LINKING MUNICIPAL EMISSIONS TRADING SCHEMES ACROSS ASIA: THE MERITS IN ATTAINING CARBON DIOXIDE ABATEMENT TARGETS AND REDUCING ITS COSTS

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Abstract: In Asia, many municipalities are actively tackling an issue of global warming by setting their respective voluntary targets of carbon dioxide (CO_2) emissions abatement. Some of them in China, India, and Japan have already introduced or plan to introduce municipal emissions trading schemes. These movements would lead to a good preparation towards a new international framework under the United Nations Framework Convention on Climate Change (UNFCCC) starting in 2020 after the termination of the Kyoto Protocol because Asia's developing countries such as China and India are likely to have legally-binding obligations of CO_2 emissions abatement under the new international framework. Furthermore, these movements indicate the possibility that currently emerging municipal emissions trading schemes in Asia will be linked to seek potential benefits from such linking. Discussing that municipal emissions trading schemes must be more feasible than national emissions trading schemes, this paper tests the potential benefits of linking municipal emissions trading schemes across Asia. More specifically, the paper empirically investigates merits of linking municipal emissions trading schemes across a region, where CO_2 abatement technologies are diverse, in attaining an overall CO_2 abatement target for a region as well as CO_2 abatement targets for respective municipalities and in reducing an overall CO_2 abatement costs for a region as well as CO_2 abatement costs for respective municipalities. To investigate these merits, the paper first reviews theoretical frameworks and implications of a general economic model of emissions trading and secondly conducts a simulation analysis on an extended model of emission trading assuming that private firms in municipalities trade carbon permits each other across a region. Simulations are conducted for a hypothetical region, where CO_2 abatement technologies are diverse like in Asia, to compare following three points for three cases: (1) a case of no linking municipal emissions trading schemes; (2) a case of linking municipal emissions trading schemes at home; and (3) a case of linking municipal emissions trading schemes across a region. The first point to be compared for these three cases is an overall CO_2 abatement costs for the region to attain its overall CO_2 abatement target. The second point is costs for each of municipalities to attain its CO_2 abatement target. The third point is cost savings/revenues for each of municipalities gained from trading carbon permits. A major result of simulations using hypothetical marginal abatement cost functions for private firms is that, the case (3), that is, linking municipal emissions trading schemes across the region has the least overall CO_2 emissions abatement costs for the region.

Keywords: Asia, Carbon dioxide emissions, Carbon permits, Marginal abatement costs, Municipal emissions trading scheme

INTRODUCTION

Research background

In Asia, many municipalities are actively tackling an issue of global warming by setting their respective voluntary targets of carbon dioxide (CO_2) emissions abatement. Furthermore, some municipalities in China, India, and Japan have already introduced or plan to introduce emissions trading schemes. In addition to Tokyo and Saitama in Japan that introduced emissions trading schemes in 2010 and 2011 respectively, it is expected that China will launch pilot emissions trading schemes in two provinces (Hubei, Guangdong) and four cities (Beijing, Shanghai, Tianjin, Chongqing) before 2013 [1] and that India will complete the pilot study of emissions trading schemes in three states (Gujarat, Maharashtra, Tamil Nadu) in 2012 and start them in 2013 [2]. These movements in Asia must be a good preparation towards a new international framework of the United Nations Framework Convention on Climate Change (UNFCCC) starting not later than 2020 after the termination of the Kyoto Protocol because under the new international framework many Asian countries including China and India are likely to have legally-binding obligations of CO_2 emissions abatement and to use Certified Emission Reduction (CERs), carbon credits produced from Clean Development Mechanism (CDM) projects in their countries to attain their CO_2 emissions abatement targets though they currently sell CERs as host countries of CDM projects to developed countries. It is expected that more municipalities in Asia will introduce emissions trading schemes to abate CO_2 cost-effectively. Moreover, emerging municipal emissions trading schemes in Asia suggest the possibility that they will be linked to exploit potential merits from such linking. As of 2009, China (excluding Hong Kong) is the largest CO_2 emitter accounting for 23.6% of the world's CO_2 emissions, India the third accounting for 5.5%, and Japan the fifth accounting for 3.8% [3]. In spite of the importance of Asia in mitigating global warming and of emissions trading as a cost-effective instrument in abating CO_2 emissions, there are not enough studies addressing the use of emissions trading as a strategy for CO_2 emissions abatement in the context of Asia [4]. This study fills this gap in academic literature on emissions trading schemes.

Research purpose

The purpose of this study is to empirically investigate the merits of linking municipal emissions trading schemes across a region, particularly Asia where marginal abatement costs of CO_2 (hereafter MAC) are diverse among countries, in attaining CO_2 emissions abatement targets (hereafter abatement targets) and reducing CO_2 emissions abatement costs (hereafter abatement costs) by conducting a numerical simulation. An interest of this study is emissions trading schemes at municipal levels rather than national levels. Municipal emissions trading schemes are supposed to be more practical than national emissions trading schemes in two perspectives. Firstly, it is easier at municipal levels to reach a consensus among stakeholders than at national levels in determining the abatement targets and the criteria for the allocation of emissions allowances (hereafter allowances) to regulated entities. Secondly, it is less cumbersome at municipal levels to monitor actual emissions and trading of allowances or carbon credits between regulated entities than at national levels because of a much smaller number of regulated entities at municipal levels. Not listing all of the existing emissions trading schemes in the world, Table 1 shows some of them that are classified based on the space level covered under the scheme and the type of implementing authority of the scheme. International Emissions Trading (IET) under the Kyoto Mechanism is a global emissions trading scheme where participating countries are primarily responsible for implementing the scheme. EU Emissions Trading Scheme (EU ETS) is a regional emissions trading scheme where participating EU member countries are primarily responsible for allocating allowances to industries and firms. United Kingdom, New Zealand, and Korea introduced or plan to introduce national emissions trading schemes where their central governments implement the schemes. Municipal governments of Tokyo and Saitama in Japan already introduced emissions trading schemes. Linking municipal emissions trading schemes across a region is a regional emissions trading scheme where participating municipalities are responsible for implementing the scheme. A few examples of this type already exist. They are Western Climate Initiative (WCI) in which seven western states in the U.S. and four western states in Canada participate, and Midwestern Greenhouse Gas Accord (MGGA) in which six western and central states in the U.S. and one state in Mexico participate. Under WCI and MGGA participating states are responsible for implementing the scheme. Furthermore, there is another type of region-wide emissions trading scheme called Regional Greenhouse Gas Initiative (RGGI) in which ten states in the northeastern U.S. participate. A main difference between WCI and MGGA on the one side and RGGI on the other side is that under the former schemes the states are linked beyond national borders while under the latter scheme the states are linked within the country. Linking municipal emissions trading schemes across Asia addressed in this study belongs to the former type.

Outline of paper

The next section reviews a basic economic model of emissions trading with focusing on its theoretical frameworks and implications.

Table 1: Classification of Existing Emissions Trading Schemes

Space level covered under the scheme	Implementing authority of the scheme	
	Central governments	Municipal governments
Globe	IET under Kyoto Mechanism	
Region	EU ETS	WCI (U.S. & Canada), MGGA (U.S. & Mexico)
Domestic region		RGGI (U.S.)
Country	United Kingdom, New Zealand, Korea	
Municipality		Tokyo, Saitama

Linkage of municipal emissions trading schemes across a region

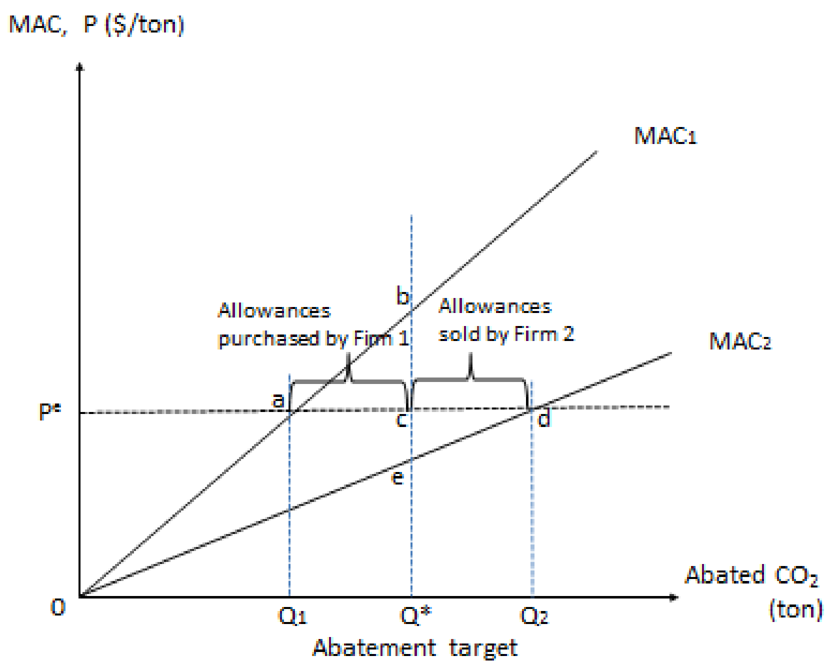

Figure 1: Basic Economic Model of Emissions Trading

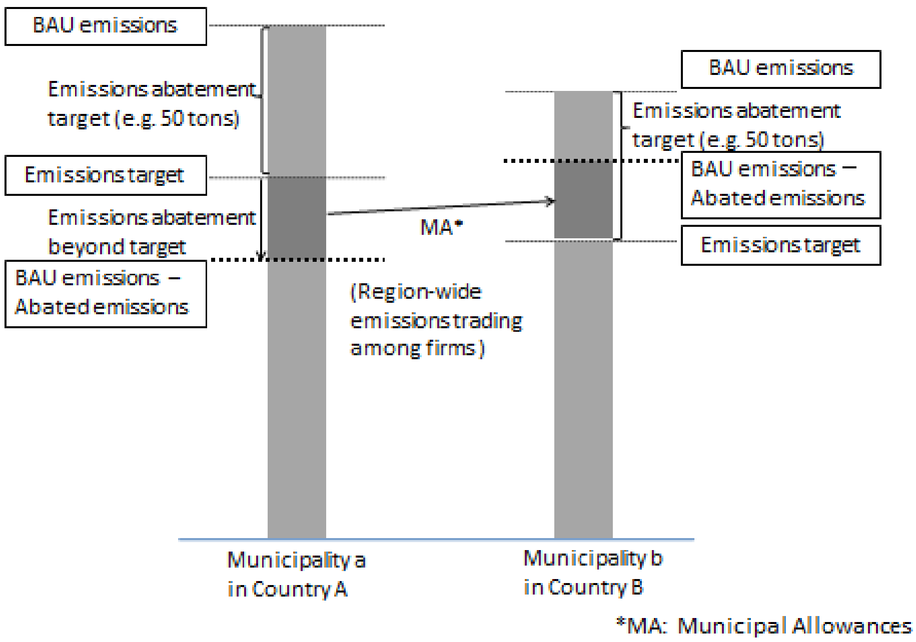

Figure 2: Linking Municipal Emissions Trading Schemes across a Region

Table 2: Assumptions in Numerical Simulation

Country	CHN				IND				JPN			
CO_2 emissions abatement target for municipality (tons)	CHNa 100		CHNb 100		INDa 100		INDb 100		JPNa 100		JPNb 100	
CO_2 emissions abatement target for firms (tons)	CHNa1 50	CHNa2 50	CHNb1 50	CHNb2 50	INDa1 50	INDa2 50	INDb1 50	INDb2 50	JPNa1 50	JPNa2 50	JPNb1 50	JPNb2 50
CO_2 MAC function for firms ($/ton)	$1/16\ x^2$	$1/15\ x^2$	$1/14\ x^2$	$1/13\ x^2$	$1/12x^2$	$1/11\ x^2$	$1/10\ x^2$	$1/9\ x^2$	$1/4\ x^2$	$1/3\ x^2$	$1/2\ x^2$	x^2

x denotes abated CO_2 emissions.

Then, following sections firstly discuss the conceptual frameworks of the linkage of municipal emissions trading schemes across a region based on the basic economic model of emissions trading, secondly explain how the numerical simulation was conducted to investigate the merits of linking municipal emissions trading schemes across Asia, where MAC are diverse among countries, in attaining abatement targets and reducing its costs, thirdly analyze the results of numerical simulation, and finally summarize the findings of this study and discusses some relevant issues.

BASIC ECONOMIC MODEL OF EMISSIONS TRADING

Environmental tax vs. emissions trading

Before reviewing theoretical frameworks and implications of the basic economic model of emissions trading, environmental tax and emissions trading are compared here. Both of them are market-based instruments, which are theoretically expected to abate emissions at least cost, and often compared in the literature on environmental economics, global warming in particular [5] [6]. Here the purpose of comparing them is not to argue the superiority of either one over the other, but to draw attention to main features of emissions trading by comparing it with environmental tax. For example, Nordhaus compares them by characterizing environmental tax as price-oriented control mechanism and emissions trading as quantity-oriented control mechanism [5]. In environmental tax, on the one hand, a regulatory authority determines an appropriate tax level (that is, a price of emitting one unit of CO_2) so that its pre-determined abatement target can be attained. But, it is not guaranteed for the pre-determined abatement target to be attained when tax level is not appropriate. In emissions trading, on the other hand, a regulatory authority determines an abatement target and allocates allowances to regulated entities based on the target. Then, a price of allowances determined in carbon-credit market adjusts the demand for and supply of allowances so that the pre-determined abatement target is attained. In emissions trading, therefore, it is guaranteed for the pre-determined abatement target to be attained. However, emissions trading has difficulty in determining the criteria for allocating appropriate allowances to regulated entities.

Basic economic model of emissions trading: Theoretical frameworks and implications

As mentioned above, main features in emissions trading are, firstly that an abatement target can be attained at least cost, and secondly that a regulatory authority can control its abatement target by allocating allowances to regulated entities [7] [8]. Fig. 1 shows how the abatement costs in attaining the abatement target are minimized by emissions trading. In this simple case there are two regulated entities, Firm 1 and Firm 2. A horizontal axis is the quantity of abated CO_2 emissions by each of two firms. Q* is the quantity of abatement target which each of two firms has to attain respectively (otherwise they have to pay penalties to a regulatory authority). The aggregate abatement target is therefore $2 \times Q^*$. Vertical axis is the MAC for each of two firms and also the market price of allowances denoted by P. Two lines depicted from the origin are MAC curves for two firms. A MAC curve for Firm 1 is denoted by MAC_1 and a MAC curve for Firm 2 MAC_2. Firm 1 has higher MAC than Firm 2. This is indicated by the slope of MAC_1 which is steeper than the one of MAC_2. Both firms determine how much of CO_2 to abate taking into consideration their current quantity of abated CO_2, the quantity of their abatement targets, their MAC curves, and a market price of allowances. For example, if a firm's MAC at its additional quantity of abated CO_2 is higher than a market price of allowances and the current quantity of abated CO_2 is short of its abatement target, then the firm decides to purchase allowances instead of abating CO_2 by itself and to offset its CO_2 emissions since it can save its abatement costs to attain its abatement target. In Fig. 1 Firm 1 abates CO_2 emissions up to Q_1 by itself, but beyond Q_1 purchases allowances from Firm 2 until attaining its abatement target, Q*. On the other hand, if a firm's MAC is lower than a market price of allowances at its additional quantity of abated CO_2 and the current quantity of abated CO_2 is in excess of its abatement target, then the firm decides to sell the surplus since it can gain the profits. In Fig. 1 Firm 2 abates CO_2 emissions more than its abatement target, Q*, and sell the surplus of its allowances to Firm 1. Fig. 1 shows that a market price of allowances is at an equilibrium denoted by P^e where the quantity of allowances purchased by Firm 1 ($Q^* - Q_1$) and the one sold by Firm 2 ($Q_2 - Q^*$) are equal (1 unit of allowance is equivalent to 1 ton of CO_2). When both of the following Eq. 1 and Eq. 2 are satisfied, the aggregate abatement target ($2 \times Q^*$) is attained at least cost.

$$P^e = MAC_1 = MAC_2 \quad (1)$$

$$(Q_1 - Q^*) + (Q_2 - Q^*) = 0 \text{ at } P^e \quad (2)$$

where MAC_1, MAC_2, and Q* are given.

This basic economic model of emission trading for the simple case of two firms indicates that with emissions trading the aggregate abatement costs in attaining an aggregate abatement target ($2 \times Q^*$) can be minimized. Without emissions trading the aggregate abatement costs are the area 0bQ* + 0eQ*. With emission trading, however, the aggregate abatement costs is the area $0aQ_1$ + $0dQ_2$, or equivalently the area 0acQ* + 0eQ* - cde. The reduced abatement costs are composed of two parts, cost savings and profits. This reduced abatement costs can be shown by the area abc + ace, or equivalently the area abc + cde. A firm with a relatively steep MAC curve can save its abatement costs through emissions trading. The saved abatement costs are the area abc. It can be derived by subtracting the area acQ^*Q_1 (the purchasing cost of allowances) from the area abQ^*Q_1. A firm with a relatively gradual MAC curve can gain the profits through emissions trading. This profit is the area cde. It can be derived by subtracting the area edQ_2Q^* from the area cdQ_2Q^* (the revenue from selling allowances).

CONCEPTUAL FRAMEWORKS IN THE LINKAGE OF MUNICIPAL EMISSIONS TRADING SCHEMES ACROSS A REGION

The basic economic model of emissions trading for the simple case of two firms reviewed in the previous section shows that with emissions trading the aggregate abatement costs in attaining the aggregate abatement target can be minimized. How do the aggregate abatement costs change as more and more firms are linked by the linkage of emissions trading schemes? Several studies analyze the merits of linking emissions trading schemes in the abatement costs for attaining the abatement compliance [9] [10]. They argue that such a linkage brings more abatement options available and make the market of allowances or carbon credits larger and more liquid. This section extends the basic economic model of emissions trading in the previous section to apply it for the case of the linkage of municipal emissions trading schemes across a region. Here it is assumed that there are several municipalities with their own emissions trading schemes in a region. Under each of municipal emissions trading schemes, a regulatory authority determines a municipal abatement target and allocates the allowances equivalent to the quantity of a municipal abatement target to regulated firms in the municipality. Then, regulated firms trade allowances each other within the country and regionally to attain their respective abatement targets. How do the aggregate abatement costs to attain the aggregate target change for the case of the linkage of municipal emissions trading schemes in which a relatively large number of firms are linked each other domestically and regionally? Graphically it could be shown simply by putting MAC curves of all of the participating firms into Fig. 1. The two conditions at an equilibrium price of allowances, Eq. 1 and Eq. 2 in the previous section, can be generalized as the following Eq. 3 and Eq. 4. When both of Eq. 3 and Eq. 4 are satisfied, the aggregate abatement target ($n \times Q^*$) is attained at least cost.

$$P^e = MAC_1 = MAC_2 = \text{----------} = MAC_i$$

$$i = \text{ firm } 1, 2, \text{------------}, n \qquad (3)$$

$$(Q_1 - Q^*) + (Q_2 - Q^*) + \text{-------------} + (Q_i - Q^*) = 0$$

$$\text{at } P^e \quad i = \text{ firm } 1, 2, \text{------------}, n \qquad (4)$$

where MAC_i and Q^* are given.

Fig. 2 shows the conceptual image of emissions trading among participating firms under the linkage of municipal emissions trading schemes across a region. Municipality ‘a’ in Country A and Municipality ‘b’ in Country B have their respective emissions trading schemes. BAU emissions are the emissions in business as usual. Participating firms in Municipality ‘a’ abate their emissions beyond the emissions abatement target of Municipality ‘a’ (for example, 50 tons). The surplus is measured by subtracting the emissions abatement target of Municipality ‘a’ from its abated emissions. Then, participating firms in Municipality ‘a’ can sell the surplus. On the other hand, participating firms in Municipality ‘b’ abate their emissions below the emissions abatement target of Municipality ‘b’ (50 tons). The shortfall is measured by subtracting its abated emissions from the emissions abatement target of Municipality ‘b’. In Fig. 2 participating firms in Municipality ‘a’ sells theirs surplus of allowances (named Municipal Allowances) to participating firms in Municipality ‘b’.

NUMERICAL SIMULATION

There are several studies that empirically investigated the cost-effectiveness of different types of emissions trading schemes. Lee conducted a numerical analysis to investigate the cost-effectiveness of IET under the Kyoto Mechanism and found that IET could bring the cost-savings for both the Annex I countries as a whole and the individual countries but sacrifices the ancillary benefits from domestic abatement [11]. Smith and Swierzbinski assessed the economic efficiency and environmental effectiveness of the UK Emissions Trading Scheme which began in 2002 [12]. In this section the cost-effectiveness of the linkage of municipal emissions trading across a region, particularly in the context of Asia, is investigated by conducting the numerical simulation. Main interests in the numerical simulation are how the aggregate abatement costs in attaining the aggregate abatement target and also the abatement cost savings and the profits for the participating municipalities as a whole and individual municipalities change as the linkage of municipal emissions trading schemes are extended.

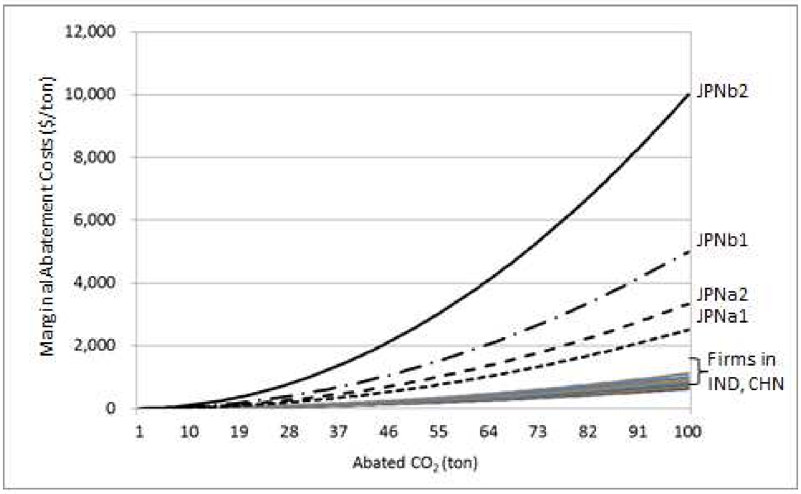

Figure 3: Marginal Abatement Cost Curves for 12 Firms in 6 Municipalities of 3 Countries

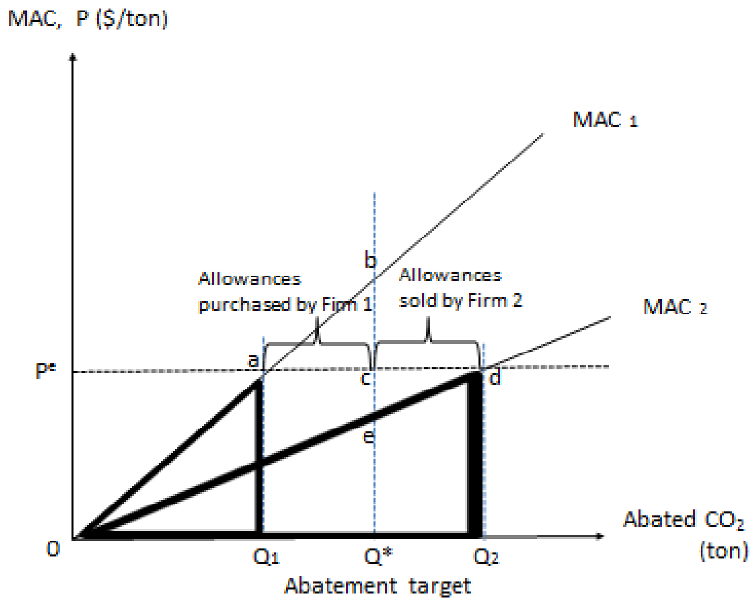

Figure 4: Aggregate Abatement Costs in Emissions Trading

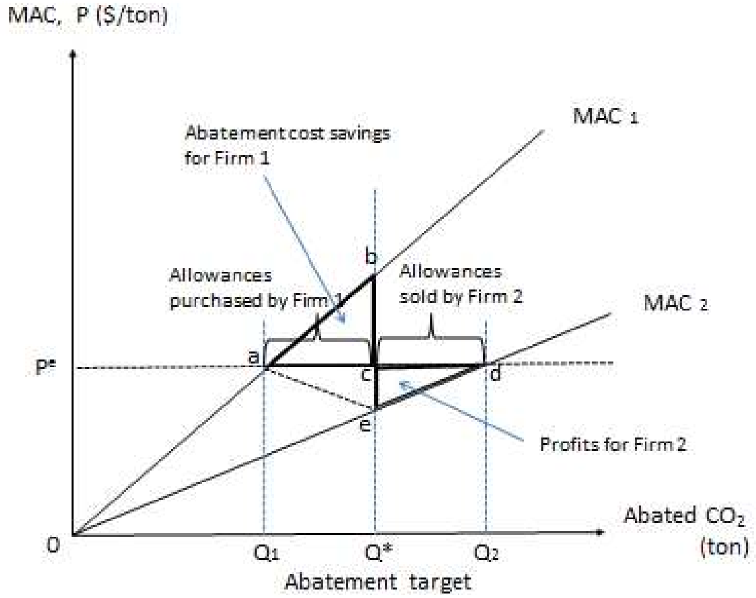

Figure 5: Abatement Cost Savings and Profits from Emissions Trading

Table 3: Merit in Aggregate Abatement Cost

Municipality	Case (1) No Linking Municipal Schemes			Case (2) Linking Municipal Schemes at Home			Case (3) Linking Municipal Schemes across a Region		
	Abated CO_2 (ton)	Eq. Price ($/ton)	Abatement Cost ($)	Abated CO_2 (ton)	Eq. Price ($/ton)	Abatement Cost ($)	Abated CO_2 (ton)	Eq. Price ($/ton)	Abatement Cost ($)
CHNa	100.0	161.3	5,377.1	103.5	172.7	5,954.5	137.6	305.8	14,035.8
CHNb	100.0	185.2	6,174.5	96.5		5,556.8	128.5		13,098.5
INDa	100.0	217.5	7,250.1	104.8	238.8	8,339.2	118.6		12,088.6
INDb	100.0	263.3	8,777.0	95.2		7,578.6	107.8		10,986.0
JPNa	100.0	718.0	23,933.8	121.4	1,058.9	42,865.6	65.3		6,653.4
JPNb	100.0	1,715.6	57,184.5	78.6		27,729.2	42.2		4,304.0
Total	600.0	N/A	108,697.0	600.0	N/A	98,023.9	600.0	N/A	61,166.3

Assumptions in numerical simulation

Numerical simulation assumes the linkage of municipal emissions trading schemes across three countries in Asia, namely China, India, and Japan. Assumptions in the numerical simulation are summarized in Table 2. It is assumed that a total of six municipalities having their respective emissions trading schemes are linked: two municipalities in each of three countries, China (denoted as CHN), India (IND), and Japan (JPN). These six municipalities are denoted as CHNa, CHNb, INDa, INDb, JPNa, and JPNb. It is then assumed that a total of twelve firms participate in the linkage: two firms in each of six municipalities. Two firms in CHNa are denoted as CHNa1 and CHNa2. Other ten firms are denoted in a similar manner. In addition, it is assumed that there are four main sectors in terms of CO_2 emissions in each of three countries and four firms in each of three countries represent those four sectors. Each of the six municipalities has an equal CO_2 abatement target of 100 tons per year. It means that the aggregate abatement target for six municipalities as a whole is 600 tons per year. Six municipalities impose an equal abatement target of 50 tons per year on the firms in their respective municipalities and allocate the allowances (1 unit of allowance = 1 CO_2 ton) to the firms according to the firm's abatement target of 50 tons. In addition to these assumptions, a crucial assumption is CO_2 MAC functions for twelve firms since the extent of their difference determines the amount of reduced abatement costs by emissions trading (refer to Fig. 1). MAC functions for twelve firms in Table 2 are hypothetically determined to reflect three points. The first point is that an additional cost to abate an additional unit of CO_2 gradually increases as abated emissions increases. The second point is that MAC curves for Japanese firms are much steeper than those for Chinese and Indian firms because of the higher opportunity costs of abatement for Japanese firms while the difference between MAC curves for Chinese firms and those for Indian firms is small though MAC curves for Indian firms are slightly steeper than those for Chinese firms. The third point is that MAC functions are different for the firms in different sectors. Ellerman and Decaux report the first and second points in their study on the benefits of emissions trading in attaining abatement targets using estimated marginal abatement curves of major countries including China, India, and Japan [8]. In their study the marginal abatement curves of CO_2 are estimated based on shadow prices of CO_2 equal to marginal opportunity costs of CO_2. Hypothetical MAC curves for twelve firms are shown in Fig. 3. The numerical simulation was conducted assuming the emissions trading for one-year during which MAC functions for twelve firms are static and the equilibrium price is reached.

Measuring the merit in aggregate abatement costs

As already discussed, one of the main features in emissions trading is that the aggregate abatement target can be attained at least cost. Fig. 4 shows this feature graphically. Fig. 4 is basically the same as Fig. 1 except that the abatement costs with emissions trading for Firm 1 and Firm 2 are indicated by the areas with bold lines, $0aQ_1$ and $0dQ_2$ respectively. Since the assumed MAC curves in simulation are not straight lines like in Fig. 4 but curved lines, the areas can be calculated by integration. Then, these abatement costs can be added to derive the aggregate abatement costs.

Measuring the merit of abatement cost savings and profits

The reduced aggregate abatement costs by emissions trading are composed of the abatement cost savings for the firms purchasing allowances and the profits for the firms selling allowances. Fig. 5 shows this graphically. Fig. 5 is basically the same as Fig. 1 except that the abatement cost savings for Firm 1 and the profits for Firm 2 are indicated by the areas with bold lines, abc and cde respectively. These abatement cost savings and profits can be added to derive the aggregate abatement costs savings and the aggregate profits.

RESULTS OF NUMERICAL SIMULATION

Merit in aggregate abatement costs

Numerical simulation based on the assumptions in Table 2 was conducted to explore the merits in aggregate abatement costs for three cases: (1) Case of no linking municipal emissions trading schemes; (2) Case of linking municipal emissions trading schemes at home; (3) Case of linking municipal emissions trading schemes across a region. In Case (1) six municipal emissions trading schemes in China, India, and Japan are not linked each other. Therefore, firms buy and sell their allowances with their counterparts only within their respective municipalities. In Case (2) they are domestically linked. Therefore, firms buy and sell their allowances with their counterparts in the municipalities at home. In Case (3) they are regionally linked. Therefore, firms buy and sell their allowances with their counterparts in any municipalities of three countries. The process of numerical simulation is as follows. For Case (1) there are six markets of allowances since six municipal emissions trading schemes are independent. The quantities of abated CO_2 at the equilibrium price of allowances were determined for each of twelve firms by changing the values of the prices of allowances in six markets arbitrarily starting from US$10.00 until it reached the equilibrium prices at respective markets. Then, the abatement costs in attaining the abatement target of 100.0 tons were calculated for each of six municipalities. For Case (2) there are three markets of allowances since two municipal emissions trading schemes at home are linked. The quantities of abated CO_2 at the equilibrium price of allowances were determined for each of twelve firms in the similar manner as in Case (1). Then, the abatement costs in attaining the abatement target of 200.0 tons were calculated for each of six municipalities. For Case (3) there is only one market since six municipal emissions trading schemes are regionally linked. The quantities of abated CO_2 at the equilibrium price of allowances were determined for each of twelve firms in the similar manner as in Case (1) and Case (2). Then, the abatement costs in attaining the abatement target of 600.0 tons were calculated for each of six municipalities. Table 3 shows the results of numerical simulation. In Case (1), CHNa having firms with the most gradual MAC curves has the smallest abatement costs to attain its abatement target of 100.0 tons while JPNb having firms with the highest MAC curves has the largest abatement costs to attain the same abatement target of 100.0 tons. The aggregate abatement costs to attain the aggregate abatement target of 600.0 tons are U.S.$108,697.0. In Case (2), one of two municipalities at home abates CO_2 emissions more than its abatement target and sells the surplus of allowances while the other one abates CO_2 emissions less than its abatement target and buys the shortfall of allowances. The aggregate abatement costs to attain the aggregate abatement target of 600.0tons are U.S. $98,023.9 which is smaller than in Case (2). In Case (3), the municipalities in China and India abate CO_2 emissions more than their respective abatement targets and sell the surplus of allowances to the municipalities in Japan while the municipalities in Japan abate CO_2 emissions less than their respective abatement targets and buy the shortfall of allowances from the municipalities in China and India. The aggregate abatement costs to attain the aggregate abatement target of 600.0tons are U.S.$61,166.3 which is further smaller than in Case (2). The absolute values of the aggregate abatement costs and equilibrium prices in Table 3 are not so important since the MAC functions used in this numerical simulation are hypothetically determined. More important are their relative values which clearly indicate that the aggregate abatement costs become smaller as the linkage of the municipal emissions trading schemes are more extended.

Merits of abatement cost savings and profits

Numerical simulation was also conducted to explore the merits of abatement cost savings and the profits by emissions trading for three cases. The abatement cost savings for the firm can be calculated using Eq. 5. On the other hand, the profits for the firms can be calculated using Eq. 6.

Abatement cost saving = (Abatement cost without emissions trading) – (Abatement cost with emissions trading) ‐ (Purchasing cost of allowances) (5)

Profits = (Revenue from selling excess allowances) – (Abatement cost for excess abatement) (6)

Table 4 shows the results of numerical simulation. In Case (1) there are only slight merits both in the abatement cost savings and profits from emissions trading for Chinese and Indian municipalities. This is attributed to slight difference in MAC curves for Chinese and Indian firms in the assumptions. On the other hand, there are relatively large merits both in the abatement cost savings and profits for Japanese municipalities since there is a relatively bigger difference in MAC curves for Japanese firms in the assumptions. The aggregate abatement cost savings and the aggregate profits for six municipalities as a whole are US$6,966.8 and US$4,472.0 respectively. In Case (2) the municipalities having firms with steeper MAC curves make the abatement cost savings while those having firms with more gradual MAC curves gain the profits within each of three countries. The aggregate abatement cost savings and profits are US$24,345.6 and US$8,440.3 respectively, both of which are larger than in Case (2). This is consistent with the result in the numerical simulation on the aggregate abatement costs. In Case (3) the municipalities in China and India sell allowances and gain the profits on the one hand, those in Japan buy allowances and save the abatement costs on the other hand. The aggregate abatement cost savings and the aggregate profits are US$95,109.0 and 8,540.4 respectively, both of which are further larger than in Case (2). Again, this is consistent with the result in the numerical simulation on the aggregate abatement costs.

CONCLUSION

In this study two important points are found. One important point is that the aggregate abatement costs in attaining the aggregate abatement target become smaller as the linkage of municipal emissions trading schemes are extended. Another important point is that the municipalities having firms with relatively steep MAC curves can save abatement costs in attaining their abatement targets by purchasing allowances while those having firms with relatively gradual MAC curves can make profits by selling allowances. These abatement cost savings and profits become larger as the linkage of municipal emissions trading schemes are extended.

Table 4: Merits of Abatement Cost Savings and Profits for Municipalities

Municipality	Case (1) No Linking Municipal Schemes			Case (2) Linking Municipal Schemes at Home			Case (3) Linking Municipal Schemes across a Region		
	Abated CO_2 (ton)	Cost Savings ($)	Profits ($)	Abated CO_2 (ton)	Cost Savings ($)	Profits ($)	Abated CO_2 (ton)	Cost Savings ($)	Profits ($)
CHNa	100.0	2.2	2.1	103.5	0.0	23.9	137.7	0.0	2,870.6
CHNb	100.0	3.3	3.1	96.6	28.0	0.0	128.5	0.0	1,795.3
INDa	100.0	5.3	5.0	104.8	0.0	61.5	118.6	0.0	854.3
INDb	100.0	9.5	8.8	95.2	76.5	0.0	107.8	0.0	185.3
JPNa	100.0	204.4	168.9	121.4	0.0	4,146.7	65.3	7,029.4	0.0
JPNb	100.0	3,259.9	2,049.2	78.6	12,068.3	0.0	42.2	40,525.0	0.0
Total	600.0	6,966.8	4,472.0	600.0	24,345.6	8,440.3	600.0	95,109.0	8,540.4

Two important points hold, however, only when MAC curves of the firms in municipalities are diverse across the region like Asia. Though the institutional design for the linkage of municipal emissions trading schemes in Asia is beyond the scope of this study, the followings must be carefully considered in actually designing such a linkage. Firstly, the criteria in determining abatement targets for participating firms as well as participating municipalities must be carefully determined. Secondly, the limitation on the allowances purchased and used to offset emissions should be imposed. That is, only a part of abatement target can be allowed to be offset by purchasing allowances. Thirdly, to provide developing countries/municipalities in Asia with incentives to participate in the linkage like what is addressed in this study, Certified Emissions Reduction (CERs) produced from Clean Development Mechanism (CDM) projects under the framework of the Kyoto Protocol should be allowed to use in attaining their abatement targets and to sell the surplus. China and India, in particular, share about 47% and 20% respectively of the registered CDM projects in the world [13] and about 72% and 2% respectively of the primary CERs sold in the world carbon market [14]. Though it is not certain whether CDM continues to exist under a new international framework starting not later than 2020, this kind of mechanism which can provide developing countries/municipalities with incentives to abate CO_2 should be incorporated into designing the linkage of municipal emissions trading schemes particularly in the context of Asia where developing countries share the majority. The linkage of municipal emissions trading schemes across Asia must create the opportunities that municipalities in the region collaborate each other to implement CDM projects. The collaborative implementation of CO_2 abatement projects must contribute to the dissemination of CO_2 abatement technologies across Asia.

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