A STUDY ON ESTIMATION OF MARGINAL ABATEMENT COST CURVES FOR TRANSPORT SECTOR IN A CGE CONTEXT: THE USE OF THE AIM/CGE MODEL

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1. Introduction

This study aims to estimate abatement costs of CO_2 emissions and generate marginal abatement cost (MAC) curves for transport sector by region through a computable general equilibrium (CGE) model. The framework of a multi-sector CGE modeling in consideration of CO_2 emissions is illustrated. Then, a global CGE model namely the AIM/CGE is extended to generate MAC curves for transport sector by region. The developed MAC curves are further utilized in analyzing impacts of emission reduction targets introduction in order to curb CO_2 emissions in transport sector for the post-2012 climate mitigation.

2. Modeling CO_2 Emissions in a Multi-Sector CGE Model

In a CGE model, CO_2 emissions are primarily associated with the use of fossil fuels (i.e. coal, oil and gas) as intermediate inputs in production sectors and as final consumption demand to household as shown in Figure 1. The main actors in the diagram are households, who own primary factors of production (e.g. capital, labor, land, natural resources, and emission permits) and the final consumers of produced commodities, and firms, who rent the factors of production from the households for the purpose of producing goods and services that the household then consume[1]. Each production sector produces single commodity or service by inputting intermediate goods and primary factors. Intermediate inputs for production and produced goods for final consumption can be divided into non-energy and energy goods. Some production sectors of non-energy goods/services use a relatively large proportion of energy goods (i.e. fossil fuels and electricity) as inputs, such as energy intensive productions, metal and machinery, and transport. Energy goods include fossil fuels which are carbon content goods, and electricity. Then, each fossil fuel (i.e. coal, oil and gas) is modeled as a composite with carbon emissions by a Leontief form, i.e. the elasticity of substitution equals zero. These fossil fuels composites are crucially important that we can deal with CO_2 emission tax by introducing price of CO_2 emission permits. Similar to production sectors, the representative agent of households chooses non-energy goods and energy to maximize utility under the income constraint. The final energy consumption is a constant elasticity of substitution (CES) aggregate of electricity and fossil fuels composite. Then, the fossil fuels consumption is identical to aggregations in the typical productions. We can track fossil fuels consumption and its CO_2 emissions in final consumption sector through this consumption structure as well.

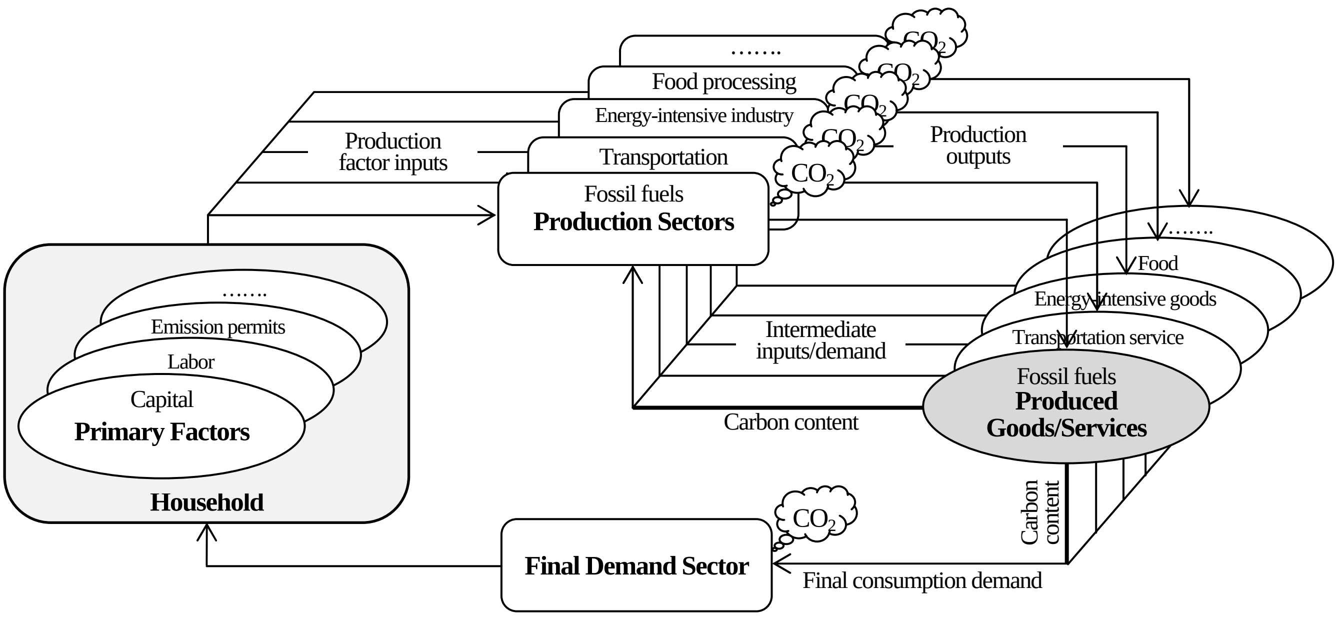

Figure 1: A Multi-sector CGE Model with CO_2 Emissions

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3. Application of the AIM/CGE Model to Generate MAC Curves for Transport Sector by Region

In this paper, the AIM/CGE model[2)], a global CGE model developed by the National Institute for Environmental Studies (NIES) of Japan, is employed. The global AIM/CGE model is developed by the GAMS/MPSGE modeling language, based on GTAPinGAMS and GTAP-EG datasets, therefore, the structure of the model is mostly identical to GTAP-EG[3)]. Nevertheless, the model was added many items, for example, more GHGs, biomass, and power generation technologies. The model aggregates the GTAP dataset into 24 regions (see Table 1), 22 production sectors and a final consumption sector as presented in Table 2.

Table 1: Countries and regions in the AIM/CGE model

Annex I Regions	Non-Annex I Regions
Japan (JPN)	Korea (KOR)
Australia (AUS)	China (CHN)
New Zealand (NZL)	Indonesia (IDN)
Canada (CAN)	India (IND)
United State of America (USA)	Thailand (THA)
EU15 in Western Europe (XE15)	Other South-east Asia (XSE)
EU10 in Eastern Europe (XE10)	Other South Asia (XSA)
Russia (RUS)	Rest of Asia-Pacific (XRA)
Rest of Europe (XRE)	Mexico (MEX)
	Argentine (ARG)
	Brazil (BRA)
	Other Latin America (XLM)
	Middle East (XME)
	South Africa (ZAF)
	Other Africa (XAF)

Table 2: Production and final consumption sectors

Non-Energy	Energy
1. Food	17. Coal
2. Energy intensive products	18. Crude oil
3. Metal and machinery	19. Petroleum products
4. Other manufactures	20. Gas
5. Water	21. Gas manufacture distribution
6. Construction	22. Electricity
7. Transport	
8. Communication	
9. Public service	
10. Other service	
11. Investment	
12. Agriculture	
13. Livestock	
14. Foresty	
15. Fishing	
16. Mining, except fossil fuels	
Household	**Production factors**
Final consumption	Capital
	Labor
	Land
	Natural resources

In the AIM/CGE model, CO_2 emission is modeled as other goods, which sticks with each fossil fuel. We can track the flow of emissions into each production sectors by following the flow of fossil fuel inputted to sectors directly. CO_2 emissions generated by sector can be calculated by intermediate inputs of fossil fuels into that sector in conjunction with emission factor of each fossil fuel. In the benchmark data (i.e. base case), the price of CO_2 emission permit is equal to zero, and we can estimate CO_2 emissions in base case. Once we introduce the CO_2 emission taxes, then CO_2 emission will be priced and the price of each fossil fuel will be increased as it is carbon-content goods. The price increased is a multiple of its emission factor and the carbon tax levied. Analogously, household also chooses level of fossil fuel consumption concerning to price increased by the CO_2 emission tax. The CO_2 emission reduction of each sector of each region due to the introduction of CO_2 emission taxes can be calculated by subtracting the emissions of the taxing case from the emissions of the base case.

In order to generate sectoral marginal abatement cost (MAC) curves by region, we introduced a CO_2 emission tax into and varying from 0 up to 200 USD/t CO_2 by interval of 50 USD/t CO_2. Consequently, the outputs of the model for each level of the emission tax result the corresponding CO_2 emissions by sector by region by time. With having the coordinates of CO_2 emission taxes and corresponding emission reductions, we can plot MAC curves for each sector by region. Figure 2 shows the MAC curves for transport sector by region in 2020, which are derived from the outputs of the AIM/CGE model. It shows obviously that USA has high potential of CO_2 emission reductions in transport sector, i.e. abatement cost of CO_2 emissions is cheapest and very much cheaper than other countries. Therefore, in the next round of the international climate regime, i.e. 2012-2020, USA should have the emission reduction target even only in transport sector and it would meet the target due to high potential of CO_2 mitigation in transport sector.

4. Utilization of Sectoral MAC Curves towards Analyzing Impacts of CO_2 Emission Permits in Transport Sector

In this paper, we suppose to introduce emission permits in transport sector to five major Annex I countries, including USA, EU15, Russia, Japan and Canada which cover over a half of global CO_2 emissions in transport sector in 2020. Consequently, the five Annex I countries have to cut their emissions in 2020 to their emission levels in 2000. Based on the time series GHG data of the UNFCCC (see http://unfccc.int/2860.php), we can project emissions of five countries in 2020 based on the relationship between GHG emission levels and times. Emission reductions targets in transport sector for each country can be calculated as shown in Table 3. These targets proposed in this paper are not intended to be accepted by countries but only used to show the way of analyzing the impacts on participating countries when sectoral emission reduction targets are introduced. The real targets should be in the negotiation under the UNFCCC. Once having known the real targets in transport sector, then this idea can be applied to analyze those targets directly. In Table 3, Russia has no target in transport sector in 2020 because of its projected emission level in 2020 is below than the permit level in 2000. Therefore, Russia is not required to reduce emissions in transport sector, on the other hand, it holds a 'Hot Air'—the difference emission amount below the permit level—might be able to sell out to the emission trading market of the transport sector, if allowed.

Table 3: CO_2 emissions and reduction targets in transport sector

Region	Emission in 2000 ($MtCO_2$)	Emission in 2020 ($MtCO_2$)	Reduction Target in 2020 ($MtCO_2$)
USA	1,811.8	2,395.5	583.7
EU15	840.5	1,085.2	244.7
Russia	178.6	149.5	-
Japan	264.1	306.8	42.7
Canada	182.5	249.5	67.0
Total			938.1

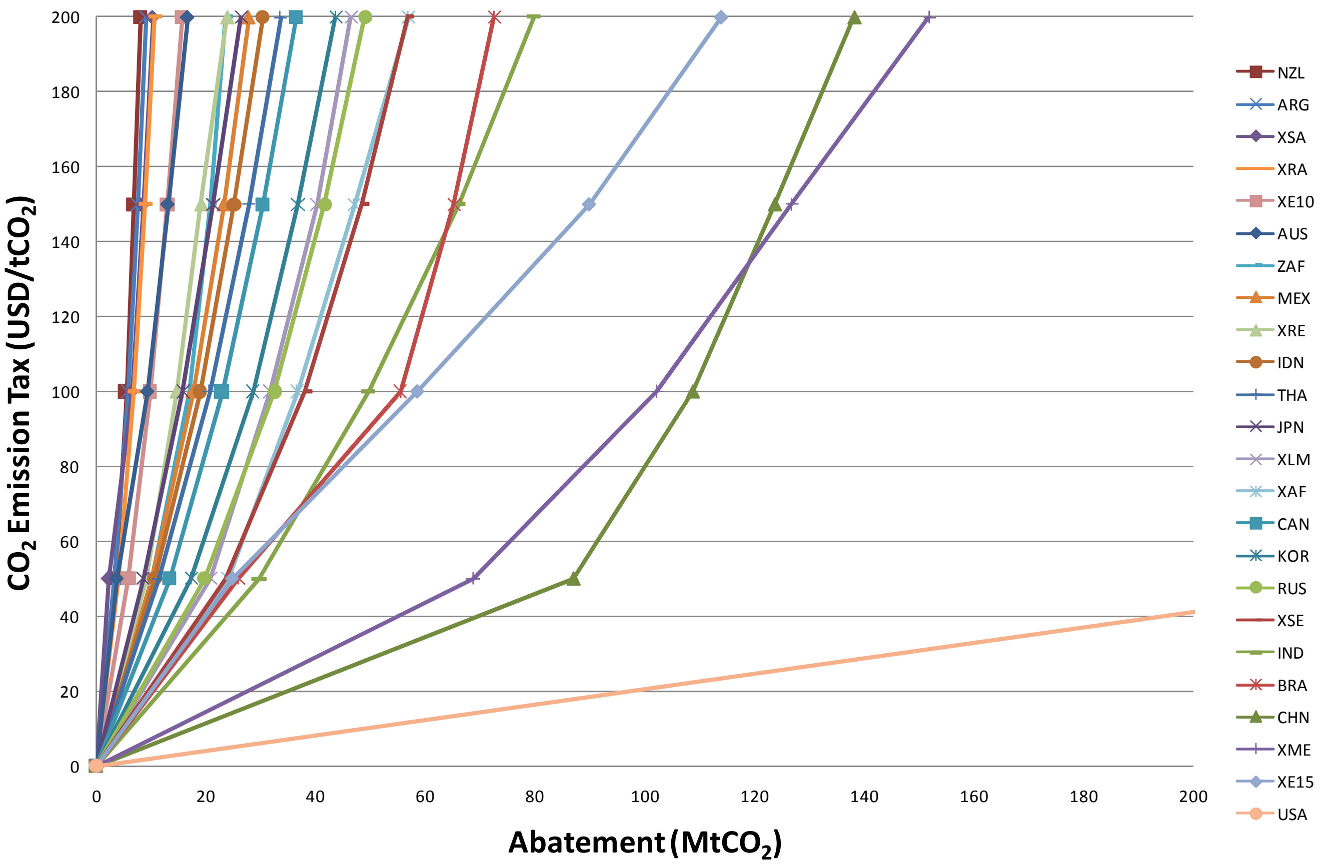

Figure 2: MAC curves for transport sector by region in 2020

From the MAC curves for transport sector in 2020 generated, we can determine relationship between CO_2 emission reductions (x) and marginal costs or prices of CO_2 emission permit (y) for the five Annex I regions as show in Figure 3. Based on the equations of the MAC curves for transport sector in 2020, we can calculate the cost for the last ton of CO_2 reduction or marginal abatement cost in transport sector. The total abatement costs of CO_2 emission reductions (i.e. the area under the curve) to meet the targets for each region for two cases of analysis including (1) no trading, and (2) trading. In this paper, we do not include Russia in the analysis of emission trading.

(1) No trading

The cost of meeting the commitment of emission reduction target in transport sector for each country can be calculated by determining the area under the MAC curve up to the emission reduction target as shown in Figure 3. From the MAC curves, we can calculate marginal abatement cost when having known the emission reduction target as mentioned. In case of no trading, i.e. each country reduce emissions in transport sector domestically to meet the target, Canada has highest marginal abatement cost, 534.0 \$/tCO_2; following by EU-15, Japan, and USA as 459.4, 401.8, and 194.2 \$/tCO_2, respectively. Then, total abatement costs of meeting the targets for EU-15, USA, Canada and Japan are 54.74, 43.43, 13.84, and 7.16 billion \$/tCO_2, respectively, as shown in Table 4. Even the USA has the biggest target, 583.7 $MtCO_2$, but its abatement cost is not highest, due to cheapest marginal abatement costs. On the other hand, Japan has the most expensive MAC curve, but its abatement cost is lowest due to the lowest target.

(2) Trading Case

If the emission trading in transport sector is allowed for countries that has targets, i.e. USA, EU-15, Canada and Japan;

total abatement cost for each country becomes decreasing. The abatement in each country will be changed according to demand and supply of emission permits of other countries. Each country will reduce emissions domestically up to the level that has marginal abatement cost equal to other countries; we call this equal marginal abatement cost as 'market price'. As the marginal cost to meet the target of USA is still lower compare to other countries, therefore, USA will prefer to reduce emissions in transport sector domestically more up to the amount that has marginal abatement cost equal to the market price. On the other hand, other countries have marginal abatement cost than the market will reduce emission abatement in their owner country to amount that has marginal abatement cost equal to the market price. To meet the targets, those countries have to buy emission permit rights from USA through the market. With the emission trading system, EU-15 gains most benefit through buying emission permit, 8.76 billion $/tCO_2$. USA gains 5.14 billion $/tCO_2$ through reducing more emission and sold out to the market as shown in Table 4.

5. Conclusions

In this paper, we clearly illustrated how to model CO_2 emissions in a CGE model and estimate abatement costs for sectors. The AIM/CGE model is extended to generate MAC curves for transport sector by region through introducing CO_2 emission taxes. Based on the developed MAC curves for transport sector by region in 2020, the USA—the world biggest GHG emitter—has the cheapest abatement cost in transport sector. In addition, we analyzed the potential of CO_2 emission reductions in transport sector for key Annex I countries and impacts of the emission trading in transport sector. It found that the sectoral MAC curves by region are useful for estimating abatement costs when the sectoral emission reduction targets are introduced and it could determine optimal emission reductions for each region that minimize total abatement cost.

References

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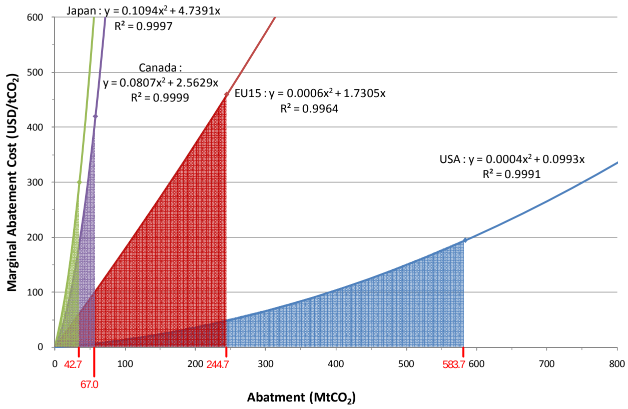

Figure 3: Abatement costs to meeting targets (no trade)

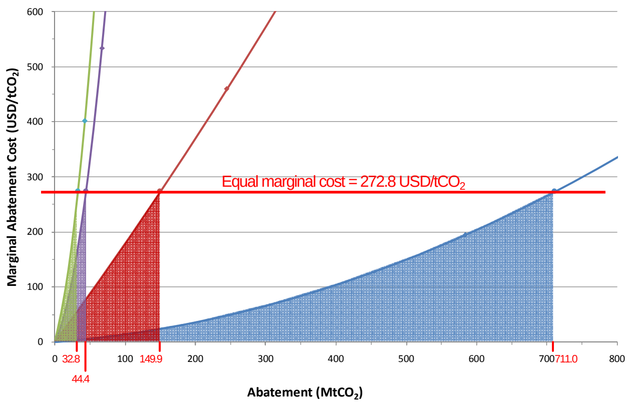

Figure 4: Abatement costs to meeting targets (trading case)

Table 4: Annex I regions meeting their transport sector's emission reduction targets in 2020

	USA	EU15	Japan	Canada	Total
Emission reduction targets ($MtCO_2$)	583.7	244.7	42.7	67.0	938.1
No trading:					
Marginal costs ($/tCO_2$)	**$194.2**	**$459.4**	**$401.8**	**$534.0**	-
Cost of abatement ($billion)	43.43	54.74	7.16	13.84	119.17
Trading:					
Domestic emission reduction ($MtCO_2$)	711.0	149.9	32.8	44.4	938.1
Market price of permits ($/tCO_2$)	**$272.8**	**$272.8**	**$272.8**	**$272.8**	**$272.8**
Cost of abatement ($billion)	73.02	20.12	3.84	4.88	101.86
Emission permits exp(-)/(+) ($MtCO_2$)	-127.3	+94.8	+9.9	+22.6	0
i.e. percent of commitment (import)	-	38.7%	23.1%	33.7%	-
Flows exp(-)/(+) ($MtCO_2$)	-34.73	+25.86	+2.70	+6.17	0
Total cost ($billion)	38.29	45.98	6.54	11.05	101.86
Gains from trading ($billion)	5.14	8.76	0.62	2.79	17.31