The Costs and Benefits of Pre-action before Kyoto Compliance

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Abstract: Transaction costs have negative effects on emissions trading. Recent debates on Kyoto Protocol have become aware of the potential threat of transaction costs to the implementation of emissions trading for the Protocol and consequently to the successful compliance of the Protocol. One way to suppress transaction costs is to use experience. In line with the EU Green Paper, we propose that a pre-action before the Kyoto period could be helpful to reduce the transaction costs in emissions trading for the Kyoto compliance. However, because pre-action will incur additional costs, the final gain due to pre-action will be the pre-action cost saving net of the pre-action costs. This paper explores the relationship between the transaction costs in emissions trading and the pre-action effort to reduce transaction costs in the case of Kyoto Protocol. We find that low-cost countries have greater incentive for pre-action than high-cost countries, because they are more sensitive to transaction costs. Furthermore, we conclude that small-scale pre-action would be more likely to bring benefits, therefore pre-action is necessary and a well-prepared emission trading system plays key role in ensuring the Kyoto compliance.

Keywords: Transaction costs, Pre-action, Kyoto compliance

1 INTRODUCTION

A central problem blocking the process of ratification of the Kyoto Protocol is the possibly high costs for the committed industrial countries. The Protocol recommends flexible mechanisms to alleviate emissions reduction loads in high-cost countries. In particular, the current negotiations among Annex I countries have shown that the success of the Kyoto Protocol may depend critically on the use of the cooperative, flexible mechanisms, (Weyant and Hill, 1999).

The flexible mechanisms recommended in Kyoto Protocol aiming to improve cost efficiency, include Emissions Trading (ET), Joint Implementation (JI), and Clean Development Mechanism (CDM). Among the three, ET is often considered as the most cost-effective, because it operates at full scale.[1]

However, emission trading will inevitably involve transaction costs, which are ubiquitous in emissions trading markets and in any case will erode the efficiency of emissions trading or even hinder the implementation of the instrument (Stavins, 1995). Historically, many precedent emissions trading systems have not been successful. One of the reasons was the higher transaction costs (Tietenberg, 1999).

One way to avoid or reduce potential transaction costs is to use experience. In the past, emissions trading has been successful in several environmental agreements (Tietenberg, 1999). However, most of these precedents are national schemes, from which one can not draw full experience for the international scheme of Kyoto Protocol. Considering that a well-prepared emissions trading system could reduce transaction costs and uncertainty, the industrial countries that have committed to reach their targets during the period of 2008-2012 could aquire practical knowledge on emissions trading through pre-action.

The Green Paper recently published by European Community (2000) goes into this direction. A pre-action could increase efficiency through "learning by doing", but it also induces costs of emissions reduction. The actual gain or loss of a pre-action thus depends on the pre-action effort, the transaction costs, and the efficiency of "learning by doing".

The present paper attempts to identify what could be the impact of pre-action by Annex I regions on transaction costs. The paper focuses on CO2 emissions only. Following the Green Paper, it simulates international CO2 emissions trading during pre-action between energy and energy-intensive sectors only. In the simulation, we measure the costs of pre-action for each region by the direct cost, equal to each region's domestic emission reduction cost net of emission trading payments, and by the total welfare cost. In this paper, pre-action will benefit the Kyoto compliance by reducing the transaction costs. The final gain thus is the difference between the benefit of Kyoto compliance and the direct cost of pre-action.

2 THE METHOD

2.1 The model

We model emission trading using GEM-E3 world version, a CGE model, which provides details on the global macro-economy, and its interaction with the environment and the energy system. The model has multi-nation, multi-agent, multi-sector, and dynamic features, and it is based on GTAP database. In this study, we adapt the model for our purpose by a number of specific arrangements.

We aggregate the world economies into seven regions: EU15 (European Union), CEU (Central Europe and Former Soviet Union), USA, JAPAN, OEC (Other Europe, Canada, Australia and New Zealand), ASIA (China, India and the rest of southeastern Asian countries), and the Rest of the World. The first five regions constitute the entire Annex I countries.

The GEM-E3 model identifies 18 sectors. We consider that energy and energy-intensive sectors can trade on both the domestic and international emissions markets, the other sector and the household can only trade on the domestic market.

We run the model for two periods: the period between 2000-2005 for pre-action and the period between 2005-2010 for Kyoto compliance[2]. During the first period, international emission trading is available for pre-action for energy and energy-intensive trading. During the second period, both domestic and international emission trading are available for Kyoto compliance. However, while domestic emission trading happens in all sectors and households, international emission trading is limited to trading sectors.

2.2 Direct cost

We measure abatement cost by direct cost, a dead-weight loss, which conceptually equals to the integral under marginal abatement cost curve and often is calculated as one-half of marginal abatement cost (or permit price) times emission reduction, net of the value of traded permits.

Let *DO* and *IN* represent domestic and international markets for CO2 emission trading. Denote *EM* as the quantity of baseline CO2 emission and *ER* as the quantity of emission reduction. And, denote *k* as Kyoto target of emission reduction, which accounts for a percentage of *EM*, and α as the part of the Kyoto target abated domestically, which is a percentage of *k* and determined by traded permits. With the availability of international emission trading, the country committed to an agreement is able to allocate its task between domestic and international options by varying α in order to minimise total cost:

$$ER = \alpha \cdot k \cdot EM + (1-\alpha) \cdot k \cdot EM$$

where the second part of RHS represents the traded permits, either purchased when it is positive, or sold when it is negative, or no-trade when it is zero, $\alpha > 1$ indicates that a country is a permit seller; Otherwise $0 < \alpha < 1$ indicates that a country is a permit buyer.

Denote *DC* and *P* as direct cost and permit price, respectively. Direct cost can be calculated as

$$DC = (1 - \frac{1}{2} \cdot \alpha) \cdot k \cdot EM \cdot P \qquad (1)$$

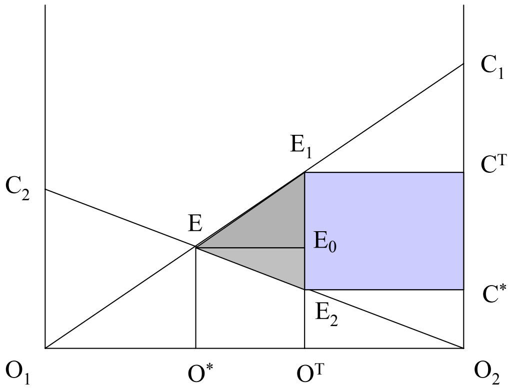
where we use *P* to represent the unique marginal abatement cost across both domestic and international markets of emission trading, since $P^{DO} = P^{IN}$.

2.3 Transaction costs

Transaction costs in general are not easily determinable, because the sources that generate the costs are complex and uncertain. Stavins (1995) assumes transaction costs to be a function of traded permits and puts marginal transaction cost as a mark-up on permit price. Following this assumption, we use an example to illustrate the role of transaction costs in costs and benefits in emission trading. We assume transaction costs to be afforded entirely by the buying country.[3]

Figure 1 shows two countries with different marginal abatement costs. Emissions trading price was in E. Added transaction costs, it now jumps to C^T. As the result, country 1 abates O^T domestically and purchases O_2-O^T permits from country 2. Compared to its gain in the original emission trading without transaction costs, country 1 now suffers a loss, which consists of the direct transaction costs, $E_1E_0C^*C^T$, and the dead-weight loss, EE_0E_1. Country 2 also suffers a dead-weight loss, EE_2E_0. Apparently, because country 1 has steeper marginal abatement cost curve than country 2, it will suffer large dead-weight loss than country 2.

Figure 1. Impact of transaction costs on cost efficiency of emissions trading



Based on above analysis, we adapt equation (1) to incorporate transaction costs. Denote *TC* as transaction costs, which is assumed to be the function of traded permits, ER^{IN}, then the buyer is to minimise its direct cost by determining the permit quantity to purchase the optimum

$$\frac{\partial DC}{\partial ER^{IN}} = -P^{DO} + P^{IN} + \frac{\partial TC}{\partial ER^{IN}} = 0. \qquad (2)$$

Since buyer affords transaction costs, seller does not consider the costs, therefore $P^{IN}=P^S$ where we use P^S to represent seller's marginal abatement costs. Equation (2) implies that on buyer side domestic marginal abatement cost equals to international marginal abatement cost (the permit price) plus the marginal transaction cost in term of traded permits. Hence, marginal transaction cost equals to a mark-up. Transaction costs insert an additional cost to permit trading. This distortion on emission trading markets will cause multiplier effect on total costs of emission reduction. The higher price of emission trading raised by transaction costs will force buyer to buy less and consequently seller to sell less, and therefore reach a new equilibrium that is less efficient than the one without any transaction costs. As the result, overall induced economic inefficiency will exceed transaction costs.

In practice, transaction costs are frequently evaluated as certain percentage of total value of emission trading (either the value of permit purchases or the value of permit sales plus other costs). According to Woerdman (2000), US lead phasedown program accounts 10% of total costs for transaction costs (Kerr and Mare, 1997). US SO_2 emission trading scheme incurs transaction costs to be 8% of total cost (Montero, 1997).

In this study, we assume transaction costs to be a proportion of total cost of emission trading rather than an assumed form that shows explicit relationship between transaction costs and quantity of traded permits.

$$P^{DO} = (1+\gamma)\cdot P^{IN}$$

where γ apparently can be regarded as a mark-up on international permit trading price, and domestic marginal abatement cost augments by the mark-up. Equation (3) reveals that at equilibrium the domestic marginal abatement cost equals to the price of international permit trading plus a mark-up of transaction costs. For example, $\gamma = 0.1$, *or* an 11% mark-up on permit price, will correspond to transaction costs account 10% of total trading cost.

The direct cost including transaction costs therefore is determined at equilibrium:

$$DC^{TC} = (1+\gamma)\cdot\left(1-\frac{1}{2}\alpha\right)\cdot ER \cdot P^{IN}. \qquad (3)$$

Compared to equation (1), equation (3) shows that the direct cost augments with the transaction costs when they exist.

2.4 "Learning by doing"

Transaction costs arise because of many reasons, one of which is incomplete information. Nevertheless, efforts on acquiring information will be helpful to reduce transaction costs. The accumulation of experience in emission trading therefore could be one type of the efforts. In this research, we set up this type of effort by a "learning by doing" approach that a pre-acted emission trading will benefit a later emission trading.

We define the process of "learning by doing" as an exogenous elasticity between the pre-action scale during pre-period and the avoidance of transaction costs during Kyoto compliance, which in other words captures the efficiency rate of pre-action to efficiency improvement. For instance, an elasticity of 1 means that if pre-action reduces the emission that is equivalent to 1% of Kyoto target, it will benefit from 10% reduction of transaction costs during Kyoto period by "learning by doing". Given this value, with a pre-action target for an emission reduction that is equivalent to 10% of Kyoto target, all transaction costs during Kyoto period could be avoided.

The pre-action effort certainly induces costs, which however is closely relevant with the pre-action efficiency. Denote *e* as pre-action effort that is defined as the percentage of k and ε as the elasticity between pre-action scale and transaction cost reduction for Kyoto compliance, the transaction costs resulted after pre-action are

$$\gamma_{KC} = \gamma - \varepsilon \cdot e$$

where $\varepsilon = \frac{e}{\gamma} \cdot \frac{\partial \gamma}{\partial e}$.

Let *PA* and *KC* represent the pre-action and the Kyoto compliance period, respectively, we then have the direct costs in each of the periods as follows:

$$DC_{PA} = (1+\gamma)(1-\frac{1}{2}\alpha) \cdot e \cdot ER \cdot P_{PA}^{IN}, \qquad (4)$$

and

$$DC_{KC} = (1+\gamma-\varepsilon \cdot e)(1-\frac{1}{2}\alpha) \cdot ER \cdot P_{KC}^{IN}. \qquad (5)$$

2.5 Cost saving

Let *DCS* represent direct cost saving resulted from pre-action, which is the difference between the direct cost without and with pre-action for Kyoto compliance:

$$DCS_{KC} = DC_{KC}^{TC} - DC_{KC}^{PA}$$
$$= \left[(1+\gamma) \cdot P_{KC} - (1+\gamma-\varepsilon \cdot e) \cdot P_{KC}^{PA}\right] \cdot (1-\frac{1}{2}\alpha) \cdot ER.$$

(6)

(For simplicity, thereafter we omit the superscript, *IN*, in price *P*.)

2.6 The gain

The gain *G* due to pre-action equals to the cost saving in Kyoto compliance subtracted by the direct cost for pre-action:

$$G = (P_{KC} - P_{KC}^{PA} - e \cdot P_{PA}) \cdot (1+\gamma)(1-\frac{1}{2}\alpha)$$
$$\cdot ER + \varepsilon \cdot e \cdot (1-\frac{1}{2}\alpha) \cdot P_{KC}^{PA} \cdot ER.$$

It is clear that a pre-action will gain when $P_{KC} - P_{KC}^{PA} > e \cdot P_{PA} > 0$. The intuition behind this condition is that to achieve a gain for cost saving, the pre-action must be able to gain a margin that is equal to the difference between the international marginal abatement cost without and with pre-action. However, the marginal gain has to be deducted by the marginal abatement cost for pre-action. The more effort is put for pre-action, the more marginal gain could be achieved, but at meantime the higher marginal abatement cost is incurred with pre-action.

3 THE EMPIRICAL ANALYSIS WITH GEM-E3

3.1 The baseline

Recent empirical studies on the costs of the Kyoto Protocol have reported a wide range of differences in baseline emission projections, due to the different assumptions about economic growth, fuel costs, capital stock turn over, etc (Weyant and Hill, 1999). In order to increase the modelling credibility, we have set up a comparable baseline between GEM-E3 and POLES[4], an energy model. The basic assumptions regarding GDP growth and CO2 emission are given accordingly (Pan and Van Regemorter, 2001). The baseline covers the period 1995 - 2010.

3.2 Emission trading for Kyoto compliance in Annex I region

In this exercise, we consider two extreme scenarios: a no-trade scenario and an Annex I trading scenario, to show the potential for cost saving of emissions trading. In particular, the scenario of Annex I trading will serve as a benchmark for the following scenarios exploring transaction costs and pre-action effort.

Because GEM-E3 model runs from period before 1995, the targeted emission is defined to be a percentage of CO2 emission in 1995. In particular, EU15 is required to emit in 2010 8% lower than its 1995 level, USA 7%, JAPAN 6%, and OEC 1%, while CEU can maintain its emission level as in 1995. The Annex I wide CO2 emission in 2010 should be 5.2% below the 1995 level.

If the five regions commit their respective targets independently, EU15 will have the highest marginal abatement cost of \$80/t and CEU the lowest at \$15/t, at 1995 price level, The full compliance will cost nearly \$100 billions.

Emission trading, however can reduce the overall cost by re-allocating emission reduction among the regions according to the least-cost approach. EU15, USA, JAPAN and OEC can emit above the targeted levels in 2010, while CEU reduces its CO2 emission much below the targeted level. This means that EU15, USA and JAPAN only need to commit 65%, 93% and 64% of their targets in domestic. For the situation, EU15, USA, JAPAN and OEC all buy emission permits from CEU. The emission price is unique, about \$39/t at 1995 price level, in the case. The overall compliance cost in

Annex I region accounts for about $72 billions, which is about 23% less than the cost of no-trade.

3.3 Transaction costs and inefficiency

The scenario in the previous section shows a pure case of emission trading in Annex I region, which brings about 23% gain in cost efficiency compared to no-trade. However, it is an ideal case. In this section, we include transaction costs into the trade scenario, assuming that transaction costs add a mark-up on permit price defined in the previous section. Because there is no information available regards transaction costs, we ad hoc assume mark-ups of 5%, 10% and 20%, respectively.

If transaction costs change from 5% to 20%, the permit price, including transaction costs, for a buying region will rise from $39/t to $42/t, while the permit price for a selling region will decreases from $39/t to $35/t. EU15 and JAPAN, with higher domestic marginal abatement costs, will not cut demands for permits greatly, in response to the price changes. However, the regions like CEU and USA, which have lower domestic marginal abatement costs, will response largely.

Adding transaction costs causes an increase of the cost and permit price, reducing the level of emission trading and therefore the efficiency of emission trading relative to no-trade. Compared to the full-trade without transaction costs, a mark-up of 20% transaction costs will erode the total cost by 22%.

The inefficiency due to transaction costs is unbalanced among regions. The ratios of inefficiency to transaction costs reveal that the low-cost regions shall have more incentive for pre-action than the high-cost regions. At 20% level of transaction costs, USA suffers $3.6 inefficiency per dollar transaction costs, whereas the figure is around 0.8 in both EU15 and JAPAN.

3.4 The pre-action

This section extends the scenario from the Kyoto compliance period to the pre-period between 2000-2005. We assume that during the pre-period Annex I regions jointly practice emission trading system for the purpose of accumulating experience in order to avoid the potentially high transaction costs during the Kyoto compliance period, which they otherwise have to suffer. Because there is no reason for the full establishment of emission trading system during the pre-period, we limit our analysis to the emission trading in energy and energy-intensive sectors only. This arrangement in fact is in line with the promotion of EU Green Paper, which argued that the emission trading among energy and energy-intensive sectors could be the most efficient way to gain experience as the trading will be the cheapest.

The effectiveness of pre-action emission trading depends not only on the permit price but also on the efficiency of the process of "learning by doing". A fast "learning by doing" will require less pre-action effort, vice versa. However, because the elasticity of "learning by doing" in response to pre-action effort cannot be known prior to the pre-action, we run scenarios under three different values of the elasticity, which are 0.5, 1 and 2. Typically, an elasticity of 1 means that the pre-action that reduces CO_2 emission equivalent to 1% Kyoto target can gain a 10% reduction of transaction costs of the emission trading for Kyoto compliance.

During the pre-action period, emission reduction targets are set to 1%, 5% and 10% of Kyoto target. If pre-action executes 10% of Kyoto target, permit price for buyers is $2.17/t, which includes 10% transaction costs. It is noticeable that pre-action shows a large percentage of emission trading. According to the figures on the percentage of domestic reduction, EU15 and JAPAN abate domestically only 34% and 42% of their targets, respectively, whereas CUE as a seller abates over 2.5 times its targets. Therefore, pre-action is suitable for the accumulation of experience in emission trading. Furthermore, direct cost is very low, only $2.6 millions, when reduction target is 1% of Kyoto target, but the cost increases rapidly from 1% to 10% of Kyoto target.

The Kyoto period will benefit from the reduction of transaction costs due to pre-action. As pre-action effort increases, Kyoto compliance avoids more transaction costs, and emission trading moves towards the full-trade without transaction costs. When pre-action eliminates all transaction costs, emission trading will come back to the full trade without transaction costs.

Both the cost and benefit of pre-action emerge if pre-action effort is put. Compared to the situation where no pre-action corrects transaction costs, cost saving in Kyoto period due to pre-action is obvious. Overall cost saving in Annex I region reaches over 2.5 billions $, when pre-action effort is 10% of Kyoto target. The difference between the Kyoto cost reduction and pre-action cost accounts for the net gain of pre-action. As the result, the pre-action gain, which is the cost saving in Kyoto period subtracted by the pre-action cost, amounts nearly 2 billions $. The minimum cost states the unavoidable cost because of the existence of transaction costs. In the situation where pre-action eliminates all or some transaction costs, the minimum cost is identical to the pre-action cost.

3.5 The optimal pre-action

We further studied the cases with 5% and 20 % of transaction costs and 0.5 and 2 elasticity of the reduction of transaction costs to pre-action, and determined the optimal pre-action effort. The best situation is with 5% transaction costs and 2 elasticity, where optimal pre-action effort accounts 2.5% of Kyoto target, maximum gain reaches over 1.2 billion $ and minimum cost is 30 million $. The worst case is when the mark-up of transaction costs is 20% but elasticity is 0.5, pre-action can do 15% of Kyoto target at maximum, the maximum gain is 0.8 billion $ and the minimum cost nearly $40 billion.

4 CONCLUSION

This paper is based on two assumptions that transaction costs are an additional cost to permit purchase during emission trading and that pre-action could serve as a measure to correct economic inefficiency caused by the transaction costs. We have used different values on the potential of transaction costs and the elasticity of the reduction on transaction costs in response to the pre-action effort. These values are given hypothetically, but are crucial for exploring the economics of the Kyoto pre-action given the fact that both "learning by doing" benefits and potential transaction costs are unobservable and uncertain at current stage.

The paper reveals that transaction costs will cause cost inefficiency unevenly to all parties of emission trading. The high-cost regions do not response to the transaction costs greatly, while the low-cost regions do. As the result, the low-cost regions will suffer relatively more loss in cost efficiency than the high-cost regions. The result suggests that low-cost region should have stronger incentive for pre-action than high-cost regions even in the case that buyer affords transaction costs.

We also find that the pre-action could effectively offset transaction costs as long as it is implemented at small scale. In particular, compared to its benefit potential, pre-action is profitable and attractive. The extent of net gain from pre-action however depends crucially on the speed of the "learning by doing" process, which is represented in the model by the elasticity of the reduction in transaction costs in response to pre-action effort. If the elasticity is higher or in other words the "learning by doing" is fast, the pre-action is effective and the cost inefficiency eroded by transaction costs can be corrected at low minimum cost. Otherwise, the pre-action is less effective and only able to correct a small part of the inefficiency.

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[1] Woerdman (2000) recently argued that JI and CDM are more efficient than ET.

[2] Here, we regard the year 2010 as a representative year during the Kyoto period between 2008-2012.

[3] Transaction costs could be also afforded by the selling country or shared between countries.

[4] For POLES model, see Criqui, P. et al. (1996).