Fondazione Eni Enrico Mattei

Meeting the Kyoto Targets: The Importance of Developing Country Participation

ZhongXiang Zhang*

NOTA DI LAVORO 30.2001

APRIL 2001

CLIM – Climate Change Modelling and Policy

*Faculty of Economics and Faculty of Law
University of Groningen, The Netherlands

Fondazione Eni Enrico Mattei
Corso Magenta, 63, 20123 Milano, tel. +39/02/52036934 – fax +39/02/52036946
E-mail: letter@feem.it
C.F. 97080600154

Meeting the Kyoto Targets: The Importance of Developing Country Participation

ZhongXiang Zhang[1]
Faculty of Economics and Faculty of Law
University of Groningen
P.O. Box 716
9700 AS Groningen
The Netherlands
Tel: +31 50 3636882
Fax: +31 50 3637101
Email: Z.X.Zhang@Rechten.RUG.NL
Web: http://www.eco.rug.nl/medewerk/zhang/

This paper formed part of the presentations at the Asian Development Bank/United Nations Environment Programme's Workshop for Policymakers on the Institutional Design of the Kyoto Protocol Cooperative Implementation Mechanisms, Bangkok, 12-14 October 1999; the International Workshop on Enhancing GHG Mitigation through International Cooperative Mechanisms in Asia, Kanagawa, Japan, 26-27 January 2000; China - US Workshop on Economic and Environmental Modeling, Beijing, 5-6 March 2000; the 3rd Biennial Conference of the European Society for Ecological Economics, Vienna, 3-6 May 2000; the 10th Annual Conference of the European Association of Environmental and Resource Economists, Crete, Greece, 30 June - 2 July 2000; the Joint Meeting of the Energy Modeling Forum and the International Energy Workshop, Stanford University, 20-22 June 2000; and at the 40th Congress of the European Regional Science Association, Barcelona, 29 August - 1 September 2000; as well as at a seminar at Tsinghua University, Beijing, 17 March 2000. The author would like to thank participants in the above workshops, conferences and seminar, anonymous referees, J.R. Bhatt, A. Denny Ellerman, Erik Haites, and Adam Rose for useful discussions and comments on an earlier version of the paper. The views expressed here are those of the author. The author bears sole responsibility for any errors and omissions that may remain.

[1] ZhongXiang Zhang is jointly appointed as a senior fellow at the Faculty of Law and Faculty of Economics, University of Groningen, The Netherlands. He also holds a part-time professor of economics both at Chinese Academy of Social Sciences and at Peking University, Beijing. He has served as an expert/consultant to many national and international organizations. Currently, he is serving on editorial boards of the six international journals and one Chinese journal.

SUMMARY

This paper investigates the implications of progressively broadening the scope of the market of tradable permits from no emissions trading to full global trading. We start with the no emissions trading case where each Annex I country must individually meet its Kyoto targets. Next, we consider a case where trading of emissions permits is limited to Annex I countries only. We then expand the scope of the market to include all the non-Annex I countries but China. Finally, to investigate the role China plays in bringing down Annex I countries' compliance costs, we further broaden the market to include China into full global trading. Our results clearly demonstrate that the gain of the OECD as a whole increases as the market expands. Our results also show that developing countries themselves benefit from such an expansion too because it not only provides them for additional financial resources, but also helps to cut their baseline carbon emissions by a big margin. By contrast, the former Soviet Union tends to become worse off as the market expands. The potential conflict of interest between the former Soviet Union and developing countries underlines the importance of establishing clear rules of procedure about admitting new entrants before emissions trading begins.

Keywords: Emissions trading; Clean development mechanism; Greenhouse gases; Marginal abatement costs; Price of permits

JEL: Q28, Q25, Q48, Q43

NON TECHNICAL SUMMARY

The Kyoto Protocol incorporates emissions trading, joint implementation and the clean development mechanism (CDM) to help Annex I countries to meet their Kyoto emissions targets at a lower overall cost. However, to what extent their compliance costs can be lowered depends on the scope of the market of tradable permits. This paper aims to investigate the implications of progressively broadening the scope of the market from no emissions trading to full global trading. We start with the no emissions trading case where each Annex I country must individually meet its Kyoto target without any trading of permits across countries. Next, we consider a case where trading of emissions permits is limited to Annex I countries only. We then expand the scope of the market to include all the non-Annex I countries but China. To investigate the role China plays in bringing down Annex I countries' compliance costs, we further broaden the market to include China into full global trading. Finally, we undertake a sensitivity analysis to examine the implications of alternative EU baseline emissions for both Annex I countries and non-Annex I countries as well as for the market price of permits.

Our results show that if each Annex I country were required to individually meet its Kyoto target without any trading of permits across countries, Japan and the US would face much higher compliance costs than the EU. For this reason, trading would lower their costs substantially. Moreover, the gains of these two countries increase by very big margins as the market expands from Annex I trading only to full global trading. In the mean time, the EU benefits greatly in the Annex I trading case from taking otherwise very little domestic actions in the no trading case and generating more permits for sale. But, as the market expands to include China and other non-Annex I countries, the gain of the EU reduces because the international price of permits becomes closer to its autarkic marginal abatement cost. However, because the US and Japan have much more influence on the overall gain of the OECD than the EU does, the gain of the OECD as a whole increases as the market expands.

While the OECD countries enjoy the gains from the inclusion of developing countries, the expansion of the market is beneficial to developing countries too. If trading of emissions permits were broadened to include China, the OECD would gain 10% more than without the inclusion of China. Such a gain would become even larger if there were a sharp discrepancy between the Kyoto target and the EU baseline projection as

our sensitivity analysis suggests. In the mean time, such an expansion would not only provide China for additional financial resources, but also help to bring down its baseline CO_2 emissions by a big margin.

By contrast, the gain of the former Soviet Union tends to decrease as the market expands. This is mainly because the inclusion of low-cost carbon abatement options form China and other non-Annex I countries on the supply side depresses the market price received for its sold permits. The potential conflict of interest between the former Soviet Union and non-Annex I countries may have influence on future expanding trading to non-Annex I countries, thus underlining the importance of establishing clear rules of procedure about admitting new entrants before emissions trading begins.

Finally, our sensitivity analysis shows that the low EU baseline projection restricts the total Annex I countries' demand for permits and thus depresses the market price of permits. Consequently, in percentage terms, the gains of Japan and the US as importers of permits on the basis of the low official EU baseline projection would be overestimated in comparison with the case of the high EU emissions baseline, whereas the gains of the Former Soviet Union as exporters of permits and of developing countries as suppliers of the CDM credits would be underestimated. Instead of being an exporter of permits in the case of the low official EU baseline projection, the EU becomes an importer of permits in the case of the high EU baseline. Thus, in the latter case its gain increases as the market expands in contrast with the exactly reverse trend in the former case.

CONTENTS

1. Introduction

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) commits Annex I countries[2] to reduce their emissions of six greenhouse gases (GHG) by 5.2% below 1990 levels over the commitment period 2008-2012, with the European Union (EU), the United States and Japan required to reduce their emissions of such gases by 8%, 7% and 6% respectively (UNFCCC, 1997). The Protocol also incorporates emissions trading, joint implementation and the clean development mechanism (CDM) to help Annex I countries to meet their Kyoto targets at a lower overall cost.

However, to what extent their compliance costs can be lowered depends on the extent to which the flexibility mechanisms will be allowed to contribute to meet the Kyoto targets. Assuming that trading of emissions permits would take place globally among all the countries, Zhang (2000a) analyses the implications of imposing restrictions on imports and exports of permits for both Annex I countries' compliance costs and gains of non-Annex I countries (i.e., developing countries). While that study sheds light on the contributions of abatement actions at home and abroad to meeting Annex I countries' Kyoto targets, it neglects a very important aspect. That is the scope of the market of tradable permits and its implications. This paper aims to fill this gap by investigating the implications of progressively broadening the scope of the market of tradable permits from no emissions trading to full global trading. We start with the no emissions trading case where each Annex I country must individually meet its Kyoto target without any trading of permits across countries. Next, we consider a case where trading of emissions permits is limited to Annex I countries only. We then expand the scope of the market to include all the non-Annex I countries but China. To investigate the role China plays in bringing down Annex I countries' compliance costs, we further broaden the market to include China into full global trading. Finally, we undertake a sensitivity analysis to examine the implications of alternative EU baseline emissions for both Annex I countries and non-Annex I countries as well as for the market price of permits. To our knowledge, this is the first study to disentangle the impacts of China on Annex I countries' compliance costs from those resulting from the rest of the world by examining the markets with and without the inclusion of China. Thus, the study provides a valuable addition to Zhang (2000a).

[2] Annex I countries refer to the OECD countries and countries with economies in transition. These countries have committed themselves to greenhouse gas emissions targets.

2. The Economic Effects of Progressively Broadening the Scope of the Market

In this section, we will examine the economic effects of progressively broadening the scope of the market from no emissions trading to full global trading both on Annex I countries and on non-Annex I countries, using a global model based on the marginal abatement costs of 12 regions.[3] The twelve regions considered are given in Table 1. The first six regions are Annex I regions, whereas the other six are non-Annex I regions whose emissions are unconstrained under the Kyoto Protocol.

Table 1 - *Definitions of Countries and Regions*

Annex I countries and regions	Non-Annex I countries and regions
1. United States	7. Energy Exporting Countries
2. Japan	8. China
3. European Union	9. India
4. Other OECD Countries	10. Dynamic Asian Economies
5. Eastern Europe	11. Brazil
6. Former Soviet Union	12. Rest of the World

Using the model, we will examine the following four scenarios, which are each described in ascending scope of the market.

- No trading scenario: Each Annex I country must individually meet its Kyoto target without any trading of permits across countries;
- Annex I trading scenario: Trading of emissions permits is allowed to take place among Annex I countries only;
- Trading without China scenario: Trading of emissions permits is expanded to include all the non-Annex I countries but China;
- Full global trading scenario: Trading of emissions permits is further broadened to include China.

[3] The marginal abatement cost functions are derived from econometric estimation of the EPPA runs for the amount of abated emissions and the corresponding marginal abatement costs (Ellerman and Decaux, 1998). As in other economic models, they are atemporal, namely, estimates at a specific point in time (i.e., without considering the time path of abatement actions). In real practice, countries presumably choose progressive abatement actions rather than delay them until the commitment period commences in order to avoid drastic shocks later. See Zhang (1999, 2000a) for a detailed description of the model and other applications of the model.

It should be pointed out that although under the Kyoto Protocol non-Annex I countries currently have no obligations to reduce their GHG emissions, the last two scenarios treat these countries as if they agreed to constrain their emissions in such a manner that they are allocated permits equal to their projected baseline emissions. As such, non-Annex I countries only reduce their emissions by an amount equal to the number of permits they wish to sell. Following the definition of certified credits from CDM projects, the amount of emissions reductions below the country-wide baseline trend is termed as the supply of certified CDM credits from each non-Annex I countries.[4] This means of obtaining low-cost abatement options from non-Annex I countries will further increase Annex I countries' potential for efficiency gains relative to the Annex I trading case.

As Zhang (2000), this study also takes the year 2010 as representative of the first commitment period 2008-2012. To run the model, we need the aggregate magnitude of emissions reductions required of each Annex I region and the size of hot air in 2010. The former represents the amount of the mandated reductions from projected business-as-usual (BAU) emissions levels, whereas the latter represents those assigned amounts under the Kyoto Protocol that exceed anticipated emissions requirements even in the absence of any limitation. The two types of data are derived from the individual national communications (to the UNFCCC) of the following 35 Annex I countries with emissions targets: Australia, Austria, Belgium, Bulgaria, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russia Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, the United Kingdom, and the United States. This involves three steps. The first step is to determine GHG emissions for each Annex I country in the base year. The second step is to determine the Kyoto target for each Annex I country in 2010. The third step is to estimate baseline GHG emissions for each Annex I country in 2010. By adding up the amount of the mandated reductions from projected baseline emissions levels for each Annex I country, the aggregate magnitude of emissions reductions required of Annex I

[4] This implies that in this modelling exercise we treat the CDM synonymously with emissions trading as many other modellers do (Weyant, 1999). In real practice, the CDM is a project-based mechanism. Unlike homogenous permits under emissions trading, concerns about additionality and the inherent difficulty of establishing counterfactual baselines for heterogeneous CDM projects and monitoring emissions reductions below the baselines may impose high transaction costs and thereby limit the supply of CDM credits from non-Annex I countries (Ellerman and Decaux, 1998; US Administration, 1998).

countries in 2010 is estimated to be 620.6 million tons of carbon (MtC) equivalent, as given in Table 2. Similarly, the size of hot air in 2010 is calculated to be 105.0 MtC.[5] See Zhang (1999, 2000a) for detailed discussion on procedures and results.

Table 2 - *Annex I Regions' Projected Baseline Emissions, Emissions Reductions Required and the Size of Hot Air in 2010*

Annex I regions	Projected baseline emissions in 2010 (MtC)	Emissions reductions required in 2010 (MtC)	The size of hot air in 2010 (MtC)
United States	1943.9	423.9	0
Japan	388.2	71.2	0
European Union	1095.9	40.6	12.7
Other OECD Countries	382.2	57.3	0
Eastern Europe	358.3	27.6	10.9
Former Soviet Union	1032.2	-	81.4
Annex I Total	5198.7	620.6	105.0

Sources: Zhang (1999, 2000a).

2.1. No Emissions Trading

In the absence of emissions trading, the autarkic marginal abatement cost is highest in Japan, where it requires US$ 311.8 per ton of carbon to comply with its Kyoto target in 2010 (see Table 3), and lowest in the Former Soviet Union whose autarkic marginal abatement cost is zero because it has been allocated more than needed. The above results are in line with findings from other studies (e.g., Ellerman and Decaux, 1998; MacCracken *et al*., 1999). By contrast, our estimate of the autarkic marginal abatement cost in the EU is very low in comparison with those estimates from Ellerman and Decaux (1998) and MacCracken *et al*. (1999). This is mainly because the official projections of baseline GHG emissions in 2010 by most EU member countries are very close to their targets. Thus, the EU only needs to take very little abatement actions to meet its targets. This leads to a very low marginal abatement cost in the EU.

[5] Note that in some regions there is the co-existence of hot air and the required emissions reductions within the same region. This is simply because of the sums across countries within each of these regions. For an individual Annex I country, it is either required to reduce its emissions to meet the Kyoto target or not required if it has hot air.

Table 3 - *Autarkic Marginal Abatement Costs in the No Trading Case, and Domestic Prices and the International Price of Permits in 2010 under the Three Trading Scenarios (at 1998 US$ per ton of carbon)*

Scenarios	United States	Japan	European Union	Other OECD	Eastern Europe	International price
No emissions trading	160.1	311.8	9.1	33.4	4.5	-
Annex I trading	40.7	40.7	40.7	40.7	40.7	40.7
Trading without China	18.6	18.6	18.6	18.6	18.6	18.6
Full global trading	9.6	9.6	9.6	9.6	9.6	9.6

2.2. Widening the Scope of the Market: From Annex I Countries only to Full Global Trading

When trading of emissions permits is allowed across Annex I countries freely, the marginal cost of domestic abatement for each Annex I region equalizes. The resulting market price of permits, which is endogenously determined, is equal to US$ 40.7 per ton of carbon (see Table 3). It is well below the autarkic marginal abatement costs for Japan and the US, but above those for the EU, other OECD countries and the Eastern Europe. Consequently, Japan and the US are importers of permits, whereas other Annex I regions are exporters of permits. Every region achieves some gains through trading, but the magnitude of the gains from trading differs substantially among Annex I countries. Given that Japan and the US have the highest autarkic marginal abatement costs, these two countries will meet 81.2% and 53.6% of their emissions reductions required in 2010 by purchasing permits, respectively (see Table 4). As a result, the total abatement costs of Japan and the US are cut by 73.0% and 49.6% under the Annex I trading scenario in comparison with the no trading case (see Table 5). In the mean time, because the market price of permits is well above the autarkic marginal abatement cost in the EU, it can benefit greatly from taking otherwise very little domestic actions in the no trading case and generating more permits for sale. As indicated in Table 4, by almost doubling domestic actions in the no trading case, the EU gains substantially (790.9%) in the Annex I trading case.

When trading is enlarged to include non-Annex I countries but China, more low-cost abatement options become available. Consequently, the market price of permits is pushed down to US$ 18.6 per ton of carbon (see Table 3). As a result, a distinction between the international price and the autarkic marginal abatement costs of buying countries like Japan and the US becomes larger. Thus, these two countries can benefit from the expansion of the market by avoiding their undertaking of more costly domestic abatement

actions by purchasing even more permits abroad. Their gains from trading, namely, the reductions in abatement costs relative to the no emissions trading case, rise to 87.0% and 73.3% under the trading without China scenario, respectively. When trading of emissions permits is further broadened to include China, even more low-cost abatement options from China are included. This increased supply will further push the market price of permits down to US$ 9.6 per ton of carbon. As would be expected, the gains of Japan and the US from trading further rise to 93.1% and 85.2% under the full global trading scenario, respectively.

Table 4 - *The Share of Domestic Abatement Actions in 2010 (%)*

	Annex I trading	Trading without China	Full global trading
US	46.4	28.9	18.9
Japan	18.8	9.1	4.8
EU	196.0	116.0	71.4
Other OECD	109.3	77.6	59.0
Eastern Europe	201.6	132.9	92.4
Annex I total	65.7	41.5	27.7

Table 5 - *The Gains in 2010 under the Three Trading Scenarios (%)*[a]

Scenarios	United States	Japan	European Union	Other OECD	OECD	Former Soviet Union
Annex I trading	49.6	73.0	790.9	3.6	57.8	563.0
Trading without China	73.3	87.0	84.0	16.3	76.2	217.7
Full global trading	85.2	93.1	0.2	45.3	86.5	100.0

[a] The gains are measured relative to the total abatement costs in the absence of trading for the OECD countries or the total benefits under the full global trading scenario for the former Soviet Union.

By contrast, the international price of permits becomes close to the autarkic marginal abatement cost in the EU when trading is enlarged to include non-Annex I countries but China. This will reduce the incentive for the EU to abate domestically in order to generate more permits for sale. Thus, its gain reduces substantially in comparison with the no trading case. Further expansion to include China will push the international price of permits ever closer to its autarkic marginal abatement cost. Thus, the EU is expected to experience a very small gain from such an expansion.

Because the emissions reductions required of the US and Japan to meet their Kyoto targets are about 18 times that of the EU, the two countries have much more influence on the overall gain of the OECD than the EU does. Because the gains of the US and Japan increase as the market expands, the gain of the OECD as a whole also increases. As shown in Table 5, the expansion of abatement options increases the OECD's gain from 57.8% under the Annex I trading only scenario to 76.2% under the trading without China scenario and to 86.5% under the full global trading scenario. The gain of 10% more with China than without China underlines the importance of the inclusion of China.

As far as the former Soviet Union is concerned, its gain tends to decrease as the market expands. The former Soviet Union is expected to experience the highest gain when trading is limited to Annex I countries only. If trading of emissions permits were broadened to include non-Annex I countries but China, its gain would be reduced by about 61% (see Table 5) in comparison with that in the Annex I trading only case. Its gains would further drop to 17.8% of that in the case of Annex I trading only, if trading of emissions permits were further broadened to include China. This is mainly because the inclusion of low-cost abatement options form China and other non-Annex I countries on the supply side reduces the market price received for its sold permits from US$ 40.7 per ton of carbon under the Annex I trading scenario to US$ 18.6 under the trading without China scenario and to US$ 9.6 under the full global trading scenario.

2.3. Effects on the CDM Market and China

As shown in Table 6, the supply of certified CDM credits in 2010 is estimated to be higher under the full global trading scenario than under the trading without China scenario. But, the value of the CDM market, which is derived from multiplying the endogenously-determined, international price of permits by the supply of certified CDM credits from each non-Annex I country and summing over all the corresponding products, is lower in the former case than in the latter case. This is mainly because the inclusion of China makes more low-cost abatement options available, but in the meantime cuts the market price of permits in half. Because the reduction in the price of permits is much more than the increase in the supply of CDM credits when trading is broadened to include China, the product of the price and the supply tends to be lower under the full global trading scenario than under the trading without China scenario.

Table 6 - *The Size and Value of the CDM Market and the Geographical Distribution in 2010*

	Trading without China	Full global trading
Size of the CDM market (MtC)	185.7	292.1
Value of the CDM market (million US$)	3455.7	2795.6
of which:		
China	0.0%	60.28%
India	36.83%	15.08%
Energy Exporting Countries	16.63%	6.07%
Dynamic Asian Economies	13.49%	4.91%
Brazil	0.72%	0.25%
Rest of the World	32.33%	13.41%

With respect to the geographical distribution of the CDM flows, because of a great deal of low-cost abatement opportunities available in the energy sector of China and its sheer size of population, China is expected to emerge as the dominant host country of CDM projects. This is confirmed in Table 6, which shows that about 60% of the total CDM flows go to China. This share is broadly in line with those from other studies examined in Table 7. If China were not included, the CDM flows to other countries would at least double in comparison with the case where China were included, with India emerging as the dominant host country of CDM projects.

Table 7 - *A Comparison of the Size of the CDM Market and the Share of China in 2010*

	Size of the CDM market (MtC)	Total emissions reductions required of Annex I countries (MtC)	Contribution of the CDM (%)	Certified CDM credits	
				From China (MtC)	Share of China (%)
EPPA	723	1312	55	437	60
G-Cubed	495	1102	45	300	61
GREEN	397	1298	31	228	57
SGM	454	1053	43	341	75
Our projection	292	621	47	176	60

Sources: Ellerman and Decaux (1998); MacCracken *et al.* (1999); McKibbin *et al.* (1999); Van der Mensbrugghe (1998); Own calculations.

It should be pointed out that the inclusion of China is beneficial not only to Annex I countries because it increases potential of their efficiency gains, but also to China. Table 8 gives estimates of baseline CO_2 emissions in China up to the year 2020 from a variety of economic modelling studies. Although estimates of the magnitude of increase in emissions differ among the studies examined, there is a consensus that CO_2

emissions in China are expected to at least double over the period 1990-2010. On the current trends, China is expected to surprise the US to become the world's largest CO_2 emitter by 2020 (see Figure 1). Thus, getting China involved in combating global climate change is an issue of perennial concern at the international climate change negotiations. If trading of emissions permits were broadened to include China, it would not only provide the country for additional financial resources, but also help to bring down its CO_2 emissions by 176-437 MtC. Expressed as a percentage of its baseline emissions, this amount of emissions reductions amounts to 11.1-40.1%. In addition to the reductions in CO_2 emissions, it will also contribute to the reductions in local pollutants and thus will be beneficial to a more sustainable development of the Chinese economy.

Table 8 - *Carbon Emissions in China (MtC), 1990-2020*

Sources	1990	2000	2010	2020
ADB (1998)	567	915	1320	1695
CASS (2000)	n.a.[a]	841	1090	1330
EIA (1999)	620	930	1586	2031
IEA (1998)	657	n.a.[a]	1450	1929
World Bank (1994)	650	987	1512	2045
Zhang (1997)	587	899	1441	n.a.[a]

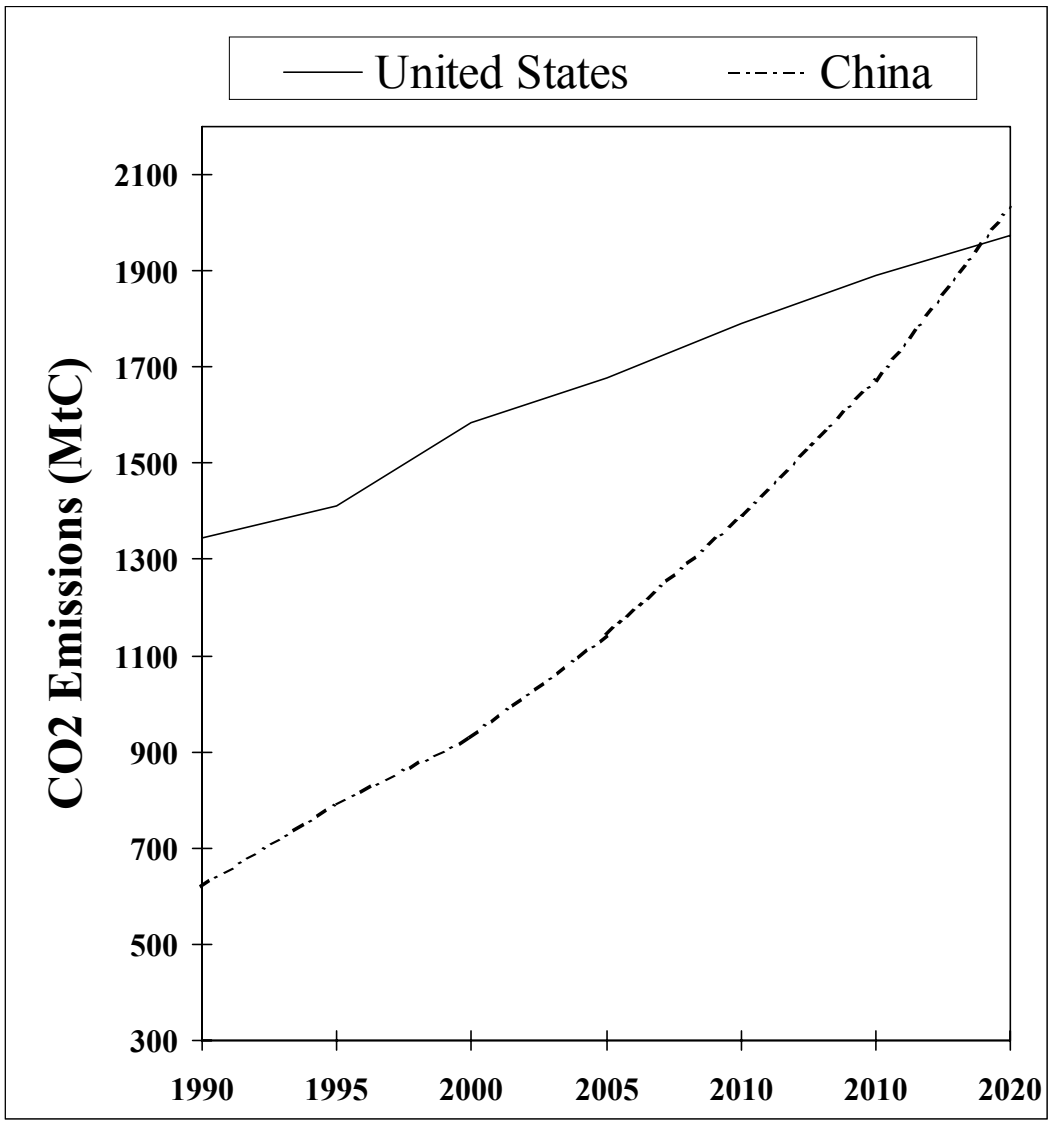
[a] n.a. = not available.

3. Sensitivity Analysis

Zhang (2000a) has compared the differences in estimates of the EU baseline emissions in 2010. In contrast with those projections from the economic modelling studies examined, our projection based on compilation of the national communications indicates that there is no sharp discrepancy between the Kyoto target and the official EU projection of baseline GHG emissions in 2010 (see Table 2). This low EU baseline projection is attributable in large part to internal burden sharing of the Kyoto commitments among the member countries, having incorporated the impacts of energy policies that are currently being either implemented or negotiated in response to climate change (from this perspective, it could be argued that the EU official baseline projection does not represent their BAU trends in conventional sense because they seem to reflect their hope to constrain GHG emissions), and to the choice of 1990 as a base year other than

1995.[6] In this section, we will examine the implications of alternative EU baseline emissions for both Annex I countries and non-Annex I countries as well as for the market price of permits.

Figure 1 - *CO_2 Emissions in China and the United States, 1990-2020*



Source: Drawn based on data from EIA (1999).

[6] See Zhang (1999, 2000a) for detailed discussion on the EU baseline projections.

Table 9 summarizes the EU baseline emissions estimated by the four economic modelling studies. The last two rows show the average and the median values. For the following sensitivity analysis, we rely on the median value for the EU baseline emissions in 2010 (hereafter labelled as the high EU baseline) in order to prevent disproportionate influence of the outliers (fortunately, the average and the median are almost identical in this case).

Table 9 – *Estimates of the EU Baseline Emissions in 2010*

	Baseline emissions in 2010 (MtC)
EIA (1999)	160
EPPA (Ellerman and Decaux, 1998)	308
GREEN (Van der Mensbrugghe, 1998)	296
SGM (MacCracken *et al.*, 1999)	176
Average	235
Median	234

To a large extent, the cost of meeting a given emissions target is determined by the emissions baseline (Zhang, 1997). The larger the size of the gap between the baseline emissions and the Kyoto target, the higher the marginal abatement cost of meeting the target. Because net emissions reductions required of the EU in 2010 rise to 234 MtC from 27.9 MtC (40.6 MtC minus hot air of 12.7 MtC) in the case of the low official EU baseline projection, it should come as no surprise that the autarkic marginal abatement cost in the EU sharply rises to US$ 249.9 per ton of carbon. Because this sharp increase in emissions reductions required of the EU drives up the total Annex I countries' demand for permits, consequently the market price of permits under each of the three trading scenarios examined is pushed up in comparison with the case where the low official EU baseline projection is used (see Table 10).

Table 10 - *Autarkic Marginal Abatement Costs in the No Trading Case, and Domestic Prices and the International Price of Permits in 2010 under the Three Trading Scenarios (at 1998 US$ per ton of carbon)*

Scenarios	United States	Japan	European Union	Other OECD	Eastern Europe	International price
No emissions trading	160.1	311.8	249.9	33.4	4.5	-
Annex I trading	74.5	74.5	74.5	74.5	74.5	74.5
Trading without China	32.4	32.4	32.4	32.4	32.4	32.4
Full global trading	15.9	15.9	15.9	15.9	15.9	15.9

As the market price of permits rises, it becomes more costly for Japan and the US to purchase permits abroad than abate domestically. As a result, the gains of the two countries from trading become less in the case of the high EU baseline than in the case of the low official EU baseline projection (see Tables 5 and 12). Because the market price of permits is now well below the autarkic marginal abatement cost in the EU, the EU shifts from an exporter of permits to an importer of permits. Consequently, the EU undertakes much less domestic actions in the case of the high EU baseline than in the case of the low official EU baseline projection (see Tables 4 and 11). By contrast, other OECD countries and the Eastern Europe abate more domestically in the case of the high EU baseline than in the case of the low official EU baseline projection because the increase in the market price of permits provides an incentive for them to generate more permits for sale. As an exporter of permits, the former Soviet Union benefits from an increase in Annex I countries' demand for permits, but as the market expands its gain decreases faster in the case of the high EU baseline than in the case of the low official EU baseline projection.

Table 11 - *The Share of Domestic Abatement Actions in 2010 (%)*

	Annex I trading	Trading without China	Full global trading
US	65.6	40.5	26.2
Japan	32.2	15.3	7.8
EU	49.6	29.3	18.0
Other OECD	144.0	98.6	72.6
Eastern Europe	276.4	178.5	122.0
Annex I total	70.7	43.8	28.8

Table 12 - *The Gains in 2010 under the Three Trading Scenarios (%)*[a]

Scenarios	United States	Japan	European Union	Other OECD	OECD	Former Soviet Union
Annex I trading	24.0	54.6	43.4	99.2	37.5	665.9
Trading without China	57.8	78.1	70.9	0.1	65.7	235.0
Full global trading	76.7	88.8	84.5	23.2	81.3	100.0

[a] See Table 5.

As far as the role of China is concerned, as the aggregate Annex I countries' demand for permits in 2010 increases from 621 MtC in the case of the low official EU baseline projection to 814 MtC in the case of the high EU baseline, China's participation becomes increasingly important. As indicated in Table 12, in

the case of the high EU baseline the OECD in 2010 would gain 15.6% more with the inclusion of China than without the inclusion of China, in comparison with the gain of 10.3% in the case of the low official EU baseline projection.

Given that the sharp increase in emissions reductions required of the EU drives up the total Annex I countries' demand for permits and hence the market price of permits, thus there is a significant increase in demand for the certified CDM credits. As a result, the size of the CDM market increases almost a half in the case of the high EU baseline in comparison with the case of the low official EU baseline projection. Of the total emissions reductions required of Annex I countries in 2010, the contribution of the certified CDM credits rises to 52% in the case of the high EU baseline from 47% in case of the low official EU baseline projection. In the mean time, the value of the CDM market increases almost one and a half as a result of the increase in both the price and the supply, although its geographical distribution remains almost unchanged (see Tables 6 and 13).

Table 13 - *The Size and Value of the CDM Market and the Geographical Distribution in 2010*

	Trading without China	Full global trading
Size of the CDM market (MtC)	268.8	420.7
Value of the CDM market (million US$)	8700.9	6685.0
of which:		
China	0.0%	60.41%
India	35.91%	14.69%
Energy Exporting Countries	17.65%	6.46%
Dynamic Asian Economies	14.36%	5.24%
Brazil	0.82%	0.28%
Rest of the World	31.25%	12.93%

4. Conclusions

This paper has investigated the implications of progressively broadening the scope of the market of tradable permits from no emissions trading to full global trading. Our results show that if each Annex I country were required to individually meet its Kyoto target without any trading of permits across countries, Japan and the US would face much higher compliance costs than the EU. For this reason, trading would lower their costs substantially. Moreover, the gains of these two countries increase by very big margins as the market expands from Annex I trading only to full global trading. In the mean time, the EU benefits greatly in the

Annex I trading case from taking otherwise very little domestic actions in the no trading case and generating more permits for sale. But, as the market expands to include China and other non-Annex I countries, the gain of the EU reduces because the international price of permits becomes closer to its autarkic marginal abatement cost. However, because the US and Japan have much more influence on the overall gain of the OECD than the EU does, the gain of the OECD as a whole increases as the market expands.

While the OECD countries enjoy the gains from the inclusion of developing countries, the expansion of the market is beneficial to developing countries too. If trading of emissions permits were broadened to include China, the OECD would gain 10% more than without the inclusion of China. Such a gain would become even larger if there were a sharp discrepancy between the Kyoto target and the EU baseline projection as our sensitivity analysis suggests. In the mean time, such an expansion would not only provide China for additional financial resources, but also help to bring down its baseline CO_2 emissions by a big margin.

By contrast, the gain of the former Soviet Union tends to decrease as the market expands. This is mainly because the inclusion of low-cost abatement options form China and other non-Annex I countries on the supply side depresses the market price received for its sold permits. The potential conflict of interest between the former Soviet Union and non-Annex I countries may have influence on future expanding trading to non-Annex I countries, thus underlining the importance of establishing clear rules of procedure about admitting new entrants before emissions trading begins (Zhang, 1998).

It should be pointed out that different attitudes towards the AIJ (Activities Implemented Jointly) as a pilot programme, which was endorsed in the first Conference of the Parties to the UNFCCC in Berlin in April 1995, among the Chinese ministries concerned at the beginning put China at the slow starter of AIJ projects.[7] As a result, (as of 18 September 2000) only 4 projects implemented in China were reported to the UNFCCC Secretariat (see Table 14). Consequently, China has gained little experience in, e.g., baseline setting, monitoring and verification at project levels, these aspects most relevant to all prospective projects

[7] As far as the AIJ projects in China are concerned, the State Development Planning Commission is in charge of approval for any proposed AIJ project and the project financing and construction, while the Ministry of Science and Technology (MOST) is in charge of AIJ project evaluation and negotiation and the implementation of national AIJ program. Authorized by the Chinese government, the MOST will confirm whether a project jointly implemented with the investor country is regarded as an AIJ project under the pilot phase (Zhang, 2000b).

under the CDM. Thus, although several economic models (see Table 7) have suggested very large CDM flows to China according to its rapid economic growth and demand for energy, such limited experience gained from few AIJ projects in China, together with other barriers to CDM investors (in real practice, private investors do not only go to where marginal abatement costs are lowest, but also to where general investment conditions are favourable) might limit China's capacity to capitalise such a potential. If this would be the case, the role of the CDM in helping to slow down the growth rate of China's baseline greenhouse gas emissions would be reduced. This would not be beneficial to a more sustainable development of the Chinese economy or to the global climate either.

Table 14 - *The Reported AIJ Projects in China (as of 18 September 2000)*

Project	Type[a]	Parties involved (host/investor)	Lifetime (years)	Emissions reductions per year (tons of CO_2-equivalent)	Unit abatement cost (US$ per avoided ton of CO_2-equivalent)
Installation of a coke dry-quenching facility	Energy efficiency	China/Japan	20	68265	19.6
Model project for energy conservation in electric furnace used for ferro-alloy refining	Energy efficiency	China/Japan	20	29050	22.6
CFBC & CHP project in Shangqiu thermal power plant in Henan Province of China	Energy efficiency	China/Norway			
Model project for utilization of waste heat from incineration of refuse in Harbin of China	Fugitive gas capture	China/Japan	20	62896	31.1

[a] The Intergovernmental Panel on Climate Change (IPCC) has classified type of AIJ project as energy efficiency; renewable energy; fuel switching; forest preservation, restoration or reforestation; afforestation; fugitive gas capture; industrial process; solvents; agriculture; waste disposal; or bunker fuels.
Source: Zhang (2000b).

Finally, our sensitivity analysis shows that the low EU baseline projection restricts the total Annex I countries' demand for permits and thus depresses the market price of permits. Consequently, in percentage

terms, the gains of Japan and the US as importers of permits on the basis of the low official EU baseline projection would be overestimated in comparison with the case of the high EU emissions baseline, whereas the gains of the Former Soviet Union as exporters of permits and of developing countries as suppliers of the CDM credits would be underestimated. Instead of being an exporter of permits in the case of the low official EU baseline projection, the EU becomes an importer of permits in the case of the high EU baseline. Thus, in the latter case its gain increases as the market expands in contrast with the exactly reverse trend in the former case.

References

ADB (1998). *Asian Least-Cost Greenhouse Gas Abatement Strategy: People's Republic of China.* Manila: Asian Development Bank (ADB).

CASS (2000). China's Energy and Economy in the 21st Century. Unpublished Manuscript, Chinese Academy of Social Sciences (CASS), Beijing.

EIA (1999). *International Energy Outlook 1999*. Energy Information Administration (EIA), DOE/EIA-0484(99), Washington, DC.

Ellerman, A.D., and A. Decaux (1998). Analysis of Post-Kyoto CO_2 Emissions Trading Using Marginal Abatement Curves. MIT Joint Program on the Science and Policy of Global Change, Report No. 40, Massachusetts Institute of Technology.

IEA (1998). *World Energy Outlook 1998*. Paris: International Energy Agency (IEA).

MacCracken, C.N., Edmonds, J.A., S.H. Kim, and R.D. Sands (1999). The Economics of the Kyoto Protocol. *Energy Journal* 20 (Special Issue on the Cost of the Kyoto Protocol): 25-71.

McKibbin, W.J., Ross, M.T., Shackleton, R., and P.J. Wilcoxen (1999). Emissions Trading, Capital Flows and the Kyoto Protocol. *Energy Journal* 20 (Special Issue on the Cost of the Kyoto Protocol): 287-333.

UNFCCC (1997). Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). FCCC/CP/1997/L.7/Add.1, Bonn.

US Administration (1998). The Kyoto Protocol and the President's Policies to Address Climate Change: Administration Economic Analysis. Washington, DC.

Van der Mensbrugghe, D. (1998). A (Preliminary) Analysis of the Kyoto Protocol: Using the OECD GREEN Model. Presented at the OECD Workshop on the Economic Modelling of Climate Change, 17-18 September, Paris.

Weyant, J.P. (ed., 1999). The Cost of the Kyoto Protocol: A Multi-Model Evaluation. *Energy Journal* 20 (Special Issue): 1-398.

World Bank (1994). *China: Issues and Options in Greenhouse Gas Emissions Control.* Report of a Joint Study Team from The National Environmental Protection Agency of China/The State Planning Commission of China/United Nations Development Programme/The World Bank. Washington, DC.

Zhang, Z.X. (1997). *The Economics of Energy Policy in China: Implications for Global Climate Change*. New Horizons in Environmental Economics Series. England: Edward Elgar.

Zhang, Z X. (1998). Greenhouse Gas Emissions Trading and the World Trading Systems. *Journal of World Trade* 32 (5): 219-239.

Zhang, Z.X. (1999). Estimating the Size of the Potential Market for All Three Flexibility Mechanisms under the Kyoto Protocol. Report Prepared for the Asian Development Bank under Contract TA-5592-REG.

Zhang, Z.X. (2000a). Estimating the Size of the Potential Market for the Kyoto Flexibility Mechanisms. *Weltwirtschaftliches Archiv - Review of World Economics* 136 (3): 491-521.

Zhang, Z.X. (2000b). Implementation of the Climate Change Convention: The Case of China. In K. Ramakrishna, B. Bamberger and L. Jacobsen (eds.), *Asia Looking Ahead: Initial Stages of National Communications Reporting*. Massachusetts: The Woods Hole Research Center.