Global Climate Change:

International Agreements and Economics

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Introduction

The effort to create international agreements to reduce greenhouse gases represents a confluence of two fields of endeavor, one scientific and one economic.
The scientific development is the increasing evidence that global warming is occurring and that it may be caused by human activity. The economic development is the mounting body of theory and proposals of ways to expose each user to the full cost of exploiting natural resources.
This paper will cover the economic aspects:
how, why, and what economic proposals have been set forth to expose users to the true cost of the use of resources;
what role these proposals have played in the international negotiations beginning with the signing of the UNFCCC (United National Framework Convention on Climate Change) and continuing through the Kyoto Protocol;
what economic models are used to evaluate the costs and benefits of the various proposed measures and agreements.

The Economic Framework

In economic theory, price arbitrates between supply and demand to bring about an optimal equilibrium. When the price for every product reflects the relative intensity of demand for the product, together with the relative difficulty of supplying it, the amounts of products produced will represent the optimal possible allocation of resources. This optimal allocation of resources will satisfyas nearly as possible, given the unavoidable fact of scarcitythe basket of demands.

This theoretical optimum is possible only if the price of a product or resource accurately reflects not only the intensity of demand for that resource, but also the difficultythat is the costof supplying it.

The problem is that resources readily available to alloften called "common property resources" or CPRare frequently unpriced or underpriced. They are underpriced because the cost to produce the pre-existing resource is frequently no more than the cost of tapping it, while the cost to produce more of itthat is, its replacement costcan be much higher, if replacement is even possible.

As a result of this underpricing of common property resources, they can be overexploited to the point that the allocation of resources is far from optimal. To remedy this situation, something should be done to expose the true cost of the use of these resources to their users.

The Public Property Solution

A CPR can be viewed as public property, the property not only of all members of this generation but of all members of future generations as well. As such, its value should be preserved. Therefore, it should not be sold for less than replacement value. This replacement value is construed to mean the replacement not only of the resource itself but of all the services that its removal interrupts. Hence, for example, the cutting of a forest removes not only the trees but the water-retentive properties of the forest and a number of other useful services.

To ensure that the resource is not sold for less than the replacement value of its services, the public must exact a cost to the user in excess of the usually much-lower cost to tap the resource. This cost is exacted in the form of a tax. Thus,

to calculate the tax, it is necessary to estimate the cost to replace the resource itself and/or the services that the resource performs.

An objection can be raised at this point, however. In spite of the dogma of "sustainability", many observe that there is no reason why economic actors should desire to continue to do the same thing and have access to the same resource throughout the future. The nature of economic changeof economic progressis to make constant improvements to satisfy evolving preferences and adjust to supply changes by substituting one resource for another, one product for another, one service for another. Why, then, should it be assumed that the goal is necessarily to preserve the same resource or service for eternity?

The latter objection complicates the task of estimating the "true" value of a resource. One way of taking the objection into account is to estimate the value of a resource not as its replacement value, but as the cost of its nearest substitute, if that is less than the resource's replacement value.

The Private Property Solution

Some say that the problem is that common property resources are not privately owned. The value of a privately-owned resource is determined by its competitive price in the market. If all of a resource were in the hands of numerous private owners, each owner would try to maximize the profit from either selling it, or retaining it as an investment for its future increase in value. Some resources of greatand not immediately commercializablevalue might be maintained, undeveloped and unsold, as investments indefinitely.

The private property solution avoids the difficulties of estimating a resource's "true value" that are entailed by the public property solution. The market sets the price of the resource, which is by definition its true value. It will not be undervaluedas it is when it is owned in commonbecause its owner sees the resource's value as its potential for future revenue generation, not just the cost to tap it.

Exploration of the private property solution has given rise to a wide range of proposals for "privatization" of common property resources. But many of these resources are what is called "fugitive resources"that is, they are hard to contain in one place. For example, flowing water is a fugitive resource, as is the atmosphere. Hence, it is difficult to assign ownership to any particular identifiable portion of the resource. It is, therefore, instead common to assign ownership of a "right" to the resource. This right can be the right to extract from the resource, but it can also be a right to emit into the resource, or otherwise to alter the resource *in situ*.

Because this privatization solution entails conferring on users the ownership of a right to emit into a common property resource, it has been castigated by some environmentalists as a "right to pollute". (Many of these environmentalists also have a philosophical objection to the profit motive that drives market transactions between property owners.)

Once these rights are assigned, they can be "transferable"that is, the rights themselves can be bought and sold by participants in the market for the rights.

A problem with the administration of private ownership rights to fugitive resources is that of "transactions costs". Any ownership right needs to be recorded and enforced by government authority, which must also monitor and enforce transfers of ownership. It is a challenge to design an administrative, ownership, and market structure in which market participants have incentives not to cheat, and monitoring and enforcement is possible with not too great a cost for government oversight or for the administration of private market transfers. One objection to the rights-privatization solutionas opposed to the taxation solutionis that the administrative or transaction costs are too high. However, many of the same problems apply in different form also to the taxation solution, which itself requires a high degree of governmental monitoring, oversight and enforcement.

The taxation solution versus the rights solution

In economic theory, the taxation solution can be made equivalent to the rights solution if the tax level is set right, and if tax rates in different sovereignties are "harmonized". "Equivalent" means that the price exposed to the user of a resource will be the same, and the incentive to trade off exploitation and preservation of the resource in the optimal way will be the same, under either the taxation or privatization scheme. "Harmonization" of tax rates in different sovereignties does not necessarily mean the tax rates are the same. It merely means that taxes are calculated everywhere on the same principle that they should make up the difference between the cost to produce or extract the

resource and the resource's true value. This difference could vary widely from place to place.

However, the practical and political problems associated with the taxation solution and the rights solution are very different. In some countriesnotably the United Statesthe taxation solution is regarded as much more of a government intrusion than if government merely administers a market for privately-owned rights. The taxation solution requires government to estimate the "true value" of a resourcean extremely difficult taskwhereas the rights solution, at least in principle, allows the market to make that estimate.

Combinations of solutions

In practice, a wide variety of policies that combine variants of the taxation and rights solutions, and other approaches, are being proposed and implemented. In one proposed approach, the rights solution is implemented but the government caps the price of rights by buying rights at a fixed, capped price if the market price exceeds it. This is like the way in which governments control their currencies' exchange rates, by buying or selling as much as necessary of their currencies at fixed exchange rates on the open market.

Initial stage of implementation of the "rights" approach: allocation of rights

One of the most difficult problems in implementing the rights approach is how to allocate rights initially. The two main possibilities usually considered are grandfathering or auctioning.

When rights are grandfathered, those who are currently using rights to a resource are allocated rights in proportion to their current use. These rights might be ratcheted down in the future, probably in proportion to their initial allocation. A disadvantage to this approach is that it produces no revenue for the governing bodyunlike either a tax on the resource, or the auctioning method. The grandfathering method also ratifies the status quo of resource usage, whether or not it is in any sense "correct". (Developing countries object to ratifying the status quo in which industrialized countrieshaving emitted more pollutants in the past, but having reaped the economic development benefits of itare, through grandfathering, allocated more rights to continue to emit in the future.)

In the auctioning method, rights are initially auctioned off. This produces revenue for the government that can be used to administer the program, but also to reduce other taxes that may be relatively economically inefficient. Thus, it is theoretically possible that an auction-based rights system can actually reduce overall economic costs by reorganizing the tax system so that it produces less distortions in the economy.

In practice, rights are usually grandfathered, because it is often politically necessary to obtain buy-in from current users of the rights; those users will object to suddenly having to pay for something they are now getting for free.

Another possible allocation of rights is on a per capita basis. Developing countries argue that this is the only correct way. But in the case of greenhouse gas emissions this would entail either allocating such a large number of total emissions rights worldwide that the overall cap would be too high, or capping industrial countries' emissions rights at a level so low it would be politically unacceptable.

Cap-and-trade systems

Once an initial allocation of rights has been created, the right to the resource owned by any particular individual, corporation, or government entity is "capped" by the allocation of rights to that entity. If that entity desires to exercise a greater right to the resource than the capped amount that it owns, it is free to obtain more of the rights by trading with other rights-owners. Conversely, if the owner of rights desires to exercise less than the number of rights it is allocated, it is free to sell those rights to a buyer. Such systems are called "cap-and-trade".

The effort to create international agreements on greenhouse gases

Having covered the economic background in principle, let us now set it in the context of the international agreements on climate change that have been more than ten years in the making.

The granddaddy of common property resources is the global atmosphere. Because no one owns the atmosphere there is no one to pay for the use of it, even though there is in fact a "cost" to provide it. That cost may be in the form of

foregone services. For example, the atmosphere provides the service of retaining heat, but not too much of it. If using the atmosphere for some other economic purposesuch as a receptacle for waste CO_2reduces its ability to perform the climate control service, then the use of the atmosphere as a receptacle incurs a cost in foregone climate control. (Such is the terminology of economics.)

If the cost of the foregone service is not reflected in the price charged the user for use of the atmosphere as a receptacle, then the atmosphere will be overused as a receptacle for emissions, and its climate control service will be underused.

Of course, emitters of greenhouse gases are now not charged at all for their use of the atmosphere. From an economic perspective, it is this condition that the measures being proposed are designed to rectify.

The United Nations Framework Convention on Climate Change

The initial salvo in the effort to form international agreements to address the potential problem of climate change was the Framework Convention on Climate Change (FCCC or UNFCCC). This convention was opened for signing at the United Nations Conference on Environment and Development (UNCED, or the Earth Summit) at Rio de Janeiro in 1992. So far 181 countriesnearly all countries on earthhave signed. In spite of its recent recalcitrance, the United States, under then-president George H. W. Bush, was one of the first to sign, though only after insisting that no binding commitments to reduce greenhouse gases be contained in the treaty.

The key statement of the treaty is its purpose, "to achieve … stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." The treaty does not, however, create enforceable agreements toward achieving this goal. It states as an "aim" that emissions be returned to each country's 1990 level. This has been regarded as a voluntary goal, but it is a goal that most countries have fallen woefully short of. Few countriessuch as those whose economies have collapsed, like Russia and Ukraine-have achieved the goal.

The treaty does commit countries to keep inventories of their greenhouse gas emissions, and creates a framework for economic assistance from industrialized countries to less developed countries to help them do that.

The precautionary principle

The UNFCCC sets forth the precautionary principle that action should be taken to prevent potentially serious or irreversible damage even in the absence of "full scientific certainty". The precautionary principle, though it sounds unexceptionable, is a subject of some controversy.

Objections to the precautionary principle are usually stated in economic terms. It is argued that the precautionary principle implies that action must be taken, *whatever the cost of that action*, to prevent the possibility of serious or irreversible damage, *however unlikely that possibility may be*. (The statement in the UNFCCC is actually much milder than that.)

From an economic perspective, absolute statements like this should never be made. One should never say that action should be taken to prevent a possible damage, whatever the cost of that action. Instead, one should say that the cost of taking action should be weighed against the benefit of preventing the damage (or, perhaps, against the probability-weighted benefit of preventing the possible or probable damage).

Economic models that project the costs and benefits of various climate change actionswhich we shall take up laterare aimed at doing precisely the latter. That is, they are aimed at determining whether the benefit of a preventive action exceeds its cost; or, in some cases, the models are used to compare the costs of various proposed preventive actions. The precautionary principle approachthat action *must* be taken to prevent global warming whatever the costhas generally taken a back seat to the cost-benefit approach in assessing potential collective actions.

Conference of the Parties

The UNFCCC set in motion a continuing process. It established a Conference of the Partiesconsisting of the signatories to the UNFCCCto meet annually to work out the details of effective implementation of the treaty. There

have been six such meetings to date. These meetings are referred to as COP-1, COP-2, and so on, the most recent, in November of 2000, being COP-6. COP-3 was held in Kyoto, Japan in 1997. There, the so-called Kyoto Protocol to the UNFCCC was adopted.

The Kyoto framework

The Kyoto Protocolthough its wording is hedged and couched in the language of political compromisehas been nonetheless powerful enough to set off a flurry of activity, both in national governments and in large corporations.

The salient feature of the Kyoto Protocol is the agreement by a list of industrialized countries* to individually cap their emissions of greenhouse gases over the five years 2008-2012. The caps are stated as a percentage of base-year emissionsfor most countries, the base year is 1990 (see Table 1).(The base is different for"countries that are undergoing the process of transition to a market economy".)

This list of capstogether with language in the Protocol that allows for the transfer of "emission reduction units" (ERUs)appears to create a classic cap-and-trade system. In this system, ERUs can be obtained or relinquished through various transfer mechanismspresumably including open-market trading.

In the post-Kyoto environment there are two huge uncertainties: (1) whether the Protocol can be ratified and can come into force in anything even vaguely resembling its current form; and (2) whether the complicated details of the emissions trading system can be made to work in an international framework.

Can the Protocol be ratified?

To come into force the Protocol must be ratified by at least 55 of the signatories to the UNFCCC, including enough Annex B countries to represent at least 55 percent of the 1990 greenhouse gas emissions.

Greenhouse gas emissions of a number of the Annex B countrieschiefly, but not only, the United Stateshave grown significantly over the last decade and continue to grow. These countries could meet their 2008-2012 emissions caps only through: (1) a crash program of internal reductions to a degree that would probably be politically and economically unacceptable; or (2) international political compromises that could impair the meaningfulness of the Kyoto Protocol. If the Protocol is ratified, but is then widely violated and not effectively enforced, it will be worse than no treaty at all.

Hence, there is grave doubt as to whether the Kyoto Protocol can be ratified in its current formor even should be ratified.

Can the cap-and-trade system work in an international context?

Much of the motivation for the Kyoto Protocol'is having resorted implicitly to a cap-and-trade approach is the success ofthe United States' cap-and-trade system for sulphur dioxide emissions from power plants, which was embedded in the Clean Air Act of 1990. This program brought costs for controlling SO_2 emissions far lower than anticipated.

At about the same time the success of the Montreal Protocol for reducing emissions of ozone-destroying chlorofluorocarbons (CFCs) appeared to show that international agreements to control atmospheric environmental pollution could work.

But some doubt that the cap-and-trade system can work in an international context. Some analysts point to unavoidable facts that differentiate the proposed greenhouse gas agreement from the two examples above. In the case of the Montreal Protocol, immediate, economically-viable substitutes for CFCs were available in most applications. In the case of the U.S. SO_2 emissions program, enforcement was in the hands of the U.S. government. The fact that international enforcement is much weaker than national enforcement casts doubt on the enforceability of many features of the Kyoto Protocol.

From one perspective, however, the Kyoto Protocol and negotiations surrounding it constitute nothing less than a grand venture into the possibilities for international agreements and international governance, especially regarding the global environment.

Part of the fascination with the Kyoto process is that it may be forging new ground in the areas of international agreements, international governance, economics, and the global environmentthough as yet it is far from certain where the process will end up. At this point it does not seem likely that an agreement will be signed soon; very few countries have as yet ratified the Kyoto Protocol. It is more likely that the process of building toward an agreement or a set of agreements will continue for a long time, through trial and error and negotiation.

The current state of this process is, however, represented by the Kyoto Protocol. It is therefore important to look more closely at the features of that Protocol, with attention to the controversies surrounding them.

Features of the Kyoto Protocol

Almost every detail of the Kyoto Protocol is surrounded by controversy. We shall itemize the principal features, together with the difficulties posed by them.

Transfers of ERUs

First, we outline the various means outlined in the Protocol whereby emissions reduction units can be transferred from one country to another.

Joint Implementation

Article 6 of the Protocol authorizes "joint implementation" (JI) between Annex B countries. JI allows Annex B countries, under certain provisions, to transfer credits from one country to another by engaging in joint projects that reduce greenhouse gas emissions. Two of these provisions, the "additionality" and "supplementarity" criteria, are of particular importance.

The additionality criterion requires that "any such [JI] project provides a reduction in emissions … that is additional to any that would otherwise occur". Thus a JI project, to be eligible to allow the transfer of ERUs from one country to another, must effect emissions reductions that would not occur if the project were not implemented. This provision becomes important when we consider (see below) the possibility of countriesespecially Eastern European countries such as Russia and Ukrainetransferring their excess ERUs to other countries for payment.

The supplementarity criterion requires that "the acquisition of emission reduction units shall be supplemental to domestic actions for the purpose of meeting commitments". Thus countries should do what they can domestically to meet their emission reduction commitments before seeking transfers of emission reduction units between countries.

Bubbles

Article 4 recognizes that "Parties acting jointly in the framework of a regional economic integration organization" may satisfy the agreement by achieving their total combined level of emission reductions. This joint action by a regional economic integration organization has come to be called a "bubble"; in particular, joint action by the countries of the European Union is called the "EU bubble". The EU has explicitly formed a bubble and reallocated its combined commitment to an 8% emission reduction among its 15 members, as shown in Table 2.

Clean Development Mechanism

Article 12 of the Protocol defines a "clean development mechanism" (CDM) whereby Annex B countries (those that agree to cap their emissions) may implement emissions reduction projects in non-Annex B countries and claim ERU credit. This is similar to joint implementation, except that one of the parties is a non-capped country. The CDM allows emissions reductions in projects starting any time from the year 2000 to be credited against the funding countries' 2008-2012 emissions budgets.

Doubts have been expressed about the workability of the CDM, particularly as to whether projects can be effectively monitored to ensure that emission reduction really takes place. Nonetheless, progress appears to have been made in this area. A number of emissions-reduction projects are already underway in developing countries, funded by Annex B countries, under the auspices of the "activities implemented jointly" program of the UNFCCC. Furthermore, a Prototype Carbon Fund has been created by the World Bank and funded, so far, by a number of European and Japanese corporations and governments to pool resources to finance CDM projects.

Emissions trading

Article 17 calls for future COP meetings to define the framework for emissions trading, and therefore implicitly accepts it as a possible mechanism for meeting the emissions requirements of Annex B countries. However, like Article 6, it again invokes the "supplementarity" criterion, stating that "Any such trading shall be supplemental to domestic actions for the purpose of meeting quantified emission limitation and reduction commitments".

While emissions trading may not seem much different from joint implementation in which transfers of ERUs occur, it could be quite different in that open-market implementation of emissions trading might circumvent the additionality and supplementarity criteria.

The initial allocation

As implied above, the initial allocation is seriously problematic. It is problematic for different reasons for (1) the advanced industrialized countries; (2) "countries that are undergoing the process of transition to a market economy" (i.e. the ex-Communist countries of Eastern Europe and the Soviet Union); and (3) developing countries.

Industrialized countries

Several of the most advanced industrialized countries are unlikely to be able to reduce their emissions sufficiently to adhere to their agreed-upon caps by the required 2008-2012 time frame. The United States, for example, is required by the cap to reduce its emissions by 7% below their 1990 level. But without further action, the U.S. is likely to *increase* its emissions by that time frame at least 30%. Hence, the U.S. would have to take action within ten years to reduce its emissions by about 40% as compared with a business-as-usual scenario. It is not theoretically impossible, but it may well be politically impossible.

U.S. negotiators have grasped at two straws in hopes that the U.S. may be able to adhere to the cap and the timetable.

The first straw is unlimited emissions trading. If the better part of the emissions reductions could be accomplished through U.S. investments in emissions-reductions projects in developing countries and by buying ERUs from countries with an excess (such as Russia and Ukraine) then it might be possible to avoid politically difficult, or impossible, domestic emissions reductions.

However, other Annex B countriesnotably, European countriesobject to the U.S. getting off the hook for domestic reductions by obtaining all its emissions elsewhere. Europeans regard Americans as profligate energy users who should alter their lifestyles to use less energy. They regard it as unseemly for the U.S. to wriggle out of this obligation by using its wealth to buy emissions reduction credits for itself elsewhere.

Some have argued that to adhere to the "supplementarity" condition it should be required for a country to accomplish at least half its required emissions reductions domestically. At the COP-6 meeting in The Hague in November 2000, this was one of the issues that caused the negotiationswhich were supposed to work out the details of the Kyoto Protocolto fail.

The second straw at which U.S. negotiators have grasped is "sinks". Vast quantities of carbon are sequestered in biomass, primarily forests, and in soils. The amount of carbon sequestered in this manner can be increased by afforestation (or reforestation where forests have been cut down), and by changes in agricultural practices to retain more carbon in the soil. *These measures, of course, do not sequester carbon forever, and do not have the potential to sequester more carbon each year forever.* However, some of these measures could certainly draw a significant amount of carbon out of the atmosphere by the 2008-2012 time frame, and could thus be counted as reductions against emissions.

A difficulty arises in how to do the accounting for these sinksas well as whether it is fair to count all of the carbon sequestered, for example, in an afforestation project when some of that carbon must be returned to the atmosphere when the new trees die. But the United States, at the COP-6 negotiations, also made proposals to count a larger emissions withdrawal for already-accomplished afforestation and soil sequestration than other countries' negotiators thought proper. This was another disagreement on which the COP-6 negotiations broke down.

Countries that are undergoing the process of transition to a market economy

Some of the ex-Communist countriesnotably Russia and Ukrainehave seen their economies collapse in the last ten years with the result that greenhouse gas emissions have plummeted also. Their likely emissions in the period 2008-2012 are therefore substantially less than their caps, and hence they have emissions reduction units to spare. These excess ERUs aresomewhat sarcasticallyreferred to as "hot air". If other Annex B countries engage in joint implementation projects with Russia that meet the "additionality" criterionthat is, each project must bring about emissions reductions that would not occur otherwisethen emissions will be reduced. But if other countries merely purchase Russia's "hot air"its excess ERUsthen those countries will be aided in meeting their emissions caps, and yet the transaction will cause no further emissions reductions to occur. This purchase of "hot air" is outlawed in principle by the additionality provision, but it might be difficult to enforce if emissions trading becomes widespread on the open market, and ERUs thereby become fungible.

Less-developed countries

The economically-developed industrialized countries have been the major factor causing increased greenhouse gases in the atmosphere. This increase has occurred as the industrialized countries have used massive quantities of fossil fuels to drive their economic development.

Less-developed countries have historically used far less fossil fuel. They understandably feel it would not be fair for their future economic development to be hindered by having caps placed on their fossil fuel useespecially caps that are (as they necessarily must be to contain greenhouse gases) lower on a per-capita basis than those of industrialized countries.

Because of the difficulty of resolving this problem greenhouse gas emission caps were not imposed on the less-developed countries in the Kyoto Protocol. This presents the problem of "leakage". Economic activities in Annex B countries that produce greenhouse gases may be moved to non-Annex B countries where greenhouse gas emissions are not capped. The result would be no net reduction in emissions, and yet the industrialized countries could meet their caps.

It has been assumed, however, that developing country emissions will be capped in the future. How this will come about is not clear, and the path is fraught with peril. Developing countries might volunteer to enter the agreement, but with very high emissions caps, providing them with plenty of headroom to raise their emissions far above current levels. In the extreme, they could propose levels that would create "hot air" that they could sell (that is, sell the ERUs) to industrialized countries to help them meet their capsand yet, as in the case of potential "hot air" sales by Russia and Ukraineno new emissions reduction benefits would actually accrue.

Greenhouse gas equivalence

Six greenhouse gases are covered in the Protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Equivalences are drawn among these greenhouse gases based on their radiative forcing, or potential for creating greenhouse warming. Thus, reducing an amount of methane emissions is equivalent to reducing a fixed amount of carbon dioxide emissions.

One criticism of this provision is that while the greenhouse gases may be near-equivalents in terms of their radiative forcing, in other respects they are not equivalent at all. They have, for example, very different residence times in the atmosphere.

Enforcement mechanisms

The details of enforcement of the Protocol were to be worked out in future negotiations. Some doubt exists, however, whether adequate enforcement is possible at an international level. International governance is significantly weaker than national governance. Its ability to enforce agreements depends on adherence to the agreements being beneficial to both sides. The World Trade Organization (WTO), for example, enforces trading agreements where the ability to continue to trade is beneficial to both sides. Some proposals for implementing the Kyoto Protocol suggest that it be tied to the trade agreements implemented by the WTO.

Post-Kyoto implementation by governments and corporations

In the wake of the Kyoto Protocol, action has been taken by some governments and corporations to ready themselves for the eventual signing into force of the Protocol (or something like it).

Actions by governments

Most governments of European countries have adopted internal plans to control emissions so as to meet their commitments to the Kyoto caps. These rules and regulations are generally scheduled to come into force simultaneously with the coming into force of the Kyoto Protocol.

The rules and regulations vary widely for different countries. One surprise is that some of the countries that were earlier most opposed to the cap-and-trade conceptsuch as Francehave themselves adopted emissions trading systems internally to meet their own emissions limitations.

Actions by corporations

Perhaps one of the most significant Kyoto spin-offs has been action by the corporate sector to initiate greenhouse gas reduction measures. Led by British Petroleum, Shell, and other large corporations, and frequently working with the environmental organization Environmental Defense as well as with private sector consultants and brokers, several forward-looking corporations have begun programs to seek emissions reductions and begin emissions trading internally as well as externally.

Corporations have several motives for doing so. The search for measures to reduce greenhouse gas emissions is a spur to internal innovation, as well as to cost-saving from energy use reductions. The corporations are also engaging in this process to see how emissions trading systems would work administratively, to ready themselves for a future when such systems go into effect nationally and internationally. The corporations are also trying to position themselves to play a major role in the creation of the details of the emissions-trading rules. They also, of course, reap public relations benefits from being early adopters of environmentally-friendly actions.

Some of the companies are mainly doing emissions trading internally, and some only externally. British Petroleum, for example, has instituted internal trading in its business units in several countriesthough little between business units in different nations, because of the different regulatory regimes, tax and accounting laws, etc. in different countries. Ontario Hydro, on the other handhaving already greatly increased energy efficiency internallyis engaging in external trading by paying for emissions reduction projects elsewhere, in hopes it will be able to reap governmentally-sanctioned credits eventually for these emissions reductions.

Economic projection models

Economic models are required, at a minimum, to appease the modern need for quantification. But even if their quantitative outputs are not taken too seriously, these modelsand the process of constructing themare useful because they add the discipline of an economic framework to the discussions of climate change.

The purpose of economic modeling is widely misunderstood; the first to say that would be the modelers themselves. The purpose of economic modeling is not to produce the final answer in quantitative termsthe cost of reducing global warming over the next 50 years by 1º C., for example. The range of uncertainty in the results is far too broad for that. The uncertainty bands for economic projections should be considered wider than those for meteorological projections.

The purpose of economic modeling is to provide a disciplinedif oversimplifiedway to explore the sensitivity of results to changes in assumptions and policy measures. As such, it adds another way of thinking about the problems, one that complements less-quantitative considerations of policies and impacts.

More than 15 reputable economic models of climate change exist. They use a wide variety of methods, but some similarities can be outlined.

The fundamental elements of an economic model of climate change

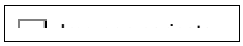
Economic models have been created to project the cost of policy measures to reduce greenhouse gas emissions and hence to reduce the likelihood of climate change. But models may also project the cost of the climate change itself, and thus the benefit of reducing it. When an economic model projects both the cost of measures to reduce greenhouse

gas emissions and the benefit of that reduction, it can compare the cost with the benefit.

An economic model must have at a minimum the following features:

A formula to project future economic output

Economic output is typically measured as the Gross Domestic Product (GDP) of a country or group of countries. Aggregate economic output is frequently modeled using a so-called Cobb-Douglas production function, which may take the form



where Q(t) is the output or GDP in year t, K(t) is the capital input in year t, L(t) is the labor input in year t, and γ is a constant usually determined by fitting the equation to past history. The factor *A(t)* is the technology input. Assumptions about the future values of the independent variables can vary widely, and may be a function of policy measures, especially the technology factor. The variables *K(t)* and *L(t)* are usually updated from one time period to the next using standard economic and demographic projection formulas.

When run for future years using the "base" assumptions for A, K, L and γ, such a formula will create the base projection for future economic output or GDP. By "base" assumptions is meant assumptions in the absence of policy measures to reduce greenhouse gases.

A formula or set of formulas to project the reduction or increase in future GDP given the implementation of greenhouse gas reduction policy measures

In the most elementary models the cost of reducing greenhouse gases is represented by a single formula equating change in GDP to a simple function of the percent decrease in greenhouse gas emissions.

But for most models this part of the projection is far more complex, depending on assumptions about the details of the policy measures and particularly on changes in the pace of technological innovation, and on supply and technology substitutions as a function of the policy measures. Sometimes the formulas are for the whole economy, and sometimes formulas are constructed for each industry or sector and aggregated to obtain results for the whole economy.

A formula or formulas to project the reduction (or increase) in future GDP due to climate changes caused by the projected greenhouse gas emissions

Not all models contain this feature, because some models are intended only to compare the costs of different policy measures to reduce greenhouse gases, or to explore the sensitivity of the costs to various assumptions, not to project the benefit of emissions reductions.

In simple aggregate models, temperature increase is projected as a function of greenhouse gas emissions, then the reduction in economic output is calculated as a function of the temperature increase. More attention is usually given to the projection of costs than to the projection of economic benefits from greenhouse gas reductions, due to the complexity of climate modeling.

A means of calculating a figure of merit for different scenarios

The projections of economic output are year-by-year projections, hence to compare projections for different scenarios-say, with and without policy measures to reduce greenhouse gasessome means of summarizing the multi-year GDP projections in a single figure is needed. This figure may be the GDP in a single future year, such as the 20^{th} year; it may be the present value of GDP using some appropriate discount rate; or it may be the present value of the *utility* of GDP, assuming an appropriate utility function.

The chief determinants of cost

Though models can use a wide variety of methods, the chief determinants of cost can be reduced to a short list.

Assumptions for the base case

Since the cost associated with a greenhouse gas policy is the reduction in GDP from the base case, it matters substantially what assumptions are made for the base case. If it is assumed, for example, that very little substitution of one energy source for another will be made in the base case, then policy measures to induce such substitution may realize substantial greenhouse gas reductions per unit cost. But if it is assumed that a great deal of energy source substitution will be made even without policy measures to reduce greenhouse gases, then the policy measures will appear to cost a lot per unit of reduction.

Assumptions about changes in behavior and technology as a response to policies

Policies that tend to increase the cost of energy are likely to cause both short- and long-term responses. They will bring about changes in behavior, substitutions of one energy source for another and one energy-use technology for another, and new technological innovations to conserve energy. The rate at which these events occur, and in what time frames, are assumptions of the model. Different assumptions about the rates of technological innovation, supply substitution, and behavior change will create widely varying projections.

The details of the policy measures undertaken to reduce greenhouse gases

In general, costs are substantially reduced if policy measures allow "joint implementation", that is, transfers of greenhouse gas emission reduction measures from countries where reductions are more costly to countries where they are less costly.

The time frame for implementation matters also. One widely-cited result is that if implementation of greenhouse gas emission reductions is delayed past the 2008-2012 time frame specified in the Kyoto Protocol, the cost of those reductions will be significantly lessened. This is because more of the capital stock of energy-using technologies will have time to be replaced after its useful life is over, rather than being replaced when it still has useful life leftwhich would be more costly.

Another important consideration in the modeling of policy measures is what is done with any revenues accruing to government from the policy measures. (If the measures include taxation or auctioning of emissions rights then substantial government revenue will accrue.) If the revenue is used to reduce existing inefficient taxes, it has been argued there could even be a net economic benefit, without regard to the benefit of greenhouse gas emissions (a so-called "double dividend").

The spread of projections using different assumptions and methodologies

Figure 1, from Repetto and Austin, shows how widely the projections can vary, depending on the assumptions and methodologies incorporated into the models. Projections of the change in GDP for the U.S. in the year 2020 from stabilizing emissions at the 1990 level vary from about minus-2.5% to plus-2.5%. Thus, model results are not very meaningful in themselves but must be considered conjointly with the assumptions and methodologies that the models use.

Are policy measures even needed?

The main thing the proposed policy measures will do is to increase the cost of using fossil fuels. Models have projected that the cost of emissions rights may be as low as U.S. $20 per ton of carbon or as high as U.S. $400 per ton. In the former case the cost of using coal would be increased by about 25%; the cost of using other energy sources would be increased significantly less.

Some argue that the cost of energy is already high enough to induce far more energy conservation than is taking place today, without cost increases resulting from policy measures. For example, Amory Lovins of Rocky Mountain Institute believes that so many profitable opportunities to use energy-efficiency technologies are available today, and will soon become available, that if users took advantage of all these opportunities greenhouse gas emissions would be reduced to acceptable levels.

Multinational corporations that have become frontrunners in the effort to institute internal emissions trading programs are partially driven by the possibility that this proposition may be true. They believe their programs may uncover large

numbers of previously untapped opportunities to save energy cost-effectively, and that this will justify their programs even if the Kyoto Protocol does not come into force.

Hence, the Kyoto Protocol, and all the negotiations to create an enforceable system of greenhouse gas emissions policies, may, if nothing else, lead to a greater awareness of the technological possibilities for profitable reductions in fossil fuel use.

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Table 1

Annex B

Party Quantified emission limitation or reduction commitment
(percentage of base year or period)

Australia 108

Austria 92

Belgium 92

Bulgaria 92*

Canada 94

Croatia 95*

Czech Republic 92*

Denmark 92

Estonia 92*

European Community 92

Finland 92

France 92

Germany 92

Greece 92

Hungary 94*

Iceland 110

Ireland 92

Italy 92

Japan 94

Latvia 92*

Liechtenstein 92

Lithuania 92*

Luxembourg 92

Monaco 92

Netherlands 92

New Zealand 100

Norway 101

Poland 94*

Portugal 92

Romania 92*

Russian Federation 100*

Slovakia 92*

Slovenia 92*

Spain 92

Sweden 92

Switzerland 92

Ukraine 100*

United Kingdom 92

United States of America 93

** Countries that are undergoing the process of transition to a market economy.*

Table 2

Burden-sharing Agreement among the European Union

Country	*% change from 1990 Emissions*	*% Share of 1990 EU Emissions*
Luxembourg	-28.0	0.3
Germany	-21.0	27.7
Denmark	-21.0	1.7
Austria	-13.0	1.7
United Kingdom	-12.5	17.9
Belgium	-7.5	3.2
Italy	-6.5	12.5
Netherlands	-6.0	4.8
Finland	0.0	1.7
France	0.0	14.7
Sweden	+4.0	1.6
Ireland	+13.0	1.3
Spain	+15.0	7.0
Greece	+25.0	2.4
Portugal	+27.0	1.6
European Union	-8.0	100

ONE FIGURE IS MISSING

Source: Repetto and Austin, page 13