Chapter 11

Equity and Efficiency in Emission Markets: The Case for an International Bank for Environmental Settlements

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11.1 Introduction

Global institutions created after World War II—the World Bank, the International Monetary Fund (IMF), and the General Agreement on Tariffs and Trade (GATT)[1]—led the world into an unprecedented period of industrialization, material expansion, and global commerce. Called the Bretton Woods institutions, they emerged from the premise that trade and economic growth could help defuse international conflicts and accelerate the reconstruction after the

The proposal for the International Bank for Environmental Settlements (IBES) was officially presented at the May 1994 Workshop on Joint Implementation organized with the support of the Global Environmental Facility (GEF) and the Framework Convention on Climate Change (FCCC) at Columbia University, in various FCCC meetings and at an invited address to the annual meetings of the World Bank in December 1995, see also Chichilnisky [4]. In the preparation of this proposal, I have benefited from the discussions of several members of the Intergovernmental Negotiating Committee (INC) of the FCCC, who provided important insights: Minister Raúl Estrada-Oyuela, chair of the INC/FCCC; H. E. Ismail Razali, ambassador, permanent mission of the Malaysian to the United Nations; Mr. Xialong Wang, third secretary, Chinese permanent mission to the United Nations; Mr. James Baba, deputy permanent representative of Uganda to the United Nations; and Dr. John Ashe, counsellor, permanent mission of Antigua and Barbuda to the United Nations. In addition to emissions trading, the proposal included the creation of an IBES, which could help reconcile efficiency and equity in emissions markets; the two key features are deeply connected in these type of markets, as shown in this chapter. This chapter originally was presented at a workshop organized by New York Law School at the Villa La Pietra in Florence in the summer of 1996. I thank the participants of the workshop, especially Richard Stewart, Stephen Breyer, and Richard Ravel, for valuable comments and suggestions.

[1] Among others. GATT is now the World Trade Organization (WTO).

devastations of war.[2] Under the aegis of these institutions, economic growth led to record industrial expansion and resulted in an ever-increasing use of energy and natural resources. At the end of this 50-year period, we face global environmental challenges that originate from the success of industrialization itself: For the first time in history, economic activity has reached levels at which it can alter[3] the atmosphere of the planet and the complex web of species that constitute life on earth. Humans have the ability to destroy in a few years the massive infrastructure that supports the survival of the human species, the global habitat to which humans have adapted optimally throughout the ages. Industrial societies' intensive use of the earth's resources is reaching its logical limits and is now under close scrutiny.

An international body, the UN Framework Convention on Climate Change (FCCC), is responsible for negotiating a response to the problems created by the rapidly increasing emission of greenhouse gases into the planet's atmosphere. Two aspects that play an important role in the climate negotiations are *efficiency* and *equity* in the use of the world's resources. Efficiency is crucial in a period in which we seek to reduce the use of resources, as adopting efficient measures can by itself lessen resource use without negative consequences. However, fairness is also key, as many of the environmental issues considered in the global negotiations (the rights to use the planet's atmosphere and the world's biodiversity) involve the use of global *public goods* and require international negotiations in which fairness plays an important role. There is no agreed way to reach a fair allocation in the use of the world's resources, yet without one it is difficult to visualize solutions that are both politically feasible and stable in the long run.

This chapter looks at the issues of equity and efficiency in the allocation of environmental resources and examines the global institutions that may be needed to implement solutions that are both equitable and efficient. It starts from the premise that environmental markets will play an important role in the allocation of environmental resources. Such markets already exist in some countries, for example, those to trade the rights to emit sulfur dioxide (SO_2) in the Chicago Board of Trade. Others are being created, such as water markets and the carbon dioxide (CO_2) markets provided by the Kyoto Protocol for the trading of carbon emission rights among Annex B nations. Carbon emission markets are based on the limitations on emissions for Annex B countries

[2]See G. Chichilnisky, "The Greening of Bretton Woods," *The Financial Times,* January 10, 1996, Business and Environmental Section, and C. Bernandes, "Environmental Assets and Derivatives," *Derivatives Week* 5, no. 22 (June 3, 1996).

[3]In many cases irreversibly.

agreed in the Kyoto Protocol and require specific developments before they can be implemented. Prior results in Chichilnisky, Heal, and Starrett [13] and chapter 3 of this book (hereafter referred to as the CHS chapter) show that traditional market approaches might not ensure efficiency. The CHS chapter proposes a global mechanism or institution to overcome this shortcoming, one that has sensitivities where the Bretton Woods institutions fell short. Called an International Bank for Environmental Settlements (IBES), the mechanism proposed could be stand-alone or part of other global institutions. Its overall role would be to offer financial incentives for economic progress that is harmonious with environmental conservation.[4] How the IBES could work in practice is the concern here.

The proposal for an IBES arises from the need to overcome the shortcomings of traditional markets in the environmental area: These do not ensure efficiency. The shortcomings arise from a somewhat unexpected connection between efficiency and the initial allocation of property rights in environmental markets, a connection that is not present in standard markets (see Chichilnisky, Heal, and Starrett [13] and the CHS chapter). Building on this connection, the present chapter goes further to show in the Appendix that in certain cases market efficiency requires a preferential treatment for lower-income groups. Here a new concept is introduced: the "manifold of efficient distributions of property rights," which is the set of initial allocations of rights from which the competitive market can achieve efficient solutions.

A preferential treatment of lower-income nations would give these countries proportionately more rights of use of the atmosphere as a global public good. It would in effect require that the first countries to abate carbon emissions should be the industrial nations. These were the same conclusions obtained theoretically in Chichilnisky [19] and Chichilnisky and Heal [10] and later accepted by 166 nations in the 1997 Conference of the Parties 3 (COP3) and the resulting Kyoto Protocol, which was recently signed by the United States. More recently, the conclusions were endorsed in the COP4 in Buenos Aires in November 1998. In all cases the commitments to abate carbon emissions are from the industrial nations (Annex B countries): a 5.2% decrease by the period 2008–12, representing a 30% drop from current projections. The Appendix offers further theoretical and empirical support for the desirability of this outcome.

It might be useful to point out that the economic principles discussed here apply to other environmental assets, such as biodiversity, water, soil, and for-

[4] See Chichilnisky [14].

ests. However, the examples and data provided in this chapter concentrate on the use of the atmosphere in the emission of greenhouse gases, mostly derived from the burning of fossil fuels—coal and petroleum—to generate energy. The Appendix provides runs of the GREEN/PIR global model that is different from that in the CHS chapter because it does not incorporate environmental quality in the utility function. Yet even in the GREEN/PIR model it can be seen that the runs that assign more rights to emit to lower-income nations have somewhat lower costs of meeting the emission reduction targets. A possible explanation is provided in the historical data analyzed in the Appendix: On average a dollar invested in developing nations has a higher return that the same dollar invested in industrial nations. To the extent that abating emissions leads to lower investment, for efficiency abatement should initiate in the industrial nations, as doing this minimizes the negative effect of a drop in investment. Theoretical results supporting these conclusions appear also, within a different model, in Chichilnisky [19] and Chichilnisky and Heal [11].

The overall role of the IBES must be seen in the context of promoting a new form of economic development that contrasts with the resource-intensive policies followed by the Bretton Woods institutions. The imperative suggesting a real change in the use of resources appears clear enough. There is in addition a global economic trend that could ease the transition to a society that is more conservative in the use of resources: Industrial society is in the process of transforming itself into a knowledge society. This transformation, which has been called the "knowledge revolution"[5] is acquiring a global reach. The new economy that emerges is not a service economy as previously thought, as it involves mostly highly skilled labor. Through this ongoing transformation humans could achieve a new form of economic organization in which the most important input of production is no longer machines but human knowledge. Instead of burning fossil fuels to power machines, we could burn information to power knowledge. Information is a much cleaner fuel than coal or petroleum and can put humans rather than machines at the center of economic progress, leading to a knowledge-intensive rather than a resource-intensive form of growth.

11.1.1 IBES: A Two-Sided Coin to Overcome the North-South Divide — This chapter seeks to explain why a new mechanism or institution (IBES) might be required to complement the Bretton Woods institutions, how this

[5] A concept introduced and studied in Chichilnisky [5,6,8]; the expression itself is a trademark of the author.

would work in practice, and why its role would complement environmental markets but go further than anything that unaided markets can achieve. The global financial mechanism proposed here would exceed that of a standard market for trading emission rights. A standard market—for example, a stock market—trades private goods, and when private goods are traded, competitive markets are efficient independently of the allocation of property rights. However when *public goods* are traded, competitive markets might not reach efficient outcomes without an appropriate distribution of initial user rights, which are also called property rights (CHS chapter). The *manifold of user rights* from which efficient allocations could be reached is defined in the Appendix; it shows that in certain cases lower-income regions should be assigned a larger share of the use of the global commons in order to reach efficiency. Within the global climate negotiations, this means that developing countries should be assigned proportionately more user rights on global environmental assets, such as the planet's atmosphere, to ensure efficient market solutions. From these findings it follows that new global institutions, such as the proposed IBES, would be needed to complement the Bretton Woods institutions in order to implement global emissions markets and ensure their efficiency. For example, the IBES could help to negotiate global user rights or a basic borrowing and lending rate[6] or to help to establish property rights.[7]

The IBES would be like a two-sided coin, in that it would combine market-based instruments with political mechanisms. The latter would involve political representation and would give all nations effective participation, providing a continuous role of the type that the FCCC plays today in yearly meetings. This type of participation is more congenial to developing nations that are not comfortable with financial markets. For industrial countries, the situation is reversed. The United States has advocated market-based solutions, and the European Community might be following suit. By combining the two distinct elements, the "two sides of the coin," namely, markets and political participation, the IBES could offer a solution that meets the objectives of the two groups of countries.

The following sections explain the background of the climate negotiations in which the proposal of the chapter emerges and how the IBES can help meet the needs of the various nations in the negotiations.

[6] As the Federal Reserve does in the United States.

[7] As done by the Federal Communications Commission in Washington, D.C., with the help of auctions of the airwaves.

11.2 Background of the Climate Negotiations: Rio, Berlin, Geneva, Kyoto, and Buenos Aires

11.2.1 The Global Environment — The 1992 Earth Summit in Rio de Janeiro emerged from widespread concern with ozone depletion, biodiversity destruction, and global climate change. One hundred nations met at the Earth Summit to consider reducing the threat of global warming by rolling back emissions of greenhouse gases in the industrialized countries to 1990 levels by the year 2000. The summit emphasized the importance of achieving sustainable development. For this purpose UN Agenda 21, adopted in 1992 by 150 nations, has, as an explicit objective to achieve patterns of consumption oriented toward the satisfaction of *basic needs.*[8]

Despite the interest generated by the Rio Summit, the implementation of its goals has been slow. Part of the problem is scientific uncertainty about the impact of greenhouse gases on the atmosphere. However, science increasingly supports the view that human activity is causing climate change;[9] therefore, this justification for inertia is being removed.

A second and more difficult factor hindering the negotiations is the divergence in the perception of the problem in industrialized and developing countries. Most carbon emissions have originated, and continue to originate, from the industrial countries.[10] Many developing countries take the position that only changes to this pattern can have an impact on the problem, whereas many industrialized countries see the biggest threat in the harm that developing countries can do in the future.[11]

11.2.2 Rio Targets and the Berlin Mandate — After Rio the next most important international meeting on climate change was the Berlin Conference of

[8]The concept of *development oriented toward the satisfaction of basic needs* was introduced theoretically and developed empirically by the author in 1977 (Chichilnisky [1] and [2]) in the context of studies of sustainable development in five continents. Following this, the Brundlant Report's definition of sustainable development is also anchored to *basic needs:* "sustainable development satisfies the needs of the present without compromising the needs of the future" (Chichilnisky [5], chap. 2, para. 1).

[9]See the report of the 1996 Intergovernmental Panel on Climate Change (IPCC), which states that there is a "discernable" effect of human activity in the concentration of CO_2 in the atmosphere and the world's climate.

[10]For CO_2, the most important greenhouse gas, the breakdown is as follows: 60% to 70% of all emissions originate from industrial nations currently and about 70% historically, even though industrial countries contain about 20% of the world's population.

[11]Indeed, the 60% reduction that scientists believe might be required to have a substantial effect in lowering the risks of climate change can come only from decreasing the industrial nations' emissions. All developing nations together add up to only about 30% of emissions, and therefore nothing within their power could decrease emissions as required.

the Parties. It concluded on April 7, 1995, by adopting a call for action. It found that the Rio articles were not adequate. A mandate adopted in Berlin—the *Berlin Mandate*—required the negotiation of an emissions-reduction protocol to set hard, quantified limitations on the greenhouse gas emissions in 2005, 2010, and 2020. Another major decision in Berlin was to establish a pilot phase for *joint implementation,* a way in which two nations can cooperate in achieving a reduction in emissions.[12]

Many developing countries have seen joint implementation as a mechanism for transferring responsibility for emissions reduction away from the countries that account for most of the emissions of the planet: the industrialized countries. In addition, because joint implementation is a bilateral process, it can miss many of the opportunities available in multilateral markets and could lead a powerful industrial nation to take advantage of a smaller and less powerful nation in the terms of trade, missing the desirable equal treatment that prevails in competitive markets. To address these concerns the FCCC decided that industrialized countries may not take credit for any reduction of their emissions during the pilot phase, toward their commitments at this stage of the negotiation to reach 1990-level emissions reduction by 2000.

11.2.3 Geneva, Kyoto, and Buenos Aires — Following Berlin, COP2 of the FCCC met in Geneva in July 1996. In the meeting the United States adopted a new position that supports for the first time the concerns of developing countries to establish hard targets for the greenhouse gas emissions by industrialized nations.

Taking a leading position, the Hon. Timothy Wirth, then undersecretary of global affairs of the United States,[13] advocated a market approach for the trading of rights to emit greenhouse gases among the industrialized nations—the approach originally proposed by this author to the UNFCCC earlier in 1994 and presented officially at the third annual World Bank Conference on Effective Financing for Sustainable Development in Washington, D.C., in October 1995. The United States' approach did not, however, go as far as recommending the creation of an international bank for environmental settlements (IBES), which is the natural next step, as argued here.

In December 1997 the COP3 in Kyoto took matters a great deal further. It reached for the first time an agreement for hard quotas from industrial nations[14]

[12]*Joint implementation* refers to one or more parties taking actions or financial actions in the territory of other parties, and it is seen as a prelude to emissions trading by a number of governments and observers.

[13]Currently president of the UN Foundation.

[14]Formally Annex B nations.

by which they will decrease their emissions by 5.2% by the period 2008–12, using as a baseline the level of emissions prevailing in 1990. In addition, the "Kyoto surprise" was an agreement memorialized in Article 12 for the creation of a Clean Development Mechanism (CDM), which incorporates explicitly both industrial and developing nations in a flexible way in the achievement of the Convention's goals. This agreement, still in an embryonic form, is reminiscent of a joint implementation provision that for the first time incorporates both groups of countries. The CDM emerged historically from a proposal advanced by Brazil suggesting the creation of a global development fund that would be capitalized by funds arising from the collection of fees applied to nonperforming abatement duties by developing countries in the context of this protocol. Finally, the Kyoto Protocol introduced Article 17, which is an embryonic agreement on the creation of emissions markets among the industrial nations.

In summary, the Kyoto Protocol limits industrial nations' emissions and provides three "flexibility" mechanisms to help achieve these limits: joint implementation, the CDM, and emissions trading. Of these, only the CDM incorporates both the industrial and the developing nations. The three mechanisms could, however, be linked in the future in innovative ways, together with the technology transfer issue that is crucial for breaking the link between carbon emissions and economic progress.[15] The financial mechanisms implicit in such linkages would be the natural sphere of the IBES. Indeed, Article 12 provides for the creation of an executive committee to monitor the execution of the CDM, which could be a natural overseeing body for the activities associated with the IBES. Following Kyoto, COP4 took place in Buenos Aires in 1998 in order to start the process of developing, completing, and refining what was achieved in Kyoto. Much work remains to be done, and despite the successful advances at Kyoto, the road ahead seems steep and hard.

A brief summary of the political issues involved in the climate negotiations might help explain where the main roadblocks are and how the proposals advanced here could help meet the concerns of the various parties.

11.2.4 Key North-South Issues in the Global Negotiations — Developing countries fear the imposition of limits to their growth in the form of emissions restrictions, on the use of their own resources, as well as unrealistic population targets. Because most environmental damage currently originates and originated historically in the industrialized countries, whose patterns of develop-

[15]Such connections were proposed by the author at the workshop "From Kyoto to Buenos Aires: Technology Transfer and Emissions Trading" with the participation of the major players in the global negotiations at the Italian Academy of Columbia University in April 1998.

ment are at the root of the environmental dilemmas we face today [9, 15], the developing countries have consistently required that the industrial countries take the lead in reducing emissions. To a certain extent the Kyoto Protocol has met this requirement, as its emission limits are placed solely on Annex B nations.

In the Buenos Aires COP4, November 2 to 14, 1998, China, India, and the OPEC countries played an important role in holding up the position of the developing nations. Within the group of developing nations, the members of the OPEC are especially concerned with the changes that the protocol decisions could precipitate in their export markets if petroleum prices increase. A similar position is taken by other resources-intensive exporters, such as Australia.[16] The island nations (Bangladesh, Indonesia, Marshall Islands, and Maldives) are an especially vulnerable group whose plight represents a challenge to humankind. Nothing has been done to address their concerns so far.

Industrialized countries have a different set of concerns. They fear excessive population growth in developing countries and the environmental damage that it could bring. While recognizing their historical responsibility for excessive environmental use, they focus on a long-term future in which global environmental problems could originate mostly in developing countries. The U.S. Senate and the House have voted not to implement any agreement that does not include a commitment on reducing emissions by the developing nations. The United States is the largest emitter (at present about 25% of all carbon emissions originate in the United States), and together with Japan it could block the ratification of the Kyoto Protocol. The North-South issue therefore has practical consequences for the global negotiations. Their success depends on resolving the North-South divide, a divide that has been present since the beginning of the negotiations.

The climate negotiations demonstrate the pivotal role of the developing nations in the process. Indeed the future of industrialization is in the hands of the developing nations. Because industrialization has led to the global environmental problems we have today, if the developing nations were to industrialize and retrace the steps of the industrial nations, the problems' severities would increase severalfold. Simultaneously, the Bretton Woods institutions have traditionally advocated resource-intensive development policies in the developing nations. The traditional style of development based on the intensive and extensive extraction of resources, which are exported and overconsumed in the industrial nations, has come to its logical end. It must be replaced by another

[16]The author gave invited presentations to the Group of 77 and to the OPEC nations providing the recommendations embodied in this article at a workshop organized by UNDP in UN headquarters in New York, September 2 and 3, 1998, and in OPEC headquarters in Vienna, October 28 to 29, respectively.

form of development, the aspiration for which has led to coin the phrases "sustainable development" or "clean industrialization." Here I refer to the knowledge revolution as it evolves and is transmitted throughout the world economy. At the level of the negotiations, however, we are still facing a North-South divide. The road ahead is long and steep. International agreements are customarily adopted by consensus. How to achieve this? It seems that the policies suggested here could set up a cooperative process for industrial and developing nations in the achievement of the goals of the Climate Convention. The following will explain why and how.

11.3 Win-Win Solutions

Implementing the Kyoto Protocol requires a substantial and concerted effort on the part of all parties to communicate and understand each other's concerns, to address in depth the problems and possible solutions, and to reach consensus. An updated understanding (developed here) of the economic aspects of the issues is valuable because it can foster that consensus. In developing consensus it helps to build from common interests. Whereas the main concerns are ecological and environmental, the main stumbling blocks in reaching solutions are economic. To abate carbon emissions means, in the short term, burning less fossil fuel and therefore producing less energy. This means less economics output. This leads to a natural question: Who should abate?[17]

Both industrialized and developing countries face significant abatement costs in the short run because current patterns of development are resource intensive and it is costly to change them. Although the outcome of the policy is uncertain because we know relatively little about the impact of human activity on the environment of the planet, the risks we face are nevertheless sufficient to make it compelling that precautionary steps be taken now.[18] How much is it worth paying to improve our environment, and who should pay? Here I discuss who should abate and why, the role of public goods in determining the outcome, and how to arrive at a cooperative solution that can help bring about consensus.

11.4 The Economics of Climate Change: How to Determine Emissions Limits?

A range of policies to limit emissions trading have been discussed in chapter 2 of this volume. This covers command-and-control instruments that establish

[17] See Chichilnisky and Heal [10].
[18] See Chichilnisky and Heal [9].

bounds on economic behavior, taxes, joint implementation, and markets for emissions permits. Chapter 2 also explains how markets with emissions trading work. The simplest form of emissions markets restrict total quantities emitted (as done by the Kyoto Protocol for Annex B countries) and allows countries the freedom to make choices about how to implement these limits and within these limits to trade quotas among themselves (Article 17). A country will buy permits if it wants to emit more than its quota and will sell them otherwise. Prices are flexible, determined by supply and demand.

As already pointed out, the implementation of the Rio targets and the Kyoto Protocol require a measure of consensus about the policy instruments to be used. These policy instruments are new: Emissions trading involves the trading of commitments to reduce emissions, which can be understood as trading "temporary rights" to emit. These instruments share a novel and unusual characteristic. Rights to use the atmosphere of the planet to emit CO_2 are rights to use a *public good:* the planet's atmosphere. As explained below, this unusual characteristic means that unaided markets to trade emissions permits cannot reach efficiency solutions and that backup institutions are needed for the trade in public goods.

Another new aspect of the environmental problem is that emissions, although producing a public good in the quality of the atmosphere, are not produced by governments as are the standard public goods such as law and order.[19] Every person on the planet emits greenhouse gases through driving a car, heating their homes, or producing energy by burning fossil fuels. Emissions markets are therefore markets to trade *privately produced public goods.* Such markets are quite different from standard markets. The allocation of rights to use privately produced public goods requires special attention.

Although the Kyoto Protocol has reached an agreement on limiting industrial countries' emissions such an agreement seems difficult to achieve with the developing nations without first reaching an understanding of what would be fair and efficient at the global level. The Kyoto Protocol limits the emission of Annex B countries, requiring a 5.2% reduction in their emissions by the period 2008–12. Under current patterns this means a reduction of about 30% from projected emissions. If developing nations would join this part of the protocol, how should their emission limits be decided? The general question is, Who should contribute most of the improvement of the atmosphere, to the recovery of the "global commons"? One answer often heard is that this should be the developing countries because they have lower abatement costs. This answer is

[19] In contrast with the classic case examined by Lindahl, Bowen, and Samuelson, the public good that interests us here is *privately produced.*

based on the belief that abatement of carbon emissions costs less in developing countries and that abatement carried out in developing countries would achieve the same goal in lower dollar terms and ensure efficiency. Is this argument valid? Only in markets with private goods. In markets for public goods, it is not the dollar value of the abatement that counts for efficiency but rather the opportunity cost of that dollar value in terms of the utility that it can provide. The point is that the same dollar provided brings about very different utility gains in a rich country than in a poor country. Marginal utility gains are what counts to determine efficiency. Chapter 7 in this volume establishes the point rigorously. Here I provide a simple example.

Suppose that abatement of an extra cost ton of carbon costs $1.00 of output in India and $2.00 in the United States. Abatement of an extra ton of carbon costs less in India. Who should abate? The real loss of utility from abatement in India can be much higher than in the United States because $1.00 of goods can have a major impact on the average citizen of India, whereas a $2.00 loss in the United States has only a marginal impact for the average citizen. The point is simple: The marginal utility of income decreases with income. The more income we have, the less our utility increases with the additional dollar. There is a separate but parallel argument from the supply side: Each dollar invested in developing nations leads on average to more production than a dollar invested in industrial countries (see the data in the Appendix) so that if abatement reduces investment, initially it should take place in industrial nations, for efficiency.

These matters do not count in economies with private goods because everyone chooses independently of one another and traders can adjust their consumption to equate the marginal gains they derive from the markets.[20] However, with privately produced public goods they do. In these cases the condition of equal marginal costs is not appropriate for efficiency.[21] It is appropriate only when all countries have the same marginal utility of income. In other words, only when (free) transfers are made between countries so as to equate their marginal valuations of private consumption does efficiency require that marginal abatement cost be equal. However, such transfers would be unrealistically large.[22] Therefore, in general, efficiency implies that abatement will come pro-

[20]Marginal rates of substitution must all be equal across markets and must equal the marginal rates of transformation in those markets.

[21]See Atkinson and Stiglitz in reference [1] of chapter 1 in this volume. The rule is typically that the sum of marginal rates of substitution equals the marginal rate of transformation when the government produces the public good. See Chichilnisky, Heal, and Starrett [13] for the case in which free international trade in permits is allowed. The answer is the same.

[22]Paid transfers, such as those that occur within international markets, need not equate the marginal utility of consumption across trading regions.

portionately more from those countries that have higher income because they have a lower marginal utility from increased consumption than poorer countries.[23] Under general conditions, the proportion of income dedicated to abatement should increase with the level of income. Therefore, an answer to the question "Who should abate?" should be: First of all, the industrialized countries.[24] This has been the position of the developing countries for many years. As reported previously, even the United States agreed with this position in Geneva in June 1996, and now the Kyoto Protocol signed in November 1998 by the United States makes implicitly the same point. The Kyoto Protocol provides only for abatement obligations on the part of the industrial nations.

Requiring abatement from developing countries first would be a regressive measure, like taxing the poor the most. There are other concerns about regressive measures. They can cause problems because environmental degradation and poverty are closely connected. Anything that worsens poverty is likely to lead to further environmental degradation and to increased rates of population growth.[25] For example, a policy that lowers the price of wood and therefore the income of harvesters can lead to more than less extraction of wood [16]. Because the purpose of taxing the price of wood is to discourage extraction of wood, by decreasing the income of the harvesters the tax could achieve the opposite effect from what is intended.[26]

Until now the issue of user's rights on the atmosphere has been left to the political arena, with the understanding that it involves exclusively a transfer of wealth between countries. An implicit assumption is that markets themselves function efficiently; the matter to be decided was the distribution. The two issues, efficiency and distribution, were seen as separate. The latter, distribution, was seen as a major political hurdle and a divisive issue that complicated matters and interfered with the development of consensus. Emissions trading has as its goal an efficient allocation of emissions within the global limit. However, in order to trade, one must know who owns what. This means that users' rights must be established: One must establish who has the rights to emit and how much. This is not necessary for taxes, but it is for markets.

Building on recent advances in the economics of climate change presented elsewhere in this book, the Appendix shows a somewhat unexpected source of common interest among industrialized and developing countries.[27] There is

[23] See Chichilnisky and Heal [10].

[24] See Chichilnisky and Heal [10].

[25] See, e.g., *World Development Report* [15], 1992.

[26] See Chichilnisky [16].

[27] See the Appendix, Chichilnisky [19], Chichilnisky and Heal [10], and Chichilnisky, Heal, and Starrett [13] and chapter 3.

a new role for distributional issues: The appropriate equitable distribution is needed for markets to function efficiently. Somewhat surprisingly, a measure of equity can lead to efficient allocation.

11.5 Win-Win Solutions in the Climate Negotiations

The somewhat unexpected link between the distribution of emission limits and overall efficiency established in the CHS chapter (3) and extended here presents an opportunity for advancing the climate negotiations: a source of common interest between industrialized and developing countries. Efficiency is often favored by industrial countries that have the most developed markets, whereas equity is an issue that concerns the developing countries most. It seem useful to explain intuitively how the connection between equity and efficiency arises in this context; for the formal results the reader is referred to prior work [28] and to chapters 2 and 3 and the Appendix.

Efficiency in a competitive market requires that the total amount emitted across the globe, which determines the quality of the atmosphere for all, be precisely the choice that individual traders themselves would make independently, given their other holding of private goods. The connection between distribution and efficient operation of the world economy stands in sharp contrast with the properties of markets for private goods. With private goods, no matter what the distribution of property rights, an efficient allocation is always reached by a competitive market. When markets trade private and public goods simultaneously, they achieve efficiency only when the initial conditions are such that the traders who own fewer private goods own more users' rights on the environment than the rest. Market efficiency requires a somewhat flexible but inverse relationship between property rights in private goods and property rights in public goods. In practice this means that industrialized countries, which have a much larger initial allocation of property rights on private goods, should initially be given relatively smaller endowments of property rights on public goods as a precondition for market efficiency. This unique property of markets with privately produced public goods is developed formally in the Appendix and leads us to the policy proposal of this chapter: the creation of an IBES.

11.6 IBES: A Self-Funding Mechanism?

In contemplating a new global financial institution, a natural question is how to fund it. The Bretton Woods institutions are funded by voluntary contribu-

[28] See Chichilnisky [19], Chichilnisky and Heal [10], and Chichilnisky, Heal, and Starrett [13].

tions from the rich countries that are collected from taxes raised in their territory. However, voluntary contributions have declined and seem more difficult to achieve in today's political climate; the continuing and escalating indebtedness of the United States with respect to its dues to the United Nations offers a good example. Using the same voluntary approach the Global Environment Facility (GEF) requires periodic replenishments of its fund in a difficult environment in which aid has fallen well below the amounts targeted by the United Nations.[29] Funding a new institution using existing voluntary mechanisms seems therefore unrealistic.

The recommendation I have proposed is the creation of global financial mechanisms that are self-financing. This might be possible in some cases and not in others; for example, humanitarian disaster aid cannot generally be self-financing, and it would be counterproductive to ignore this fact. However, in the environmental area several possibilities exist for self-funding mechanisms, for example, by developing financial instruments that use *as collateral the environmental assets of the planet.* This possibility emerges from the provisions of the Kyoto Protocol, which can be a basis for developing self-financing mechanisms that do not rely on taxation or voluntary contributions. Indeed the limits on emissions that it sets for Annex B countries create de facto a new store of economic value arising from the scarcity in the use of the atmosphere implied by the Kyoto Protocol's emission restrictions. Limits on emissions and the ability of trading unused credits as provided in Article 17 create a source of value that can be realized in environmental markets.

The type of institutions that we have in mind is crystallized in the IBES,[30] but the type of solutions can take many forms and are not restricted to the creation of a single institution. Global environmental assets include the world's forests and bodies of water, its minerals, and biodiversity. These include some of the most valuable resources known to humankind, on which depends our ability to survive. Yet today most forests in developing nations (such as Ecuador and Brazil) are destroyed to produce minerals and agricultural products for sale in the international market. The right financial mechanisms are needed to realize their value without destroying them. An analogy is provided by traditional mortgages, in which assets (such as buildings) serve as collateral for obtaining financial value from the asset (the building) without destroying the asset itself. Without mortgages the only way to obtain value from a building might be to break its walls and sell the bricks one by one in the market. This is

[29]Overseas development assistance (ODA) was targeted at 0.7% gross domestic product (GDP) of the industrial countries, but it is close to one-third of that target at present.

[30]Chichilnisky [14].

possible, but it is not economically desirable: Little money would be obtained, as the value of the building is much larger than the sum of its bricks, and the building itself would be destroyed in the process. Today's economic policies toward the environment have a similar flavor. Often we destroy enormous and valuable ecosystems by selling their trees one by one because the economic need is pressing and in many cases because no one has a clear title to the property, so that they treat it on a first-come, first-served basis. This situation is typical in developing nations that hold resources under a common property regime and leads to overexploitation of resources that are exported to industrial nations at prices that are below replacement costs (Chichilnisky [16]). Resolving this situation might require institutional arrangements for clarifying, assigning, and protecting property rights when needed and organizing, executing, and monitoring the trading of emissions permits, loans on these, and derivative instruments associated with them. The sections below show (1) how an IBES could work in practice, and (2) why the role of such a global institution would complement markets but go much further than anything that unaided markets can achieve.

11.7 How the IBES Would Work

The IBES would be led by industrial and developing nations, represented politically in an equal footing, extending the current negotiating role of the FCCC to a continuing management role on behalf of the international community. The IBES could provide the backbone of the global environmental markets, extending existing institutions to the global level and ensuring their efficiency and integrity.

Markets involving SO_2 nitrous oxides (NOX) and various water pollutants constitute interesting precedents for the IBES. In 1993 the Chicago Board of Trade introduced SO_2 emissions trading, following the United States Clean Air Act, which introduced ceilings and rights to emit for US utilities. These markets are regulated by the Commodity Futures Trading Commission to ensure their efficiency and integrity. The SO_2 markets are less appropriate than CO_2 markets because, as opposed to CO_2, SO_2 does not mix uniformly and stably in the atmosphere. As a result, trading between states can lead to violations of the Clean Air Act because states that buy more permits can end up with higher emissions levels. In addition, the primary traders are rather few, therefore offering little market depth: about 150 utilities in the United States as a whole. Since localized trading is necessary in some cases this additionally limits market depth. However, SO_2 markets have been rather successful in helping implement the ceilings of the Clean Air Act at relatively little cost, leading to

about $14 per ton of emissions saved. Similarly, the IBES could also do the following:

1. fulfill the role of a clearing and settlement institution
2. offer credit enhancements for the carbon emissions permits sold by adding credit worthiness to contracts and perhaps by ensuring that the counterpart to each contract is the bank rather than another country or corporation, as in the case in the commodities clearinghouse
3. determine which type of instruments will be traded—for example, derivative securities (options or futures)—and if so, how
4. serve as a forum for recording environmental accounts that could be used to monitor the successes and failures of implementation
5. regulate the relationship between primary and secondary markets, a matter of great importance in ensuring market liquidity
6. run open-market operations and, in general, have an impact on borrowing and lending rates, such as the Federal Reserve does in the United States and all central banks do around the world

In addition to CO_2, other environmental markets could be involved in the IBES, such as water markets and markets for biodiversity use. The IBES could incorporate other environmental markets and financial mechanisms: water markets, such as those currently emerging in southern California, and markets for trading environmental risks, such as hurricanes, which are believed to have become more unpredictable and violent owing to the global climate change.[31] Chichilnisky and Heal studied the securitization of watersheds. Recently, a proposal for securitizing the emission reductions attendant to clean technology transfer on the basis of emissions markets was advanced in Chichilnisky [18].

11.8 The Role of the Regional Banks

As part of the FCCC system, the IBES could offer developing nations the ability to participate in orderly voting procedures to regulate and monitor the performance of the global emissions markets, the periodic allocation of emis-

[31] In 1992 the creation of an instrument that would offer contracts contingent on an unknown frequency of losses was proposed (in Chichilnisky and Heal, [9]) that is now traded on the Chicago Board of Trade under the name of Catastrophe (CAT) Futures. Another instrument has been proposed more recently, obtained by "bundling up" mutual insurance contracts as well as securities. Chichilnisky [17] studies the use of profit-sharing agreements to obtain value from biodiversity without destroying it, using the Merck-INBIO deal as an example, and proposes deeper access to capital by securitizing such deals.

sion reduction obligations by the different countries and regions, and the monitoring of the compliance with the contracts. To achieve consensus on the voting rules within the IBES, these could be adapted from existing regional banks' procedures, involving participants from industrial and developing nations, such as the Interamerican Development Bank (IADP), in which 50% of the vote is in the hands of the borrowers and 50% in the hands of the lenders. In addition to the IADB, other regional institutions such as the Asian Development Bank and the African Development Bank could participate in creating a task force of the world's regional development banks that would be in charge of creating and offering credit enhancement for the securities that IBES would offer. This would attract private financing for clean technology products in the various regions. These securities could be backed by certain assets: the emission reduction certificates corresponding to each clean technology project. Once these certificates are traded in the Annex B market provided by Article 17 of the Kyoto Protocol, they acquire a market value; however, this value is in the future. Credit enhancement facilities from regional banks would reduce these instrument's risks and therefore make them easier to place in the world's capital markets. In summary, the role of the regional banks would be to help the transition between the present and the future by offering credit enhancement facilities for these securities so that they can be placed in the world's capital markets.

11.9 The IBES Mandate

As part of its mandate, the IBES would ensure the following:

1. The trading of greenhouse gas emissions should not compromise the future ability of developing countries to grow.
2. The trading of emissions rights should not conflict with humanitarian aid or other international flows, such as overseas development assistance.
3. The IBES should provide more access to capital for development. It should not induce selling of emissions rights under unfavorable prices.
4. The trading of emissions rights will be initially among industrial nations. Indeed in the Kyoto Protocol trade is contemplated only among Annex B countries.
5. The IBES should help ensure fair markets and equal access to information and to trading; it will also ensure market integrity and depth.
6. Deals should be structured so that they can be reversed without undue penalty to the selling countries, which may revise their priorities in the future.

11.10 Policy Recommendations

The following policy recommendations have been discussed with members of the FCCC and government agencies various nations:[32]

- *Recommendation 1.* A migration from "joint implementation" to multilateral procedures involving global markets for emissions rights. The emissions markets would involve only industrialized countries initially. The recommendation was supported by the United States in Geneva in June 1996.
- *Recommendation 2.* Emissions rights could be loaned, instead of (or in addition to) sold, with the lending and borrowing managed by the IBES.[33] A key aspect of a loan rather than an outright sale of emissions rights is that developing countries need not be concerned about unforeseen long-term consequences of an irreversible transfer of their emissions rights to other countries or with making irreversible deals at prices that will subsequently look unreasonable. Lending rather than selling these rights avoids many uncertainties faced by developing countries entering into an emissions abatement agreement. Furthermore, lending rates can be regulated by the IBES.
- *Recommendation 3.* Developing countries may wish to lend emissions rights for limited periods until their needs for these are clear, whereas industrialized countries are likely to want to borrow for longer periods. The IBES could match these positions by borrowing short and lending long in the traditional manner of financial intermediaries. In exchange for the risk involved, it would charge a borrow-lend spread. Commercial capital and international financial institutions, private or not, would undoubtedly be attracted to such as operation.
- *Recommendation 4.* To ensure fair prices to developing countries, it might be desirable for the IBES to establish a market rate of interest on emissions permits in a market open only to industrialized countries and then to pay this rate on deposits from developing countries.

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[32]Including Minister Raúl Estrada-Oyuela, 1994 chair of the INC/FCCC and 1997 chair of the Negotiating Committee of the Kyoto Protocol; H. E. Ismail Razali, ambassador, permanent mission of the Malaysian to the United Nations; Mr. Xialong Wang, third secretary, Chinese permanent mission to the United Nations; Mr. James Baba, deputy permanent representative of Uganda to the United Nations; Dr. John Ashe, counsellor, permanent mission of Antigua and Barbuda to the United Nations; and Carlos Sersale de Serisano, currently special adviser to the secretary general of the UN Industrial Development Organization (UNIDO).

[33]I am grateful to Geoffrey Heal for this suggestion.

- *Recommendation 5.* It might be desirable to securitize carbon emission reductions from new technologies and products so as to attract funding from global capital markets and generate self-funding mechanisms to fund such technologies and products, therefore fostering clean industrialization and advancing the knowledge revolution in developing nations.[34]
- *Recommendation 6.* It might be desirable to securitize some of the world's watersheds in order to attract private funding for the conservation of clean water resources.[35]
- *Recommendation 7.* The securitization of the planet's biodiversity and global reinsurance of environmental risks that are associated with developing areas could be equally handled by the IBES.
- *Recommendation 8.* A similar treatment of the earth's airways would be desirable.
- *Recommendation 9.* The establishment of a system to monitor and account for the successes and the failures of the trading agreements should be developed.

11.11 Conclusion: Resource-Intensive versus Knowledge-Intensive Growth

This chapter argues that new institutional mechanisms are needed to achieve the goals of the Climate Convention and implement the Kyoto Protocol, especially with respect to the emissions markets provided for in its Article 17. This is because of the idiosyncratic nature of these markets, which require special patterns of users' rights, favoring lower-income groups, in order to achieve efficient use of resources. An institution, the IBES, was proposed, and its role was specified as leading the development of the world economy in a new form of clean industrialization the way that the Bretton Woods institutions led the world economy into resource intensive industrialization after World War II. A ray of hope that requires careful consideration is the knowledge revolution, which the IBES could help orient into a resource-conserving direction. The knowledge revolution is a global trend that is taking place whether or not the Climate Convention reaches its objectives. The most dynamic sectors in the world economy today are not resource intensive but knowledge intensive: biotechnology and entertainment, software and hardware, communications, and

[34] See Chichilnisky and Heal [12].

[35] See Chichilnisky and Heal [12].

financial markets. These sectors are relatively friendly to the environment, use relatively few resources, and emit little CO_2; figures 11.1–11.7 illustrate the case of the United States. Knowledge-intensive sectors include financial markets and health services, consumer electronics and telecommunications, and biotechnology. These are the high-growth sectors in the United States and in the most industrialized countries and are developing rapidly in other regions of the world, such as Singapore, parts of India, Bermuda, and Barbados. See the figures provided in the Appendix. Some of the most dynamic developing countries are making a swift transition from traditional societies to knowledge-intensive societies. Mexico produces computer chips, India's Bangalore is fast becoming one of the world's largest exporter of software,[36] and Barbados has recently unveiled a plan to become an information society within a generation. There is nothing new about policies that steer a nation away into knowledge-intensive growth. These are precisely the policies followed by the Asian Tigers: Hong Kong, the Republic of Korea, Singapore, and Taiwan Province of China, all countries that have achieved extraordinarily successful performances over the last 20 years, not relying on resource exports but rather knowledge-intensive products such as consumer electronics. By contrast Africa and Latin America emphasized resource exports and lost ground.

The lessons of history are clear, steering us away from a reliance on resource exports as the foundation of economic development. Africa and Latin America must update their economic focus. Indeed the whole world must shift away from resource-intensive economic processes and products. In doing so fewer minerals and other environmental resources will be extracted, and their price will rise. This is as it should be because today's low resource prices are a symptom of overproduction and inevitably lead to overconsumption.[37] Not surprisingly, from an environmental perspective one arrives at exactly the same conclusion: Higher resource prices are needed to curtail consumption. Producers will sell less but at higher prices.

This is not to say that all will gain in the process. If the world's demand for petroleum drops, petroleum producers might lose unless they have diversified into products that involve fewer resources and higher value. Most international oil companies are investigating this strategy. The main point is that nations do not develop on the basis of resource exports, and at the end of the day development can make all better off. As the trend is inevitable, the sooner one makes the transition, the better.

[36]Bangalore exports at present about $2 billion worth, having initiated this sector about 11 years ago.
[37]See Chichilnisky [16].

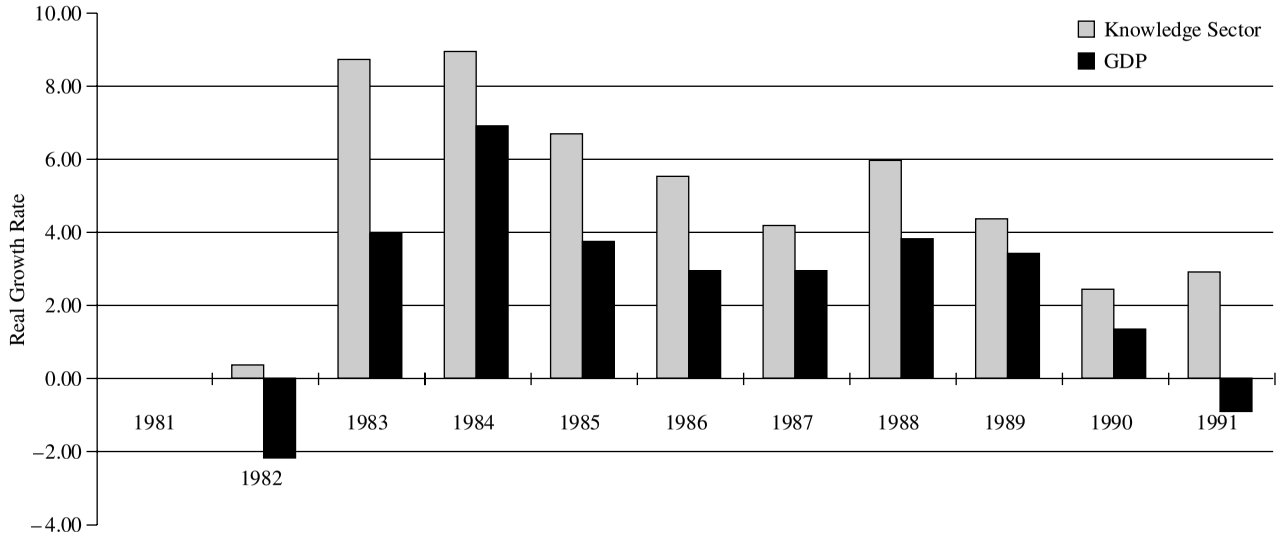

FIGURE 11.1 Growth rate of U.S. GDP and of its knowledge sector, 1982–1991 (including communication, finance, entertainment, electronics, computers and scientific instruments, pharmaceuticals, aerospace, and biotechnology).
Source of figures 11.1–11.7: Chichilnisky and Heal [10].

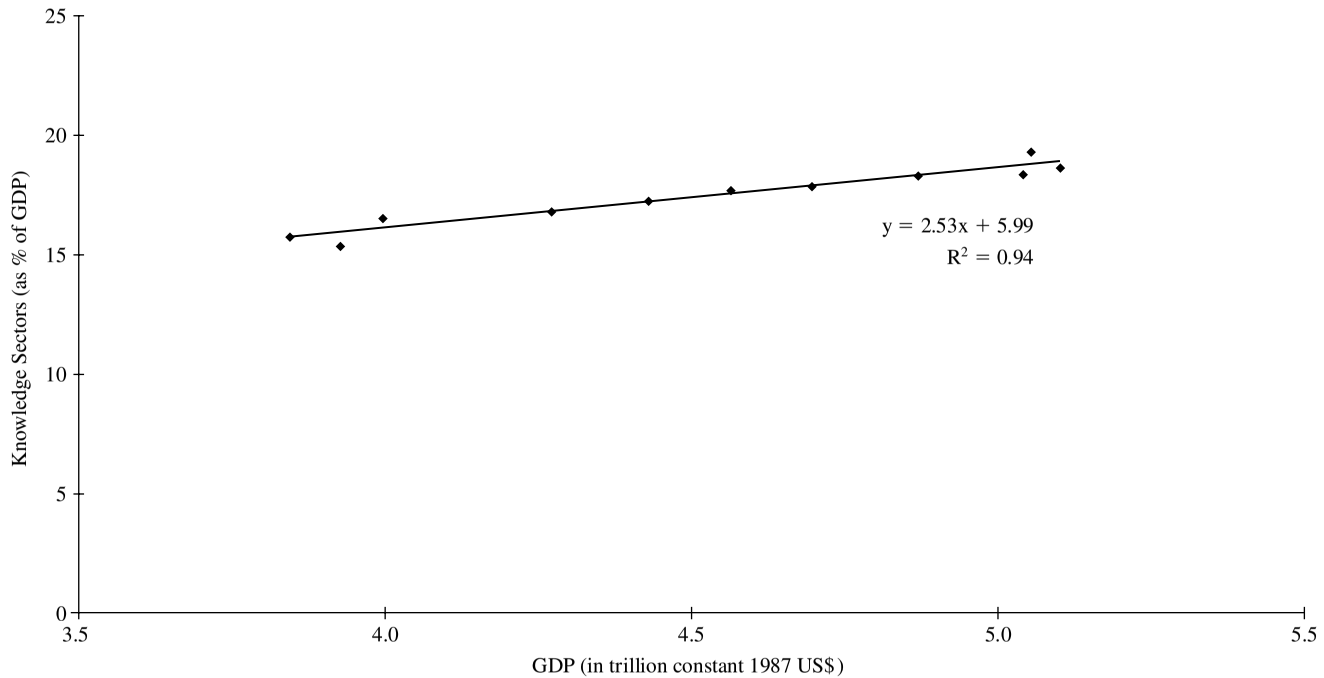

FIGURE 11.2 Knowledge sectors (as % of GDP) vs GDP, USA 1981–1991.

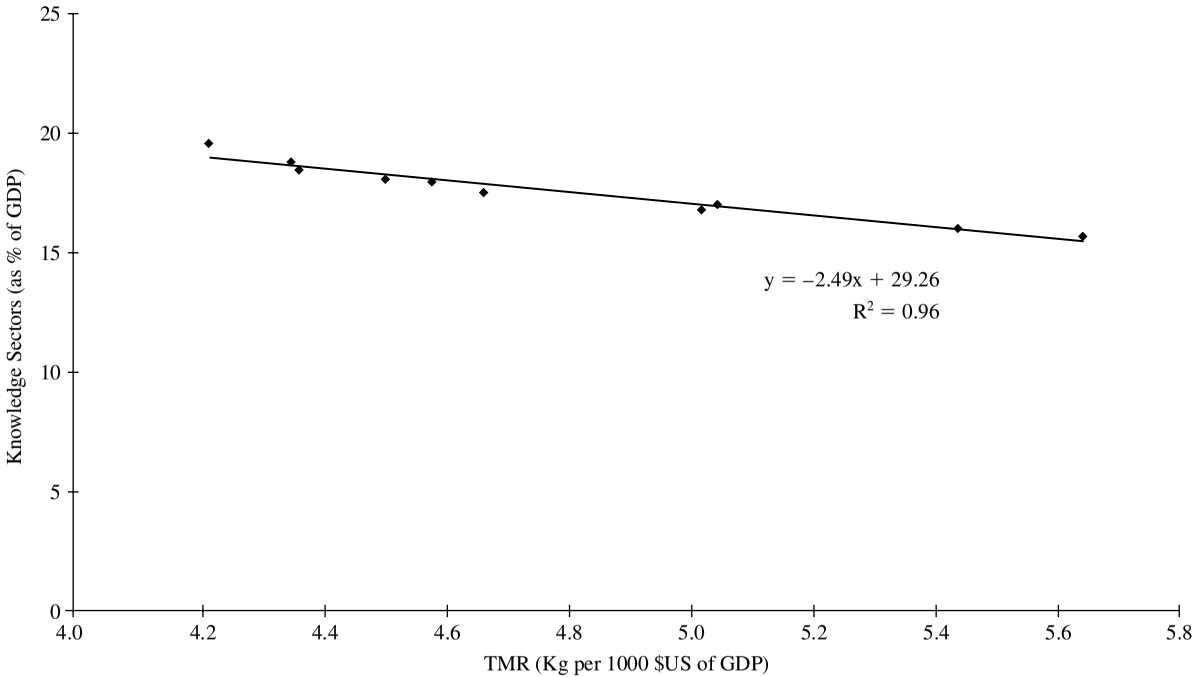

FIGURE 11.3 Knowledge sectors (as % of GDP) vs total material requirement, USA 1981–1991.

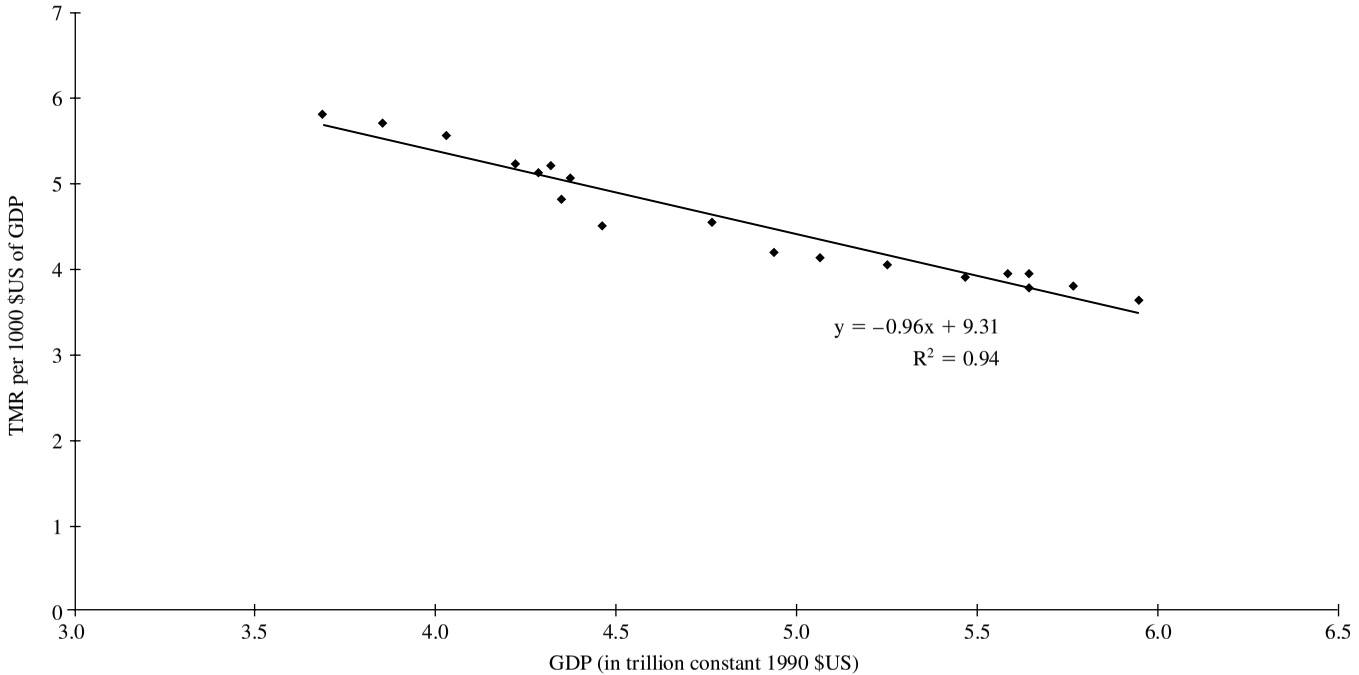

FIGURE 11.4 Total material requirement vs GDP, USA 1975–1983.

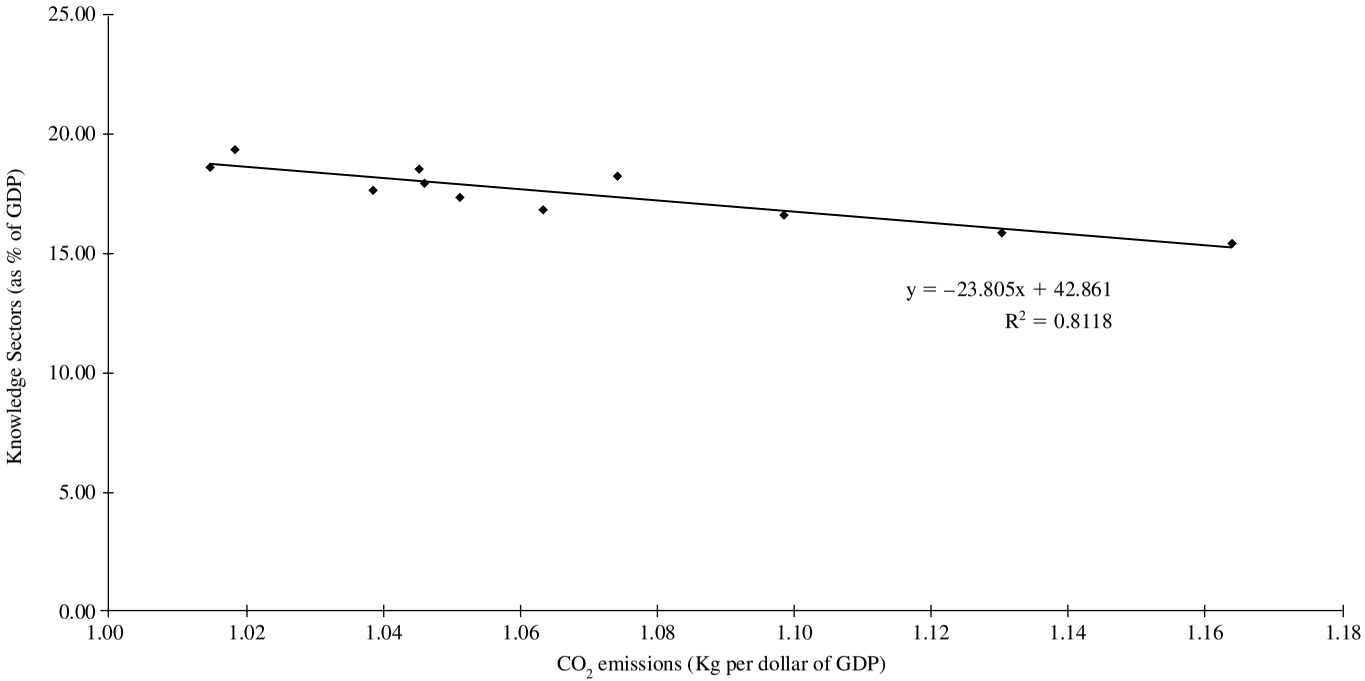

FIGURE 11.5 Knowledge sectors (as % of GDP) vs CO_2 emissions, USA 1981–1991.

FIGURE 11.6 Increases in personal spending as reported in *Business Week,* March 23, 1998.

To understand the issues and develop policy toward knowledge-intensive development, conceptual advances in economics are needed. The economics of climate change involve challenging questions, such as the following:

1. Which policy instruments or combination of instruments at the national and international levels—carbon taxes, joint implementation, or tradable emissions for CO_2—are preferable for reducing emissions?

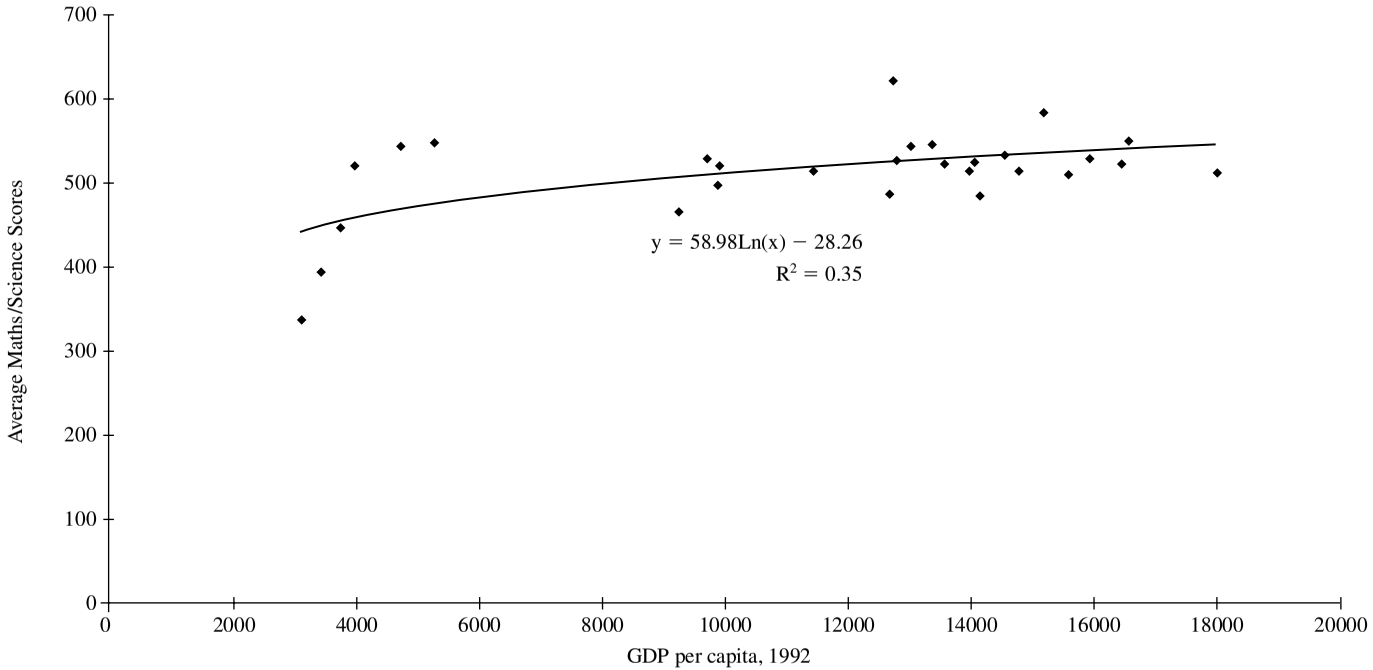

FIGURE 11.7 Cross section GDP vs math/science scores (27 countries).

2. How can an acceptable degree of equity in the use of global carbon be ensured?
3. How would the notions in this chapter impact trade among industrial and developing countries?
4. Which instruments might be needed to support and regulate the trading, clearing and settlement of emission rights and related assets, and to ensure the efficiency and integrity of the market?
5. What type of environmental accounts will help record and monitor the success or failure of taxes, joint implementation schemes, or emissions markets?
6. When do market prices accurately reflect the value of resources, and when should new institutions be created?
7. What is the scope of applying the proposals in this chapter—beyond greenhouse gas emissions—to tackle other cross-border problems, such as desertification or soil erosion and deforestation?
8. What are the implications of the results in this chapter to policies toward markets involving knowledge goods, which, as environmental goods, are often privately produced public goods?

Appendix

A Manifold of Efficient Allocations of Users' Rights

In chapter 3 of this volume, Chichilnisky, Heal, and Starrett (CHS) develop a model of a competitive market with several traders whose utility depends on their consumption of private goods and one privately produced public good, for example, the gaseous composition of the planet's atmosphere. The traders trade private goods as well as the rights to use the public good, for example, the rights to emit. An overall ceiling is placed on their rights to emit that is shared by the traders in fixed given amounts, namely, their respective users' rights (also called "property rights").

This Appendix simplifies the CHS model to one with only two goods and two traders and extends it to allow for a variable limit on total global emissions. This is done in order to show graphically two results that appear in this chapter and not in CHS: (1) With a variable amount of total emissions, the initial allocations of users' rights that yield efficient market solutions define a *one-dimensional manifold of efficient users' rights.* By comparison, in the standard market with private goods, the set of initial allocations that yield efficient market equilibria would be two-dimensional. The implication from this is that efficiency is more difficult to achieve in environmental markets and requires

setting up correctly the initial conditions. (2) For each level of global emissions, there is an inverse relation between the initial ownership of private goods and the users' rights on public goods that is needed to achieve efficient market equilibrium.

A brief summary of the model in chapter 3 follows. There are two traders (North and South) trading a private good x and a privately produced public good a, which represents the concentration of greenhouse gases in the world's atmosphere. By definition a is available to both in regions in the same quantity. Each region denoted $i = 1, 2$ produces private goods using as an input different amounts of the public good, that is, emitting different amounts of CO_2: $x_i = \phi_i(a_i)$, $\phi' < 0$. The private good is the numeraire ($p_x = 1$). Trader i has a utility function $u_i(x_i, a)$, which is increasing in both variables, and an initial allocation $\overline{a}_i$ of total amount of emissions, which varies over an open interval $I \subset R$. Total emissions limits are given by $\overline{a} = \overline{a}_1 + \overline{a}_2$, and they vary over the set $I + I \subset R$. For each initial allocation $\overline{a}_1, \overline{a}_2 \in R^2$ of users' rights, a *market equilibrium* is defined by (1) a (relative) trading price paid for the rights to emit, π^*; (2) an amount of the public good used in each region a_i^* to produce private goods (i.e., the emissions) and the amount of emission rights purchased or sold: $a_i - \overline{a}_i$; and (3) an amount of private good produced and consumed by each region x_i^*. In a market equilibrium, each trader maximizes the utility $u_i(x_i, a)$ over the budget set defined by the equation $x_i = \phi(a_i) + \pi(a_i - \overline{a}_i)$, which indicates that the regions' consumption of private goods cannot exceed the value of its production of private goods $\phi(a_i)$ plus the income derived from selling (or buying) permits. In addition, markets clear; that is, $a_1^* + a_2^* = \overline{a}_1 + \overline{a}_2$.

When ϕ and u are smooth, CHS established the following result for a generic set of economies.

THEOREM 1 Given a total level of emissions for the world economy $\overline{a}$, there is a finite way to allocate the rights to emit among the various regions so that the resulting competitive equilibrium is Pareto efficient.

In contrast with the CHS chapter, here the total amount of emissions is allowed to vary; that is, the value $\overline{a}$ is a real variable defined over $I \subset R$; as $\overline{a}$ varies one obtains different equilibria of the world economy. According to CHS, for a fixed $\overline{a}$ the equilibria are locally unique. This follows from Sard's theorem and the global implicit function theorem. In our case, as $\overline{a}$ varies we obtain a larger set of equilibria, and, under generic conditions, this set describes a one-dimensional manifold of the same dimension as the parameter space I. Therefore, for a generic set of two-trader economies as specified previously, Theorem 2 below follows.

THEOREM 2 By allowing total carbon emissions to vary, one obtains a one-dimensional manifold of property rights (rights to emit, or obligations to abate) from which the competitive market with tradable permits achieves a Pareto-efficient allocation of resources in the two-region world economy (Chichilnisky [8]).

PROOF. This follows from the global version of the implicit function theorem, Sard's theorem, and Theorem 1. ■

In a generic two-trader economy as specified previously, one therefore obtains the following:

COROLLARY 3 In an economy with Cobb-Douglas utilities that are the same for all regions, the set of initial allocation of users' rights that lead to an efficient equilibrium allocation exhibits a negative association between the ownership of private and public goods. At the initial conditions leading to the efficient equilibrium, the traders who own smaller endowments of private goods own a higher allocation of public goods and vice versa.

PROOF. See Chichilnisky and Heal [10] and chapter 7 of this volume. ■

Figure 11.8 illustrates how a change in the property rights regimes assigning to the developing nations an increasing amount of rights to emit and fewer rights to emit to the industrial nations can be Pareto improving to all regions. Observe that this result is not possible in markets with private goods in which competitive equilibria are always Pareto efficient.

Simulations on Emissions Trading in GREEN/PIR

Computer simulations were carried out at the Program on Information and Resources (PIR) of Columbia University for the OECD GREEN model modified to incorporate the possibility of trading emissions permits between the countries (hereafter the GREEN/PIR model). This model differs from that of CHS in that there is no environmental quality variable in the utility of the traders: Utility is derived exclusively from the consumption of private goods. Under these conditions the results on equity and efficiency reported previously do not follow, although it is clear that there is no reason to consider abatement of emissions unless there exists a disutility associated with it, making the model less realistic. In any case the runs reported have exhibited a result similar to that discussed previously, although in a different sense. We say that a run is

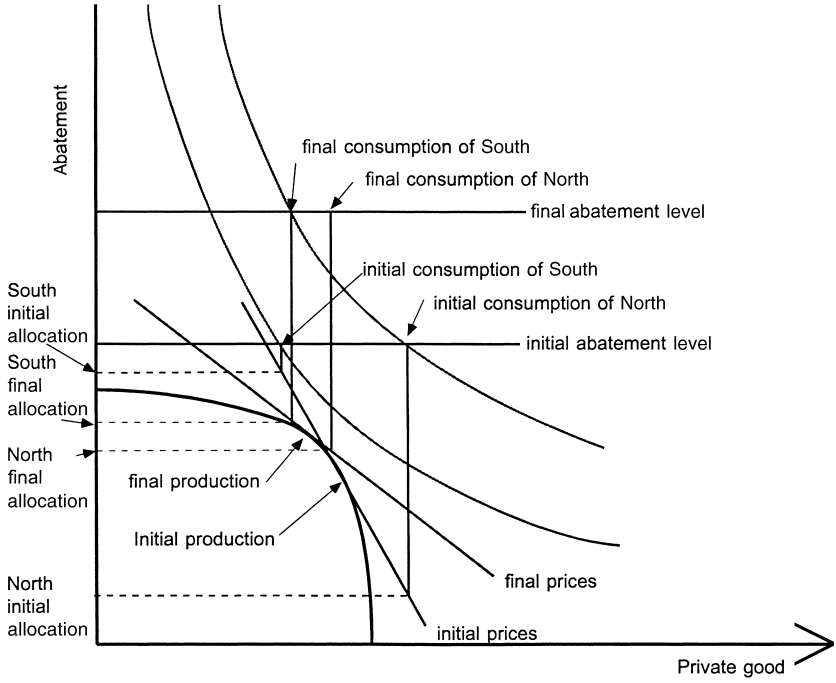

FIGURE 11.8 Only specific distributions of property rights lead to Pareto efficiency.

more efficient than another when it achieves the same level of carbon emission reductions with higher amount of private goods produced. In the runs reported here, it is shown in table 11.1 that the most efficient runs, in terms of minimizing the loss of economic growth that abatement induces, are those in which the distribution of emission permits favors the developing countries. In observing why this happens within the GREEN/PIR model, it appears that the productivity in developing nations (such as China) is on average higher than in industrial nations, so that the abatement of a ton in carbon in industrial nations decreases economic growth by less than it would do in China. Because China imports private goods from the industrial nations, the final result is that all benefit from the abatement rule adopted.

Empirical Analysis

The experience of the last 20 years confirms the GREEN/PIR simulations. On average, a dollar invested in a developing nation has a larger productivity than

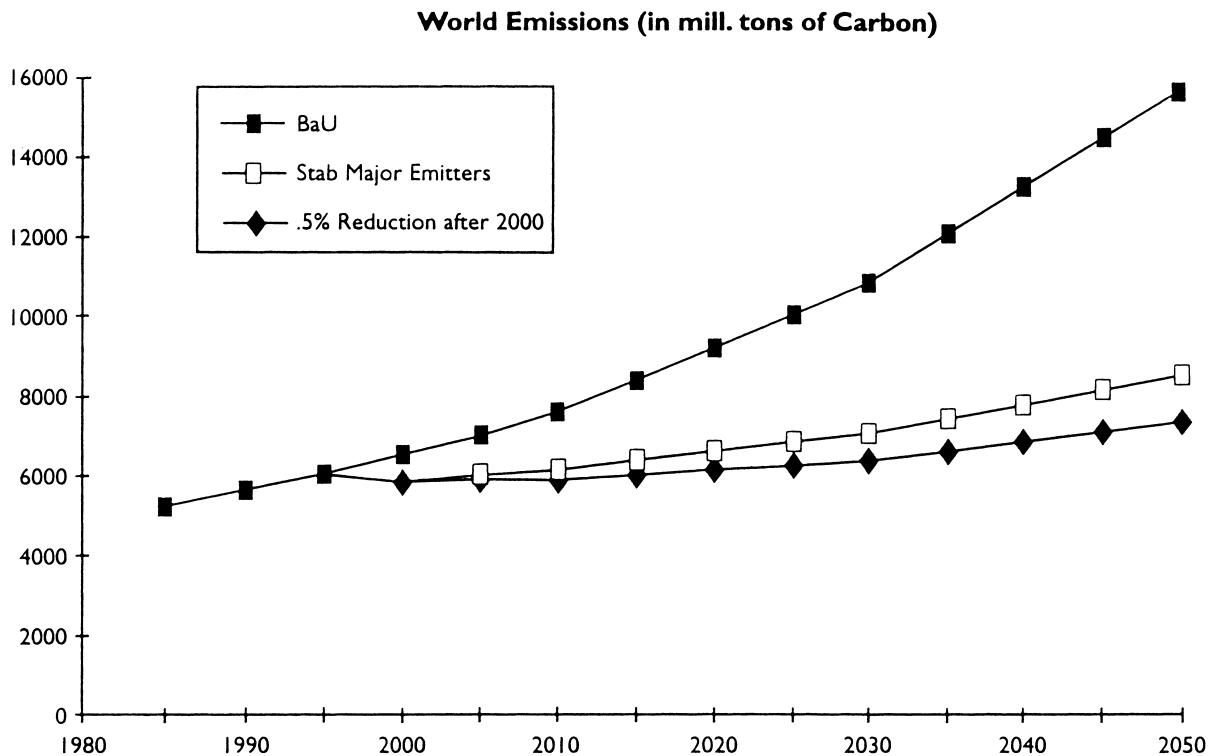

FIGURE 11.9 World carbon dioxide emissions (in mil. tons of Carbon).

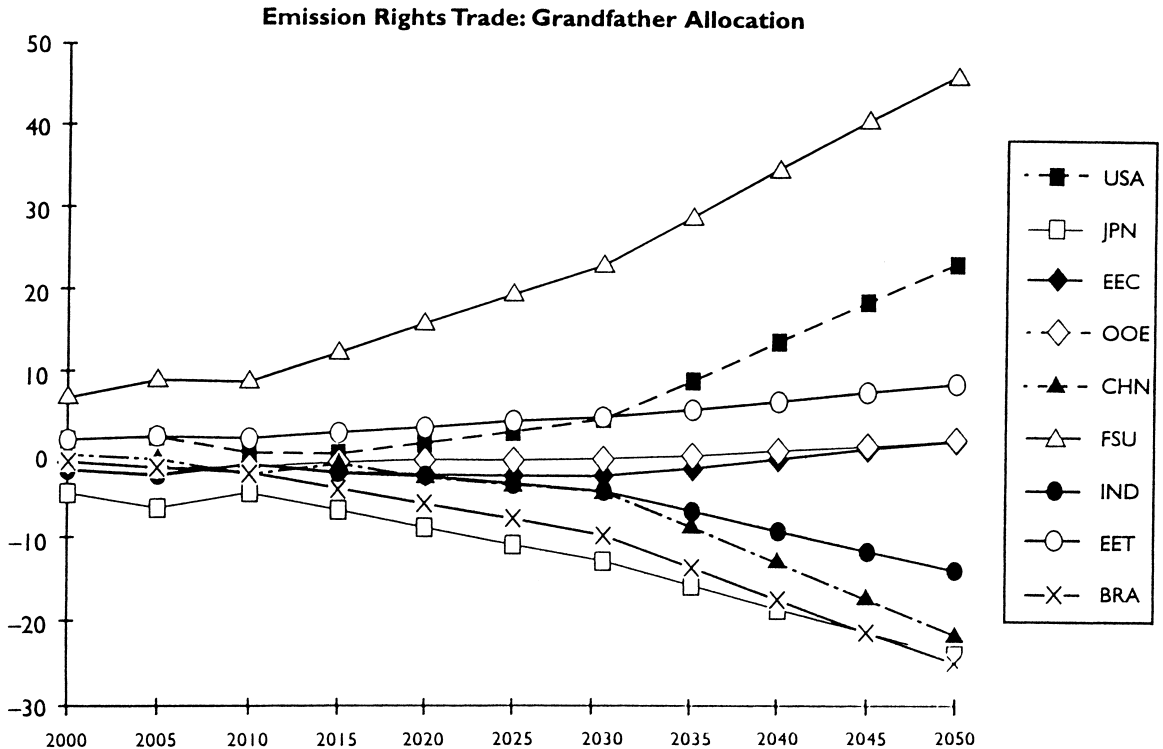

FIGURE 11.10 Emission rights trade: Grandfather allocation.

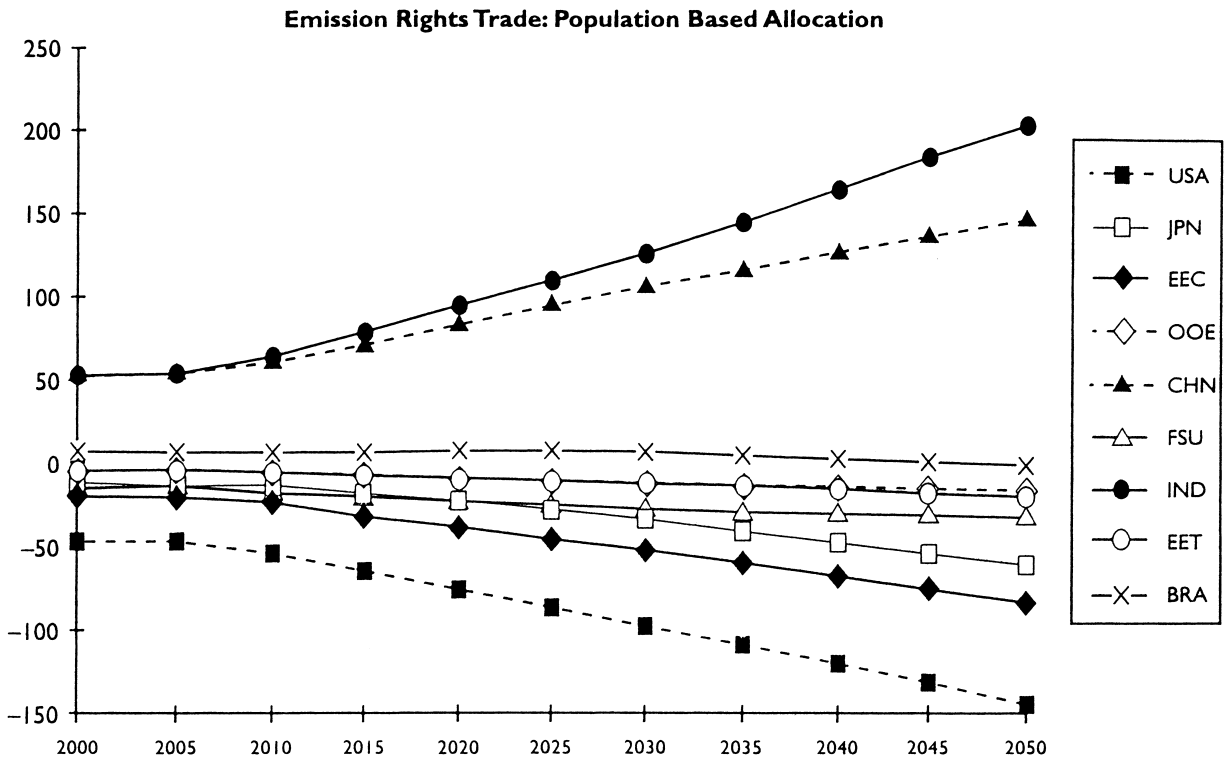

FIGURE 11.11 Emission rights trade: Population-based allocation.

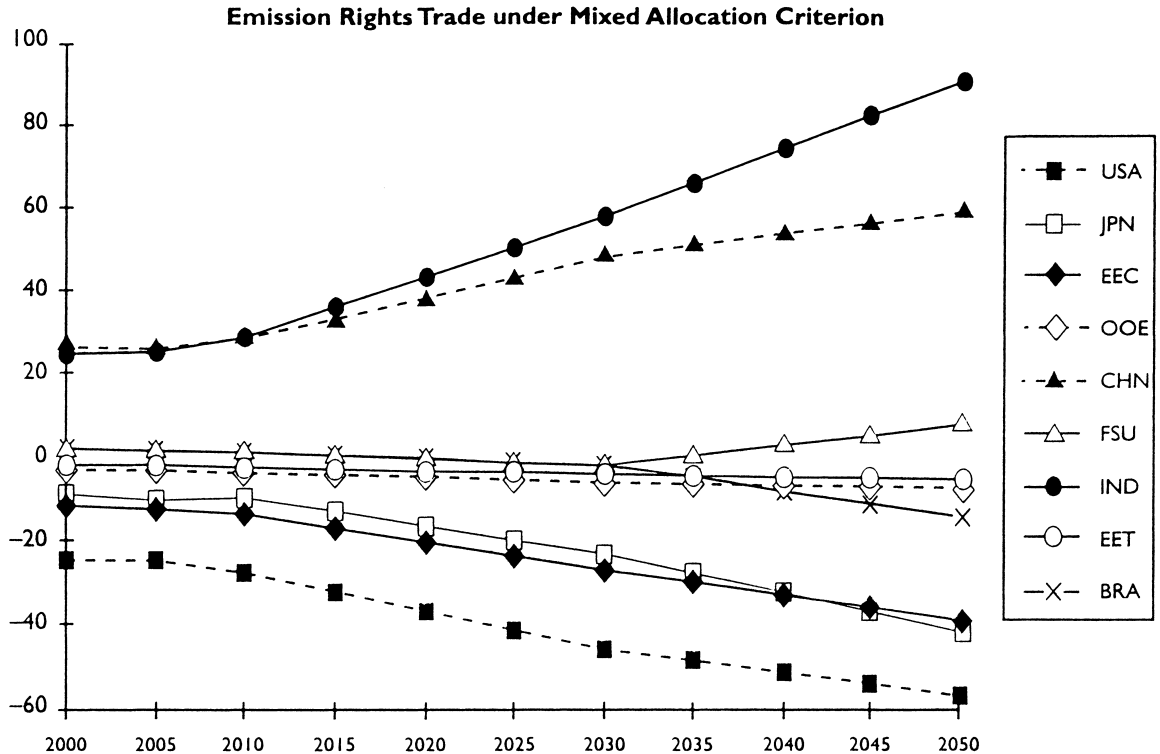

FIGURE 11.12 Emission rights trade: Mixed allocation.

Table 11.1
Real Income Loss over 2000–2050
(in percentage deviation relative to BaU)

	Indiv. Stab.	**Uniform Tax**	**Grandfathering**	**Pop. Based**	**Mixed**
USA	−0.79	−0.90	−0.76	−2.94	−1.84
JPN	−2.41	−1.24	−1.83	−2.84	−2.34
EEC	−1.23	−1.16	−1.22	−3.13	−2.19
OOE	−0.58	−0.55	−0.54	−1.53	−1.04
EEX	−3.39	−0.83	−0.78	0.09	−0.39
CHN	−3.88	−3.47	−4.14	6.02	1.04
FSU	−1.42	−2.66	1.08	−7.13	−2.92
IND	−2.61	−2.00	−2.94	14.62	7.00
EET	−0.33	−1.09	0.81	−5.94	−2.51
DAE	−0.29	0.16	0.20	−0.19	−0.05
BRA	−1.60	−1.78	−4.40	−0.55	−2.45
ROW	−0.40	−0.01	0.05	0.21	0.12
World	−1.65	−1.16	−1.17	−1.06	−1.07

Note: World Emission Stabilized at 1990 level after 2000.

the same dollar invested in industrial nations. If carbon abatement leads to decreased investment, then it is more efficient to decrease investment by one dollar in industrial nations, as the economic loss is relatively lower than if decreasing investment in industrial nations.

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