China and the Evolution of the Present Climate Regime

Barbara Buchner and Carlo Carraro

NOTA DI LAVORO 103.2003

NOVEMBER 2003

CLIM – Climate Change Modelling and Policy

Barbara Buchner, *Fondazione Eni Enrico Mattei*
Carlo Carraro, *University of Venice, Fondazione Eni Enrico Mattei, CEPR, CESifo and CEPS*

China and the Evolution of the Present Climate Regime

Summary

The recent events that followed the US decision not to comply with the Kyoto Protocol seem to drastically undermine the effectiveness of the Protocol in controlling GHG emissions. Therefore, it is important to explore whether there are economic factors and policy strategies that might help the US to modify its current policy and move back to the Kyoto-Bonn agreement. For example, can an increased participation of developing countries induce the US to effectively participate in the effort to reduce GHG emissions? Is a single emission trading market the appropriate policy framework to increase participation in the Kyoto-Bonn agreement? This paper addresses the above questions by analysing whether the participation of China in the cooperative effort to control GHG emissions can provide adequate incentives for the US to move back to the Kyoto process and eventually ratify the Kyoto Protocol. This paper analyses three different climate regimes in which China could be involved and assesses the participation incentives for the major world countries and regions in these three regimes.

Keywords: Agreements, Climate, Incentives, Negotiations, Policy

JEL: C72, H23, Q25, Q28

This paper is part of the research work being carried out by the Climate Change Modelling and Policy Unit at Fondazione Eni Enrico Mattei. The authors are grateful to Igor Cersosimo for great research assistance and to the participants to the 2nd World Congress of Environmental Economists in Monterey, June 2002, to those at the ECF Annual Conference in Berlin, November 2002, and at the ESRI International Conference in Tokyo, March 2003, for useful comments and suggestions. The usual disclaimer applies.

Address for correspondence:

Carlo Carraro
Department of Economics, University of Venice
S. Giobbe 873
30121 Venice
Italy
Phone: +39 041 2349166
Fax: +39 041 2349176
E-mail: ccarraro@unive.it

China and the Evolution of the Present Climate Regime

1. Introduction

In March 2001, the President of the United States, George W. Bush, announced that the US would not comply with the Kyoto Protocol in its present form. Following this decision, some countries reacted by strengthening their commitment to continue the Kyoto process, whereas other countries decided to fall in line with the US strategy (Cf. Section 2 below). In particular, Russia has adopted an ambiguous position, thus raising a lot of uncertainty as to whether and when the Kyoto Protocol will come effectively into force. What economic forces have led to what seems to be a major drawback in the international effort to combat climate change?

According to a recent strand of economic literature (Cf. Buchner, Carraro and Cersosimo, 2002 for a survey), the main economic consequences of the US withdrawal from the Kyoto Protocol can be summarised as follows:

- The US withdrawal and the new provisions included in the Marrakech agreement imply a strong decline in the environmental effectiveness of the Kyoto Protocol.
- The US defection induces a decreasing demand for emission permits and consequently a decline in the permit price, thus reducing the incentives to abate emissions and invest in climate friendly technologies in all countries.[1]
- The smaller permit price after the US defection reduces the permit suppliers' benefits from participating in the Kyoto agreement. This provides additional incentives for Russia to use its increased bargaining power in climate negotiations.[2]

[1] Some studies highlight feedback effects that can mitigate the fall in the permit price. Strategic market behaviours can indeed modify the size of the expected changes in prices and abatement costs. In particular, these changes are much smaller than initially suggested. For example, banking and monopolistic behaviour in the permit market (Manne and Richels, 2001; Den Elzen and de Moor, 2001; Böhringer and Löschel, 2001) or strategic R&D behaviour (Buchner, Carraro and Cersosimo, 2002) can offset the demand shift and reduce the decline of the permit price consequent to the US withdrawal from the Kyoto Protocol.

[2] A condition for the Kyoto Protocol to come into force is that at least 55 Parties to the Convention, representing at the same time at least 55% of 1990 carbon dioxide emissions of Annex B Parties, must have ratified the treaty. After the US withdrew from the Protocol, the participation of some countries, in particular of Russia, has thus become crucial. The outcome of COP 7 in Marrakech includes considerable concessions to Russia and thereby confirms Russia's increased bargaining power. In addition, at the Climate Conference in Moscow in September 2003, President Putin backed away from Russia's earlier pledge to swiftly ratify the treaty, stating that a decision on Kyoto will only be taken when the work on clarifying and analysing the issues related to the complex problem of climate change has been concluded. (Reuters, Sept. 29th, 2003). The fact that there is no provision for timetables provides additional evidence of Russia's strategic behaviour designed to exploit its increased bargaining power.

The US withdrawal from the Kyoto Protocol is thus responsible for a number of serious environmental and economic problems, ranging from the deterioration of the environmental effectiveness of the Protocol to the increase in Russia's bargaining power.

Accordingly, several doubts have emerged on the appropriateness and sense of pursuing the Kyoto Protocol in its actual form. In particular, the low environmental impact of this policy framework has induced new debates about the need to increase the number of participating countries. On the one hand, the need to involve the US again in international efforts to combat climate change is emphasised, while on the other hand the role and future participation of developing countries has assumed greater importance.

Therefore, one of the goals of this paper is to analyse how climate negotiations may evolve after the Marrakech, Delhi and Milan Conferences of the Parties. The crucial question is what participation incentives are provided by the present constellation of Kyoto countries, and consequently what the future participation decisions of some key players might be. The most important of these key players is certainly the US. It is widely recognised that US participation would strongly increase the environmental effectiveness of the Kyoto/Bonn agreement. Therefore, this paper addresses the following questions: Are there incentives for the US to move back to the Kyoto Protocol, i.e. do the US benefits from joining the current climate regime? What kind of climate regime could provide adequate incentives for the US to join a climate coalition? In order to reduce abatement costs, do the US finds it profitable to sign a bilateral deal with a low abatement cost country?

Some of these questions have been explored in other recent papers. For example, in Buchner, Carraro, Cersosimo and Marchiori (2002) the effectiveness of a strategy that links climate and R&D cooperation is assessed, whereas Buchner and Carraro (2003a) analyse whether a climate regime entirely based on technological cooperation, without binding emission targets, could be supported by the US. In both papers, the main goal is to identify policy strategies that increase US participation incentives.

This paper also addresses the above questions, but from a different viewpoint. Here the goal is to ascertain whether China, by ratifying the Kyoto Protocol and eventually participating in an international emissions trading market, can provide the US with adequate incentives to join a climate coalition and to achieve the emission targets defined in Kyoto. In Section 2, this paper analyses the evolution which led to the current climate regime, by identifying the economic and political forces that are responsible for the present situation. Then, in Section 3, some game theory results on the incentives that China's participation in a climate agreement provides for the US to modify its decision not to ratify the Kyoto Protocol are discussed. The presence of China in a climate coalition could indeed reduce GHG abatement costs in a way that could make the Kyoto Protocol the most economically attractive climate strategy for the US. Therefore, this paper shows costs and benefits of China's decision to cooperate with the Annex B_{-US} countries (all Annex B countries less the US and Australia) in controlling GHG emissions. In addition, the paper provides a quantitative game theory analysis of US participation incentives, both in the case of a single coalition in which the Annex B_{-US} countries, China and the US participate, and in the case of a bilateral deal between China and the US (a two country coalition) which could be complementary to the Kyoto coalition. A final section summarises our conclusions.

2. Policy evolution after the Marrakech negotiations. A short overview

The political deal reached in Marrakech at the Seventh Conference of Parties (COP-7) has legally confirmed the existence of a "tri-polar climate change regime" (Egenhofer and Legge, 2001), where the first group of cooperating countries consists of the industrialised countries less the US and Australia, the second one consists of the developing countries, while the last one is formed by the United States of America and Australia.

Within the other two major groups, some sub-groups can be identified. In particular, the group of industrialised countries can be divided into: (i) the European Union, including "its near abroad"; (ii) Russia; and (iii) the Umbrella Group, which after COP-7 still included Japan, Canada and New Zealand. After the US defection and given the EU commitment to the Kyoto Protocol, the Umbrella group countries and Russia achieved notable bargaining power in climate negotiations. As a consequence of the increased stringency of the 55% provision of Art. 25 of the Kyoto Protocol – and after the ratification of the EU, Japan and Canada – Russia has become the key player. Moreover, Russia also plays a special role in the prospective permit market, because of the amount of emission allowances ("hot air") that Russia possesses, at least in the first commitment period.

Another group of countries includes the developing countries, which are not bound by any emission reduction targets in the first commitment period of the Kyoto Protocol, being however already involved in mitigation activities through various obligations, e.g., reporting requirements. Nevertheless, since they are going to represent the largest future CO_2 producers, their participation in a climate agreement is necessary – at least in the medium term – for emission reductions to attain a level consistent with the stabilisation of GHG concentration below 600ppmv. In addition, this involvement is also needed in order to create the pre-conditions to induce some countries, e.g. the US, to re-join the international climate change control coalition[3].

In the light of this complex situation, what happened after the Marrakech Conference of the Parties? One month after COP-7, in December 2001, the EU had already made some progress by compiling a "Draft Proposal for a Council Decision concerning the approval, on behalf of the European Community, of the Kyoto Protocol to the United Nations Framework Convention on Climate Change and the joint fulfilment of commitments thereunder" (EC, 2001). The European Union announced the ratification of the treaty on May 31st, 2002. Moreover, within the context of COP-8 in New Delhi, the EU clearly stated that Kyoto must be considered as "the only show in town", urging other countries to participate and criticising again the US for their refusal to ratify Kyoto (The Hindu, Oct. 24th, 2002).

In Japan, the decision process towards the ratification of the Kyoto Protocol met with a number of contradictory signals. In January 2002, The Japan Times reported that Japan was planning to ratify the Kyoto Protocol early in 2002 (The Japan Times, Jan. 21st, 2002)[4]. Despite these early promising signs, the ratification was postponed several times due to internal problems, first to March 2002 and then to late Spring 2002. Widely divergent views held by two government ministries over climate change control strategies – in particular over domestic measures to be taken to meet the emission targets – and uncertainties over the plans of other key players, e.g. Canada and Australia, were main reasons behind Japan's delayed ratification.[5] Furthermore, although Japan did manage to achieve a number of concessions in Marrakech, business groups still were reluctant to support the Kyoto Protocol. They feared that the commitment to the Kyoto emission reduction targets could lead to a competitive disadvantage with respect to the US[6]. However, despite these controversies, the Japanese Cabinet approved the Kyoto Protocol on June 4th, 2002.[7]

---

[3] The lack of participation by developing countries has been one of the main US criticisms of the Kyoto Protocol.

[4] Even if the ratification was postponed, on February 1st 2002 the government announced an anti-global warming bill in line with the Kyoto Protocol which would be implemented soon (Kyodo News, Feb. 1st, 2002).

[5] For more detailed information see for example CO2e.com, Feb.13th, 2002; Asahi Shimbun, Feb. 11th, 2002; Christian Science Monitor, March 12th, 2002; Japan Today News, Feb. 26th, 2002 and Kyodo News, Feb. 21st, 2002.

[6] For more detailed information see for example BBC, Jan, 3rd, 2002; CO2e.com, Jan. 8th, 2002; The Japan Times, Jan. 17th, 2002; The Japan Times, Jan. 18th, 2002.

[7] Due to the strong links with the US economy, Japan is still particularly worried about the US plans on climate change control and there are signs that Japan plans to enhance its cooperation with the US on climate change control. Even before ratifying the Kyoto Protocol, Japan started preliminary talks with the US aimed at discussing how Japan and the US might cooperate to reduce GHG emissions (The Japan Times, Feb. 27th, 2002; Japan Today News, Feb. 27th, 2002). In early April 2002, government officials from Japan and the US agreed on 15 steps to prevent global warming (CO2e.com, April 5th, 2002). Although Japan finally decided to ratify the Kyoto Protocol, its parallel initiatives with the US and its efforts to convince other countries of the advantages and necessity to participate in the Kyoto agreement demonstrate that Japan is still dubious and concerned about

Russia has also had (and still has) some difficulties in deciding on a clear position with regard to the Kyoto Protocol after the US withdrawal. The increase in its bargaining power has motivated Russia to further exploit its strong negotiating position. As the outcome of COP-7 demonstrated, the need to induce Russia to participate in the agreement translated into various concessions to Russia, e.g. less stringent targets or increased flexibility (e.g. increased sinks allowances). As a consequence, in March 2002, the Russian Energy Minister Igor Yusufov announced that Russia intends to ratify the Kyoto Protocol soon (RBC network, March 11th, 2002). However, some weeks after this announcement, Russia emphasised that its ratification was far from guaranteed and would depend strongly on both the EU and Japan's future strategies. Russian government officials said that Russia may delay ratification of the Kyoto Protocol until these countries give their official consent to buy carbon dioxide emission credits from Russia (Financial Times, March 22nd, 2002; Yomiuri Shimbun, March 28th, 2002). In addition, at a high level ministerial meeting in New Delhi during COP-8, Russia called upon all developed countries to comply, in particular those who are members of the UNFCCC, and also called on the need for the active future participation of the developing countries (The Hindu, Oct. 31st, 2002).

Although never seriously threatening to formally defect, Russia clearly exploits its high bargaining power and continues to send contradictory signals with respect to its position on the Kyoto treaty. In particular, the recent Climate Change Conference, held in Moscow from September 29th to October 3rd, 2003, was tempered by announcements indicating that the Kyoto Protocol is unlikely to come into force in the near future. President Putin's opening address explained that Russia's position had considerably changed during the last year. Putin said that Russia has not made a decision on whether to ratify the Kyoto Protocol and will not do so until it had finished studying the implications that ratification would have for the country, looking also at the benefits that could arise from global warming to a northern country like Russia: "The government is thoroughly considering and studying the entire complex of difficult problems linked with it. A decision will be made only after this work has been completed and it will be made in accordance with the national interest of the Russian Federation." (RFE/RL, Sept. 29th, 2003). The insistence that more research is needed seems to represent a further piece of Russia's strategic bargaining strategy, rather than indicating that it does not intend to ratify the Kyoto Protocol at all[8]. The debate on Kyoto is still ongoing in Russia, as recent official announcements that Kyoto will be ratified in 2004 clearly indicate (Dow Jones Newswires,

---

the present climate regime. See for example Japan Today News, Jan. 19th, 2002 and Japan Today News, Feb. 27th, 2002; Japan Today News, June 4th, 2002.

[8] As already indicated above, the link between Russian emission credits and the European emission trading system appears to play a key role vis-à-vis Russia's official position.

Oct. 28th, 2003), This is also because Russia's industry and NGOs both seem to be in favour of ratification[9].

An important step forward in the Kyoto process was achieved at the UN World Summit on Sustainable Development (WSSD) held in Johannesburg from August 26th to September 4th, 2002[10], where China announced it would ratify the Kyoto Protocol. Already in January 2002, China had expressed its favourable views on the Kyoto Protocol and surprised the world by calling it a "win-win deal for industrialised and poorer countries alike" and by pushing for an earliest possible enforcement of the treaty (Planet Ark, Jan. 18th, 2002). This statement showed that China was getting serious not only about domestic environmental protection, but also about international cooperation to control climate change. China confirmed its willingness to participate in the Kyoto framework by approving the treaty on August 30th, 2002. Despite the lack of a reduction target for greenhouse gas emissions[11], Beijing's decision to ratify the Kyoto Protocol is generally considered as an important boost to the domestic and international fight against global warming (ABC Online, Sept. 3rd, 2002).

After China, on September 2nd, 2002, Canada's Prime Minister Jean Chrétien announced in Johannesburg that the Canadian Parliament would be asked to ratify the Kyoto Protocol by the end of 2002 (The Globe and Mail, Sept. 2nd, 2002). Notwithstanding some strong criticisms on the Prime Minister's strategy by Canadian provincial governments (see, e.g., Toronto Star, Sept. 4th, 2002), Canada ratified the Kyoto Protocol on December 17th, 2002 (Toronto Star, Dec. 17th, 2002).

During all the aforementioned discussions, the two main countries that refused to ratify the Kyoto Protocol, the US and Australia, have been both nationally and internationally strongly criticised for "taking positions solely on the basis of national interests" (The Age, August 30th, 2002). Subsequently, the US President George Bush was urged by a delegation of US congressmen to ratify the Kyoto Protocol, while the Australian Prime Minister John Howard softened his initial stance on Kyoto (ABC News, Sept. 4th, 2002). Nonetheless, Australian Federal Environment Minister David Kemp then defended his country's refusal to ratify the Kyoto Protocol (Sky News, Sept. 4th, 2002). Both the US and Australia have justified their opposition to Kyoto by pointing at the lack of participation by the large developing countries above all.

---

[9] In particular Russian industries see the potential benefits arising from joint projects where European countries invest in the introduction of cleaner technologies in Russian plants (see e.g. The International Herald Tribune, Oct. 28th, 2003).

[10] For an overview on the key outcomes of the Johannesburg Summit see e.g., United Nations (2002).

[11] China has said it is open to exploring cooperation opportunities under the Kyoto agreement, in the short run and primarily with respect to financial and technical aid deals. Chinese officials emphasise that the government will voluntarily try to restrict the growth of CO2 emissions, but is strictly opposing binding GHG reduction targets (The Japan Times, Jan. 26th, 2002).

The above overview of the recent process towards the ratification of the Kyoto Protocol seems to provide little indication that the Protocol will come into force soon.[12] The September 2003 Conference on Climate Change held in Moscow added additional doubts on the timetabling of the ratification. Still, recent Russian announcements raise expectations for the Protocol's ratification towards the end of 2004 (bearing in mind that Russia is likely to wait for the US elections in autumn 2004), thus confirming that the number of signatory countries necessary for the Kyoto Protocol to come into force may be achieved (Dow Jones Newswires, Oct. 28th, 2003).

However, even if it eventually comes in to force, the environmental effectiveness of the Kyoto Protocol without the US is very low. The US, the world's largest producer of GHG emissions, not only remains outside the Kyoto framework, but has also announced a weak alternative climate change policy. Therefore, total GHG emissions are unlikely to be reduced, at least in the first commitment period. As a consequence, three issues need to be explored: (i) What are the incentives for the US to re-join the Kyoto coalition or to form another parallel coalition cooperating on GHG emission reduction? (ii) What strategy can Japan, Russia and the EU try to implement in order to induce the US to ratify the Kyoto Protocol? (iii) Can climate cooperation better be achieved outside the Kyoto framework ?

This paper addresses the first question, by looking at the incentives for the US to participate in future climate regimes. The second question is partly answered in Buchner, Carraro, Cersosimo and Marchiori (2002), whereas the third question is addressed in Buchner and Carraro (2003a, 2003b). In particular, the analysis presented in the next sections will be centred on the role of China and on the new incentives that China's participation in an international permit market may provide to the other countries.

3. An empirical assessment of the role played by China in possible future climate regimes

The first climate regime that we plan to analyse using the FEEM-RICE model (Cf. the Appendix) is the one in which the European Union, Japan, the Former Soviet Union (the so called Annex B_{-US}

[12] As it stands now, 119 countries have ratified the Kyoto Protocol. The 119 countries account for 44.2 percent of carbon dioxide emissions, and Russia's 17.4 percent would push the tally over the 55 percent requirement.

countries) and China cooperate to reduce GHG emissions.[13] This is not to claim that a climate regime with Annex B_{-US} countries and China is the most likely scenario. We simply aim to quantify the benefits that China's participation in a cooperative effort to control GHG emissions could provide to the Annex B_{-US} countries. Therefore, as a first step, we analyse gains and losses that would result from the formation of a climate coalition formed by the European Union, Japan, Russia and China. To achieve this goal, we quantify changes in welfare, emissions, abatement costs and R&D investments induced by the formation of this coalition. These changes are computed with respect to the values of the above variables in the present Annex B_{-US} regime, namely a coalition formed by the EU, FSU and Japan, which we thus consider as our benchmark, or business-as-usual scenario. In this benchmark scenario, the EU, FSU and Japan meet their Kyoto targets in the first commitment period and beyond (see below), whereas the other countries set their abatement levels unilaterally.[14]

As stated above, our main goal is to assess whether the presence of China in the coalition provides sufficient incentives for the US to comply with the Kyoto Protocol. In particular, we analyse whether China's adoption of quantitative emission limits provides new incentives for the US to cooperate within the Kyoto cap-and-trade framework. After China's decision, GHG abatement costs may indeed become much lower and may therefore make the Kyoto Protocol the economically most attractive climate strategy, even for the US.

To address the above issue, we need to consider a second scenario in which a coalition formed by the US, EU, FSU, Japan and China adopts policies to reduce GHG emissions. Again, changes of welfare, emissions, abatement costs and R&D investments induced by the formation of this coalition are going to be quantified using the FEEM-RICE model. This makes it possible to compare the net benefits of a large coalition in which the US participates, with the net benefits gained if the US is out, but China is in. However, the US may decide to participate in the international effort to control GHG emissions not by joining the Annex B_{-US} coalition, but by forming another parallel coalition with China. Therefore, we will compute the economic consequences of this third scenario and compare its strengths and weaknesses with those of the other two scenarios.

As shown in the Appendix, the FEEM-RICE model is a version of Nordhaus' RICE model in which endogenous and induced technical change are represented. In this version, technical change plays a twofold role: on the one hand, via increasing returns to scale, it yields endogenous growth; on the

[13] Given the geographical disaggregation of the FEEM-RICE model, it is not possible to account for the presence of Canada in the coalition. Moreover, Russia cannot be distinguished from the other countries of the Former Soviet Union.

[14] Therefore, in our BAU, the US and other countries that do not comply with the Kyoto Protocol may reduce emissions, although in a non cooperative manner.

other hand, by affecting the emission/output ratio, it accounts for the adoption of cleaner and energy-saving technologies.[15] In addition, international technological spillovers are accounted for.

In the FEEM-RICE model, six countries/regions (US, EU, Japan (JPN), former Soviet Union (FSU), China (CHN) and rest of the world (ROW)) optimally set the intertemporal values of four strategic variables: investments, R&D expenditure, abatement effort and net demand for emission permits[16]. When no coalition forms, each country/region maximises its own individual welfare given the other countries' strategy. When coalitions form, countries belonging to the same coalition maximise their joint welfare. Given the interdependency of countries' decisions, the equilibrium values of the policy variables are obtained by solving a dynamic open-loop Nash game between the six countries/regions.

Three important assumptions qualify our results. First, it is assumed that all countries/regions which adhere to the Kyoto/Bonn agreement meet the Kyoto constraints from 2010 onward.[17] We therefore adopt the so-called "Kyoto forever" hypothesis (see, for example, Manne and Richels, 1999 and many others). As a consequence, our reference to the Kyoto/Bonn agreement is partly imprecise because, for the sake of brevity, we will sometimes call "Kyoto Protocol" or "Kyoto/Bonn agreement" a "Kyoto forever" scenario. In another paper (Buchner and Carraro, 2003c) we test the robustness of the results with respect to changes in the assumption about future commitments.

Second, it is assumed that all countries adopt cost-effective environmental policies. In particular, cost-effective market mechanisms (e.g. emission trading) are chosen over "command-and-control" measures in order to guarantee the efficient implementation of environmental targets. Please note that our analysis focuses only on CO2. There are other man-made greenhouse gases and the Kyoto Protocol takes some of them into account. Moreover, both the Bonn agreement and the subsequent Marrakech deal emphasise the role of sinks in meeting the Kyoto targets. However, in the FEEM-RICE model only CO2 emissions are accounted for.

---

[15] The FEEM-RICE model has already been used in Buonanno, Carraro, Castelnuovo and Galeotti (2001), Buonanno, Carraro and Galeotti (2002), Buchner, Carraro and Cersosimo (2002) and in Buchner, Carraro, Cersosimo and Marchiori (2002). A brief description is contained in the Appendix.

[16] Notice that, in all climate regimes, abatement is a strategic variable, which is optimally set at its welfare maximising level by countries both inside and outside the coalition. Coalition members adopting the emission targets decided in Kyoto may decide to reduce emissions below the target.

[17] The use of the "Kyoto forever" hypothesis is a strong assumption. However, the CO2 concentration levels implicit in this assumption (if RICE is a good description of the world) coincide with those in the A1B scenario (IPCC, 2001) which can be considered the "median" scenario among those currently proposed. We thus use the "Kyoto-forever" hypothesis not because it represents a realistic scenario, but as a benchmark with respect to which policy alternatives can be compared.

Third, when China belongs to a climate coalition, it is assumed that it adopts quantitative emission limits. However, China's emission targets over time are assumed to coincide with its business-as-usual emission levels, which take into account unilateral emission reductions that may be decided by China.[18] This implies that when China enters a coalition and decides to cooperate on GHG emission abatement, it becomes a net supplier of permits.

Our analysis focuses on changes in the main economic variables (welfare, as measured by discounted future consumption levels, R&D expenditure, global CO2 emissions and abatement costs, for which an indicator is the equilibrium price in the permit market[20]) with respect to the business-as-usual scenario in which the Annex B_{-US} coalition forms. Results shown below must be interpreted as an application of a game-theory model designed to identify incentive mechanisms and the economic factors behind them, rather than to provide realistic figures on the outcomes of future policy scenarios.

3.1 A single coalition with the EU, Russia, Japan and China

Let us start by examining the economic consequences of the formation of a climate coalition in which four countries/regions – EU, FSU, JPN and CHN – cooperate to reduce GHG emissions. An emission trading market is implemented and all cooperating countries are allowed to trade in this market without restrictions.[21] The coalition formed by the EU, FSU, Japan and China plays a dynamic open loop Nash game with the other world regions. The equilibrium of the game determines the values of welfare changes that will be used to assess a country's incentive to participate in a given coalition.

Figure 1 shows the impacts on welfare, emissions and R&D investments of the climate coalition formed by the EU, FSU, Japan and China. When these countries cooperate to reduce GHG emissions, the permit price is obviously lower than in the case of the Annex B_{-US} coalition. The estimated change of the permit price is -78.6%. The reason for this massive decline of the permit price is China's participation in the permit market, which implies an increase in the supply of emission permits. The large boost to the supply side of the emission market is taken to be an expected result since, under our

---

[18] This scenario is often assumed in the literature on climate policy (see for example Criqui and Philibert, 2003).

[20] As we have said, a permit market is assumed to be implemented by all coalitions and even by singletons (domestically). Therefore, in our competitive setting, the price of permits is equivalent to an emission tax.

[21] This assumption is not consistent with the Kyoto Protocol, in which China is allowed to participate only in CDM projects. However, our analysis is a counterfactual analysis, designed to assess what would happen if China could be involved in the emission permit market.

assumptions on future commitments, China can sell permits whenever its emissions are below the business-as-usual levels.[22]

Thanks to this reduction in the permit price, the EU and Japan can achieve their own emission targets at a lower cost than in the case of the Annex B_{-US} coalition. Hence, the two countries reduce their total abatement costs. However, this new low-cost opportunity to comply with the Kyoto targets induces both the EU and Japan to invest less in R&D. Environmental-friendly technologies and cheap abatement possibilities thereby confirm themselves as possible substitutes (as already shown in Buonanno, Carraro and Galeotti, 2002). Both the EU and Japan reduce their R&D expenditures with respect to the Kyoto/Marrakech case (see Figure 1 again). As a consequence of the lower abatement costs and the reduced expenditure in R&D, both countries increase their total welfare.

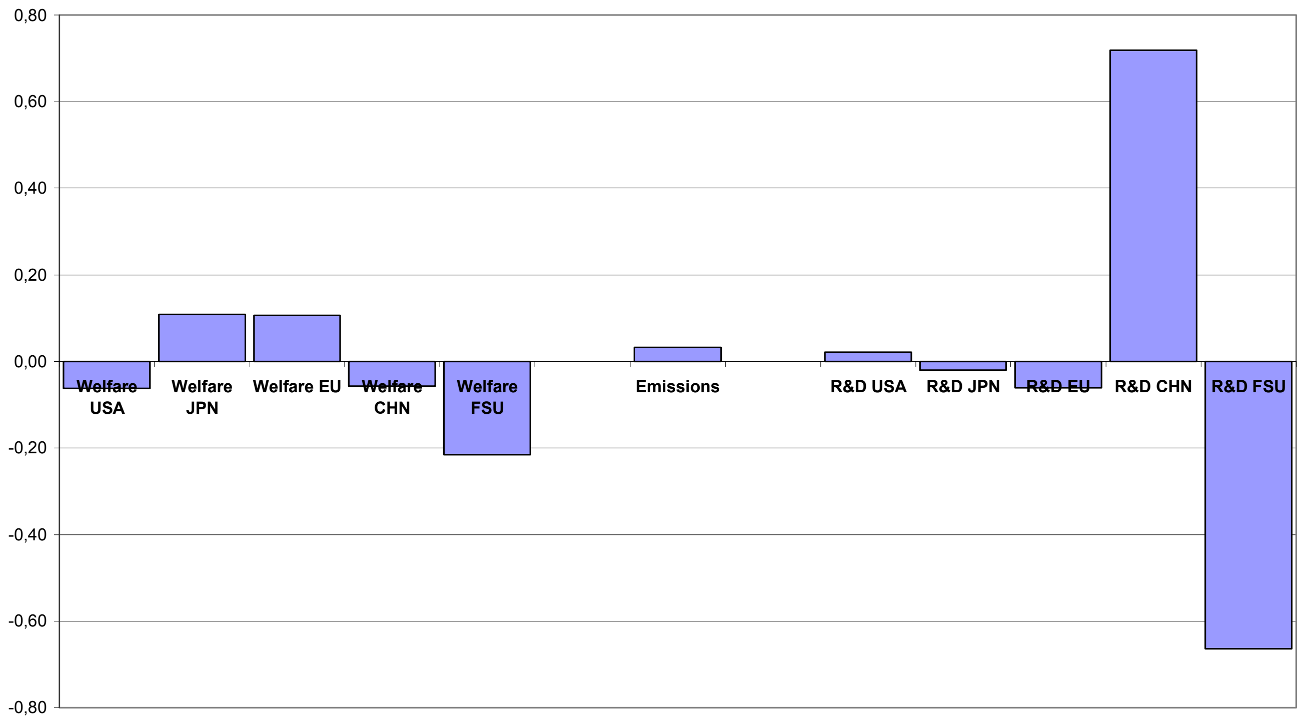
Russia suffers a high welfare loss from China's participation in a climate regime. The main reason is the lower price in the permit market induced by China's supply of permits. In addition, the presence in the market of a second large permit supplier clearly lessens the bargaining power of FSU, which previously controlled the permit market. By giving up its monopoly position, Russia reduces its profits from selling permits.

When cooperating on emission reduction, China obviously loses out in comparison with the alternative case in which China free-rides on the other countries' emission reductions. However, at the same time, China would profit from a large emission trading market. The net result of these two effects is a small welfare loss. This small loss could easily be compensated for by the existence of ancillary benefits, both environmental and economic, which are not yet accounted for by our model. A particular characteristic of the new situation is the large expansion of China's R&D investments. The reason is that China – like the FSU in the Annex B_{-US} coalition – over invests in R&D to increase its sales in the emission trading market. By strongly investing in technological innovations, China can gain profits in the permit market. With respect to the Annex B_{-US} case, China increases its R&D by more than 70%.

What are the implications of China's participation in the climate coalition for the environmental effectiveness of the protocol? Notwithstanding China's participation, total emissions increase. The reason is that China has emission targets over time that coincide with its business-as-usual emission levels. In addition, emissions in the other cooperating countries slightly increase due to the lower incentives to undertake emission-reducing R&D.

[22] In another paper, we test the robustness of equilibrium outcomes to changes in the scenarios defining abatement targets in the second commitment period and beyond. See Buchner and Carraro (2003c).

Figure 1: The perspective climate regime: Japan, CHN, EU and FSU.



As a consequence of the increased emissions, welfare in the US becomes lower because of the higher environmental damages arising from the growth in emissions. As already stated, the main reason why emissions increase is the decline in total R&D. R&D is lower because the increase in R&D efforts by China cannot offset the fall in R&D experienced by all the other participating countries. The EU and Japan face lower incentives to carry out R&D due to the large supply of emission permits. In addition, Russia reacts to the entrance of a new large permit supplier by strongly lowering its R&D investments since its incentive to undertake strategic R&D is lower.

In short, the participation of China in the climate coalition will have two negative effects on the US economy. First, the US experience higher damage from climate change because of total higher GHG emissions. Second, the US miss the opportunity to abate their own emissions at the much lower marginal cost (permit price) that the participation of China yields. Are these two effects sufficient to induce the US to change its mind and ratify the Kyoto Protocol?

3.2 A single coalition with the EU, Russia, Japan, the US and China

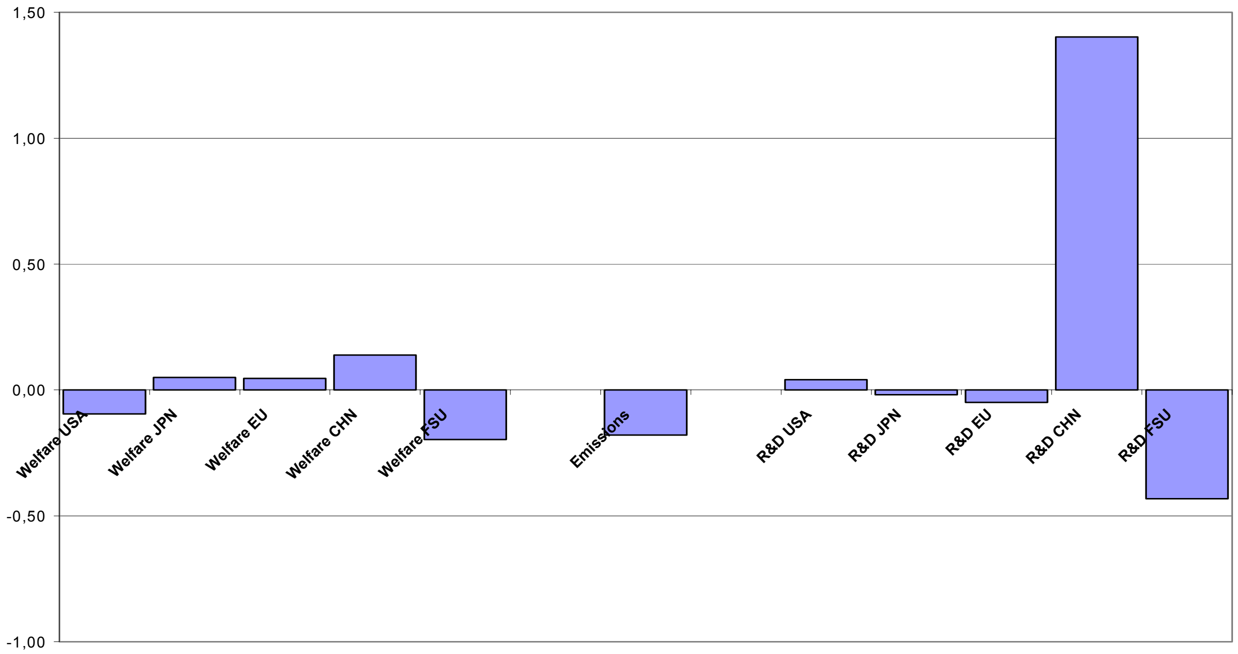
In the previous section, the participation of China in the climate coalition was shown to provide benefits to the EU and Japan, but damages to the US economy. Would then the US benefit from joining the climate coalition? In order to address this question using the FEEM-RICE modelling framework, we must analyse the economic implications of a coalition consisting of Europe, Japan, FSU, the US and China, with only one free-rider (the Rest of the World). Figure 2 and Table 1 show our results. Figure 2 illustrates changes with respect to the business-as-usual scenario. Table 1 shows the changes with respect to business-as-usual, considering both the present scenario and the one discussed in the section 3.1.

First, notice that China would be the big winner in the case of US participation. China would profit from a very large permit market, where it could supply an even larger amount of permits than in the scenario examined in section 3.1. Therefore, China's permit supply would be enhanced by strategic over-investments in R&D. With respect to the already large amount of R&D investments in the previous scenario, the enlarged coalition would induce almost a doubling of China's R&D expenditure. China would be the main permit seller in the emission market, thus benefiting more than other countries from US participation.

The FSU would like to profit from the larger emission market as well. It thus increases its strategic R&D investments in order to have more permits at its disposal, after having strongly reduced its expenditure in R&D in the previous scenario (compared to the Marrakech situation, Russia still decreases its R&D by more than 40%, but R&D increases compared to the case in which China but not the US cooperates). Therefore, the FSU increases its supply of emission permits with respect to the previous scenario.

The demand for permits also increases because of US participation in the trading market. The net effect estimated by our model is an increase in the permit price. Notice, however, that the permit price is still 63.08% lower than in the Annex B_{-US} scenario in which it is assumed that only the EU, Japan and Russia trade permits.

Figure 2: A wider single coalition climate regime: US, Japan, CHN, EU and FSU.



Notwithstanding a permit price higher than in the Annex B_{-US}+China climate coalition – which implies higher profits from selling "hot air" – the FSU is still the main loser in this scenario. However, its welfare loss with respect to the Kyoto/Marrakech coalition is lower than in the previous scenario, because of the increased demand for permits induced by US participation.

Given the higher permit price, the EU and Japan face higher abatement costs and therefore suffer a decrease in their welfare with respect to the scenario in which the Kyoto/Marrakech coalition is enlarged by China only. However, if we compare their performance in the scenario in which both China and the US adopt the Kyoto Protocol with their performance in the Annex B_{-US} scenario, we find that the larger permit market and the consequently relatively lower permit price still leads to an increase in welfare for both Europe and Japan (see Figure 2).

Table 1: Changes in welfare, emissions and R&D in the two scenarios with respect to the BAU scenario

	Coalitions	
	(JPN, EU, CHN, FSU)	(USA, JPN, EU, CHN, FSU)
Welfare USA	-6.23%	-9.46%
Welfare JPN	10.84%	4.97%
Welfare EU	10.60%	4.69%
Welfare CHN	-5.67%	13.86%
Welfare FSU	-21.54%	-19.71%
Emissions	3.26%	-17.90%
R&D USA	2.15%	4.13%
R&D JPN	-2.05%	-1.78%
R&D EU	-6.13%	-4.89%
R&D CHN	71.83%	140.20%
R&D FSU	-66.40%	-43.16%

Let us now consider the US. The two negative effects previously emphasised have been offset. On the one hand, the US participates in a permit market where the equilibrium price is quite low (63.08% lower than in the Kyoto/Marrakech scenario even though larger than in the absence of the US participation). On the other hand, total emissions are much lower and therefore the US suffers less damage from climate change.

However, total welfare in the US does not increase (see Table 1). Even though the loss is small, it is clear that the adoption of the Kyoto targets entails a cost for the US. The net loss is small because China supplies permits at a low price and because total emissions decrease. However, this is not sufficient to increase total US welfare with respect to the case in which they free-ride.

Therefore, the decision by China to comply with the Kyoto Protocol indeed creates a new environment in which it would be easier for the US to re-join the Kyoto climate coalition. However, the new incentives provided by China's participation in the permit market are not sufficient to yield a positive change in US welfare when they commit to their Kyoto target. Nonetheless, with the loss being quite small, political incentives reasons may induce the US to move back to the Kyoto negotiations in order to reap the benefits of low short-term abatement costs and to negotiate less demanding abatement targets in the second commitment period[23].

The big winner in this scenario would be the environment. As said, total emissions decrease by more than 20% with respect to the climate regime analysed in section 3.1. This result was expected, given that all big GHG emitters cooperate to achieve climate change control. This climate regime is thus the most environmental effective among those examined within this study.

3.3 A fragmented climate regime consisting of the US with China and the EU with Russia and Japan

There is a third scenario that could result from the incentives currently prevailing in climate policy. There is some evidence that a two-bloc climate regime, consisting of the Kyoto countries (EU, Japan and Russia) plus a bilateral cooperation between China and the US may not be unrealistic. Ever since the US and China normalised their diplomatic relations in the late 70s, cooperation on environment, science and technology matters has been a mainstay of U.S.-China relations[24]. In February 2002, Presidents George W. Bush and Jiang Zemin agreed to establish a U.S.-China Working Group on Climate Change which now promotes and monitors bilateral research cooperation on climate change focusing on various key areas of policy and science.

Furthermore, China's recent decision to ratify the Kyoto Protocol demonstrates that the country is getting serious about international cooperation to address climate change. China is also aware that benefits from ratification could be high because of its role as the largest permit seller. Chinese officials emphasise that the government will voluntarily try to restrict the growth of CO2 emissions, but it is strictly opposing any binding GHG reduction targets (The Japan Times, Jan. 26th, 2002).[25]

---

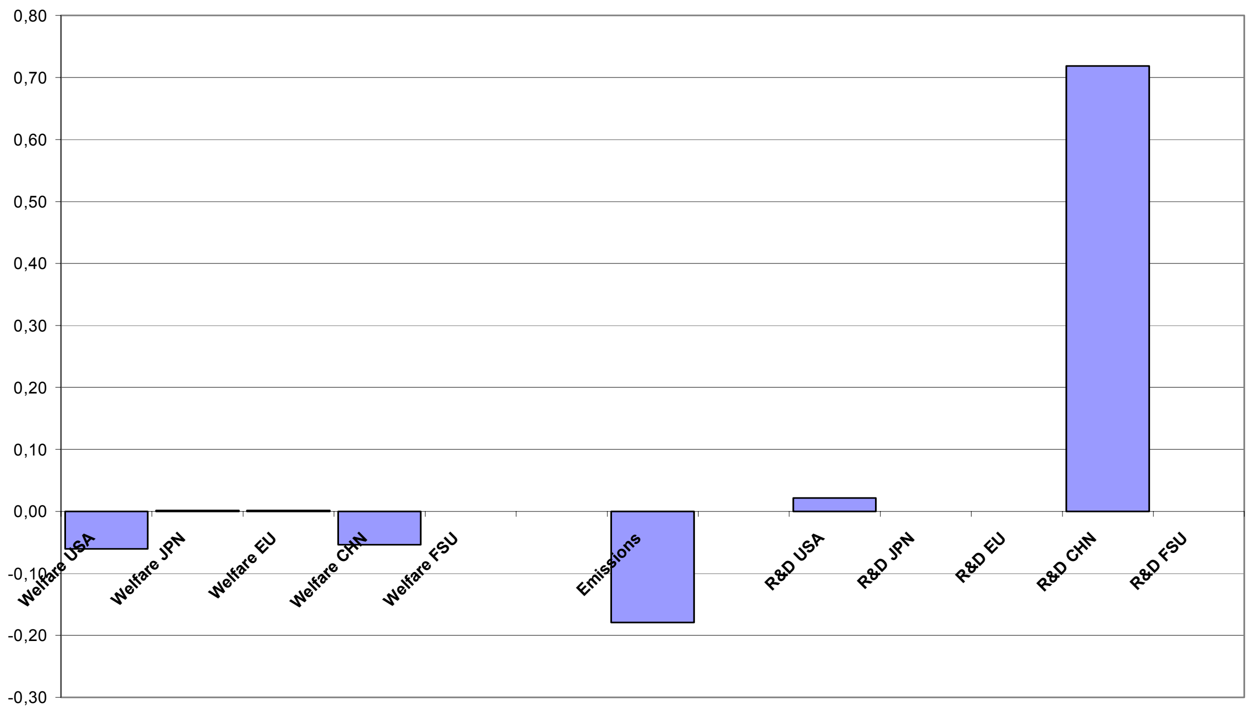
[23] Other scenarios, possibly even more attractive for the US, are discussed in Buchner and Carraro (2003b).

[24] In particular, the Agreement Between the Government of the U.S.A. and the Government of China on Cooperation in Science and Technology was one of the first between the two countries, signed during Deng Xiaoping's historic visit to the United States in January 1979. There are now more than 30 protocols under this umbrella agreement covering everything from earthquake science to fisheries, agriculture, forestry, energy, nuclear safety, meteorology, space technology, high energy physics, the environment, nature conservation, water resources management, biology, medicine, transportation and telecommunications. For more information see http://www.usembassy-china.org.cn/sandt/BilateralActivities.html

[25] However, in the longer term, China will have to cope with its role of second-largest CO2 emitter in the world. The first signs that China is recognising these political reasons are clear. The ratification of the Kyoto Protocol in

Without binding commitments and given the high amount of "hot air" which can be expected from this region, China is a very attractive partner in climate change control activities, as already evidenced by the ongoing bilateral agreements between China and several other countries[26]. This is why the US may be able to convince China to cooperate under a joint climate pact. In this way, the US could achieve two goals: (i) to satisfy domestic political requirements by involving developing countries in their climate strategy; (ii) to reap high benefits from a large bilateral emissions market (the US and China together account for more than one-third of world-wide CO2 emissions, a share which is becoming larger and larger). In particular, the US could drastically decrease its abatement costs through emission trading and China could profit from selling a large amount of permits.

Figure 3: A third climate regime with two blocs: 1) US and CHN; 2) EU, FSU and Japan



its actual form could therefore be interpreted more as a long-term commitment to emission control than as a short run strategy to reap the benefits on the emission trading market.

[26] Apart from the collaboration with the US, a bilateral cooperation on climate change has also been initiated with Australia in September 2003: see the official declaration at http://www.deh.gov.au/minister/env/2003/mr24oct203.html.

What would then be the main consequences of a two bloc climate regime with a first bloc formed by the EU, Japan and the FSU and a second bloc formed by the US and China? Some of these consequences are shown in Figure 3.

First of all, it is clear that both the US and CHN lose in comparison with the case in which they free-ride. However, the loss for the US is small and could be largely compensated for by some ancillary benefits from GHG emission abatement that are not taken into account in our model. In addition, due to the overall lower emission levels than in previous climate regimes, the welfare loss is the smallest among those attained by the US when it participates in a climate coalition.

Even the loss for China is small – and even smaller when compared to the regime in which the coalition (Annex B_{-US} + China) forms – and ancillary benefits, both environmental and economic , could be considerable. In a recent companion paper (Buchner and Carraro, 2003b), we show that the two-bloc climate regime is what would be most preferred by both the US and China when they do not free-ride. Namely, it is the most preferred among those in which they undertake some cooperative emission abatement.

The inclusion of China in a coalition with the US is slightly beneficial for the Kyoto/Marrakech climate bloc consisting of the European Union, Japan and the FSU, because of the enhanced environmental effectiveness of this two bloc regime. Indeed, GHG emissions are almost 20% lower than in the benchmark case, and also lower with respect to total emissions in the climate regime in which the coalition (Annex B_{-US} + China) forms. However, the coalition (Annex B_{-US} + China) is the one most preferred by the EU and Japan because the absence of China from the Annex B_{-US} coalition increases marginal abatement costs and thus induces welfare losses for the EU and Japan.

This two-bloc climate regime is characterised again by a large expansion of China's R&D investments. China over invests in R&D to increase its sales in the bilateral emission trading market. The segmentation of the trading market also explains why R&D investments within the Annex B_{-US} coalition do not change. However, if the comparison is made with the coalition (Annex B_{-US} + China), then it can be seen that R&D investments become higher for all Annex B_{-US} countries. The reason is again the larger marginal abatement costs when China is not a seller in the permit market. This induces higher investments in R&D in the EU and Japan and also strategic R&D investments in the FSU, which finds it optimal to increase its supply of permits.

In addition to economic and environmental benefits, there would be political benefits as well (Cf. Stewart and Wiener, 2003). The involvement of the US in international climate change control would provide evidence that the developed world is getting more serious about action against global warming. In particular, with respect to a long-term strategy, it would be difficult to call for an involvement of developing countries if the US are not engaged in climate control. This argument has been emphasised by Brazil's president who asks the US president to "show greater commitment to the global fight to protect the environment" (Planet Ark, Jan. 28th, 2002). Similarly, Stewart and Wiener (2003) point out that the coalition between the US and China could actually improve the global climate regime and lead to a comprehensive approach to climate control that includes all major emitting countries.

4. Conclusions

This paper has analysed the evolution of climate change policy after the Marrakech negotiations, focusing on the one hand on the political and economic forces which have led to the emergence of the present climate regime and on the other hand on the implications of this situation for the future of climate negotiations.

Our analysis has drawn attention on the role of China and of the new incentives that China's adoption of the Kyoto Protocol and its participation in the international permit market could provide. What emerges from this analysis is a situation in which the decision of China to participate in the climate coalition is beneficial for both the EU and Japan, because it lowers abatement costs. However, China's participation penalises Russia, because it lowers Russia's profits from selling permits.

We have shown that the US is also damaged by China's participation in the coalition with the EU, Japan and Russia. The reason is the increase in GHG emissions induced by the lower incentives to adopt climate friendly technologies. In addition, the US misses the opportunity to abate emissions at the low abatement cost that China's participation induces. Therefore, one may wonder whether the US would be better off by cooperating with China – as well as with the EU, Japan and FSU – on GHG emission control. The answer is negative. Although cooperation provides some benefits, total welfare does not increase and the US are still better off by free-riding on the other countries (small) emission reductions.

However, cooperation between the US and the other countries could take a different form. For example, the US could propose a bilateral deal to China that may be induced to cooperate with the US rather than with the Annex B_{-US} countries. In this scenario, the US and China form their own bilateral permit market, whereas the EU, Japan and Russia trade in a second different market. We have shown that, in this scenario, the environmental effectiveness of the climate regime is greatly increased and welfare losses are small in all countries.

Our conclusions can be summarised as follows. The participation of the US in a climate regime is not likely, at least in the short run. The US is more likely to adopt unilateral policies than to join the present Kyoto group (even when it includes China). However, a two-bloc regime would become the most preferred option if both China and the US, for political or environmental reasons, decide to cooperate on GHG emission control. If the US decide to cooperate, the climate regime that provides the highest incentives to the cooperating countries is the one in which China and the US cooperate bilaterally, with the Annex B_{-US} countries remaining within the Kyoto framework.

Is it sufficient to suggest that climate change negotiations could take a new direction by abandoning the Kyoto architecture to adopt a new multi-bloc approach similar to the one prevailing in international trade negotiations? Probably not. The above conclusions need cautious consideration. In particular, our empirical analysis focuses on economic incentives, whereas recent climate negotiations have shown that political decisions are often taken on the basis of other types of incentives. In addition, the model used in our analysis is a simplified representation of the world economic system, even though it captures the main economic mechanisms and the related incentive schemes. However, our analysis clearly suggests that moving out of the Kyoto framework could provide important economic and environmental benefits and therefore calls for additional research on this issue.

A further development of our analysis could be the comparison of different multi-bloc climate regimes. Blocs could be identified at regional level (e.g. EU, NAFTA, ASEAN) or could be defined by political or environmental interests (e.g. G77, AOSIS). Including more climate coalitions in the analysis could of course change the ranking of the regimes. Some preliminary results are in Buchner, and Carraro (2003b), where the economic consequences of the formation of a wide range of partial and/or regional climate coalitions are analysed.

References

ABC News Online, Kyoto protocol gets boost as China signs, September 3rd, 2002. Online at www.abc.net.au

ABC News Online, Kemp addresses Earth Summit, defends Govt position on Kyoto, September 4th, 2002. Online at www.abc.net.au

Asahi Shimbun, Bureaucratic battle raises hurdle for emissions control, February 11th, 2002. Online at http://www.asahi.com/english/op-ed/K2002021100204.html

BBC, Japan cools on climate pact, January 3rd, 2002. Online at www.news.bbc.co.uk

Böhringer, C. and Löschel, A. (2001), Market Power in International Emissions Trading: the impact of U.S. withdrawal from the Kyoto Protocol, ZEW Discussion Paper 01-58, Mannheim.

Buchner, B., Carraro, C. and Cersosimo, I. (2002), Economic Consequences of the U.S. Withdrawal from the Kyoto/Bonn Protocol. *Climate Policy*, 2 , 273-292.

Buchner, B. and Carraro, C. (2003a), Economic and Environmental Effectiveness of a Technology-based Climate Regime, Working Paper, FEEM, Milan.

Buchner, B. and Carraro, C. (2003b), Regional and Sub-global Climate Regimes, Working Paper, FEEM, Milan.

Buchner, B. and Carraro, C. (2003c), The Future of the Kyoto Protocol. Some Scenarios, Working Paper, FEEM, Milan.

Buchner, B., C. Carraro, I. Cersosimo and C. Marchiori, (2002), Back to Kyoto? US Participation and the Linkage between R&D and Climate Cooperation. CESifo Working Paper No. 688 (8) and FEEM Nota di Lavoro 15.02, Milan.

Buonanno, P., Carraro, C., Castelnuovo, E. and Galeotti, M. (2001), Emission Trading Restrictions with Endogenous Technological Change. *International Environmental Agreements. Law Politics Economics.*

Buonanno, P., C. Carraro, and Galeotti, M. (2002), Endogenous Induced Technical Change and the Costs of Kyoto, *Resource and Energy Economics*, 524(2002), 11-35.

Christian Science Monitor, Japan irked by US stance on Kyoto. March 12th, 2002. Online at http://www.csmonitor.com/2002/0312/p07s01-woap.html

CO2e.com, Japan plans voluntary emissions regulations: E&E Publishing, January 8th, 2002. Online at www.co2e.com

CO2e.com, Japan to ratify Kyoto Pact by late August: Jiji Press, February 13th, 2002. Online at www.co2e.com

CO2e.com, Japan, U.S. agree on 15 steps on global warming: Jiji Press, April 5th, 2002. Online at www.co2e.com

Coe, D.T., and Helpman, E. (1995), International R&D spillovers, *European Economic Review*, **39**, 859-887.

Criqui P. and. Philibert, C. (2003), Capping Emissions and Costs, paper presented at the RFF-IFRI workshop on “How to make progress post-Kyoto ?”, Paris, 19 March 2003.

Den Elzen, M.G.J. and de Moor, A.P.G. (2001), The Bonn Agreement and Marrakesh Accords: an updated analysis. RIVM Report 728001017/2001.

Dow Jones Newswires, DJ Russia to ratify Kyoto Protocol end 2004, October 28th, 2003 http://framehosting.dowjonesnews.com

Egenhofer, C. and Legge, T. (2001), After Marrakech: The Regionalisation of the Kyoto Protocol. CEPS Commentary.

European Commission (2001), Proposal for a Council Decision concerning the approval , on behalf of the European Community, of the Kyoto Protocol to the United Nations Framework Convention on Climate Change and the joint fulfilment of commitments thereunder.

Eyckmans, J. and Tulkens, H. (2001), Simulating Coalitionally Stable Burden Sharing Agreements for the Climate Change Problem, CORE Discussion Paper 9926 and CLIMNEG Working Paper 18, Université Catholique de Louvain, Belgium.

Financial Times, EU policies could mean Russia backs out of Kyoto climate agreement - MP, March 22nd, 2002. Online at http://www.FT.com/

Goulder, L.H. and Mathai, K. (2000), Optimal CO2 abatement in the presence of induced technological change, *Journal of Environmental Economics and Management,* **39**, 1-38.

Griliches, Z. (1979), Issues in Assessing the Contribution of R&D to Productivity Growth, *Bell Journal of Economics*, **10**, 92-116.

Griliches, Z. (1984), *R&D, Patents, and Productivity*, Chicago: University of Chicago Press.

IPCC (2001), Third Assessment Report, Cambridge University Press, Cambridge.

Japan Today News, Japan seeks help to get U.S. to rejoin Kyoto talks, January 19th, 2002. Online at www.japantoday.com

Japan Today News, Japan to urge Canada to ratify Kyoto Protocol, February 26th, 2002. Online at www.japantoday.com

Japan Today News, Japan, U.S. discuss gobal warming, February 27th, 2002. Online at www.japantoday.com

Japan Today News, Japan to urge U.S., Russia to ratify Kyoto pact, June 4th, 2002. Online at www.japantoday.com

Kyodo News, Anti-global warming bill in line with Kyoto pact, February 1st, 2002. Online at www.kyodo.co.jp

Kyodo News, Australia, Canada may skip Kyoto Protocol: METI official, February 21st, 2002. Online at www.kyodo.co.jp

Manne, A. and Richels, R. (1999), The Kyoto Protocol: a cost-effective strategy for meeting environmental objectives? in *The Cost of the Kyoto Protocol: A Multi-Model Evaluation*., ed. J. Weyant, Special Issue of the *Energy Journal*.

Manne, A.S. and Richels, R. (2001), US Rejection of the Kyoto Protocol: the impact on compliance costs and CO2 emissions. Working Paper 01-12, AEI-Brookings Joint Center for Regulatory Studies.

Nordhaus, W.D. and Yang, Z. (1996), A Regional Dynamic General-Equilibrium Model of Alternative Climate-Change Strategies, *American Economic Review,* **4**, 741-765.

Nordhaus, W.D. (1999), Modelling Induced Innovation in Climate-Change Policy, paper presented at the IIASA Workshop on Induced Technological Change and the Environment, Laxenburg, June 21-22.

Planet Ark (Reuters), China says Kyoto pact benefits both rich and poor, January 18th, 2002. Online at www.planetark.org

Planet Ark (Reuters), Brazil Cardoso wants Bush to fight for environment, January 28th, 2002. Online at www.planetark.org

RBC Network, Russia to ratify Kyoto soon, March 11th, 2002 Online at http://www.pointcarbon.com/article_view.php?id=1721

Reuters, Putin undecided in Kyoto, snubs U.N. appeals, September 29th, 2003. Online at www.reuters.com

RFE/RL, Russia: Putin remarks start off international climate conference on sour note, September 29th, 2003. Online at www.rferl.org

Romer, P. (1990), Endogenous Technological Change, *Journal of Political Economy*, 94, 1002-1037.

Stewart, R and Wiener, J. (2003), *Reconstructing Climate Policy*, American Enterprise Institute Press.

Sky News, Australia warms to Kyoto, September 4th, 2002. Online at www.sky.com/

The Age, Australia, US urged to be less selfish, August 30th, 2002. Online at www.theage.com.au

The Globe and Mail, Kyoto a go, PM says, September 2nd, 2002. Online at www.globeandmail.com

The Hindu, US in EU's firing line on climate change, October 24th, 2002. Online at www.hinduinnet.com

The Hindu, Russia seeks commitments on climate change, October 31st, 2002. Online at www.hinduinnet.com

The International Herald Tribune, Russia needs the Kyoto treaty, October 28th, 2003. Online at www.iht.com

The Japan Times, Carbon tax stuck in detour to Kyoto, January 17th, 2002. Online at www.japantimes.com

The Japan Times, Emissions-trading plan put on back burner, January 18th, 2002. Online at www.japantimes.com

The Japan Times, Activating the Kyoto treaty, January 21st, 2002. Online at www.japantimes.com

The Japan Times, China could help Japan by taking its money and cutting its Kyoto target, January 26th, 2002. Online at www.japantimes.com

The Japan Times, U.S.-Japan climate talks set for March, February 27th, 2002. Online at www.japantimes.com

The Toronto Star, Slow up on Kyoto, OM told, September 4th, 2002. Online at www.thestar.com

The Toronto Star, Chrétien ratifies Kyoto, December 17th, 2002. Online at www.thestar.com

United Nations (2002) Johannesburg Summit 2002: Key outcomes of the summit.

Weyant, J.P. (1997), Technological Change and Climate Policy Modeling, paper presented at the IIASA Workshop on Induced Technological Change and the Environment, Laxenburg, June 26-27.

Weyant, J.P. and Olavson, T. (1999), Issues in Modelling Induced Technological Change in Energy, Environmental, and Climate Policy, *Environmental Modelling and Assessment*, **4**, 67-85.

Yomiuri Shimbun, Russia may drag feet on Kyoto, March 28th, 2002. Online at http://www.yomiuri.co.jp/

Appendix. The FEEM-RICE Model

The FEEM-RICE model is an extension of Nordhaus and Yang's (1996) regional RICE model of integrated assessment, which is one of the most popular and manageable integrated assessment tools for the study of climate change (see, for instance, Eyckmans and Tulkens, 2001). It is basically a single sector optimal growth model which has been extended to incorporate the interaction between economic activities and climate. One such model has been developed for each macro region into which the world is divided (USA, Japan, Europe, China, Former Soviet Union, and Rest of the World).

Within each region a central planner chooses the optimal paths of fixed investment and emission abatement that maximise the present value of per capita consumption. Output (net of climate change) is used for investment and consumption and is produced according to constant returns Cobb-Douglas technology, which combines the inputs from capital and labour with the level of technology. Population (taken to be equal to full employment) and technology levels grow over time in an exogenous fashion, whereas capital accumulation is governed by the optimal rate of investment. There is a wedge between output gross and net of climate change effects, the size of which is dependent upon the amount of abatement (rate of emission reduction) as well as the change in global temperature. The model is completed by three equations representing emissions (which are related to output and abatement), carbon cycle (which relates concentrations to emissions), and climate module (which relates the change in temperature relative to 1990 levels to carbon concentrations) respectively.

In our extension of the model, technical change is no longer exogenous. Instead, the issue of endogenous technical change is tackled by following the ideas contained in both Nordhaus (1999) and Goulder and Mathai (2000) and accordingly modifying Nordhaus and Yang's (1996) RICE model. Doing so requires the input of a number of additional parameters, some of which have been estimated using information provided by Coe and Helpman (1995), while the remaining parameters were calibrated so as to reproduce the business-as-usual scenario generated by the RICE model with exogenous technical change.

In particular, the following factors are included: first, endogenous technical change affecting factor productivity is introduced. This is done by adding the stock of knowledge in each production function and by relating the stock of knowledge to R&D investments. Second, induced technical change is introduced, by allowing the stock of knowledge to affect the emission-output ratio as well. Finally, international technological spillovers are also accounted for in the model.

Within each version of the model, countries play a non-cooperative Nash game in a dynamic setting, which yields an Open Loop Nash equilibrium (see Eyckmans and Tulkens, 2001, for an explicit derivation of first order conditions of the optimum problem). This is a situation in which, in each region, the planner maximises social welfare subject to the individual resource and capital constraints and the climate module, given the emission and investment strategies (in the base case) and the R&D expenditure strategy (in the endogenous technological change case) of all other players.

The Standard Model without Induced Technical Change

As previously mentioned, it is assumed for the purpose of this model that innovation is brought about by R&D spending which contributes to the accumulation of the stock of existing knowledge. Following an approach pioneered by Griliches (1979, 1984), it is assumed that the stock of knowledge is a factor of production, which therefore enhances the rate of productivity (see also the discussion in Weyant, 1997; Weyant and Olavson, 1999). In this formulation, R&D efforts prompt non-environmental technical progress, but with different modes and elasticities. More precisely, the RICE production function output is modified as follows:

$$Q(n,t) = A(n,t)K_R(n,t)^{\beta_n}[L(n,t)^{\gamma}K_F(n,t)^{1-\gamma}] \qquad (1)$$

where Q is output (gross of climate change effects), A the exogenously given level of technology and K_R, L, and K_F are respectively the inputs from knowledge capital, labour, and physical capital.
In (1), the stock of knowledge has a region-specific output elasticity equal to β_n $(n=1,\dots6)$. It should be noted that, as long as this coefficient is positive, the output production process is characterised by increasing returns to scale, in line with current theories of endogenous growth. This implicitly assumes the existence of cross-sectoral technological spillovers within each country (Romer, 1990). In addition, it should be noted that while allowing for R&D-driven technological progress, we maintain the possibility that technical improvements can also be determined exogenously (the path of A is the same as that specified in the original RICE model). The stock accumulates in the usual fashion:

$$K_R(n,t+1) = R\,\&\,D(n,t) + (1-\delta_R)K_R(n,t) \qquad (2)$$

where $R\&D$ is the expenditure in Research and Development and δ_R is the rate of knowledge depreciation. Finally, it is recognised that some resources are absorbed by R&D spending. That is:

$$Y(n,t) = C(n,t) + I(n,t) + R\,\&\,D(n,t) \qquad (3)$$

where Y is net output (net of climate change effects as specified in the RICE model), C is consumption and I gross fixed capital formation.

At this stage the model maintains the same emissions function as Nordhaus' RICE model which will be modified in the next section:

$$E(n,t) = \sigma(n,t)[1 - \mu(n,t)]Q(n,t) \tag{4}$$

where σ can be loosely defined as the emissions-output ratio, E stands for emissions and μ for the rate of abatement effort. The policy variables included in the model are rates of fixed investment and of emission abatement. For the other variables, the model specifies a time path of exogenously given values. Interestingly, this is also the case for technology level A and of the emissions-output ratio σ. Thus, the model presented so far assumes no induced technical change, i.e. an exogenous environmental technical change, and a formulation of productivity that evolves both exogenously and endogenously. In the model, investment fosters economic growth (thereby driving up emissions) while abatement is the only policy variable used for reducing emissions.

Induced Technical Change

In the second step of our model formulation, endogenous environmental technical change is accounted for. It is assumed that the stock of knowledge – which in the previous formulation was only a factor of production - also serves the purpose of reducing, *ceteris paribus*, the level of carbon emissions. Thus, in the second formulation, R&D efforts prompt both environmental and non-environmental technical progress, although with different modes and elasticities.[27] More precisely, the RICE emission-output relationship is modified as follows:

$$E(n,t) = [\sigma_n + \chi_n \exp(-\alpha_n K_R(n,t))][1 - \mu(n,t)]Q(n,t) \tag{4'}$$

In (4'), knowledge reduces the emissions-output ratio with an elasticity of α_n, which is also region-specific; the parameter χ_n is a scaling coefficient, whereas σ_n is the value to which the emission-output ratio tends asymptotically as the stock of knowledge increases without limit. In this formulation, R&D

[27] Obviously, we could have introduced two different types of R&D efforts, respectively contributing to the growth of an environmental knowledge stock and a production knowledge stock. Such undertaking however is made difficult by the need to specify variables and calibrate parameters for which there is no immediately available and sound information in the literature.

contributes to output productivity on the one hand, and affects the emission-output ratio - and therefore the overall level of pollution emissions - on the other .

Knowledge Spillovers

Previous formulations do not include the effect of potential spillovers produced by knowledge, and therefore ignore the fact that both technologies and organisational structures disseminate internationally. Modern economies are linked by vast and continually expanding flows of trade, investment, people and ideas. The technologies and choices of one region are and will inevitably be affected by developments in other regions.

Following the work of Weyant and Olavson (1999), who suggest that the definition of spillovers in an induced technical change context be kept plain and simple (in the light of a currently incomplete understanding of the problem) , disembodied, or knowledge spillovers are modelled (see Romer, 1990). They refer to the R&D carried out and paid for by one party that produces benefits to other parties which then have better or more inputs than before or can somehow benefit from R&D carried out elsewhere. Therefore, in order to capture international spillovers of knowledge, the stock of world knowledge is introduced in the third version of the FEEM-RICE model, both in the production function and in the emission-output ratio equation. Equations (1) and (4') are then revised as follows:

$$Q(n,t) = A(n,t)K_R(n,t)^{\beta_n} WK_R(n,t)^{\varepsilon_n}[L(n,t)^{\gamma} K_F(n,t)^{1-\gamma}] \qquad (1')$$

and:

$$E(n,t) = [\sigma_n + \chi_n \, exp(-\alpha_n K_R(n,t) - \theta_n WK_R(n,t))][1-\mu(n,t)]Q(n,t) \qquad (4'')$$

where the stock of world knowledge:

$$WK_R(j,t) = \sum_{j \neq i} K_R(i,t) \qquad (5)$$

is defined in such a way as not to include a country's own stock.

Emission Trading

As mentioned above, throughout the analysis we assume the adoption of efficient policies. As a consequence, the model also includes the possibility of flexibility mechanisms. In particular we compare the two cases in which emission trading takes place amongst all original Annex I countries (including the US), first with one in which trading is allowed amongst Annex 1 countries without the US, and then one in which emission trading takes place amongst all Annex I countries without the US and Russia.

When running the model in the presence of emission trading, two additional equations are considered:

$$Y(n,t) = C(n,t) + I(n,t) + R\,\&\,D(n,t) + p(t)NIP(n,t) \qquad (3')$$

which replaces equation (3) and:

$$E(n,t) = Kyoto(n) + NIP(n,t) \qquad (6)$$

where *NIP(n,t)* is the net demand for permits and *Kyoto(n)* are the emission targets set in the Kyoto Protocol for the signatory countries and the BAU levels for the non-signatory ones. According to (3'), resources produced by the economy must be devoted, in addition to consumption, investment, and research and development, to net purchases of emission permits. Equation (6) states that a region's emissions may exceed the limit set in Kyoto if permits are bought, and vice versa in the case of sales of permits. Note that *p(t)* is the price of a unit of tradable emission permits expressed in terms of the *numeraire* output price. Moreover, there is an additional policy variable to be considered in this case, which is net demand for permits *NIP*.

In terms of the possibility of emission trading, the sequence whereby a Nash equilibrium is reached can be described as follows. Each region maximises its utility subject to its individual resource and capital constraints, now including the Kyoto constraint, and the climate module for a given emission (i.e. abatement) strategy of all the other players and a given price of permits *p(0)* (in the first round this is set at an arbitrary level). When all regions have made their optimal choices, the overall net demand for permits is computed at the given price. If the sum of net demands in each period is approximately zero, a Nash equilibrium is obtained; otherwise the price is revised as a function of the market disequilibrium and each region's decision process starts again.

NOTE DI LAVORO DELLA FONDAZIONE ENI ENRICO MATTEI
Fondazione Eni Enrico Mattei Working Paper Series
Our working papers are available on the Internet at the following addresses:
http://www.feem.it/Feem/Pub/Publications/WPapers/default.html
http://papers.ssrn.com

SUST	1.2002	*K. TANO, M.D. FAMINOW, M. KAMUANGA and B. SWALLOW*: Using Conjoint Analysis to Estimate Farmers' Preferences for Cattle Traits in West Africa
ETA	2.2002	*Efrem CASTELNUOVO and Paolo SURICO*: What Does Monetary Policy Reveal about Central Bank's Preferences?
WAT	3.2002	*Duncan KNOWLER and Edward BARBIER*: The Economics of a "Mixed Blessing" Effect: A Case Study of the Black Sea
CLIM	4.2002	*Andreas LÖSCHEL*: Technological Change in Economic Models of Environmental Policy: A Survey
VOL	5.2002	*Carlo CARRARO and Carmen MARCHIORI*: Stable Coalitions
CLIM	6.2002	*Marzio GALEOTTI, Alessandro LANZA and Matteo MANERA*: Rockets and Feathers Revisited: An International Comparison on European Gasoline Markets
ETA	7.2002	*Effrosyni DIAMANTOUDI and Eftichios S. SARTZETAKIS*: Stable International Environmental Agreements: An Analytical Approach
KNOW	8.2002	*Alain DESDOIGTS*: Neoclassical Convergence Versus Technological Catch-up: A Contribution for Reaching a Consensus
NRM	9.2002	*Giuseppe DI VITA:* Renewable Resources and Waste Recycling
KNOW	10.2002	*Giorgio BRUNELLO*: Is Training More Frequent when Wage Compression is Higher? Evidence from 11 European Countries
ETA	11.2002	*Mordecai KURZ, Hehui JIN and Maurizio MOTOLESE*: Endogenous Fluctuations and the Role of Monetary Policy
KNOW	12.2002	*Reyer GERLAGH and Marjan W. HOFKES:* Escaping Lock-in: The Scope for a Transition towards Sustainable Growth?
NRM	13.2002	*Michele MORETTO and Paolo ROSATO*: The Use of Common Property Resources: A Dynamic Model
CLIM	14.2002	*Philippe QUIRION*: Macroeconomic Effects of an Energy Saving Policy in the Public Sector
CLIM	15.2002	*Roberto ROSON*: Dynamic and Distributional Effects of Environmental Revenue Recycling Schemes: Simulations with a General Equilibrium Model of the Italian Economy
CLIM	16.2002	*Francesco RICCI* (l): Environmental Policy Growth when Inputs are Differentiated in Pollution Intensity
ETA	17.2002	*Alberto PETRUCCI*: Devaluation (Levels versus Rates) and Balance of Payments in a Cash-in-Advance Economy
Coalition Theory Network	18.2002	*László Á. KÓCZY* (liv*):* The Core in the Presence of Externalities
Coalition Theory Network	19.2002	*Steven J. BRAMS, Michael A. JONES and D. Marc KILGOUR* (liv): Single-Peakedness and Disconnected Coalitions
Coalition Theory Network	20.2002	*Guillaume HAERINGER* (liv): On the Stability of Cooperation Structures
NRM	21.2002	*Fausto CAVALLARO and Luigi CIRAOLO:* Economic and Environmental Sustainability: A Dynamic Approach in Insular Systems
CLIM	22.2002	*Barbara BUCHNER, Carlo CARRARO, Igor CERSOSIMO and Carmen MARCHIORI*: Back to Kyoto? US Participation and the Linkage between R&D and Climate Cooperation
CLIM	23.2002	*Andreas LÖSCHEL and ZhongXIANG ZHANG:* The Economic and Environmental Implications of the US Repudiation of the Kyoto Protocol and the Subsequent Deals in Bonn and Marrakech
ETA	24.2002	*Marzio GALEOTTI, Louis J. MACCINI and Fabio SCHIANTARELLI*: Inventories, Employment and Hours
CLIM	25.2002	*Hannes EGLI:* Are Cross-Country Studies of the Environmental Kuznets Curve Misleading? New Evidence from Time Series Data for Germany
ETA	26.2002	*Adam B. JAFFE, Richard G. NEWELL and Robert N. STAVINS*: Environmental Policy and Technological Change
SUST	27.2002	*Joseph C. COOPER and Giovanni SIGNORELLO*: Farmer Premiums for the Voluntary Adoption of Conservation Plans
SUST	28.2002	*The ANSEA Network*: Towards An Analytical Strategic Environmental Assessment
KNOW	29.2002	*Paolo SURICO*: Geographic Concentration and Increasing Returns: a Survey of Evidence
ETA	30.2002	*Robert N. STAVINS:* Lessons from the American Experiment with Market-Based Environmental Policies

NRM	31.2002	*Carlo GIUPPONI and Paolo ROSATO:* Multi-Criteria Analysis and Decision-Support for Water Management at the Catchment Scale: An Application to Diffuse Pollution Control in the Venice Lagoon
NRM	32.2002	*Robert N. STAVINS*: National Environmental Policy During the Clinton Years
KNOW	33.2002	*A. SOUBEYRAN and H. STAHN* : Do Investments in Specialized Knowledge Lead to Composite Good Industries?
KNOW	34.2002	*G. BRUNELLO, M.L. PARISI and Daniela SONEDDA:* Labor Taxes, Wage Setting and the Relative Wage Effect
CLIM	35.2002	*C. BOEMARE and P. QUIRION* (lv): Implementing Greenhouse Gas Trading in Europe: Lessons from Economic Theory and International Experiences
CLIM	36.2002	*T.TIETENBERG* (lv): The Tradable Permits Approach to Protecting the Commons: What Have We Learned?
CLIM	37.2002	*K. REHDANZ and R.J.S. TOL* (lv): On National and International Trade in Greenhouse Gas Emission Permits
CLIM	38.2002	*C. FISCHER* (lv): Multinational Taxation and International Emissions Trading
SUST	39.2002	*G. SIGNORELLO and G. PAPPALARDO:* Farm Animal Biodiversity Conservation Activities in Europe under the Framework of Agenda 2000
NRM	40.2002	*S .M. CAVANAGH, W. M. HANEMANN and R. N. STAVINS:* Muffled Price Signals: Household Water Demand under Increasing-Block Prices
NRM	41.2002	*A. J. PLANTINGA, R. N. LUBOWSKI and R. N. STAVINS:* The Effects of Potential Land Development on Agricultural Land Prices
CLIM	42.2002	*C. OHL* (lvi): Inducing Environmental Co-operation by the Design of Emission Permits
CLIM	43.2002	*J. EYCKMANS, D. VAN REGEMORTER and V. VAN STEENBERGHE* (lvi): Is Kyoto Fatally Flawed? An Analysis with MacGEM
CLIM	44.2002	*A. ANTOCI and S. BORGHESI* (lvi): Working Too Much in a Polluted World: A North-South Evolutionary Model
ETA	45.2002	*P. G. FREDRIKSSON, Johan A. LIST and Daniel MILLIMET* (lvi): Chasing the Smokestack: Strategic Policymaking with Multiple Instruments
ETA	46.2002	*Z. YU* (lvi): A Theory of Strategic Vertical DFI and the Missing Pollution-Haven Effect
SUST	47.2002	*Y. H. FARZIN*: Can an Exhaustible Resource Economy Be Sustainable?
SUST	48.2002	*Y. H. FARZIN*: Sustainability and Hamiltonian Value
KNOW	49.2002	*C. PIGA and M. VIVARELLI*: Cooperation in R&D and Sample Selection
Coalition Theory Network	50.2002	*M. SERTEL and A. SLINKO* (liv): Ranking Committees, Words or Multisets
Coalition Theory Network	51.2002	*Sergio CURRARINI* (liv): Stable Organizations with Externalities
ETA	52.2002	*Robert N. STAVINS*: Experience with Market-Based Policy Instruments
ETA	53.2002	*C.C. JAEGER, M. LEIMBACH, C. CARRARO, K. HASSELMANN, J.C. HOURCADE, A. KEELER and R. KLEIN* (liii): Integrated Assessment Modeling: Modules for Cooperation
CLIM	54.2002	*Scott BARRETT* (liii)*:* Towards a Better Climate Treaty
ETA	55.2002	*Richard G. NEWELL and Robert N. STAVINS*: Cost Heterogeneity and the Potential Savings from Market-Based Policies
SUST	56.2002	*Paolo ROSATO and Edi DEFRANCESCO*: Individual Travel Cost Method and Flow Fixed Costs
SUST	57.2002	*Vladimir KOTOV and Elena NIKITINA* (lvii): Reorganisation of Environmental Policy in Russia: The Decade of Success and Failures in Implementation of Perspective Quests
SUST	58.2002	*Vladimir KOTOV* (lvii): Policy in Transition: New Framework for Russia's Climate Policy
SUST	59.2002	*Fanny MISSFELDT and Arturo VILLAVICENCO* (lvii): How Can Economies in Transition Pursue Emissions Trading or Joint Implementation?
VOL	60.2002	*Giovanni DI BARTOLOMEO, Jacob ENGWERDA, Joseph PLASMANS and Bas VAN AARLE:* Staying Together or Breaking Apart: Policy-Makers' Endogenous Coalitions Formation in the European Economic and Monetary Union
ETA	61.2002	*Robert N. STAVINS, Alexander F.WAGNER and Gernot WAGNER*: Interpreting Sustainability in Economic Terms: Dynamic Efficiency Plus Intergenerational Equity
PRIV	62.2002	*Carlo CAPUANO*: Demand Growth, Entry and Collusion Sustainability
PRIV	63.2002	*Federico MUNARI and Raffaele ORIANI*: Privatization and R&D Performance: An Empirical Analysis Based on Tobin's Q
PRIV	64.2002	*Federico MUNARI and Maurizio SOBRERO*: The Effects of Privatization on R&D Investments and Patent Productivity
SUST	65.2002	*Orley ASHENFELTER and Michael GREENSTONE*: Using Mandated Speed Limits to Measure the Value of a Statistical Life
ETA	66.2002	*Paolo SURICO:* US Monetary Policy Rules: the Case for Asymmetric Preferences
PRIV	67.2002	*Rinaldo BRAU and Massimo FLORIO*: Privatisations as Price Reforms: Evaluating Consumers' Welfare Changes in the U.K.
CLIM	68.2002	*Barbara K. BUCHNER and Roberto ROSON*: Conflicting Perspectives in Trade and Environmental Negotiations
CLIM	69.2002	*Philippe QUIRION*: Complying with the Kyoto Protocol under Uncertainty: Taxes or Tradable Permits?
SUST	70.2002	*Anna ALBERINI, Patrizia RIGANTI and Alberto LONGO*: Can People Value the Aesthetic and Use Services of Urban Sites? Evidence from a Survey of Belfast Residents
SUST	71.2002	*Marco PERCOCO:* Discounting Environmental Effects in Project Appraisal

NRM	72.2002	*Philippe BONTEMS and Pascal FAVARD*: Input Use and Capacity Constraint under Uncertainty: The Case of Irrigation
PRIV	73.2002	*Mohammed OMRAN:* The Performance of State-Owned Enterprises and Newly Privatized Firms: Empirical Evidence from Egypt
PRIV	74.2002	*Mike BURKART, Fausto PANUNZI and Andrei SHLEIFER:* Family Firms
PRIV	75.2002	*Emmanuelle AURIOL, Pierre M. PICARD:* Privatizations in Developing Countries and the Government Budget Constraint
PRIV	76.2002	*Nichole M. CASTATER*: Privatization as a Means to Societal Transformation: An Empirical Study of Privatization in Central and Eastern Europe and the Former Soviet Union
PRIV	77.2002	*Christoph LÜLSFESMANN*: Benevolent Government, Managerial Incentives, and the Virtues of Privatization
PRIV	78.2002	*Kate BISHOP, Igor FILATOTCHEV and Tomasz MICKIEWICZ*: Endogenous Ownership Structure: Factors Affecting the Post-Privatisation Equity in Largest Hungarian Firms
PRIV	79.2002	*Theodora WELCH and Rick MOLZ*: How Does Trade Sale Privatization Work? Evidence from the Fixed-Line Telecommunications Sector in Developing Economies
PRIV	80.2002	*Alberto R. PETRUCCI*: Government Debt, Agent Heterogeneity and Wealth Displacement in a Small Open Economy
CLIM	81.2002	*Timothy SWANSON and Robin MASON* (lvi): The Impact of International Environmental Agreements: The Case of the Montreal Protocol
PRIV	82.2002	*George R.G. CLARKE and Lixin Colin XU:* Privatization, Competition and Corruption: How Characteristics of Bribe Takers and Payers Affect Bribe Payments to Utilities
PRIV	83.2002	*Massimo FLORIO and Katiuscia MANZONI*: The Abnormal Returns of UK Privatisations: From Underpricing to Outperformance
NRM	84.2002	*Nelson LOURENÇO, Carlos RUSSO MACHADO, Maria do ROSÁRIO JORGE and Luís RODRIGUES*: An Integrated Approach to Understand Territory Dynamics. The Coastal Alentejo (Portugal)
CLIM	85.2002	*Peter ZAPFEL and Matti VAINIO* (lv): Pathways to European Greenhouse Gas Emissions Trading History and Misconceptions
CLIM	86.2002	*Pierre COURTOIS*: Influence Processes in Climate Change Negotiations: Modelling the Rounds
ETA	87.2002	*Vito FRAGNELLI and Maria Erminia MARINA* (lviii): Environmental Pollution Risk and Insurance
ETA	88.2002	*Laurent FRANCKX* (lviii): Environmental Enforcement with Endogenous Ambient Monitoring
ETA	89.2002	*Timo GOESCHL and Timothy M. SWANSON* (lviii): Lost Horizons. The noncooperative management of an evolutionary biological system.
ETA	90.2002	*Hans KEIDING* (lviii): Environmental Effects of Consumption: An Approach Using DEA and Cost Sharing
ETA	91.2002	*Wietze LISE* (lviii): A Game Model of People's Participation in Forest Management in Northern India
CLIM	92.2002	*Jens HORBACH*: Structural Change and Environmental Kuznets Curves
ETA	93.2002	*Martin P. GROSSKOPF:* Towards a More Appropriate Method for Determining the Optimal Scale of Production Units
VOL	94.2002	*Scott BARRETT and Robert STAVINS*: Increasing Participation and Compliance in International Climate Change Agreements
CLIM	95.2002	*Banu BAYRAMOGLU LISE and Wietze LISE:* Climate Change, Environmental NGOs and Public Awareness in the Netherlands: Perceptions and Reality
CLIM	96.2002	*Matthieu GLACHANT*: The Political Economy of Emission Tax Design in Environmental Policy
KNOW	97.2002	*Kenn ARIGA and Giorgio BRUNELLO*: Are the More Educated Receiving More Training? Evidence from Thailand
ETA	98.2002	*Gianfranco FORTE and Matteo MANERA*: Forecasting Volatility in European Stock Markets with Non-linear GARCH Models
ETA	99.2002	*Geoffrey HEAL*: Bundling Biodiversity
ETA	100.2002	*Geoffrey HEAL, Brian WALKER, Simon LEVIN, Kenneth ARROW, Partha DASGUPTA, Gretchen DAILY, Paul EHRLICH, Karl-Goran MALER, Nils KAUTSKY, Jane LUBCHENCO, Steve SCHNEIDER and David STARRETT*: Genetic Diversity and Interdependent Crop Choices in Agriculture
ETA	101.2002	*Geoffrey HEAL:* Biodiversity and Globalization
VOL	102.2002	*Andreas LANGE*: Heterogeneous International Agreements – If per capita emission levels matter
ETA	103.2002	*Pierre-André JOUVET and Walid OUESLATI*: Tax Reform and Public Spending Trade-offs in an Endogenous Growth Model with Environmental Externality
ETA	104.2002	*Anna BOTTASSO and Alessandro SEMBENELLI*: Does Ownership Affect Firms' Efficiency? Panel Data Evidence on Italy
PRIV	105.2002	*Bernardo BORTOLOTTI, Frank DE JONG, Giovanna NICODANO and Ibolya SCHINDELE*: Privatization and Stock Market Liquidity
ETA	106.2002	*Haruo IMAI and Mayumi HORIE* (lviii): Pre-Negotiation for an International Emission Reduction Game
PRIV	107.2002	*Sudeshna GHOSH BANERJEE and Michael C. MUNGER*: Move to Markets? An Empirical Analysis of Privatisation in Developing Countries
PRIV	108.2002	*Guillaume GIRMENS and Michel GUILLARD*: Privatization and Investment: Crowding-Out Effect vs Financial Diversification
PRIV	109.2002	*Alberto CHONG and Florencio LÓPEZ-DE-SILANES*: Privatization and Labor Force Restructuring Around the World
PRIV	110.2002	*Nandini GUPTA*: Partial Privatization and Firm Performance
PRIV	111.2002	*François DEGEORGE, Dirk JENTER, Alberto MOEL and Peter TUFANO*: Selling Company Shares to Reluctant Employees: France Telecom's Experience

PRIV	112.2002	*Isaac OTCHERE*: Intra-Industry Effects of Privatization Announcements: Evidence from Developed and Developing Countries
PRIV	113.2002	*Yannis KATSOULAKOS and Elissavet LIKOYANNI*: Fiscal and Other Macroeconomic Effects of Privatization
PRIV	114.2002	*Guillaume GIRMENS:* Privatization, International Asset Trade and Financial Markets
PRIV	115.2002	*D. Teja FLOTHO:* A Note on Consumption Correlations and European Financial Integration
PRIV	116.2002	*Ibolya SCHINDELE and Enrico C. PEROTTI*: Pricing Initial Public Offerings in Premature Capital Markets: The Case of Hungary
PRIV	1.2003	*Gabriella CHIESA and Giovanna NICODANO*: Privatization and Financial Market Development: Theoretical Issues
PRIV	2.2003	*Ibolya SCHINDELE*: Theory of Privatization in Eastern Europe: Literature Review
PRIV	3.2003	*Wietze LISE, Claudia KEMFERT and Richard S.J. TOL*: Strategic Action in the Liberalised German Electricity Market
CLIM	4.2003	*Laura MARSILIANI and Thomas I. RENSTRÖM*: Environmental Policy and Capital Movements: The Role of Government Commitment
KNOW	5.2003	*Reyer GERLAGH*: Induced Technological Change under Technological Competition
ETA	6.2003	*Efrem CASTELNUOVO*: Squeezing the Interest Rate Smoothing Weight with a Hybrid Expectations Model
SIEV	7.2003	*Anna ALBERINI, Alberto LONGO, Stefania TONIN, Francesco TROMBETTA and Margherita TURVANI:* The Role of Liability, Regulation and Economic Incentives in Brownfield Remediation and Redevelopment: Evidence from Surveys of Developers
NRM	8.2003	*Elissaios PAPYRAKIS and Reyer GERLAGH*: Natural Resources: A Blessing or a Curse?
CLIM	9.2003	*A. CAPARRÓS, J.-C. PEREAU and T. TAZDAÏT*: North-South Climate Change Negotiations: a Sequential Game with Asymmetric Information
KNOW	10.2003	*Giorgio BRUNELLO and Daniele CHECCHI*: School Quality and Family Background in Italy
CLIM	11.2003	*Efrem CASTELNUOVO and Marzio GALEOTTI*: Learning By Doing vs Learning By Researching in a Model of Climate Change Policy Analysis
KNOW	12.2003	*Carole MAIGNAN, Gianmarco OTTAVIANO and Dino PINELLI (eds.)*: Economic Growth, Innovation, Cultural Diversity: What are we all talking about? A critical survey of the state-of-the-art
KNOW	13.2003	*Carole MAIGNAN, Gianmarco OTTAVIANO, Dino PINELLI and Francesco RULLANI* (lix): Bio-Ecological Diversity vs. Socio-Economic Diversity. A Comparison of Existing Measures
KNOW	14.2003	*Maddy JANSSENS and Chris STEYAERT* (lix): Theories of Diversity within Organisation Studies: Debates and Future Trajectories
KNOW	15.2003	*Tuzin BAYCAN LEVENT, Enno MASUREL and Peter NIJKAMP* (lix): Diversity in Entrepreneurship: Ethnic and Female Roles in Urban Economic Life
KNOW	16.2003	*Alexandra BITUSIKOVA* (lix): Post-Communist City on its Way from Grey to Colourful: The Case Study from Slovakia
KNOW	17.2003	*Billy E. VAUGHN and Katarina MLEKOV* (lix): A Stage Model of Developing an Inclusive Community
KNOW	18.2003	*Selma van LONDEN and Arie de RUIJTER* (lix): Managing Diversity in a Glocalizing World
Coalition Theory Network	19.2003	*Sergio CURRARINI:* On the Stability of Hierarchies in Games with Externalities
PRIV	20.2003	*Giacomo CALZOLARI and Alessandro PAVAN* (lx): Monopoly with Resale
PRIV	21.2003	*Claudio MEZZETTI* (lx): Auction Design with Interdependent Valuations: The Generalized Revelation Principle, Efficiency, Full Surplus Extraction and Information Acquisition
PRIV	22.2003	*Marco LiCalzi and Alessandro PAVAN* (lx): Tilting the Supply Schedule to Enhance Competition in Uniform-Price Auctions
PRIV	23.2003	*David ETTINGER* (lx): Bidding among Friends and Enemies
PRIV	24.2003	*Hannu VARTIAINEN* (lx): Auction Design without Commitment
PRIV	25.2003	*Matti KELOHARJU, Kjell G. NYBORG and Kristian RYDQVIST* (lx): Strategic Behavior and Underpricing in Uniform Price Auctions: Evidence from Finnish Treasury Auctions
PRIV	26.2003	*Christine A. PARLOUR and Uday RAJAN* (lx): Rationing in IPOs
PRIV	27.2003	*Kjell G. NYBORG and Ilya A. STREBULAEV* (lx): Multiple Unit Auctions and Short Squeezes
PRIV	28.2003	*Anders LUNANDER and Jan-Eric NILSSON* (lx): Taking the Lab to the Field: Experimental Tests of Alternative Mechanisms to Procure Multiple Contracts
PRIV	29.2003	*TangaMcDANIEL and Karsten NEUHOFF* (lx): Use of Long-term Auctions for Network Investment
PRIV	30.2003	*Emiel MAASLAND and Sander ONDERSTAL* (lx): Auctions with Financial Externalities
ETA	31.2003	*Michael FINUS and Bianca RUNDSHAGEN:* A Non-cooperative Foundation of Core-Stability in Positive Externality NTU-Coalition Games
KNOW	32.2003	*Michele MORETTO*: Competition and Irreversible Investments under Uncertainty
PRIV	33.2003	*Philippe QUIRION:* Relative Quotas: Correct Answer to Uncertainty or Case of Regulatory Capture?
KNOW	34.2003	*Giuseppe MEDA, Claudio PIGA and Donald SIEGEL*: On the Relationship between R&D and Productivity: A Treatment Effect Analysis
ETA	35.2003	*Alessandra DEL BOCA, Marzio GALEOTTI and Paola ROTA:* Non-convexities in the Adjustment of Different Capital Inputs: A Firm-level Investigation

GG	36.2003	*Matthieu GLACHANT*: Voluntary Agreements under Endogenous Legislative Threats
PRIV	37.2003	*Narjess BOUBAKRI, Jean-Claude COSSET and Omrane GUEDHAMI*: Postprivatization Corporate Governance: the Role of Ownership Structure and Investor Protection
CLIM	38.2003	*Rolf GOLOMBEK and Michael HOEL*: Climate Policy under Technology Spillovers
KNOW	39.2003	*Slim BEN YOUSSEF*: Transboundary Pollution, R&D Spillovers and International Trade
CTN	40.2003	*Carlo CARRARO and Carmen MARCHIORI*: Endogenous Strategic Issue Linkage in International Negotiations
KNOW	41.2003	*Sonia OREFFICE*: Abortion and Female Power in the Household: Evidence from Labor Supply
KNOW	42.2003	*Timo GOESCHL and Timothy SWANSON*: On Biology and Technology: The Economics of Managing Biotechnologies
ETA	43.2003	*Giorgio BUSETTI and Matteo MANERA*: STAR-GARCH Models for Stock Market Interactions in the Pacific Basin Region, Japan and US
CLIM	44.2003	*Katrin MILLOCK and Céline NAUGES*: The French Tax on Air Pollution: Some Preliminary Results on its Effectiveness
PRIV	45.2003	*Bernardo BORTOLOTTI and Paolo PINOTTI*: The Political Economy of Privatization
SIEV	46.2003	*Elbert DIJKGRAAF and Herman R.J. VOLLEBERGH*: Burn or Bury? A Social Cost Comparison of Final Waste Disposal Methods
ETA	47.2003	*Jens HORBACH*: Employment and Innovations in the Environmental Sector: Determinants and Econometrical Results for Germany
CLIM	48.2003	*Lori SNYDER, Nolan MILLER and Robert STAVINS:* The Effects of Environmental Regulation on Technology Diffusion: The Case of Chlorine Manufacturing
CLIM	49.2003	*Lori SNYDER, Robert STAVINS and Alexander F. WAGNER*: Private Options to Use Public Goods. Exploiting Revealed Preferences to Estimate Environmental Benefits
CTN	50.2003	*László Á. KÓCZY and Luc LAUWERS* (lxi): The Minimal Dominant Set is a Non-Empty Core-Extension
CTN	51.2003	*Matthew O. JACKSON* (lxi)*:*Allocation Rules for Network Games
CTN	52.2003	*Ana MAULEON and Vincent VANNETELBOSCH* (lxi): Farsightedness and Cautiousness in Coalition Formation
CTN	53.2003	*Fernando VEGA-REDONDO* (lxi): Building Up Social Capital in a Changing World: a network approach
CTN	54.2003	*Matthew HAAG and Roger LAGUNOFF* (lxi): On the Size and Structure of Group Cooperation
CTN	55.2003	*Taiji FURUSAWA and Hideo KONISHI* (lxi): Free Trade Networks
CTN	56.2003	*Halis Murat YILDIZ* (lxi): National Versus International Mergers and Trade Liberalization
CTN	57.2003	*Santiago RUBIO and Alistair ULPH* (lxi): An Infinite-Horizon Model of Dynamic Membership of International Environmental Agreements
KNOW	58.2003	*Carole MAIGNAN, Dino PINELLI and Gianmarco I.P. OTTAVIANO*: ICT, Clusters and Regional Cohesion: A Summary of Theoretical and Empirical Research
KNOW	59.2003	*Giorgio BELLETTINI and Gianmarco I.P. OTTAVIANO:* Special Interests and Technological Change
ETA	60.2003	*Ronnie SCHÖB:* The Double Dividend Hypothesis of Environmental Taxes: A Survey
CLIM	61.2003	*Michael FINUS, Ekko van IERLAND and Robert DELLINK*: Stability of Climate Coalitions in a Cartel Formation Game
GG	62.2003	*Michael FINUS and Bianca RUNDSHAGEN*: How the Rules of Coalition Formation Affect Stability of International Environmental Agreements
SIEV	63.2003	*Alberto PETRUCCI:* Taxing Land Rent in an Open Economy
CLIM	64.2003	*Joseph E. ALDY, Scott BARRETT and Robert N. STAVINS*: Thirteen Plus One: A Comparison of Global Climate Policy Architectures
SIEV	65.2003	*Edi DEFRANCESCO*: The Beginning of Organic Fish Farming in Italy
SIEV	66.2003	*Klaus CONRAD*: Price Competition and Product Differentiation when Consumers Care for the Environment
SIEV	67.2003	*Paulo A.L.D. NUNES, Luca ROSSETTO, Arianne DE BLAEIJ*: Monetary Value Assessment of Clam Fishing Management Practices in the Venice Lagoon: Results from a Stated Choice Exercise
CLIM	68.2003	*ZhongXiang ZHANG:* Open Trade with the U.S. Without Compromising Canada's Ability to Comply with its Kyoto Target
KNOW	69.2003	*David FRANTZ* (lix): Lorenzo Market between Diversity and Mutation
KNOW	70.2003	*Ercole SORI* (lix): Mapping Diversity in Social History
KNOW	71.2003	*Ljiljana DERU SIMIC* (lxii): What is Specific about Art/Cultural Projects?
KNOW	72.2003	*Natalya V. TARANOVA* (lxii):The Role of the City in Fostering Intergroup Communication in a Multicultural Environment: Saint-Petersburg's Case
KNOW	73.2003	*Kristine CRANE* (lxii)*:* The City as an Arena for the Expression of Multiple Identities in the Age of Globalisation and Migration
KNOW	74.2003	*Kazuma MATOBA* (lxii): Glocal Dialogue- Transformation through Transcultural Communication
KNOW	75.2003	*Catarina REIS OLIVEIRA* (lxii): Immigrants' Entrepreneurial Opportunities: The Case of the Chinese in Portugal
KNOW	76.2003	*Sandra WALLMAN* (lxii): The Diversity of Diversity - towards a typology of urban systems

KNOW	77.2003	*Richard PEARCE* (lxii): A Biologist's View of Individual Cultural Identity for the Study of Cities
KNOW	78.2003	*Vincent MERK* (lxii): Communication Across Cultures: from Cultural Awareness to Reconciliation of the Dilemmas
KNOW	79.2003	*Giorgio BELLETTINI, Carlotta BERTI CERONI and Gianmarco I.P.OTTAVIANO*: Child Labor and Resistance to Change
ETA	80.2003	*Michele MORETTO, Paolo M. PANTEGHINI and Carlo SCARPA*: Investment Size and Firm's Value under Profit Sharing Regulation
IEM	81.2003	*Alessandro LANZA, Matteo MANERA and Massimo GIOVANNINI:* Oil and Product Dynamics in International Petroleum Markets
CLIM	82.2003	*Y. Hossein FARZIN and Jinhua ZHAO*: Pollution Abatement Investment When Firms Lobby Against Environmental Regulation
CLIM	83.2003	*Giuseppe DI VITA*: Is the Discount Rate Relevant in Explaining the Environmental Kuznets Curve?
CLIM	84.2003	*Reyer GERLAGH and Wietze LISE*: Induced Technological Change Under Carbon Taxes
NRM	85.2003	*Rinaldo BRAU, Alessandro LANZA and Francesco PIGLIARU*: How Fast are the Tourism Countries Growing? The cross-country evidence
KNOW	86.2003	*Elena BELLINI, Gianmarco I.P. OTTAVIANO and Dino PINELLI:* The ICT Revolution: opportunities and risks for the Mezzogiorno
SIEV	87.2003	*Lucas BRETSCGHER and Sjak SMULDERS:* Sustainability and Substitution of Exhaustible Natural Resources. How resource prices affect long-term R&D investments
CLIM	88.2003	*Johan EYCKMANS and Michael FINUS:* New Roads to International Environmental Agreements: The Case of Global Warming
CLIM	89.2003	*Marzio GALEOTTI:* Economic Development and Environmental Protection
CLIM	90.2003	*Marzio GALEOTTI*: Environment and Economic Growth: Is Technical Change the Key to Decoupling?
CLIM	91.2003	*Marzio GALEOTTI and Barbara BUCHNER*: Climate Policy and Economic Growth in Developing Countries
IEM	92.2003	*A. MARKANDYA, A. GOLUB and E. STRUKOVA*: The Influence of Climate Change Considerations on Energy Policy: The Case of Russia
ETA	93.2003	*Andrea BELTRATTI*: Socially Responsible Investment in General Equilibrium
CTN	94.2003	*Parkash CHANDER*: The γ-Core and Coalition Formation
IEM	95.2003	*Matteo MANERA and Angelo MARZULLO*: Modelling the Load Curve of Aggregate Electricity Consumption Using Principal Components
IEM	96.2003	*Alessandro LANZA, Matteo MANERA, Margherita GRASSO and Massimo GIOVANNINI:* Long-run Models of Oil Stock Prices
CTN	97.2003	*Steven J. BRAMS, Michael A. JONES, and D. Marc KILGOUR:* Forming Stable Coalitions: The Process Matters
KNOW	98.2003	*John CROWLEY, Marie-Cecile NAVES* (lxiii): Anti-Racist Policies in France. From Ideological and Historical Schemes to Socio-Political Realities
KNOW	99.2003	*Richard THOMPSON FORD* (lxiii): Cultural Rights and Civic Virtue
KNOW	100.2003	*Alaknanda PATEL* (lxiii): Cultural Diversity and Conflict in Multicultural Cities
KNOW	101.2003	*David MAY* (lxiii): The Struggle of Becoming Established in a Deprived Inner-City Neighbourhood
KNOW	102.2003	*Sébastien ARCAND, Danielle JUTEAU, Sirma BILGE, and Francine LEMIRE* (lxiii) : Municipal Reform on the Island of Montreal: Tensions Between Two Majority Groups in a Multicultural City
CLIM	103.2003	*Barbara BUCHNER and Carlo CARRARO:* China and the Evolution of the Present Climate Regime
	1000	**Carlo CARRARO, Alessandro LANZA and Valeria PAPPONETTI: One Thousand Working Papers**

(l) This paper was presented at the Workshop "Growth, Environmental Policies and Sustainability" organised by the Fondazione Eni Enrico Mattei, Venice, June 1, 2001
(li) This paper was presented at the Fourth Toulouse Conference on Environment and Resource Economics on "Property Rights, Institutions and Management of Environmental and Natural Resources", organised by Fondazione Eni Enrico Mattei, IDEI and INRA and sponsored by MATE, Toulouse, May 3-4, 2001
(lii) This paper was presented at the International Conference on "Economic Valuation of Environmental Goods", organised by Fondazione Eni Enrico Mattei in cooperation with CORILA, Venice, May 11, 2001
(liii) This paper was circulated at the International Conference on "Climate Policy – Do We Need a New Approach?", jointly organised by Fondazione Eni Enrico Mattei, Stanford University and Venice International University, Isola di San Servolo, Venice, September 6-8, 2001
(liv) This paper was presented at the Seventh Meeting of the Coalition Theory Network organised by the Fondazione Eni Enrico Mattei and the CORE, Université Catholique de Louvain, Venice, Italy, January 11-12, 2002
(lv) This paper was presented at the First Workshop of the Concerted Action on Tradable Emission Permits (CATEP) organised by the Fondazione Eni Enrico Mattei, Venice, Italy, December 3-4, 2001
(lvi) This paper was presented at the ESF EURESCO Conference on Environmental Policy in a Global Economy "The International Dimension of Environmental Policy", organised with the collaboration of the Fondazione Eni Enrico Mattei , Acquafredda di Maratea, October 6-11, 2001
(lvii) This paper was presented at the First Workshop of "CFEWE – Carbon Flows between Eastern and Western Europe", organised by the Fondazione Eni Enrico Mattei and Zentrum fur Europaische Integrationsforschung (ZEI), Milan, July 5-6, 2001
(lviii) This paper was presented at the Workshop on "Game Practice and the Environment", jointly organised by Università del Piemonte Orientale and Fondazione Eni Enrico Mattei, Alessandria, April 12-13, 2002
(lix) This paper was presented at the ENGIME Workshop on "Mapping Diversity", Leuven, May 16-17, 2002
(lx) This paper was presented at the EuroConference on "Auctions and Market Design: Theory, Evidence and Applications", organised by the Fondazione Eni Enrico Mattei, Milan, September 26-28, 2002
(lxi) This paper was presented at the Eighth Meeting of the Coalition Theory Network organised by the GREQAM, Aix-en-Provence, France, January 24-25, 2003
(lxii) This paper was presented at the ENGIME Workshop on "Communication across Cultures in Multicultural Cities", The Hague, November 7-8, 2002
(lxiii) This paper was presented at the ENGIME Workshop on "Social dynamics and conflicts in multicultural cities", Milan, March 20-21, 2003

2002 SERIES

CLIM	*Climate Change Modelling and Policy* (Editor: Marzio Galeotti)
VOL	*Voluntary and International Agreements* (Editor: Carlo Carraro)
SUST	*Sustainability Indicators and Environmental Valuation* (Editor: Carlo Carraro)
NRM	*Natural Resources Management* (Editor: Carlo Giupponi)
KNOW	*Knowledge, Technology, Human Capital* (Editor: Dino Pinelli)
MGMT	*Corporate Sustainable Management* (Editor: Andrea Marsanich)
PRIV	*Privatisation, Regulation, Antitrust* (Editor: Bernardo Bortolotti)
ETA	*Economic Theory and Applications* (Editor: Carlo Carraro)

2003 SERIES

CLIM	*Climate Change Modelling and Policy* (Editor: Marzio Galeotti)
GG	*Global Governance* (Editor: Carlo Carraro)
SIEV	*Sustainability Indicators and Environmental Valuation* (Editor: Anna Alberini)
NRM	*Natural Resources Management* (Editor: Carlo Giupponi)
KNOW	*Knowledge, Technology, Human Capital* (Editor: Gianmarco Ottaviano)
IEM	*International Energy Markets* (Editor: Anil Markandya)
CSRM	*Corporate Social Responsibility and Management* (Editor: Sabina Ratti)
PRIV	*Privatisation, Regulation, Antitrust* (Editor: Bernardo Bortolotti)
ETA	*Economic Theory and Applications* (Editor: Carlo Carraro)
CTN	*Coalition Theory Network*