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The economics of Kyoto flexible mechanisms: a survey

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Abstract

Scientific study has revealed that man-made greenhouse gas emissions are causing global warming. A milestone of international effort for combating global warming was the establishment of the Kyoto Protocol to the United Nations Framework Convention on Climate Change in 1997. The Protocol sets out a 5% emission reduction target from 1990 level for Annex I region in 2010.

Economic research has foreseen that it will be very costly for some industrial countries to comply the target individually and therefore suggested international co-operation through flexible mechanisms - Emissions Trading, Joint Implementation and Clean Development Mechanism. Because main greenhouse gases have the uniform-mixing feature, the use of the flexible mechanisms could be both environmentally and economically effective. Recently emerged a number of theoretical and empirical studies to explore the economics of the mechanisms. This paper is intended to survey the existing research results with the mechanisms, including conceptual clarifications, cost and benefit analysis, potential problems, empirical findings, and perspectives for future research.

Keywords: Global warming, Kyoto Protocol, Flexible mechanisms

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1. INTRODUCTION

Global warming has become a noticeable phenomenon of climate change during recent decades. Since the Intergovernmental Panel on Climate Change (IPCC) provided scientific data on temperature increase, affecting forces, and potential changing trends and effects in 1990, both international and national societies have seriously considered and made efforts on greenhouse gases mitigation. A milestone of the efforts on international co-operation for combating global warming was the establishment of the Kyoto Protocol to the United Nations Framework Convention on Climate Change in 1997. The Protocol sets out that each party included in Annex I to the FCCC[1] shall achieve its quantified emission limitation and reduction commitments inscribed in Annex B under Article 3. According to the Kyoto Protocol, carbon-equivalent greenhouse gases in Annex I region shall be reduced 5% in 2010 from their 1990 level.

Main greenhouse gases have the uniform-mixing feature that mitigation taking place anywhere will have same effects in environmental aspect. On the other hand, mitigation in different places may have different effects in economic aspect. Current economic and environmental research has revealed that different nations would have different cost curves for greenhouse gases mitigation. Particularly, while some large developing countries and the countries in economic transition see very cheap opportunities, developed countries in general would face high cost curves and it might be too costly for them to achieve their emission reduction goals. There however is an efficient way to achieve the goals, in which mitigation shall take place wherever it is the cheapest. Based on the facts, the Kyoto Protocol, while maintaining domestic mitigation efforts, promotes international emissions trading to help high-cost countries to achieve their goals committed in the Protocol. The international emissions trading has three flexible forms as defined in the Kyoto Protocol that Joint Implementation (**JI**) in Article 6, Clean Development Mechanism (**CDM**) in Article 12, and Emissions Trading (**ET**) in Article 17, respectively.

An emissions trading system enables the country with reduction commitment to determine whether it shall take actions domestically or abroad, depending on the difference in marginal abatement costs between domestic and abroad. At equilibrium, marginal abatement costs will be equivalent everywhere. In the situation, countries are indifferent with abating domestically or abroad. The Kyoto Protocol defines emissions trading as that allowing Annex I countries to trade emission reduction units that are above or below their emission quotas agreed in the protocol in supplement to domestic actions. The application of ET requires a full international agreement and a well-established trading market. At the current stage of international negotiations, there is distance from the application of ET. Alternatively, the Protocol also suggests JI and CDM, which could achieve similar results, as the variants of ET.

[1] Including all OECD countries and the countries that undergoing the process of transition to a market economy.

The Kyoto Protocol approaches Joint Implementation as that allowing transfers of emission reduction units resulting from emission reduction or removal projects among the Annex I countries. JI constitutes investing countries, host countries, and a third party. The investing countries are the Annex I countries that have high cost functions of domestic commitments, while the host countries are the Annex I countries with low cost function for meeting their commitments. The investing countries invest emission reduction or removal projects in host countries in exchange for emission reduction credits, which will offset the obligations for domestic action. Third party is an international environmental agency, which shall be formed by the parties involved in the Kyoto Protocol. Its role may include providing guidelines for potential projects of both sides of the engaging countries, monitoring, evaluation, verification, and certification. A JI project may be funded by an investing country, or jointly by several investing countries, or by an international organisation whose funds come from investing countries. Both investing and host countries may be allowed to invest on or host several projects.

In the Protocol, a Clean Development Mechanism allows transfers of emission reduction units resulting from emission reduction or removal projects between Annex I and non-Annex I countries. Its principles are similar with the JI. However, the Kyoto protocol defines the CDM with two-fold objectives: namely emission reduction and sustainable development for host non-Annex I countries. In general, the CDM is regarded to have greater potential in reducing emission reduction costs than the JI. Because there exist very low cost opportunities of abatement in non-Annex I countries. A striking difference between JI and CDM is that while host countries in JI commit to emission reduction targets, host countries, non-Annex I countries, in CDM not.

In general, JI and CDM are regarded to be both economically and environmentally less efficient than ET for that they only involve partial co-operation. Firstly, JI and CDM only occur in the absence of ET or, in other words, that a full range of international agreement is not available. In this sense, some low-cost or main emitters may stand aside global combating action. Secondly, JI and CDM mean project-level emissions trading. The project possibilities vary from sector to sector and are very small in certain sectors. Therefore, the potential of efficiency improvement for JI and CDM is more limited than for ET. Thirdly, JI and CDM projects are set up and implemented between a few of nations. This situation may create a number of negative factors such as carbon leakage, free riding, and high transaction costs, inducing inefficiency.

The spirit of the flexible mechanisms is to improve cost efficiency through international co-operation and therefore to enhance environmental efficiency. Research has revealed that the maximal gain in cost efficiency is from no trading to global trading. As a global trading is unrealistic so far due to the unequal distribution of better off or worse-off across nations, current researches focus on searching alternative solutions. JI and CDM are two of those possible measures that are able to improve cost efficiency to the extent less than the full emissions trading within Annex I region and within global region, respectively.

The present paper is to review recent studies on the Kyoto flexible mechanisms with particular focus on JI and CDM. In section 2 and 3, we present background and conceptual materials for the application of JI and CDM. Section 4 explores theoretical issues with JI and CDM, where we discuss cost efficiency, benefit distribution, baselines, and a number of other problems in relation to JI and CDM. Section 5 reviews present empirical researches. Instead of discussing the details of each research[2], we focus on the scenarios that these researches have done, and the gaps that the researches have remained. Finally, in section 6 we draw our proposal of investigating macroeconomic implications of JI and CDM to Europe and Belgium through GEM-E3 modelling.

2. OVERVIEW ON MITIGATION ACTIONS AND COSTS

2.1. Global warming and its impact

The human society has become increasingly aware of the potential threat of global warming since last decade, on basis of the revelation of scientific evidences and the perception of the continuing rise in temperature during recent years. IPCC I (1990, 1995) reports that while a natural greenhouse effect has been keeping the Earth warmer than it would otherwise be, a man-made greenhouse effect caused by the fast atmospheric concentrations of the greenhouse gases emissions will result in an additional warming of the Earth's surface. During the last century, Earth's surface air temperature has increased by 0.3°C to 0.6°C, with the five global-average warmest years being in the 1980s. If human society does not take any measures to combat the global warming, the predicted increase rate of surface air temperature would be at 0.3°C per decade during this century. Recent observation reports the year 1998 was the warmest ever in human history[3].

The impacts of global warming on earth and human society are rather complex and to a large extent unpredictable so far. Scientific research has not been able to determine whether a small increase in temperature will be better or worse. However, if global temperature increases significantly and the associated climate changes fast, the negative effects of global warming will certainly dominate the positive effects. Therefore, human society may run the risk of catastrophe in future if it does not consider for controlling the global warming from now.

2.2. Action strategies

In response to this adverse situation, human society in general has three ways to protect itself -adaptation, climate engineering and abatement. Adaptation measures accept climate changes and attempt to minimise the damage of negative effects through adapting human society to the climate changes. Examples include migration, development of drought-resistant plant strains, construction of sea defences, etc. Climate engineering is to offset directly the warming in the lower atmosphere through altering the reflectivity of the earth's atmosphere, enhancing the cooling effects of water circulation and screening the earth's atmosphere from the sun's rays. Adaptation and climate engineering are able to offset both natural and man-made greenhouse effects. At current stage, however, as these strategies are limited by technological progress and involve large uncertainty, they can yet be adopted as mainstreams of the actions combating global warming.

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[2] We will not evaluate the models since they are common in principle and different mostly in assumptions. We will also not discuss the results yielded from the models because we find that the researches provide rather consistent results on basis of same assumptions.

[3] BBC broadcast program on climate change in May 2000.

Abatement, targeting at man-made emissions, is adopted to moderate the growth of concentration of greenhouse gases in the atmosphere. It includes sink enhancement and emissions abatement. Sink enhancement expands the Earth's ability in absorbing gases emissions by, for example, reforestation, but it is limited by land available and its absorbing rate in general is slower than the increase of the atmospheric concentration of greenhouse gases. Whereas emissions abatement curbs emissions at source by conducting human activity towards producing few emissions in short run and by using clean technologies in long run.

2.3. International co-operations and the Kyoto protocol

Main forms of greenhouse gases, typically CO2, are mixed uniformly at the atmosphere. Because of this feature, the abatement of these greenhouse gases has two economic implications. On the one hand, an individual abatement of the uniform mixing greenhouse gases will generate positive externality to others who can take full free riding or even make some offset. On the other hand, the abatement of these greenhouse gases is free to take place anywhere over the world for the purposes of both environmental efficiency and cost efficiency. Therefore, by nature combating climate change calls for global actions on the abatement of uniformly mixing greenhouse gases.

Historically, several international agreements on specific environmental problems have been established. The Montreal Protocol on the control of chlorofluorocarbons (CFCs), the Framework Convention on Climate Change, the Second Sulphur Protocol on the Long Range Transboundary Air Pollution, and the Rhine 'Salts' treaty were the examples.

International agreement on climate change started from the adoption of the United Nations Framework Convention on Climate Change (FCCC) in 1992. It was entered into force in 1994. The goal of the Convention is to stabilise the concentration of greenhouse gases in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. During the Third Conference of the Parties to the FCCC at Kyoto in 1997, the conference passed a Kyoto protocol, which is the first international agreement on climate change. In the Kyoto protocol, developed countries made voluntary commitments to stabilise carbon emissions at 5% less than 1990 levels by 2012. The protocol lists the six types of greenhouse gases in Annex A: namely carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6). The protocol also prescribes the committed countries and corresponding commitments (in its Annex B). These countries are identical to Annex I countries to FCCC, which include the OECD countries, the countries in Eastern Europe and the states of the former Soviet Union. The carbon-equivalent emissions reduction targets are specified that, for instance, US should reduce emission 7%, Japan 6%, and EU-wide 8% from their 1990 levels by 2012. The compliance period defined in the protocol is five years. In addition, the protocol recommends a set of flexible mechanisms to help the countries to reduce the costs achieving the targets. These mechanisms include emissions trading (ET), joint implementation (JI), and Clean Development Mechanism (CDM).

Indeed, the Kyoto protocol has outlined the forefront of industrial countries' action towards combating global warming since the launching. However, it has also received numerous arguments. At present time, it seems that the protocol will be less likely ratified because of the objections from some major nations. Two main types of the arguments against the protocol are the following. Firstly, the protocol will limit Annex B countries' emissions but do nothing to developing world among which some major developing countries are expected to increase emissions rapidly with their economic growth. For this reason, the Kyoto protocol will not ensure global environmental efficiency. Secondly, the protocol emphasis on the importance of domestic abatement and restricts the scale of international co-operation, therefore does not move towards full cost efficiency. In particular, under the restrictions some countries like US (Nordhaus, 1999) who commit to emissions reduction and will suffer high level of domestic abatement costs will not be able to relax their loads.

An enhanced argument against the Kyoto protocol is that even if the protocol were enter into force, it would not be able to fulfil FCCC's goal of stabilising greenhouse gases concentrations (Edmonds, 1999). Thus, recently there is an increasing trend to consider actions beyond the Kyoto Protocol. Edmonds (1999) summarised three critical issues needing to be dealt with -- the long-term nature of the climate change problem, the mechanisms to control costs, and the accession to non-Annex I nations in the formal mitigation process.

2.4. CO2 abatement

Among the greenhouse gases, carbon dioxide is mostly responsible for the greenhouse effects. IPCC I (1990) has detected that CO2 has the share of 65% in all greenhouse gases. Therefore, current practice primarily considers to abate CO2 emission. More specifically, economic instruments focus on curbing CO2 emission that mainly results from combustion of fossil fuels. In Ekins (1995, p241), economic instruments on CO2 abatement could induce the following consequences:

(a) Reduction in demand for carbon-based fuels

(b) Substitutions between more and less carbon-intensive fuels

(c) Changes from carbon-based to non-carbon fuels

(d) Changes from energy to other factors of production

(e) Changes between more and less carbon-intensive products and processes

(f) Improvement in the efficiency of fuel use in delivering a particular energy service

(g) And, development of new, less carbon-intensive technologies, products and processes.

2.5. Abatement costs

The actions combating global warming certainly incur costs in every step. However, we focus on the discussion on CO2 abatement costs incurred by market-based instruments. The abatement costs usually are defined in terms of incremental costs, which refer to the costs of a particular abatement action over the costs in a reference where the abatement is absent. These costs can be distinguished at four levels: the technique level, the project level, the sector level, and the economy level. At the technique level, costs are the direct engineering and financial costs of specific techniques. At the project level, costs equal to total cost that the project implies, which covers all the costs incurred during the project from the investment, to operation and maintenance, and to monitoring and verification. At the sector level, the incremental costs are identified as the variation from the reference. The costs include both the incremental costs of specific projects and the induced costs to relevant sector, but exclude the feedback effects between the behaviour of the sector and that of the overall economy. At the economy or national level, the incremental costs summarise all costs incurred from any abatement actions, including technical costs, project costs, sector variation and national economic changes.

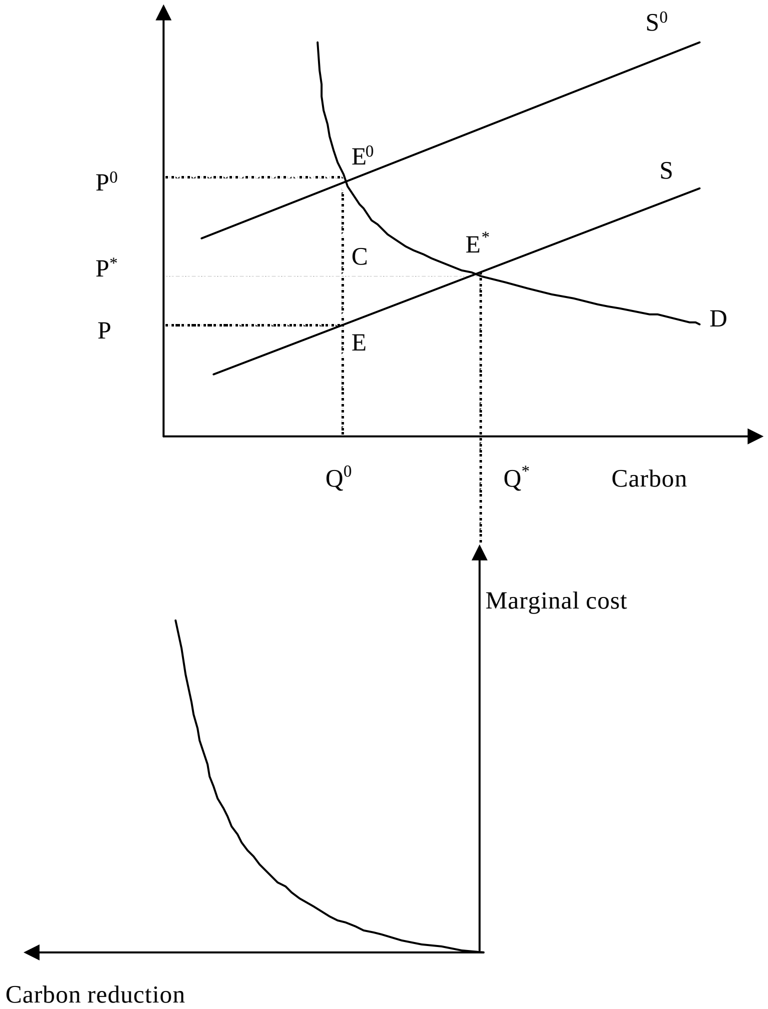
Economic instruments in general bring about costs at economy, sector or project level rather than at technique level. For CO2 abatement, if the market-based instrument is carbon tax, abatement costs are measured at economy level. Figure 1 illustrates the case. In upper figure, the original equilibrium is at point E*, where carbon quantity is Q* and equilibrium cost or price is P*. A carbon tax, T, will add an extra cost into supply price and thus shift supply curve up. The new equilibrium is at point E° now, where carbon tax, T, equals to E°C or P°P*, carbon quantity decreases by Q*-Q° and equilibrium price increases by P°-P*. The resulting loss is the area of P°E°E*EP, which consists of the loss in consumer's surplus, P°E°E*P*, and in producer's surplus, P*E*EP.

As carbon tax rises from zero at E* towards E°C or even further to left, carbon reduction shown in lower figure increases, the associated loss in consumer surplus constitutes a marginal cost curve for the case. Researches have found that marginal abatement cost is an increasing function of abatement efforts. In particular, if abatement is a small amount, abatement cost could be very low or even negative, however, if abatement targets are ambitious, the abatement costs could become too high to fulfil the targets.[4] From the figure, we can see that significant abatement will require high emission tax rate and thus incur large abatement costs.

[4] The well-known reports on the estimation of high abatement costs, cited in Ekins (1995), are Manne-Richels (1990), Nordhaus (1991), Pezzey (1991), Beckerman (1991), and Hampson (1993). Weyant (1999) provides the most recent

results on abatement costs.

Figure 1. Carbon reduction and abatement costs



2.6. The measures of abatement costs

Figure 1 illustrates abatement cost in terms of consumer surplus, which is also called equivalent variation (EV). Besides this, there exist other alternative measures of abatement costs, including carbon taxes, direct cost, total resource costs, GDP, GNP, aggregate economic consumption, and discounted aggregate consumption. Figure 1 is also able to show some of these cost measures. Carbon tax, E°C, is related to abatement cost, but it is an imperfect measure of welfare costs. Total resource costs, including the losses in consumer and producer surplus, is the area of P°E°E*EP in the upper part of Figure 1. Direct cost equals the dead-weight loss in the area of E°E*C. Its corresponding cost curve can also be seen from the lower part of the figure. GDP is an aggregate measure at economy level. It is able to capture the impacts on the overall economy of economic policies in specific sectors.

2.7. The distribution of abatement costs

Abatement costs are subject to many factors such as population growth, consumption patterns, resource and technology availability, and geographical allocation of activity, land use and transportation patterns, and trade. As the result, abatement costs are different among sectors, among regions, and among nations. The cost efficiency of Kyoto flexible mechanisms relies on the significant difference in abatement costs between countries and between sectors (Barrett 1992). Many studies[5] have reported on the distribution of CO2 abatement costs over the world. There are sharp differences in abatement costs between developed, transitional, and developing countries. A few studies also expose the abatement costs among sectors and firms within nations.

2.8. Abatement benefits

2.8.1. Revenue recycling

Economic penalisation on emissions will incur costs to agents on the one hand, and will generate revenues to the regulators on the other hand. When the intended emissions reduction is significant, the associated revenue could be a large amount. It is therefore argued that overall economic efficiency could be improved if the revenues generated from emission regulation are used to phase out some existing market distortions (Bovenberg and Guilder, 1995).

2.8.2. Net benefits (positive costs, or no regret)

Abatement may not necessarily result in net costs, rather it may bring about net benefits, if abatement scale is small (Jackson, 1995). These benefits may be due to the adoption of more efficient environmental technologies, the decrease of the distortion in economic system, the growth of stimulated innovations, and the positive externality of the abatement of other pollutants. The potential of the net benefit results associated with low-cost abatement options exists in both Annex I and non-Annex I countries. Considering the positive impacts of the improvement of tax distortion, the revenue recycling, and the secondary benefits of reducing greenhouse gases emission, a large room for the net benefit is possible. Ekins (1995) checked the net benefits mentioned in a number of reports and surveys regarding CO2 abatement costs. He concludes that it is not very definite that a moderate abatement of CO2 emission will incur net costs when it can improve unemployment and prior tax distortions, recycle revenue, and bring the secondary benefits of reducing CO2 emissions.

2.9. The bottom-up and top-down methods

During last decade, most researches focus on greenhouse gases abatement focused on the estimation of abatement costs. Despite of the short history, the methods estimating the costs have fallen into two families: bottom-up and top-down models.[6] A bottom-up method is to compare the costs of a specific environmental technology in different countries. While the method is effective for project-based abatement actions, e.g. JI or

[5] E.g. Chandler and Evans, 1996, for post-planned economies; Krause, 1996, for Europe; Shukla, 1995, and Sathaye and Christensen, 1994, for developing countries.

[6] The detailed review on these two families was in IPCC (1995); a recent review is available from Capros et al (1999).

CDM, it is limited in capturing macroeconomic implications of potential projects. On contrast, a top-down method constructs environmental system into economic system to capture the impact of environmental instruments on environmental system, the feedback of the environmental system on economic system, and the implication of economic system for the instruments. The top-down analysis is strong in sheding light on policy perspectives. In particular, the method is able to identify whether a country will benefit from the adoption of a specific mechanism and to show how the country can achieve the maximal benefit, etc.

3. ECONOMIC INSTRUMENTS

3.1. Environmental policy

By its nature, emissions abatement is particularly relevant with the application of environmental policy instruments. There exist a variety of these instruments, two main groups of which are regulatory instruments and market-based or economic instruments. In addition, there are other instruments including voluntary agreement, informational and organizational instruments.

The regulatory instruments including technology and performance-based standards or product standards or bans have been widely applied for decades. This group of instruments however can not ensure cost efficiency as it does not give emitters the incentives to use cheap options available in short run and to encourage environmental technology innovations in long run. Moreover, this group of instruments may not be well compatible with international agreement. Because nations in general face different domestic marginal abatement costs, a specific regulation that internationally fixes national emission level would result in unnecessarily high abatement costs and therefore are unacceptable for a wide range of countries (IPCC III, pp. 404).

Whereas economic instruments, by adding an extra cost to emitters to make emission more expensive for production or consumption, will induce the shift from emission activities towards less or none emission activities. This group of instruments therefore is attractive in cost efficiency and hence in environment efficiency. Recent trend shows that the market-based or economic instruments are phasing out the regulatory instruments particularly in industrial nations (Capros, 1999, pp. 27-31).

The economic instruments have two basic forms: namely emission taxes and emissions trading. Under perfectly competitive markets, an emission tax will induce emitters to reduce emission at a level where the marginal abatement cost is equal to the emission tax rate. Similarly, a scheme of emissions trading will induce emitters to reduce or increase emission at a level where the marginal abatement cost is equal to the equilibrium price of the emission quota. Therefore, an emission tax can be identical to a scheme of emissions trading if initial emission permits or quotas are distributed by auction and the markets fulfil both competitive and certainty conditions.

3.2. Emission tax

In domestic markets, greenhouse gases emission tax can be in the form of domestic carbon tax or energy tax. The former levies on the carbon content of primary fossil fuels, while the latter on energy content of fuels or the value of energy products. The carbon tax is a more efficient instrument for reducing energy sector CO2 emissions than energy tax since an energy tax will not only penalise the CO2 emission energy but also hurt the non-CO2 emission energy. Carbon tax however is not a perfect proxy for a CO2 tax. The disadvantages caused by domestic carbon and energy tax may be that these taxes will hurt the competitiveness of domestic energy firms and create carbon leakage outside domestic.

In international markets, emission tax has two general forms: namely international tax and harmonised domestic taxes. Under an internationally agreed emission target, an international tax is imposed on the nations in agreement by an international agency. The tax works similarly as domestic tax does, but it has difference from domestic tax. With international tax, the nations in agreement, rather than domestic firms, pay the tax to an international agency, rather than national governments, and it is the agency receiving and redistributing the tax revenues. Whether a nation uses domestic environmental policies or tax forms is irrelevant with the international tax obligation. However, the tax form will encounter problem when the tax revenues are huge, because it is difficult for an international agency to handle this amount of tax (Grubb, 1992). The harmonised domestic taxes require the nations in agreement levy the same domestic emission tax and compensate the losing countries from the gaining countries. Hoel (1992) concludes the harmonised domestic taxes may be the only realistic form for international taxes.

3.3. Emissions trading

Emissions trading within domestic markets, called domestic emissions trading or permits trading, consists of a given amount of emissions, an initial allocation of emission permits according to certain rules, and a trading mechanism (Capros, 1999, pp. 38-39). The emission quantity can be determined under domestic environmental regulations or with international agreements. The allocating rules could be many, but most popular ones are the grandfather and the auction. Under a grandfather allocation, government gives firms the emission permits based on historical records. Under an auction allocation, government sells the emission permits to firms by auction. In either case, a firm with emissions below its permits could sell the surplus for revenue. Otherwise, if a firm requires the emissions above its permits, it has to buy the extra permits. The drive behind the trading is that each firm decides controlling emissions or buying permits by comparing control costs with market prices of emission permits until the firm is indifferent between abating by itself and buying permits. As the result, the trading price of emission permits is determined at the permit trading market equilibrium. It is argued that the tradable permits is the most promising one among the potential economic instruments, because it allows maximal flexibility for firms' choices, ensures cost efficiency and thus environment efficiency, and stimulates environmental technological innovations (Grubb, 1992). Past experience has shown that tradable permits were a powerful and efficient mechanism in domestic emissions reduction (Tietenberg, 1999).

Emissions trading can take place among nations. The case is called international emissions trading or tradable quotas, which consist of an emission target and an allocation of the quotas agreed by a number of nations, and a trading mechanism. As international emission tax works like domestic emission tax, international emissions trading also has similar working mechanism with domestic emissions trading. The differences are that the dimensional level shall change from trading among domestic firms to among the nations in international agreement, and there need international emissions trading markets. However, the international emissions trading cannot simply follow the success of domestic emissions trading, because it may undermine developed countries' incentive for domestic abatement and may even deteriorate overall greenhouse gas effect. The Kyoto protocol has recommended Annex I countries to use international emissions trading, but it has not yet clearly defined the mechanism.

3.4. Joint implementation and Clean Development Mechanism

3.4.1. The concepts

A variant form of emissions trading is the so-called offsetting or relaxing mechanism (Grubb, 1992). The idea is that an emission party can offset or relax its emission targets by investing in emissions reduction in other parties in exchange for emission credits, rather than by purchasing emission permits. A specific application of the idea is the joint implementation, which at outset defines that a nation under international emission agreement can offset or relax its emission target by investing in other countries. The revolution of the application further distinguishes host countries between two groups: the countries in international agreement and the countries outside international agreement. By the distinction, the first group now refers to joint implementation, whereas the second group refers to a Clean Development Mechanism.

The Kyoto protocol is the first document formally addressing the distinction. The Article 6 of the Kyoto protocol explicitly defines joint implementation (**JI**) as that allowing transfers of emission reduction units resulting from emission reduction or removal projects among the Annex I countries. The objective of JI is to reduce total costs of fulfilling Annex I countries' commitments under Kyoto protocol as to ensure the targets of emission reduction. Primarily, joint implementation constitutes investing countries, host countries, and a third party. The investing countries are the Annex I countries that will face high abatement costs for meeting their commitments, while the host countries are the Annex I countries with low cost function for meeting their commitments. The investing countries invest emission reduction or removal projects in host countries in exchange for emission reduction credits to offset or relax their obligations. Third party is an international environmental agency, which shall be formed by the parties involved in the Kyoto protocol. Its role may include providing guidelines for potential projects of both sides of the engaging countries, monitoring, evaluation, verification, and certification. A JI project may be funded by an investing country, or jointly by several investing countries, or by an international organisation whose funds come from investing countries. Both investing and host countries may be allowed to invest on or host several projects.

In Article 12, the Kyoto Protocol specifies that a Clean Development Mechanism (**CDM**) allows the transfers of emission reduction units resulting from emission reduction or removal projects between Annex I and non-Annex I countries. The principle and institutions of a CDM are similar with the one of a JI. However, the Kyoto protocol specifies that the CDM is not merely intended to reduce the costs of achieving an environmental task but also to help non-Annex I countries with sustainable development.

3.4.2. The relationships between ET, JI and CDM

Since the Kyoto protocol launches the flexible mechanisms, numerous studies on them have emerged. At current stage, because most of the mechanisms have not been practised[7] and empirical simulations on the mechanisms frequently show a wild range of results, theoretical debates on the economic relationship between the mechanisms remain rather controversial.

By nature, ET would be environmentally more efficient than JI/CDM. JI/CDM in general is regarded as a step before ET (Rentz, 1995). It works when ET is yet available and will become unnecessary when ET can be implemented (Tietenberg, 1999). Compared with ET, JI/CDM is limited to reduce economy-wide emissions, because only certain sectors such as agriculture, energy and energy-intensive sectors may provide the possibility for the emission reduction projects involved with JI/CDM. For example, foreign investors may invest for improving efficiency in an electrical power plant, but may not be able to intervene in host countries' tax system by financial compensation. Whereas with ET host countries can execute whatever measures to curb domestic emissions.

However, the establishment of ET requires deliberate design, otherwise it may run the risk of environmental loss. Woerdman (2000) argues that in the case of "hot air", ET may in fact result in more emissions than the Kyoto target, whereas JI/CDM will always yield new emission reduction units in addition to Annex I countries' commitment.

Most researches consider that ET will be economically more efficient than JI/CDM. The application of JI/CDM implies that only a part of the potential parties, which otherwise would all present in ET, involve with an international co-operation. As the result, the allocation of cheap abatement opportunities with JI/CDM will not be as optimal as with ET. Furthermore, JI/CDM involves more transaction costs than ET, because of its project-based nature that transaction costs will associate with each project (Tietenberg, 1992).

Some authors however have suggested a reversal situation that JI/CDM is cheaper than ET. Woerdman (2000) compares the credit prices involved in a number of AIJ projects[8] with the permit prices in ET empirically estimated by various models, and finds that the permit prices are much higher than the credit prices. Bollen (1999) analyses that the ET within Annex I will generate a uniform permit price that equals to the marginal abatement cost in the region, whereas in the case of JI there will be one separate price for each project, which might be negotiated and will equal to the marginal abatement cost in individual project. In general, the JI prices are lower than the marginal abatement cost of the whole Annex I region. Woerdman (2000) further argues that the neo-classical style

[7] Only the activities implemented jointly (AIJ) during pilot phase have been implemented so far.

[8]

trading of ET may not be valid and that there are the methodologies available to lower transaction costs in JI/CDM. He suggests that the learning process and the region-by-project baseline matrices will be effective in cutting down transaction costs in JI/CDM projects.

CDM in general has greater potential for cost efficiency than JI. Many researches have reported that non-Annex I countries have very low abatement costs compared with Annex I region (Zhang, 2000; Shukla, 1995; Sathaye and Christensen, 1994; Krause, 1996; Chandler, et al, 1996). However, CDM may not easily achieve its cost efficiency. There are a number of adverse factors likely to erode the potential of cost efficiency. Because host countries in CDM are not subject to emissions reduction targets, they tend to take free riding by delaying or forgoing their own abatement efforts that otherwise will be made (Roland and Haugland, 1994). Also, in order to prevent both the sides of a CDM project from exaggerating the abatement effect (Roland and Haugland, 1994; Hagem, 1995; Wirl, et al. 1998), CDM has to require the strength in information collection, negotiation, monitoring, and enforcement and thus incur more transaction costs. In addition, the high price elasticity of energy in developing countries will also absorb part of abatement effort involved with CDM projects (Roland and Haugland, 1994).

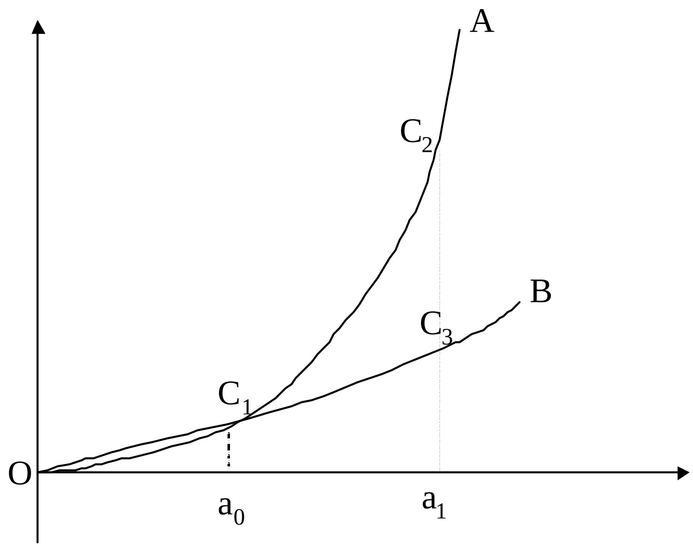
Woerdman (2000) argues that JI/CDM is more practicable than ET, as it only requires partial participation of parties. Although ET is theoretically superior to JI/CDM, it has disadvantage in application, because it has to involve the full agreement of all parties and specify the initial allocating rules of emission permits.

4. ISSUES WITH JOINT IMPLEMENTATION AND CLEAN DEVELOPMENT MECHANISM

4.1. Cost efficiency

The spirit of JI/CDM lies on that they could increase cost efficiency in case that a full range of international emissions trading is unavailable. Figure 2 illustrates how the costs could be reduced in JI/CDM. Assume that country **A** commits an emission reduction target $\mathbf{a_1}$ and country **B** is not subject to such commitment. And, assume that the two countries are facing different abatement cost curves, country **A** is lower than country **B** when abatement target is less than $\mathbf{a_0}$, and greater than country **B** thereafter to the abatement target $\mathbf{a_1}$. From the figure, it is clear that if the two countries co-operate together to abate along the least-cost paths, they can realise the cost efficiency. This co-operation can be in the form of either ET, JI, or CDM in which country **A** abates $\mathbf{a_0}$ domestically and shifts the rest of its target, $\mathbf{a_1 - a_0}$, to country **B**.

Figure 2. The least-cost curves in JI/CDM



4.2. Benefits distribution

4.2.1. Distribution rules

As the figure 2 shows, the area **$C_1C_2C_3$** indicates the potential for cost saving resulted from the co-operation between country **A** and **B.** A question naturally arisen is how this cost saving would be shared by the two countries. Since in the international context no super-countries could impose others, international emissions trading must be based on the voluntary agreement in which the nations shall share benefits equally. In Rose (1992), the cost efficiency and the benefit equity are likewise important to emissions trading. Because with emissions trading the efficiency and equity is the separate issues, according to the Coase theorem that no matter how initial allocation of emission permits is, through market exchange the emission permits will lead to efficiency. Thus, one of the most important aspects with emissions trading is to design sharing rules to ensure equity. Research has explored many these rules. Rose and Kverndokk (1998) summarise the typical rules as follows:

(a) According to allocation-based criterion: Sovereignty, Egalitarian and Ability to Pay rules

(b) According to outcome-based criterion: Horizontal, Vertical and Compensation rules

(c) According to process-based criterion: Raw's Maximin, Consensus and Market Justice rules

In the formation of emissions trading agreement, these rules could be applied individually or jointly in order for equity.

4.2.2. Investing counties' position in sharing the benefits

The main purpose that the Kyoto protocol introduces the flexible mechanisms is to assist industrial countries to avoid high costs in fulfilling their emission limitation and reduction commitments. Apparently, investing countries, which in general are industrial countries, will be the most direct beneficiaries because the countries need less investment in host countries than domestically to achieve their commitments if the flexible mechanisms are applied successfully. Thus, investing countries can achieve direct cost saving.

Furthermore, under JI/CDM, investing countries may even be able to assess indirect positive impacts on domestic markets by enforcing exports, which in turn may stimulate domestic innovation and production, of their environmental technologies and goods to host countries. From the point of view of investing countries, whether a JI or CDM project is merely costly or can bring benefit depends on its channels to funding. When JI/CDM promises a purely financial transfer, it may consume the public or private funds of investing countries. Under the consequent compressed budgets of government or private company, unemployment, public deficits, tax distortions, and foreign balances can not be improved. When JI/CDM promotes the exports of domestic environmental technologies and goods in investing countries to receiving countries, it has potential to improve domestic distortions, stimulate environmental technology innovations, and expand productions. Under the consideration of this type of benefit, the estimated cost efficiency by JI/CDM would be expected to increase. So far, the benefit however is ignored in empirical research.

Under CDM, investing countries may also gain from the negotiations and bargaining with developing countries. Because the investing countries have strong economic position and have invested much in the information required for framing CDM projects, whereas developing countries are unable to access the full information (IPCC III, 112).

However, investing countries' position in getting majority of benefits may be undermined if market power exists in host side.

4.2.3. Host countries' position in sharing the benefits

In contrast to the striking benefits to be obtained by investing countries, the benefits of host countries are ambiguous. With ET within Annex I region, delicately designed and widely agreed sharing rules could solve the problem of burden sharing. JI, as a special form of ET, can be to large extent subject to the sharing rules applied as well if it is implemented at the scale close to the emissions trading. However, if JI is limited within small range, negotiation, bargaining, information available, and other elements could affect benefit distribution.

In case of CDM, the distributions of costs or benefits however are uncertain or ambiguous. There is concern that CDM may cause unequal distribution of benefits for two reasons. Firstly, because host countries are the countries not committed to emission reduction targets, they are not ensured by the sharing rules. The benefit distribution of CDM may depend on negotiations and bargaining in which developing countries have disadvantages in general. Secondly, potential indirect costs induced by CDM project and development assistance to be required have not been explored clearly in developing countries. In general, investing countries will cover the full costs of a CDM project and host country has no worry about them. However, an introduction of a CDM project may have both positive and negative impacts on the markets in host country. The main implication of the former is that foreign investment will push domestic demands and therefore stimulate production.

The latter includes the concern that the insertion of an external CDM project into domestic markets may increase the incompatibility with the domestic economic system in host country. For example, intensive reforestation projects in China will use up numerous amount of its scarce land, in turn China has to increase its agricultural import. The estimation of indirect costs and extra benefits of CDM has to be based on specific cases and be done in economy-wide systematic framework. Unfortunately, most developing countries do not have well-established environmental and economic systems, there are few reports identifying the possible indirect impacts on host countries. On the other hand, host countries in general strongly demand for the assistance for sustainable development from developed countries. Therefore, how large the extra investment besides the project costs should be added in order to attract potential host country to accept a CDM project remains unsolved.

In the point of view of economist, under competitive markets of CDM the equilibrium price will determine the full costs of CDM projects. The problem with this proposition is that the competitive markets are more likely to be imperfect, since big countries exist in both sides of the supply and demand.[9] The market power may therefore bias the benefit distributions between and within the supply and demand parties. In particular, in case that there are large supplies available from transitional and developing countries, the equilibrium prices will be so low that host countries can not benefit significantly from the projects (Zhang, 1999).

From the long-run perspective, host country seriously concerns that it may eventually suffer a loss when it will have to commit itself to certain emission control targets in future. Because CDM projects could lead to exhaustion of cheap opportunities for emission mitigation in host country and leave only high cost options to host country. Rose et al. (1999) have explored the long run implications of CDM to developing countries, and finds that cumulative abatement effects could impose costs on the future, but the costs can be offset by technological change, market power, or compensation.

The possibility of unequal distribution of benefits under CDM may hinder the feasibility of CDM's application, unless the mechanism is designed on basis of equity. Van der Burg (1994) and a number of other propositions point out that the commitments of investing countries should be made more stringent, or even levying a tax on CDM projects to redistribute the investor's surplus.

4.3. Developed countries' motivation

The Kyoto protocol underscores the importance of domestic abatement in Annex I countries in defining that the flexible mechanisms are only supplemental to the domestic actions. This is based on a fundamental concern that allowing industrial countries to trade JI and CDM investments for emission credits will reduce their incentives for domestic action, and may undermine their commitments to achieve global climate stabilisation. For the fact that a large pool of the cheap abatement opportunities exist in the countries in economic transition and in developing countries, shifting most of their commitments through JI or CDM may be economically efficient for industrial countries. Therefore, there

[9] For instance, China and India in supply side and USA and EU in demand side.

is the possibility that developed countries may unload their obligations for domestic action onto the host countries through investing in JI or CDM projects, if they are not bounded to domestic abatement.

Industrial countries, which are mostly responsible for the increase of global greenhouse gases emission, should make most efforts in reducing domestic greenhouse gases emissions. Studies have revealed that industrial countries have large potentials for greenhouse gases reduction. In some developed countries, there are even significant benefits for the reduction options.

Jackson (1995) examines the cost potentials for JI[10] with an example of four countries, Denmark, the UK, Poland, and Zimbabwe. The research designs seven hypothetical JI cases and uses joint cost curves along the least-cost paths to analyze the implications of cost efficiency. Jackson finds out that developed countries have more potentials for no regret options than transitional and developing countries. Due to the fact, JI may not be a cheap way for developed countries to seek under certain reduction targets. JI may be helpful for developed countries only when they are obligated for some high reduction targets.

There are a number of measures being discussed to enforce developed countries to take domestic actions. The three main measures are the following. First, allowing developed country for using JI and CDM only in the case that it has used out its cheaper options and will be facing very costly options otherwise in domestic. Second, setting a ceiling on allocating JI and CDM projects to developed countries. A number of researches have been aware that due to the supplementary concept defined in the Kyoto protocol no countries may be allowed to shift their full obligations through JI or CDM. The researches therefore attempt to restrict developed countries' demands for JI or CDM by quotas. So far, how to define the restriction and distribute the quotas however remains open. Third, taking a discounting measure for distributing credits to JI and CDM projects. At the current stage how to define a ceiling and how to credit emission reduction units in relation with particular projects is under study.

4.4. Free riding

Free riding erodes environmental efficiency. It will happen when some parties are outside environmental commitment. In case of CDM, developing countries have incentive to take free riding. Since host countries can foresee the oncoming foreign investment in emissions abatement, they have no incentive to curb the emission by themselves. Roland and Haugland (1994) estimate that the free riding share could be 50% with Poland and Mexico JI projects, and 70% and 30-50% in relation to energy conservation programmes in Norway and United States, respectively. It is worthy to notice that free riding results not only from the abstention from environmental investment in host countries but also from the abstention and delay of their environmental regulations.

In order to prevent the potential free riding, a CDM project must be additional. If a CDM project is not additional, it cannot lead to a net reduction of CO2 emission from global

[10] Here, JI is a broad definition, which refers to both joint implementation and clean development mechanism.

environmental point of view. Van der Burg (1994) and many others proposed the concept of additionality to ensure efficiency of CDM projects[11]. The additionality states that a CDM project can be regarded as additional when it would not exist without the CDM. The Kyoto protocol definitely requires that any JI or CDM projects must be additional to any that would otherwise occur. There are many approaches on the additionality. The most recognized approach is that a JI or CDM project must be additional in emission limitation and reduction. The host side however emphasizes on the concept of financial additionality. Under JI, it is relatively easy to ensure the additionality, because host countries (the countries in transition) also commit to emission limitation and reduction and therefore should have established explicit reference. Under CDM, the additionality is particularly important and is difficult to be set up definitely, because at the current stage the host countries have not committed to any emission limitation and reduction obligation. Currently, the additionality remains as the mostly intractable problem with CDM.

4.5. Price elasticity

Price elasticity may cause negative effect on JI or CDM project as well. Less-developed and developing countries in general have compressed demands for energy consumption subject to budget constraints. These countries will expand their energy consumption once JI or CDM projects provide the cheap opportunity for the consumption, and therefore induce high level of emissions. Roland and Haugland (1994) review that Energidata survey in 1991 reported that the price-induced consumption increased 40% for households and 10% for commerce in a Norwegian investment support programme. They also incite Khazzoom's (1986) finding that about 67% of the initial energy saving was eroded by the effect of price decrease in an econometric study of an American residential conservation programme. Roland and Haugland argue that consumption increase in response to price decrease could be as high as 100% in some specific cases.

4.6. Asymmetric information

Several researches have stressed that asymmetric information on both investing and host countries may cause inefficiency of CDM. Roland and Haugland (1994) argue that if host country does not have emission targets, it has incentive to exaggerate its reduction potentials, and investing countries will follow to over-report emission reduction. Hagem (1995) finds that private information on cost and efficiency of the side of host country will undermine cost efficiency of CDM, as efficient rather than inefficient firms in the host will receive a positive rent. The result of the research however is partial, as it exams only the incentive of host country. Wirl et al. (1998) discusses the incentives of both sides, based on the private information on the host side,[12] and theoretically proves the argument by Roland and Haugland (1994).

Wirl et al. further proposes a remedial way to reduce the inefficiency caused by asymmetry information. He suggests that investing countries should set up JI/CDM with

[11] Although the original research defines the additionality in terms of JI, it in fact refers to CDM. The conceptual distinction between JI and CDM started only from the Kyoto protocol.

[12] Theoretically, the investor also has private information regarding its abatement costs and efficiency. So far, the existing studies have not touched this aspect.

semi-efficient or similar countries (like Korean, Taiwan and Singapore). This approach apparently violates the cost efficiency of JI/CDM and seems rather implausible. The reason is that the semi-efficient countries also have high abatement costs, which may be close to the one of efficient or investing countries, and therefore have more room for cheating. Considering the costs besides the project costs, it is almost impossible for developed countries to set up JI/CDM with the semi-developed countries. Therefore, the way to avoid the asymmetry inefficiency should be to invest in less efficient countries. In fact, the inefficiency caused by asymmetric information is closely linked with the intensity of enforcement and therefore with the increase of transaction costs. Current practice has emphasised on the role of monitoring and verification in avoiding the potential cheating. There is a trade-off between inefficiency induced by cheating and monitoring and verification costs. As CDM are carried out at large scale in future, the monitoring and verification costs can be expected to decrease significantly and the problem of asymmetric information could be avoided. Current experience has not reported large cheating with AIJ projects.

4.7. Transaction costs

Transaction costs appear whenever buyers and sellers encounter in marketplace to make transaction, and so do with any emissions trading scheme (Field, 1997; Montero, 1997). In general, the costs consist of search and information costs, negotiation costs, approval costs, monitoring and enforcement costs, and other types of costs (Stavins, 1995; Dudek and Wiener, 1996; Field, 1997). In general, transaction costs are not theoretically determinable, because the sources that generate the costs are complex and uncertain. Several authors assume transaction costs to be a function of traded permits and find that marginal transaction cost is a mark-up on permit price (Kohn, 1991; Stavins, 1995; Kerr and Mare, 1997; Pan and Van Regemorter, 2001). However, transaction costs may be increasing, constant or decreasing scale to traded permits, depending on other factors.

Practice also demonstrates that transaction costs exist in all emission trading programs, at the size of about 10% of total value of emissions 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 SO2 emission trading scheme incurs transaction costs to be 8% of total cost (Montero, 1997). Brokerage fees in US Sulfur trading scheme are about 5% of total costs. Barrett (1994) identifies that transaction costs account around 10% of the project costs in the AIJ project between Norway as an investor, and Poland and Mexico as hosts. Other estimates of transaction costs based on experience of tradable emission permits in the USA put the transaction costs for inter-firm trade between 10 and 30% of the investment costs (Houcade and Baron, 1993, p 24).

Transaction costs 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). In emissions trading markets, transaction costs insert an additional cost to permit prices. The distortion on emissions trading markets induces 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 transaction costs. As the result, overall induced economic inefficiency will multiply the transaction costs. Pan and Van Regemorter (2001) estimates that the multiplier is around 1.3.

Transaction costs take place when information on emissions trading is incomplete. Nevertheless, efforts on acquiring the information will be helpful for the avoidance of transaction costs. The accumulation of experience in emission trading therefore could be one type of the efforts. Woerdman (2000) proposes a "learning" process to suppress transaction costs in JI/CDM projects. The Green Paper published by European Community (2000) advocates the Community's members to accumulate the experience on international emissions trading through pre-action. Pan and Van Regemorter (2001) suppose that a pre-action before the Kyoto period could be helpful to reduce the transaction costs in emissions trading for the Kyoto compliance. They conclude that the efficiency of the "learning by doing" process is critical to clear up the transaction costs for the Kyoto compliance.

Direct transaction costs may be afforded by buyer or seller or shared between the traders, depending on the negotiations. However, the indirect costs induced by transaction costs will fall most heavily on the higher cost controllers (Stavins 1995; Pan and Van Regemorter, 2001). At current stage of international negotiations, it seems that investing countries will eventually cover the direct transaction costs in CDM projects.

4.8. Market power

There is debate on whether the markets of emissions trading are imperfect. When emissions trading is between nations, the markets may be influenced by market powers from both supply and demand sides, because in either side exist large nations. When emissions trading takes place among sources, the market power does not exist because potential large amount of sources will present on the markets (Zhang, 1998). The current stage of international negotiations on JI/CDM however shows that particularly in host side it is unlikely for host countries to allow project hosting at sources without any controls. Because a project that is beneficial to a hosting firm may not necessarily be beneficial to its nation. Therefore, market powers are considered in most of theoretical and empirical research.

Market power may exist in both demand and supply side of JI/CDM. The less pressure an investing country faces in emissions reduction, the less it demands for emission permits, and the more market power it can exercise in pulling down the market price (Manne and Richels, 1999). On the other hand, a host country may tend to restrict its supply of JI/CDM for the following reasons. First, since developed countries take the leader in emission mitigation by the Kyoto Protocol,[13] it is very likely that developing countries will have to commit emission limitation and reduction targets sooner or latter after the Kyoto Protocol. In order to avoid the possibility that only expensive opportunities are left after the Kyoto Protocol, developing countries may strategically limit the supply of cheap

[13] Assuming that the Kyoto Protocol will be ratified.

opportunities available to developed countries. For example, some developing countries may reserve the first cheapest opportunity and only sell the second cheapest opportunity. Second, in general an oversupply of the cheap opportunities will draw down the permit price and thus hurt supply countries' welfare. Developing countries therefore have incentive to maintain a favourable price by controlling the quantity of supply. In particular, taking the possible hot air[14] into account, developing countries may hesitate supplying cheap opportunities, because the hot air problem could draw down the emission trade price to a very low level.

4.9. Baselines

Baseline problem has drawn most concerns over CDM. There are alternative methods for setting up a baseline, namely a benchmark and a project-by-project approach. The former is a top-down method that sets up national, sector, or a group of project baselines and ensures compliance. The benchmark baseline is efficient for the compliance of emissions reduction targets by measuring the emissions reduction at macro-level. However, the latter sets up baseline on basis of single project. The project-by-project baseline is strong in monitoring and implementing emissions reduction project, but could be very costly due to transaction costs. Current trend is in favour of benchmark baseline with JI and project-by-project baseline with CDM. Because the host countries in JI with the commitment on emissions reduction will measure the emissions at macro-levels and the host countries in CDM without any commitment may not establish emissions baseline at the levels. The emissions baseline with CDM therefore need be tailor-made with specific projects. A particular aspect, which have been proposed by developing countries and denounced in the Kyoto Protocol, with CDM baseline is that the baseline should reflect the sustainable development in developing countries. Bollen, et al (1999) considered the capacity building in their research on CDM.

5. EMPIRICAL EVIDENCES

Research on the application of the flexible mechanisms to the Kyoto Protocol become intensified thereafter the Protocol was launch in 1997. The Stanford Energy Modeling Forum (EMF) recently has reported comprehensive results on the economic impacts of the Kyoto Protocol on Climate Change. In this section, we review the EMF studies. In some occasions, we also refer to other researches.

5.1. The structures of the models and the baselines

Weyant and Hill (1999) give a summarised review on the EMF studies. They divide the models used in the studies into five categories:

[14] A hot air problem could exist if a country sells its excess emission permits to demanding countries. Because the trading involves no abatement costs, the trade price could be very low. Under the Kyoto Protocol, the hot air opportunity is possible particularly with Russia.

(a) the aggregate production and cost model

(b) the energy sector detailed model

(c) the general equilibrium model

(d) the energy sector detailed general equilibrium model

(e) the macroeconomic econometric model

The FUND and RICE are the aggregate production and cost model, which defines carbon-equivalent energy input together with capital and labour into production function and captures changes in carbon intensity, production and cost in response to increases in carbon prices. This type of models includes carbon trading and carbon emissions trading, but is unable to show inter-sector interactions and trade in commodity and service markets. The CETA, MERGE3 and GRAPE represent the energy sector detailed model. Except for the detailed descriptions on energy markets, sources and technologies, these models generally are similar with the first category in many aspects. The third category includes the MIT-EPPA, WorldScan and G-Cubed, which model the response of energy use to the changes in energy prices. This type of models incorporates classified economic sectors into a general equilibrium framework; thus is able to reflect inter-sector interactions and international trade in non-energy goods. The ABARE-GTEM, AIM, MS-MRT and SGM are classified into the fourth category for that they are the combinations of the second and third categories. The fifth category, the Oxford macro-econometric model, specialises in testing macroeconomic variables such as unemployment, financial markets, international capital flows, and monetary policy.

The carbon emission baseline projected by the studies varies greatly over a long period of about 100 years. In contrast, the near term from 1990 to 2010 shows less variety than the longer term after 2010 (Weyant and Hill 1999, figure 5 and 6).

5.2. The scenarios

5.2.1. The dimensions

The EMF studies have run scenarios under some common assumptions; on the other hand, they also run other special scenarios separately. These studies in together provide a multi-dimensional picture on the costs of emissions reduction in relation to the Kyoto Protocol. Summarily, these dimensions are as follows. On action types, besides carbon abatement, some researches estimate the potential costs of carbon sink action. On emission types defined in Annex A of the Kyoto Protocol, not only carbon but also other carbon-equivalent gases are studied. On emission reduction targets, some researches extend the Kyoto forever to long-term considerations such as the Kyoto followed by arbitrary reductions, the Kyoto followed by least-cost, the Least-cost, and below 550 ppm. On emission reduction periods, time intervals vary between 1990-2100. On economic indicators, carbon tax, GDP, consumption, and total costs are evaluated. Finally, on trading schemes, all the researches examine three core situations and separately focus on a number of variants.

5.2.2. The extreme cases

The first core scenario is the case of No Trading, which assumes all Annex B countries take full domestic abatement. It is believed that this case reveals an upper bound of the costs of the Kyoto Protocol. The second core scenario is another extreme case, which allows a Full Global Trading. With the case, it is possible for Annex B countries to trade emission quotas each other and even to trade with non-Annex B countries, assuming non-Annex B countries are allocated emission quotas at their existing level. In contrast to the first core scenario, the second scenario is supposed to describe a lower bound of the costs of the Kyoto Protocol. The third core scenario situates between the two extremes by considering only Annex B countries' Trading. The costs estimated from this scenario apparently are between the upper and lower bounds. A variant of the third case is the case of Double Bubble, where EU takes abatement itself and other Annex B countries may trade each other. Because EU has relatively high abatement costs, the results of the Double Bubble would show an increase in EU's costs and a decrease in other developed Annex B countries compared to the case of Annex B countries' Trading only.

5.2.3. The restriction on sales

Other variants of the core scenarios consider possible distortions on emissions trading. One of these distortions is market power. According to the Kyoto Protocol, former Soviet Union and Eastern Europe will be the sole seller of emission quotas under Annex I trading. Thus, this seller has great potential for exercising market power in influencing the trading price of emission quotas. Bernstein et al.(1999) and MacCraken et al. (1999) have examined the effects of potential monopoly power by the former Soviet Union and Eastern Europe. They identify the monopoly power by allowing the monopolist to maximize its welfare and quota sales profit respectively. In the case, the monopolist chooses the price of emission quota supply to maximize its welfare or profits that is the difference between its revenues from emission quota trading and its costs of domestic mitigation. In response to the price, the supply of emission quotas will be determined at a low level. Hence, the market power is identical to a limit on emission quota sales imposed by the potential seller or international authority. Manne and Richels (1999) examine the seller's monopoly under the global trading. They find that if low-cost sellers are concentrated among a few countries, they may have considerable potential for extracting monopoly rents.

Besides the market power, a restriction on emission quota sales possibly imposed by international agreement are studied in Bernstein et al. (1999), Bollen et al. (1999) and MacCraken et al. (1999). Under Annex I trading, the restriction can be used to prevent potential hot air sales from the former Soviet Union. Bernstein et al. directly modeled the case of no hot air. In MacCraken et al., the allowed sales by the former Soviet Union are set to match its domestic abatement. The restriction also has important welfare distribution implications. Bernstein et al. compared the monopoly power with a case of 30% restriction on emission quota sales imposed by international agreement. They conclude that the restriction will override the sales amount of emission quota under the monopoly case. As a result, the quota price will be higher than in the monopoly case, and will harm OECD countries. The negative effect on Annex I countries spills over to non-Annex I countries and causes their welfare to be lower under the 30% case than the monopoly case. Therefore, if a restriction on quota sales can not be set in consistent with a monopoly situation, it will produce lower welfare than the monopoly for all countries. Bollen et al. find that a 15% restriction on emission quota sales will cause the quota price to rise above the price level under the full Annex I trading. As the result, the monopolists will experience a term of trade gain, but they will suffer a 28% reduction in export compared to the full Annex I trading. On the other hand, some buyer countries will suffer a loss due to the higher marginal costs and greater domestic abatement. Interestingly, in the case, the US will become a seller of emission quotas as the quota price is higher than its domestic marginal abatement costs.

5.2.4. The restriction on purchase

At demand side, a restriction is imposed on purchase, in response to the supplemental approach by the Kyoto Protocol that developed countries are allowed to use the flexible mechanisms only as a supplementary for their domestic mitigation. In Bernstein et al. (1999), a restriction on purchase may harm heavily the demanders that are urgently demanding for the emission quotas but may benefit the less urgently demanders. For example, in their 30% restriction scenario, Japan will suffer major loss while US and EU benefits are better than the case of unrestricted trading. The reason is that Japan has a relatively high marginal abatement costs and the restriction generates a trading price that is between the higher marginal costs in Japan and the lower marginal costs in EU and US. However, this situation will change with different restrictions imposed. Bollen, et al (1999) conclude that exporters of emission quotas will always suffer a terms of trade loss in the case of restriction on purchase both because less demands drive down the trading price and exports are reduced.

5.2.5. The CDM

For that a full scale of global emissions trading may still have distance from implementation, a number of the researches run the scenario of CDM. However, the CDM can not be a perfect proxy for full global trading for the reasons we discussed in Section 4. In the case, transaction costs, price elasticity, free riding and carbon leakage all could negatively affect the efficiency of CDM projects. Considering the difficulties associated with CDM, both Bernstein et al (1999) and Manne and Richels (1999) assume that a CDM can achieve at maximum only 15 percent of the total potential of cost efficiency through emissions trading. When combing Annex I trading and CDM, Bernstein finds that the CDM improves the welfare of Annex I countries very little compared to the case of Annex I trading, because the 15% restriction significantly limits non-Annex I countries' engagement. Bollen et al (1999) consider the case of a combination of No Annex I trading and CDM for 5% of Annex I target. They find that the welfare improvements to Annex I countries are significant due to the CDM, but, surprisingly, the carbon emission is increased probably because of the existence of local energy markets.

5.3. The results

The EMF Forum has explored the economic costs of the Kyoto Protocol and the related controls of climate change from multiple dimensions as briefly mentioned in last section. In the present review, we will narrow down the results yielded from these researches by focusing on the carbon taxes of the Kyoto Protocol in 2010. We summary the carbon prices with a variety of situations in Table 1. This table has two-fold uses: showing the relevant costs and the scenario coverage. In the table, we also calculate the cost efficiency improvement across different trading scenarios with respect to US, Japan, EU, Canada, Australia, the Former Soviet Union (FSU), and Eastern Europe (EEU). Taking the example of MacCracken, US's costs will decrease from no trading to 43% in Annex I Trading, to 38% in Double Bubble, and to 15% in a Full Global Trading. Japan's costs will decrease to 16% in Annex I Trading, to 14% in Double Bubble, and to 6% in a Full Global Trading. EU's costs will decrease to 56% in Annex I Trading, to 0% in Double Bubble (assuming EU countries takes domestic abatement individually), and to 20% in a Full Global Trading. The results by others show a similar trend. Figure 5.1 illustrates these changes. Clearly, Japan will be the largest winner, whereas EU can not benefit from the Double Bubble.

The scenario analyses have provided many insights into the potentials of cost efficiency. We briefly draw some main conclusions from the EMF research as follows:

With respect to the Kyoto Protocol, the EMF research reveals the upper and lower bounds of abatement costs. In general, a no trading case refers to the former, while a full global trading case refers to the latter. The no trading case could be very costly for developed countries, while the full global trading case would provide very cheap opportunities.

Any case between the two extremes shall have the abatement costs or emissions trading prices in the interval between the upper and lower bounds. The more parties joint the international cooperation or the more flexibility is given to international cooperation, the more cost efficiency

can be improved.

Any distortions on the flexibility like market power, small clubs and supplementary restriction will have negative effect on the improvement of cost efficiency. However, some distortions will undermine the interest of developed countries, some will affect transitional or developing countries' welfare negatively, and some may have both the effects.

As the international cooperation expands, there are corresponding winners and losers, which implies that some parties are in favor of small range of trading or JI, some in favor of global trading or CDM.

These studies have not found a ground on which nations will be willing to join an agreement.

	Carbon Taxes/Permit Prices for the Kyoto Protocol						
		1	2	3	4	5	6
	The author	**Manne**	**MacCracken**	**Jacoby**	**Nordhaus**	**Kurosawa**	**Bollen**
	The model	**MERGE3.0**	**SGM**	**MIT-EPPA**	**RICE**	**GRAPE**	**WorldScan**
	The price	(1990 price)	(1992 price)	(1990 price)	(1990 price)	(1990 price)	(1992 price)
1	**1. Reference**	0	0	0	0	0	0
2	**2. Full global trading (CDM)**	70	26		17	42	
3	**2.1 Limit on purchases**	140					3
4	US						39
5	EU						70
6	**2.2 Limit on sales**	145					
7	**2.3 Limit on both**						
8	**3. The double bubble**						
9	Umbrella		64				16
10	EU						41
11	**4. Full Annex I trading**		73	76	57	66	20
12	**4.1 Limit on purchases**						
13	US						26
14	WEU						48
15	FSU						-8
16	EEU						-8
17	**4.2 Limit on sales**						50
18	WEU						-50
19	FSU		-105				-50
20	EEU		-105				
21	**4.3 Limit on both**						
22	US		100				
23	JAPAN		304				
24	CANADA		197				
25	AUSTRALIA		60				
26	WEU		47				
27	FSU		-64				
28	EEU		-64				
29	**5. No emissions trading**						
30	US	240	168	193	127		44
31	JAPAN		458				
32	CANADA		350				
33	AUSTRALIA		117				
34	WEU		130				82
35	FSU		0				
36	EEU		0				
US	Annex I Trading / No Trading	0%	43%	39%	45%		45%
	Double Bubble / No Trading	0%	38%				36%
	Global Trading / No Trading	29%	15%		13%		
Japan	Annex I Trading / No Trading		16%				
	Double Bubble / No Trading		14%				
	Global Trading / No Trading		6%				
EU	Annex I Trading / No Trading		56%				24%
	Double Bubble / No Trading		100%				50%
	Global Trading / No Trading		20%				
*	"s" shared value						
*	"-" seller's price						
*	"()" hot air case						

	Carbon Taxes/Permit Prices for the Kyoto Protocol					
		7	8	9	10	11
	The author	**Kainuma**	**Bernstein**	**Tulpule**	**McKibbin**	**Cooper**
	The model	**AIM**	**MS-MRT**	**GTEM**	**G-Cubed**	**CETA-M**
	The price	(1992 price)	(1995 price)	(1992 price)	(1995 price)	(1997 price)
1	**1. Reference**	0	0	0	0	0
2	**2. Full global trading (CDM)**	38	31		23	
3	**2.1 Limit on purchases**		79			
4	US					
5	EU					
6	**2.2 Limit on sales**					
7	**2.3 Limit on both**					
8	**3. The double bubble**					
9	Umbrella	45		108	32	170
10	EU	195		176	263	932
11	**4. Full Annex I trading**	65	90	114 (97)	61	222
12	**4.1 Limit on purchases**					
13	US		230			
14	WEU					
15	FSU					
16	EEU					
17	**4.2 Limit on sales**		129			
18	WEU					
19	FSU		46s			
20	EEU		46s			
21	**4.3 Limit on both**					
22	US					
23	JAPAN					
24	CANADA					
25	AUSTRALIA					
26	WEU					
27	FSU					
28	EEU					
29	**5. No emissions trading**					
30	US	150	275	346	80	407
31	JAPAN	240	468	693	112	1067
32	CANADA	175	249s	835	261	1261
33	AUSTRALIA	95	249s	455	181	
34	WEU	195	209	714	263	932
35	FSU	0	0	0		
36	EEU		0	40		
US	Annex I Trading / No Trading	43%	33%		76%	55%
	Double Bubble / No Trading	30%		31%	40%	42%
	Global Trading / No Trading	25%	11%		29%	
Japan	Annex I Trading / No Trading	27%	19%		54%	21%
	Double Bubble / No Trading	19%		16%	29%	16%
	Global Trading / No Trading	16%	7%		21%	
EU	Annex I Trading / No Trading	33%	43%		23%	24%
	Double Bubble / No Trading	100%		25%	100%	100%
	Global Trading / No Trading	19%	15%		9%	
*	"s" shared value					
*	"-" seller's price					
*	"()" hot air case					

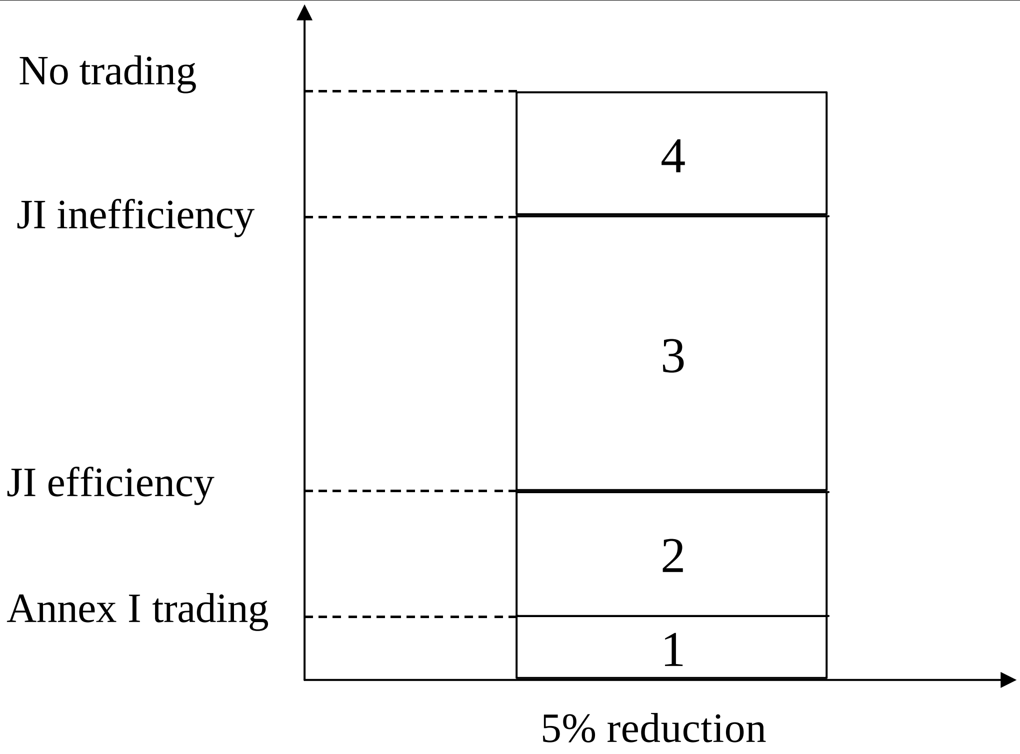
6. FURTHER EXPLORATIONS

The EMF studies and others remain gaps with the exploration of JI/CDM potentials. On the one hand, the existing conclusions may be to some extent incomprehensive and partial, depending heavily on assumptions made in different scenarios. On the other hand, the existing studies have not worked in sufficient details on modeling JI/CDM. In most cases, they simply or implicitly assume that JI/CDM are identical to some percentage restriction of emissions trading, and hence substitute the simulations of JI/CDM with the restricted emissions trading.

The gaps remain with existing research see to suggest that modeling JI/CDM should go into three dimensions: the nations joining JI/CDM, the sectors providing possibility for JI/CDM, and the factors affecting efficiencies of JI/CDM. Firstly, JI and CDM are the special forms of emissions trading between any combinations of nations within Annex I region and within global region, respectively. In the sense, the Double Bubble can be regarded as an example of one case of JI. There could be many other combinations of nations within Annex I region and within global region. These combinations can also be regarded as JI and CDM cases. All of these combinations constitute the potential for JI and CDM. The differences in cost between the JI/CDM potentials and the ET within Annex I region and within global trading also reveal the inefficiency of JI/CDM to ET. Secondly, modeling JI and CDM should be sector-specific, as different sectors may have different possibilities for JI and CDM. On the other hand, ET implies that each sector has same possibility for JI and CDM. It is argued practically that the possibility of JI and CDM will mostly exist in few sectors such as agriculture, energy, electricity sectors. Finally, modelling JI and CDM should consider the potential factors, which we have discussed in Section 4, eroding the efficiency of JI and CDM projects. To overcome the problem therefore motivates research to simulate various measures that will improve the efficiency of JI and CDM projects.

Summarily, figure 3 illustrates the potential improvement of cost efficiency in the case of JI. Similar arguments are applicable to CDM. The area 1+2+3+4 indicates the maximal costs for a 5% emission reduction, while the area 1 represents the minimal costs. The area 2+3+4 is total cost efficiency to be achieved by the ET in Annex I region. If ET is not available within the Annex I region, JI is possible, and JI projects can be implemented efficiently, the JI then can improve the cost efficiency of area 3+4 from no trading. The area also indicates the cost efficiency due to the JI, resulted from the transfer of part of emissions reduction target from high-cost to low-cost countries. Otherwise, if JI projects cannot be implemented efficiently, it can improve cost efficiency of area 4 at maximum from no trading, the inefficient implementation of JI projects erodes part of total cost efficiency of JI[15]. The area 3 therefore represents the potential loss in efficiency. Finally, the area 2 specifies the efficiency loss of JI compared to ET owing to the limited possibility in sectors.

[15] Here, the inefficiency of JI implies both cost and environmental inefficiency. In the case of environmental inefficiency, we transform carbon leakage into costs by assuming JI investors may receive discounted credits.


No trading
4
JI inefficiency
3
JI efficiency
2
Annex I trading
1
5% reduction

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