Gas
P_C	sec_NT	sec_NT	Petroleum, coal products
ELY	sec_NT	sec_NT	Electricity
I_S	***sec_ET***	sec_NT	Ferrous metals
CRP	***sec_ET***	sec_NT	Chemical, rubber, plastic products
OMN	***sec_ET***	sec_NT	Metals nec, Mineral products nec, Paper products and publishing, Other manufacturing, Trade and transport
AGR	sec_NT	sec_NT	Agriculture, forestry and fish
SER	sec_NT	sec_NT	Commercial/public services/Dwellings

Table 2: Categorisation of Regions/Countries

Region	With international trading	without international trading	Description
USA	***reg_ET***	reg_NT	United States of America
CHN	reg_NT	reg_NT	China
FSU	reg_NT	reg_NT	Former Soviet Union
JPN	***reg_ET***	reg_NT	Japan
IND	reg_NT	reg_NT	India
E_U	***reg_ET***	reg_NT	European Union
NEX	reg_NT	reg_NT	Net Energy Exporters
NEM	reg_NT	reg_NT	Net Energy Importers

E_U: Germany, The United Kingdom, Denmark, Sweden, Finland, Rest of European Union

NEX: Australia, Indonesia, Malaysia, Viet Nam, Mexico, Venezuela, Colombia, Rest of Andean Pact, Argentina, Rest of South America, European Free Trade Area, Rest of Middle East, Rest of North Africa, South African Customs Union, Rest of Southern Africa, Rest of Sub Saharan Africa, Rest of World

NEM: New Zealand, Canada, Philippines, Singapore, Thailand, Korea, Hong Kong, Taiwan, Sri Lanka, Rest of South Asia, Central America and Caribbean, Brazil, Chile, Uruguay, Central European Associates, Turkey, Morocco

2.3. Experimental sets

We carry out two sets of experiments. In the first set, we look at the impacts of emission trading at the sectoral (i.e. intra-regional/intra-national evel). In the second set, we extend the investigation into the area of inter-regional or inter-national level.

For the first set of experiments, we assume only Japan is reducing her CO_2 emission level to meet the Kyoto target (with and without domestic emission trading between specified sectors). In the second set of experiments, we assume Japan as well as the USA and the European Union (E_U) are all trying to reduce their CO_2 emission levels to meet the Kyoto target. This is done by allowing for inter-national or inter-regional trading of emissions - but with no domestic (i.e. no inter-sectoral) trading within these regions.

In both sets of experiments, we assume the non-Annex B regions are under no obligation to reduce their CO_2 emission levels, and hence these regions impose no carbon tax. As a result, the CO_2 emission levels in these regions may increase following the reduction of the CO_2 emission levels by the Annex B regions. This is called the ‘leakage effect’.

Table 3: Categorisation of experiments

Region	Experimental Set 1						Experimental Set 2					
	Reference Case			Experiment 1			Reference Case			Experiment 2		
	K	DET	IET	K	DET	IET	K	DET	IET	K	DET	IET
USA							√			√		√
CHN												
FSU												
JPN	√			√	√		√			√		√
IND												
E_U							√			√		√
NEX												
NEM												

K: Kyoto Target; **DET:** Domestic Emission Trading; **IET:** International Emission Trading.

3. Results

We evaluate the impacts of the experiments from two points of view: economic and environmental. To evaluate the economic impacts, we first estimate the welfare gains from trading. Figure 1 gives an illustration for the case of two trading sectors: sector A, having a higher marginal emission-reduction cost, and sector B, having a lower marginal emission-reduction cost. If both sectors have to reduce CO_2 emission levels by the same amount, Q_{NT} will be the result, and the marginal emission-reduction cost for sector A will be P_A while that for sector B will be P_B. If the sectors are now allowed to trade emission quota, the result will be Q_A for sector A, and Q_B for sector B, with both having the same marginal emission reduction cost of P_T. The total emission reduction level remains the same, i.e. $Q_A + Q_B = 2Q_{NT}$.

The welfare gain by sector A from trading is thus: $W_A = 0.5*(Q_{NT} - Q_A)*(P_A - P_T)$, and that for sector B will be $W_B = 0.5*(Q_B - Q_{NT})*(P_T - P_B)$. Both sectors gain from trading: sector B by ‘selling’ the surplus reduction of $(Q_B - Q_{NT})$ to sector A at a price P_T which is higher than its marginal emission reduction cost of P_B when there is no trading; and sector A by ‘buying’ the surplus reduction from A, to make up for the short fall of $(Q_{NT} - Q_A)$, at a price which is lower than its marginal emission reduction cost when there is no trading (i.e. $P_T < P_A$). The welfare gains are shown by the shaded areas in Figure 1. It can be seen from this Figure that the larger the difference in marginal emission reduction costs between the sectors, the larger will be the welfare gains.

The same figure can be used to illustrate the welfare gains when there is international trading of emissions. A and B will now stand for 'regions' rather than sectors.

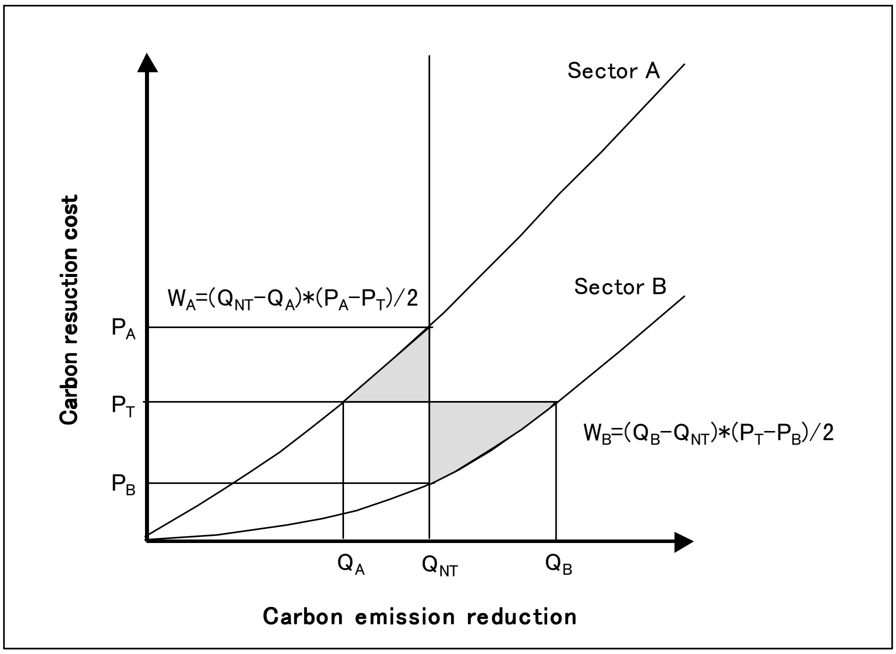

Figure 1: Impacts of emission trading on economic welfare

3.1. Domestic emission trading

To evaluate the impact of domestic emission trading on the Japanese economy, we carry out the experiments as described in 'experimental set 1' in Table 1. In the 'reference case' in this set, each sector will meet a specific carbon reduction target without domestic emission trading. The targets are set uniformly for all sectors and is the same as the national target. In 'experiment 1' of this set, the sectors are required to meet the same carbon emission reduction targets as in the reference case but with domestic emission trading allowed between the sectors. The result will be different *actual* reductions in different sectors as compared to the required targets, but leaving the *total* reduction in all the trading sectors the same as in the reference case. The trading sectors are: I_S, CRP and OMN. The non-trading sectors continue to meet the same emission reduction targets as in the reference case.

As Figure 2 indicates, it is most expensive to reduce carbon emission in the CRP sector and least expensive in the I_S sector (if there is no trading). Trading will result in a uniform marginal emission reduction cost. This cost is lower (compared to the case of no-trading) for the CRP and OMN sectors, but higher for the I_S sector.

For a specific emission reduction target of 20%, Table 3 compares the results of the ‘with’ and the ‘without’ emission trading cases, and calculate the welfare change. There is a large difference in marginal abatement costs between the I_S and the CRP sectors in the no trading case (6.5 and 63.5 US$/tonne-CO2 respectively), hence there are also potentially large welfare gains by these sectors when emission trading is introduced (180.1 and 316.7 million US$ respectively).

Table 3: Comparison of emission reduction levels and abatement costs in Experimental set 1

(% change)

	With emission trading		Without emission trading		
	Abatement cost (US$/tonne-$CO_2$)	Carbon abatement (million tonnes)	Abatement cost (US$/tonne-$CO_2$)	Carbon abatement (million tonnes)	Welfare change (million US$)
I_S	20.5	49.2	6.5	23.4	180.1
CRP	20.5	9.9	63.5	24.6	316.7
OMN	20.5	42.1	29.5	53.2	50.5

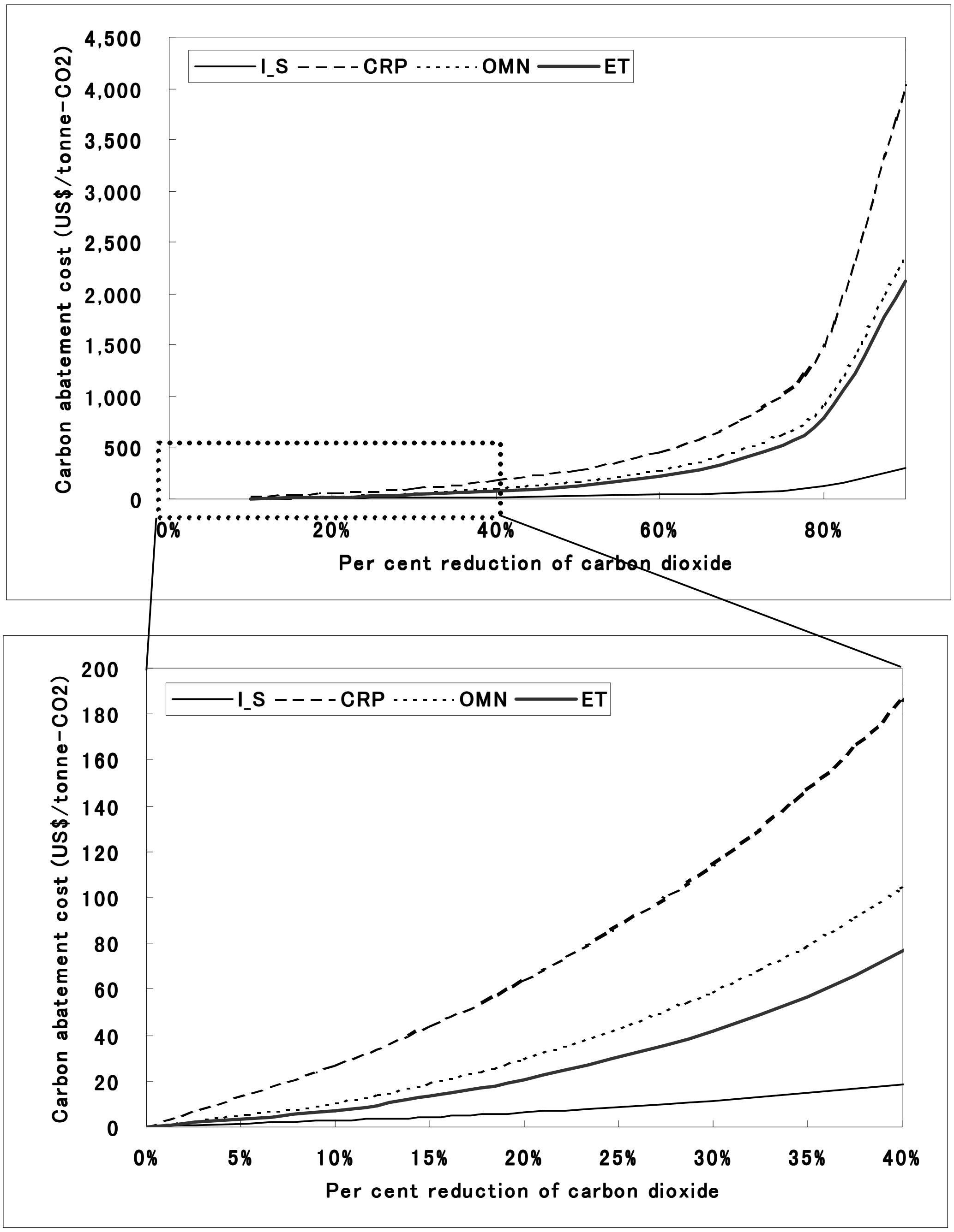

Figure 2: Comparison of carbon abatement cost among I_S, CRP, OMN and emission credit

Table 4 looks at the impact of emission trading on the production levels in each sector. Domestic emission trading improves on the production level of most (non-trading) sectors except COL and ELY sectors. For the trading sectors, domestic emission trading improves on the production level of the 'high abatement cost' sectors CRP and OMN, but worsens on the production level of the 'low abatement cost' sector I_S. This is to be expected because the high-cost sectors will benefit from emission trading by increasing its emission (and hence production) level, while the low-cost sector will do so by reducing this level.

Table 4: Output change in each sector

	With DET (% change)	Without DET (% change)	Direction of change With DET
COL	−1.00	−0.75	worsen
OIL	−0.22	−0.41	improve
GAS	1.71	1.62	improve
P_C	−3.01	−5.35	improve
ELY	1.28	1.74	worsen
I_S	−0.55	−0.31	worsen
CRP	−0.40	−0.99	improve
OMN	−0.17	−0.23	improve
AGR	−0.09	−0.13	improve
SER	−0.04	−0.06	improve
CGDS	−0.01	−0.02	improve

Table 5 looks at the sectoral output changes for the three energy-intensive sectors CRP, OMN, and I_S, in all regions. As expected, the direction of change (from the 'without' to the 'with' domestic trading cases) is different for Japan, as compared to the rest of the regions. This is because of the phenomenon of 'CO_2 leakage'. When there is decreased CO_2 emission in Japan because of the overall emission reduction target, there will be increased emissions in all other regions which do not impose such a target. This (international) leakage is related to the production levels of the various sectors in Japan and in other regions. If the introduction of domestic emission trading in Japan further decreases the production level of the low emission-cost sector (I_S) (see Table 4), then this will be 'compensated for' by a further increase of I_S production levels in all other regions. Hence, we observe the negative sign (-) for the direction of change in the I_S sector in Japan, but a positive sign (+) for the corresponding I_S sectors in all other regions (Table 5). The opposite thing happened for the high emission-cost sectors (CRP and OMN) (see Table 4), hence all the signs are reversed for these sectors in Table 5. These direction of changes can be said to be related to the 'sectoral' leakage effects, while the overall leakage effects (for all sectors) are shown in Table 6. It can be seen from Table 6 that the overall leakage effect is reduced when DET is introduced in Japan. This is as expected.

Table 5: Changes in output levels of energy intensive products

(%change)

	JPN	CHN	IND	USA	E_U	FSU	NEX	NEM
Without DET								
I_S	−0.31	0.06	0.02	0.01	0.05	0.19	0.14	0.09
CRP	−0.99	0.18	0.15	0.12	0.15	0.19	0.19	0.19
OMN	−0.23	0.02	0.03	0.01	0.02	0.04	0.07	0.01
With DET								
I_S	−0.55	0.22	0.12	0.08	0.11	0.45	0.26	0.31
CRP	−0.40	0.07	0.06	0.04	0.05	0.08	0.08	0.06
OMN	−0.17	0.02	0.02	0.01	0.01	0.02	0.05	0.01
Direction of change with DET								
I_S	−	+	+	+	+	+	+	+
CRP	+	−	−	−	−	−	−	−
OMN	+		−		−	−	−	

Table 6: CO_2 leakage rate

	Without DET (%)	With DET (%)	With DET (Direction of change)
CO2 leakage rate	0.57	0.47	negative

3.2. International emission trading

To evaluate the impact of international emission trading on the Japanese economy, we carry out the experiments in the 'experimental set 2' (see Table 1). In this experimental set, we assume the Kyoto emission reduction targets are introduced in Japan, the USA and the EU. These targets are shown in Table 7. Each region will meet the specified carbon reduction target without/with the introduction of domestic emission trading (DET).

For the 'reference case' in this experimental set, no international emission trading (IET) is introduced. Experiment 2 of this experimental set then introduces IET. The results of these two experiments are compared to reveal the effects of IET (Tables 8, 9, and 10).

Table 7: GHGs emission reduction targets

(mmt: million metric tonne)

	1990 emission level (mmt)	2010 projected level (mmt)	Emission Target (mmt)	Required reduction (%)
JPN	274	331	258	22%
USA	1,345	1,787	1,251	30%
E_U	934	1,016	859	15%

Source: Department of Energy, the United States of America

From Table 8, it can be seen that when there is no IET, the marginal emission reduction costs differ significantly between the three regions. When there is IET, however, the marginal emission reduction costs in the three regions will converge to a uniform level, as indicated by the 'With IET' column in Table 8.

Despite the fact that the USA has to reduce its emission by 30%, and Japan by only 22%, the marginal CO_2 abatement costs in Japan is higher than that in the USA when there is no trading (25.4 US$/tonne of CO_2 in Japan as compared to 24.2 US$/tonne of CO_2 in the USA). This confirms the results of many empirical studies[3] which tend to suggest that Japan is already a CO_2 efficient economy, perhaps more so then the US economy. The marginal CO_2 abatement cost for the E_U, in this experiment is 14.0 US$/tonne of CO_2, lower than that of Japan and the US, but this is perhaps also because the emission reduction target for the E_U in this experiment is much lower (at 15%).

Given the differences in marginal CO_2 abatement costs between the E_U on the one hand, and Japan and the USA on the other hand, it is expected that much can be gained by the introduction of emission trading between the E_U and Japan, or between the E_U and the USA, but not much will be gained if there is trading only between Japan and the USA. The E_U therefore stands to gain a great deal more if there is trading between all three regions, This is confirmed in Table 10 where it is seen that the welfare gain by the E_U is much larger (548 million US$) as compared to that of Japan or the USA (61 and 181 million US$ respectively).

[3] Christopher N. M., James A. D., Son H. K. and Ronald D. S. (1999)

Table 8: Comparison of carbon emission permit between with and without international emission trading (IET)

(US$/tonne-$CO_2$)

	Without International Emission Trading	With International Emission Trading
Japan	25.4	
USA	24.2	21.2
EU	14.0	

Table 9: Transaction of international emission trading among Annex regions

(million tonnes-CO_2)

	Buy	Sell
Japan	29	
USA	122	
EU		152

Table 10: Comparison of emission reduction, abatement cost and welfare change

	With IET		Without IET		Welfare gain from international emission trading (million US$)
	Abatement cost (US$/tonne-$CO_2$)	Carbon abatement (million tonnes)	Abatement cost (US$/tonne-$CO_2$)	Carbon abatement (million tonnes)	
Japan	21.2	222	25.4	251	61
USA	21.2	1,411	24.2	1,533	181
EU	21.2	628	14.0	476	548

3.3. Distributional issues and revenue recycling

In this paper, we have examined only the 'efficiency' aspect of emission trading, and concentrated mainly on a discussion of the sizes of the various potential 'welfare gains' from emission trading. The question of 'distribution' of these potential welfare gains among the member regions has not been considered. In practice, the size (and distribution) of these gains are clearly related to the size (and the method of distribution) of the *initial* CO_2 emission reduction targets (or emission permits) among the regions (e.g. whether by 'grand-fathering', or by auction, or by a combination of both). Also, related to this issue is the question of 'revenue recycling', i.e. how the income from the buying/selling of the permits are channelled back into the various economies and for various micro or macro-economic purpose (e.g. whether to reduce income tax, or to subsidise producers to invest in future CO_2 abatement technologies, etc.). Initial distribution of 'rights' and subsequent re-distribution of the income from the sales of these rights will clearly have an important feedback effect on the question of long term efficiency. However, for simplicity as well as tractability reasons, especially in a static framework, we have assumed that these two types of issues can be considered as separate. We assume firstly that the initial allocation (of the permits) are 'given', and secondly, revenue recycling, if it happens, will have a 'neutral' effect with respect to the relative sizes of the efficiency gains. We then use the Coase theorem to proceed to examine the efficiency issue. Besides, without the relative sizes of the efficiency gains being established, it would be less useful to proceed to a discussion about the 'distribution' of these gains.

4. Conclusion

We briefly described the effectiveness of domestic emission trading and the usefulness of access to international emission trading for Japan in meeting her Kyoto targets. With domestic emission trading (between the three energy-intensive sectors CRP, OMN and I_S), economic welfare in Japan is seen to be greatly improved. Looking at the welfare gain for specific sectors, the 'high abatement cost' sector of CRP will gain the most (316.7 million US$). Next comes the 'low cost' (but high volume) sector I_S (180.1 million US$). Lastly, the 'medium cost' sector of OMN will also gain, but by only a smaller amount (50.7 million US$). The introduction of domestic emission trading is seen to improve, not only on the domestic economic welfare of Japan, , but also on reducing the overall international 'carbon leakages from Japan to other regions/countries.. This is highly significant and desirable because it implies *domestic* emission trading is welfare improving, not only domestically for the country introducing it, but also for the international community as a whole. Domestic emission trading helps to achieving the overall international emission reduction target more effectively.

With international emission trading introduced between Japan and the other two major Annex B regions (USA and the E_U), the welfare gain for Japan alone is not as great (as compared to the case of domestic emission trading introduced in Japan alone). However, this does not imply that international emission trading is not desirable. It simply means that this is something to be considered *in addition to* rather than in substitution of domestic emission trading. For the international community as a whole, the gains are also greater, especially for those regions which have significantly different CO_2 abatement costs as compared to other regions. In the case of trading only between Japan, the USA and the E_U to meet the Kyoto targets, the E_U is seen to gain the most at 548 million US$. Next comes the USA with 181 million US$, and then lastly Japan, with a modest welfare gain of 61 million US$ from international emission trading.

Overall, the experiments show that both domestic emission trading and international emission trading are important, especially for Japan, where the differences in CO_2 abatement costs between domestic sectors in the Japanese economy may be more significant than the differences between Japan (as a whole) and other Annex B regions[4]. Comparing the gains from domestic as versus international emission trading exercises may be misleading, however, because in practice, the two should be considered jointly and in complement of each other rather than as substitutes. As a result, Japan is well advised to put efforts into both capacity building for domestic emission trading as well as for international emission trading. Perhaps using the former as a precursor for the latter.

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[4] The picture would be different, of course, if Non-Annex B regions are also included in the Kyoto exercises.