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Estimating the Costs of Kyoto: Uncertainties and Assumptions Driving the Model Results

by Milka S. Kirova

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Executive Summary

The Kyoto Protocol on Climate Change, negotiated in December 1997, calls for industrial economies to reduce their emissions of carbon dioxide and five other greenhouse gases between 2008 and 2012 by an average of about 5 percent relative to 1990 levels. The target for the United States is a 7 percent decrease from 1990 levels; for the European Union, an 8 percent decrease; for Japan and Canada, a 6 percent decrease; for Russia, no change; and for Australia, an 8 percent increase. A number of issues regarding the implementation of the Kyoto agreement remain to be resolved through future negotiations of the participating parties. This introduces a high degree of uncertainty in the attempts of economists to estimate the impacts of reducing carbon dioxide emissions on the United States and other economies, both developed and developing.

Data on consumption of energy per unit of production show that, among the developed economies, Canada and the United States have relatively high energy intensity of production, suggesting higher costs of bringing emissions down. Comparison of the energy intensity of production in developed and some developing countries indicates that there is a substantial potential to increase the efficiency of energy use in the developing countries, China in particular. Realizing this potential through energy source restructuring and diffusion of advanced energy-saving technology would be vital for any attempt to reduce global carbon emissions.

All of the macroeconomic forecasts examined in this report show that policies to restrict carbon emissions push up energy prices, inflation, and interest rates and lead to lower consumption, investment, and net exports, thus reducing total production and income. But there is no consensus among forecasters on the magnitude of the U.S. economic impacts. The results from various models form a wide range of estimates of the U.S. economic costs to achieving its Kyoto target—from a negligible, less than one-tenth of 1 percent decrease in GDP in the forecast by the Clinton administration to a severe impact of a more than 4 percent decrease in GDP in the Energy Information Administration forecast.

One crucial factor yielding large differences in the predicted costs to the U.S. economy is the degree of flexibility in the mecha-

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nism for international emissions trading. The forecasts examined in this report unambiguously show that the most dramatic increase in energy prices and drop in production is expected under a system where no international trading of emissions is allowed. The economic costs would be smallest under full, unlimited international trading of emissions.

Introduction

The Kyoto Protocol on Climate Change, negotiated in December 1997, calls for industrial economies (called Annex I countries) to reduce their emissions of carbon dioxide and five other greenhouse gases between 2008 and 2012 by an average of about 5 percent relative to 1990 levels. The target for the United States is a 7 percent decrease from 1990 levels; for the European Union, an 8 percent decrease; for Japan and Canada, a 6 percent decrease; for Russia, no change; for Australia, an 8 percent increase.

At present, no technology is available to capture carbon dioxide once it is produced. The only effective means to reduce carbon dioxide emissions is to replace carbon-intensive fuels with non-carbon or less carbon-intensive ones, to cut down on the use of energy, or to increase carbon sinks, which remove carbon dioxide from the atmosphere, mainly through increasing the areas covered by forests.

In order to reduce emissions without reducing the use of energy, lower-emitting fuels, such as natural gas, would have to be substituted for higher-emitting fuels, such as coal. Also, fossil fuels—coal, natural gas, and oil, would need to be replaced gradually by alternative, non-carbon-emitting nuclear, hydroelectric, and renewable energy sources. Currently non-carbon-emitting sources of energy are only a small fraction of the total world energy supply, and the time required for their share to grow would likely be long.

Reducing the consumption of energy—another way of decreasing carbon dioxide emissions—would require substantial technological and other changes in the production and consumption activities in which firms and households use energy. Existing equipment would have to be retired early and replaced with more energy-efficient capital; new energy-efficient, reduced-emission vehicles would have to be developed by makers of automobiles and other transportation equipment; the thermal integrity of houses would have to be improved; household appliances would have to be replaced with more energy-efficient ones. Such changes cannot happen overnight, but there have been continuous efforts and progress in this direction: automakers are working on a “hybrid car” that uses fuel cells and an

advanced electrical battery; aerospace producers are developing lightweight metals to reduce fuel use; producers of household appliances are developing new, more energy-efficient models. Further developments of energy-saving technologies and their worldwide diffusion will play an important role in the global efforts to reduce carbon dioxide emissions in the future.

Economists seem to agree that policies to reduce carbon dioxide emissions impose a burden on the economy by increasing energy prices and inflation generally and slowing the growth of production, wages, and living standards. However, there is no consensus among forecasters on how heavy the burden of implementing the Kyoto Protocol would be. The predictions of the impact on the U.S. economy vary wildly—from predictions of almost no losses to a grim picture of severe economic consequences.

Economists seem to agree that policies to reduce carbon dioxide emissions impose a burden on the economy by increasing energy prices and inflation generally and slowing the growth of production, wages, and living standards.

Part of the reason for the lack of consensus in the estimates of the economic impact of reducing carbon emissions is the remaining fundamental uncertainty regarding a number of questions surrounding the implementation of the Kyoto agreement. Some of the major unresolved issues concern the development of emission trading schemes and other flexible mechanisms on a national and international basis and the participation of the developing world in the global effort to reduce greenhouse gas emissions.

The Kyoto Protocol provisions allow for trading of national emissions rights among Annex I countries but the mechanism is not well-defined. Also allowed, but not defined, are project-by-project bilateral exchanges of "emission reduction units," called joint implementation, and crediting, in an unspecified way, for reductions accomplished in developing countries, called Clean Development Mechanism. It is also possible for participating countries to form "bubbles" and meet their combined assigned emission amounts jointly.[1]

This study offers an analysis of and some insights into the economic impacts of implementing the Kyoto Protocol and the uncertainties involved in estimating these impacts for the United States and other countries. The next section provides background infor-

mation on two important factors that influence the magnitude of the impacts—the level and growth of carbon emissions since 1990 and the energy intensity of production in individual countries. The third section analyzes the channels through which carbon reduction policies influence the economy. It also compares and discusses various economic model forecasts of the costs of reducing carbon emissions in the United States. The fourth section looks at the economic impacts on some other economies, both industrialized and developing. The last section presents the conclusions from this analysis.

Background Data on Carbon Emissions and Energy Intensity of Production

The extent to which a national economy would be affected by domestic and/or international limits on carbon emissions varies, depending on a number of factors. Among them are the composition of the country's energy sources, its industrial structure, the energy intensity of production in various industries, its international trade specifics, and the rates at which production, carbon emissions, and population grow over time. A factor that carries important consequences for the economic impact of emissions restrictions under the Kyoto Protocol is how fast emissions in individual countries have grown since 1990, the benchmark year in the Protocol. Among the group of participating countries, those that have had the fastest emissions growth since 1990 are likely to face the heaviest economic costs in bringing down emissions.

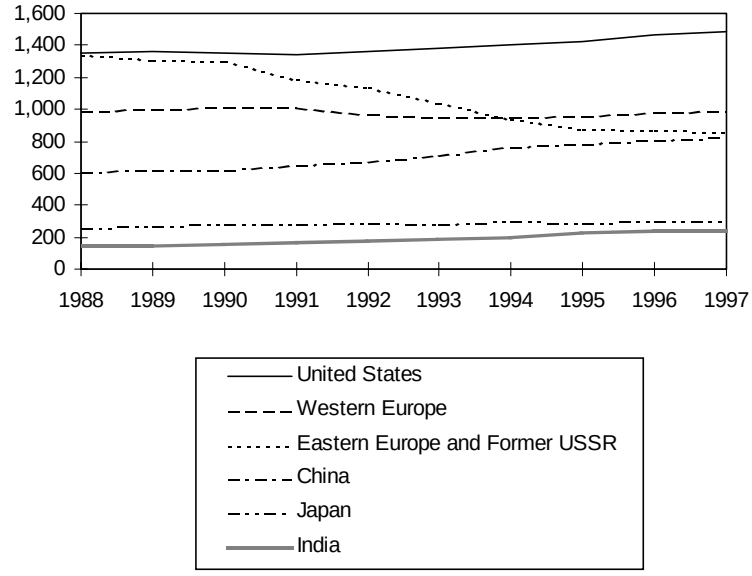
Carbon Dioxide Emissions

Carbon dioxide emissions from the consumption and flaring of fossil fuels over the last decade in selected countries and geographical areas are shown in Figure 1. Since 1990, carbon dioxide emissions in the European countries as a group have decreased—by 2 percent in Western Europe, on average, and by 34 percent in Eastern Europe and the former Soviet Union. The drastic decrease in emissions in Eastern Europe and the former Soviet Union during the 1990s has come as a result of massive structural adjustments and subsequent contractions of the former centrally-planned economies. This trend is not likely to be sustained in the long-run, because as soon as these economies exit the period of transition and start growing again, carbon dioxide emissions will increase.

Over the period 1990-97, carbon emissions from the consumption and flaring of fossil fuels in the United States, currently the

Figure 1

Carbon Dioxide Emissions from the Consumption and Flaring of Fossil Fuels (Millions of Metric Tons of Carbon)

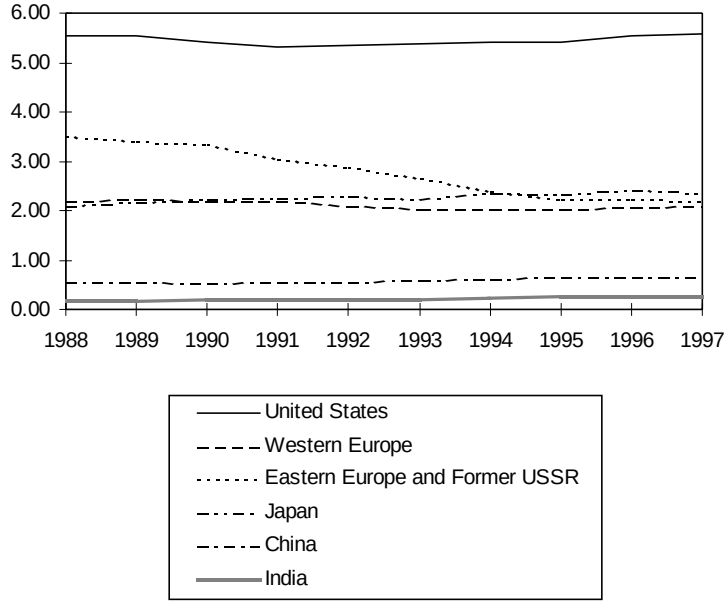


Source: Energy Information Agency, Department of Energy, *International Energy Annual 1997*.

world's largest emitter, increased by 10 percent to reach 1.47 billion metric tons in 1997. Over the same period, emissions in Japan increased by 8 percent. The fastest-growing emitters of greenhouse gases during the 1990s were China and India, with 32 percent and 52 percent increases, respectively, over 1990-1997. The high growth of emissions in China and India is no surprise, given the low base levels. In 1990 China emitted 620 million metric tons and India, only 155 million metric tons of carbon.

In the years to come, the economies of the developing countries are expected to grow more quickly than those of the industrialized countries. As their economies expand, the developing countries will consume more energy, which will presumably drive carbon emissions up. Forecasts by the Energy Information Agency suggest that, if the currently observed upward trend in carbon emissions from developing countries continues, they will emit more carbon than the industrialized economies of the world by 2015.[2] These estimates have raised legitimate concerns among

Figure 2
Carbon Dioxide Emissions per Capita (Metric Tons of Carbon)



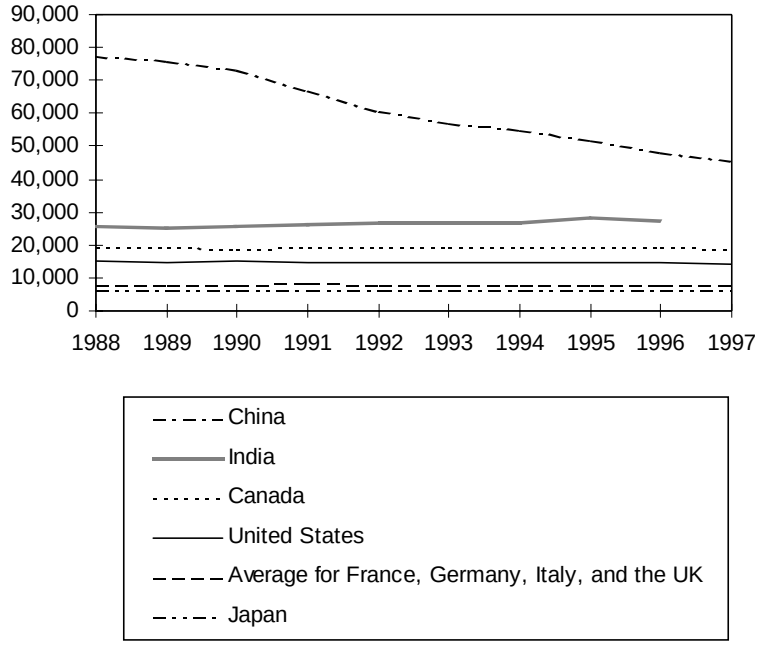
Source: Energy Information Agency, Department of Energy, *International Energy Annual 1997*.

policymakers in the United States about the effectiveness of the Kyoto Protocol in achieving the goal of reducing global carbon emissions if developing countries do not participate in the effort.

The developing countries, however, are not willing to agree to restrictions of carbon emission, because that would burden their economies and hamper the prospects for growth and development. International diplomacy could hardly be successful in persuading developing countries to impose mandatory carbon restrictions, because issues of equity and fairness inevitably arise. As can be seen in Figure 2, emissions per person in China and India have been much lower than those in the industrialized world. U.S. emissions per capita have been particularly high—more than twice as high as in Japan and Western Europe, about 10 times higher than in China, and more than 20 times higher than in India. This puts the United States in a difficult position when it criticizes other nations for their carbon emissions.

The current levels and growth trends in carbon emissions around

Figure 3
Consumption of Energy per Unit of Production (BTU per 1990$)



Source: Energy Information Agency, Department of Energy, *International Energy Annual 1997*.

the world do not necessarily imply that it is not feasible to reduce global carbon emissions in the future, or at least temper their growth. Improving the efficiency of energy use globally should be an important part of these efforts. An indicator of how efficiently energy resources are used is the energy-intensity of production, calculated as the amount of energy consumed per unit of production.

Energy Intensity of Production

Figure 3 shows the data on the energy intensity of production in selected countries. In general, countries with higher energy intensities of production are expected to suffer higher economic costs of bringing emissions down, other factors unchanged. For the developed economies, shown in Figure 3, the data on energy intensity exhibit no trend, but there appear to be significant differences

across countries. The amount of energy consumed per unit of production in Japan is not very different from that consumed in a group of four Western European economies (France, Germany, Italy, and the United Kingdom). But the energy consumed per unit of production in Canada and the United States is much higher.

Over the last decade, on average, energy consumption per unit of production in Canada has been 206 percent higher than that in Japan and 145 percent higher than that in the Western European group. The energy intensity of production in the United States has exceeded that in Japan by 133 percent and that in the Western European group by 86 percent. A recent positive development in Canada and the United States is the decrease in energy consumption per unit produced by more than 3 percent in 1997.

In general, countries with higher energy intensities of production are expected to suffer higher economic costs of bringing emissions down, other factors unchanged.

While the major reason for the observed differences in the energy intensity of production among the developed countries is most likely their industrial structure, an additional factor contributing to the relatively high energy consumption per dollar of production in Canada and in the United States could be the bias generated by the way production is measured. In the United States, for example, partly because of the lower taxation of gasoline and the smaller population density, more people drive their own cars over longer distances than in Japan and Western Europe. This translates, in economic terms, to more transportation services provided to consumers in the United States. But when someone drives her own car, the transportation services she provides to herself are not counted as part of production as they are when that person takes a taxicab, bus, or train. Thus in the United States, where people use predominantly their own cars for transportation, the measure of production would be biased downward more than in Japan, for example, where the use of public transportation prevails. Consequently, given each country's energy consumption, the energy intensity of production in the United States would be biased upward more than the energy intensity of production in Japan.

The most striking difference in Figure 3 is between the effi-

ciency of energy use in China and that in the developed countries, particularly in the late 1980s and the early 1990s. In that period, China used about six times more energy per dollar of production than the average of the developed countries included in the chart. While this suggests that China is far behind the developed world in terms of efficiency of energy use, there have been strong positive changes over the last decade. Chinese energy consumption per unit of production has followed a steep downward trend—since 1990 it has decreased about 40 percent, moving closer to that in the developed world. If this favorable trend continues, the future growth of the Chinese economy may not necessarily imply the drastic increases in energy consumption and carbon emissions that the Energy Information Agency has predicted in its forecast.[3]

What Would It Cost to Reduce U.S. Carbon Emissions to the Kyoto Target Level?

Economic Impacts of Policies to Reduce Carbon Dioxide Emissions: A General Analysis

The data on carbon emissions and energy intensity of production presented in the previous section provide some insights about the potential economic costs of reducing carbon dioxide emissions in the United States and other countries. These data cover a small fraction of the factors that affect the economic costs of reducing carbon emissions, but the indications are that in the United States the costs will be relatively high. Both U.S. emissions growth and U.S. energy intensity of production have been high compared to other developed countries. According to the Department of Energy forecast, to comply with the Kyoto agreement, the United States will have to reduce its emissions in the year 2010 by 30 percent compared to the "business as usual" case, when no restrictions on carbon emissions are imposed.[4] This drastic decrease in emissions required within a relatively short period of time will likely impose a considerable burden on the U.S. economy.

How will restrictions on carbon dioxide emissions affect the economy of a country implementing such policies? The industrial countries participating in the Kyoto agreement already know the level of carbon dioxide emissions they will need to reach and the target periods of compliance. One way to meet the target would be to determine limits or "caps" for all domestic emitters, adding up to no more than the total emissions assigned to the country. A system could be designed for individual domestic emitters to trade

emission permits, given the determined emission caps. This cap-and-trade mechanism will likely be introduced in the United States. Alternative instruments to keep national emissions at a prescribed level are domestic carbon taxes and domestic fixed-quantity standards, such as fuel-efficiency standards.

Regardless of whether domestic tradable permits, carbon taxes, or a combination of the two is introduced, consumption of carbon-emitting fossil fuels would become more costly. The added costs of fossil fuel consumption would push up energy prices. Since energy is an important input in the production of all goods and services, the overall price level, i.e. inflation, is likely to increase.

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This energy price shock would affect both consumers and producers. Rising prices of gasoline, electricity, and home heating would reduce consumer demand for these goods and services to a degree determined by the sensitivity of household energy consumption to changes in the price of energy. Businesses, facing higher energy costs, would likely cut down production, especially in high energy-intensive sectors of the economy, and attempt to develop more energy-efficient means of production. Employment in energy-intensive industries would also fall. The rise in prices would push interest rates up, affecting investment. Business purchases of machines, vehicles, and equipment and housing starts would decrease.

The fall in consumption and investment would decrease total production, or GDP. GDP would further be affected by worsening terms of trade. Because of the higher energy prices, domestically produced goods and services would become relatively more expensive and, thus, less competitive on world markets. Therefore, exports—especially to developing countries not participating in the agreement—would fall, while imports—especially from non-participating countries where energy costs are lower—would be relatively cheaper and, thus, increase. This would adversely affect the trade balance of the country. Economies engaged in active trade with

developing countries, such as the U.S. economy, would be affected the most by falling net exports, which would further decrease GDP.

The magnitude of the macroeconomic impacts on a particular country depends on a number of factors, some of which were already discussed, and others which were only mentioned. The following sections offer an overview of the results from models used by economists to predict the impact of implementing the Kyoto agreement on the United States and other countries.

Forecasts of the Economic Costs of Reducing Carbon Dioxide Emissions in the United States

Several large macroeconomic models have been used to predict the costs for the U.S. economy of reducing greenhouse gas emissions to the Kyoto target level. There seems to be a consensus that emission restrictions will slow the growth of production in the United States, but the magnitude of costs predicted by different models varies greatly. In the Clinton administration forecast annual GDP is predicted to fall by less than 1 percent, while in the Energy Information Administration (EIA) forecast it is predicted to fall by more than 4 percent, relative to the baseline scenario of no mandatory restrictions on carbon emissions. These decreases in percentage terms imply losses of total U.S. income ranging from $10 billion (inflation-adjusted) per year in the administration forecast to $400 billion per year in the EIA forecast.

Why are the costs for complying with the Kyoto protocol agreement predicted by the various models so different? Some of the major differences in the cost estimates are the result of varying assumptions about:

1) *the projected growth rates of GDP and carbon emissions in the baseline case*. The lower the assumed growth in GDP and carbon emissions, the less the needed reduction in emissions to meet the Kyoto target.

2) *the potential for extending the life of existing nuclear energy sources beyond the normal licensing period*. If the life of existing nuclear plants could be prolonged, then the increase in emissions would be lower, everything else being equal, since they would not have to be replaced by plants using fossil fuels.

3) *the amount of uncertainty about future events that decision makers face*. The higher the degree of uncertainty, the higher the costs, since decisions will have to be made

Table 1
Degree of Carbon Emissions Trading Allowed in the Macroeconomic Forecasts

	Admin. Forecast	Manne/ Richels Forecast	Charles River Assoc. Forecast	WEFA Forecast	EIA Forecast
No Trading		✔	✔	✔	✔
Some Trading		✔	✔		
Full Trading	✔	✔	✔		

without perfect knowledge about prices, demand in various markets, regulatory policies, etc.

4) *how fast and to what extent consumers will react to changing conditions in energy markets*. If price elasticity of energy demand is high, which means that consumer demand for energy is highly sensitive to changes in energy prices, then it would be easier to achieve the target levels for carbon emissions. If price elasticity of demand is low, then it would be harder to meet the target.

5) *the level of aggregation of the model.* A highly aggregated model may not capture important structural changes within and between industries that would be most affected by the climate change policies. Such a model is likely to underestimate the costs of compliance with the Kyoto agreement.

6) *whether there is emissions trading or other flexible mechanisms in place, what geographical regions participate in the flexible mechanisms, and the level of transaction costs associated with their implementation*. The more flexibility built into climate change policies and the broader the degree of country participation, the lower the expected costs of compliance.

The task of comparing the models used for climate policy cost predictions and the results they produce is difficult because each model has a different structure, different implicit and explicit

assumptions under which it is run, and its own virtues and shortcomings. One particularly important feature of these models is the degree of flexibility built into the emissions reduction mechanism. Some of the models—the ones used by Charles River Associates, Inc. (CRA) and Manne and Richels (1998), for example—forecast costs under different flexibility scenarios. Other models—the ones used by the administration, WEFA, Inc., and the EIA, for example—are run only under the extreme cases of no trading or full global trading (see Table 1). The models with greater ability to alter scenarios have a clear advantage over the models that are more rigid.

The predictions of the models that are run under different trading flexibility scenarios unambiguously show that the larger the degree of "where" and "when" flexibility in the carbon emissions trading mechanism, the lower the burden of reducing carbon emissions. The projected price of carbon emission permits is lower and the adverse effects on production, employment, and economic growth are smaller when timing and location of emissions changes are more flexible.

One important practical issue, though, is how feasible it is to develop and enforce an efficient global emissions trading mechanism by the year 2010, the midpoint of the first Kyoto target commitment period. Most experts are skeptical. Given the current state of the Kyoto protocol provisions and the negotiations that surround it, it seems unlikely that a global trading mechanism will be agreed upon and implemented within the next decade or so.

The reasons for skepticism are numerous, ranging from political to administrative to technical. The issue of international trading, itself, has not yet been resolved in detail. Some Western European countries, as well as some developing countries with influence on the negotiations, oppose unrestricted emissions trading. The United States, thus far, has insisted on an open trading scheme as a condition of U.S. participation. How the emissions trading issue will be resolved in future negotiations is uncertain. But even in the optimistic scenario—successful political agreement in favor of unrestricted trading—it is not very likely, from a practical viewpoint, that an efficient international trading mechanism will be functioning within the next decade because of the numerous administrative and technical hurdles involved.

An international emissions trading mechanism will require a number of conditions in order to function smoothly and efficiently. Among them are: initial allocation of carbon emission property rights; an efficient system of monitoring all participants; adequate measurement of the caps, holdings, permits, and emissions of all countries; a system to enforce compliance with the trading rules;

and appropriate ways to penalize participants that break those rules. It will also require a system to distribute the revenues from permit auctions. Successful accomplishment of all of these tasks would be a challenge requiring tremendous international effort and a significant amount of time. At this point, the most realistic assumption appears to be that some degree of emissions trading would be allowed, but there would not be full, unlimited international trading.

The Optimistic Forecast: Administration Estimates Under Global Emissions Trading

At the low end of the spectrum of forecasts of the macroeconomic impacts of the Kyoto protocol is the one developed by the Clinton administration. Much of the administration analysis of emission reduction costs is based on results from the Second Generation Model (SGM) developed at Pacific Northwest National Laboratory in Washington D.C. This model, as experts have pointed out, tends to produce cost estimates that are biased downward because of some of the assumptions built into the model structure.[5]

One of the SGM assumptions that has come under criticism is that of instantaneous adjustments to energy price changes in all markets except the market for electricity. The problem with this assumption is that when the model is used for predictions over a relatively short time frame, it tends to produce unrealistically low cost estimates because it reports only the direct impact on the market for energy. Thus the SGM leaves out potential changes and costs in the other sectors of the economy, while other models used for climate policy analysis usually take these changes into account, thus producing higher cost estimates.

In addition to the unaccounted costs in the non-energy sectors of the economy, the SGM misses important effects that spill beyond national boundaries. It does not allow, for example, for changes in international capital flows or shifts of energy-intensive production to countries that are not bound by carbon emission restrictions. Such shifts, however, would very likely occur if developing countries do not face emission restrictions.

The administration makes predictions of the costs of reducing emissions under two scenarios. Under Scenario I, the non-European Annex I countries and key developing countries participate in emissions trading. Under Scenario II, all Annex I countries and key developing countries participate in emissions trading. The administration predicts an annual loss of GDP between $7 billion and $12 billion compared to the baseline forecast with unrestricted energy

Table 2

Administration Forecast of the Impact of Reducing Carbon Dioxide Emissions to the Kyoto Target Level in the United States in 2010

	Scenario I: Annex I countries,[6] except the European Union, and key developing countries participate in emissions trading	Scenario II: All Annex I countries and key developing countries participate in emissions trading
Total Resource Cost (billion $1992)	$7	$12
Cost as Share of GDP	0.07%	0.11%
Estimated Increase in Annual Energy Costs per Household	$70	$100
Carbon Permit Price (per ton)	$14	$23
Electricity Price (per kWh)	6.1c (BAU*+0.2c)	6.2c (BAU+0.3c)
Gasoline Price (per gallon)	$1.293 (BAU+$0.03)	$1.314 (BAU+$0.055)
Fuel Oil Price (per gallon)	$1.140 (BAU+$0.048)	$1.170 (BAU+$0.078)
Natural Gas Price (per mcf)	$4.00 (BAU+$0.2)	$4.13 (BAU+0.33)
GDP (billion $1992)	$9,184 (BAU-$1)	$9,180 (BAU-$5)
Investment (billion $1992)	$1,346 (BAU+$1)	$1,348 (BAU+$3)
Consumption (billion $1992)	$5,959 (same as BAU)	$5,955 (BAU-$4)

*Business as usual

Source: Council of Economic Advisers, *The Kyoto Protocol and the President's Policies to Address Climate Change: Administration Economic Analysis*, July 1998.

use. Carbon permit prices are estimated at $14/ton and $23/ton in the two scenarios (see Table 2). The estimated increases in electricity prices are small, as are gasoline, oil, and natural gas price increases. The administration predicts that the energy costs of an average household would increase by a negligible amount—between $70 and $100 per year.

The administration's optimistic forecast has been received with deep skepticism because of its unrealistically low estimates of the costs of limiting carbon emissions in the United States.

The administration's optimistic forecast has been received with deep skepticism because of its unrealistically low estimates of the costs of limiting carbon emissions in the United States. The structure of the model used by the administration is one reason for the low estimates of the costs. Another key factor is the assumption that the United States will have access to unrestricted global emissions trading. As discussed earlier, though, unrestricted global emissions trading is not a very realistic scenario, especially for the first Kyoto commitment period, 2008-2012.

The Pessimistic Forecasts: WEFA and Energy Information Administration Estimates under No International Emissions Trading

At the high end of the spectrum are the cost forecasts of WEFA, Inc. and the EIA. Both WEFA and EIA use highly detailed models of the U.S. economy.

WEFA makes bold assumptions about the future energy efficiency and energy source structure of the United States. They assume that over the next 20 years the energy efficiency of production will improve at twice the rate of the previous 10 years and that the fuel with the lowest carbon content—natural gas—will increase its market share significantly. Nevertheless, given the assumed population growth and the retirement of nuclear plants, U.S. carbon emissions will be 37 percent above the Kyoto target in 2010 and 57 percent above the target in 2020 by WEFA's projec-

Table 3

WEFA Forecast of the Impact of Reducing Carbon Dioxide Emissions to the Kyoto Target Level in the United States in 2010 under No International Trading (Percent Difference from Business as Usual)

	2010 Kyoto Target Case
GDP Difference in million $1992	-3.2% $301.5
Non-Residential Fixed Investment	-3.6%
Consumption	-2.5%
Unemployment Rate	1.5%
Inflation GDP Price Deflator	14.4%

Source: WEFA, *Global Warming: The High Cost of the Kyoto Protocol, National and State Impacts*, WEFA, Inc., 1998.

tions. In WEFA's analysis, the huge reduction of carbon emissions needed is assumed to be achieved through sales of carbon emission permits, whose owners are allowed to trade them domestically. This system is similar to having a carbon tax imposed on emitters. WEFA further assumes that the revenues collected from carbon permits/taxes are given back to consumers as an annual lump-sum repayment.

WEFA predicts that reducing emissions to the Kyoto target level could produce a strong negative shock with profound effects on the energy sector and the entire U.S. economy. Their projections show that inflation would increase by more than 14 percent above the baseline case and GDP would decrease by more than 3 percent (see Table 3). This decline in GDP translates into a decrease in average annual income per household of more than $2,700. Employment and wages are also predicted to decrease. In addition, because energy costs take a much bigger share of the budget of low-income households than of higher income groups, the combination of rising

energy costs and falling incomes would be regressive, hurting people in the lower income brackets the most.[7]

WEFA argues that, because the Kyoto Protocol does not make clear whether or when an effective international trading program would be implemented, it is unlikely that within a decade or two participating countries would be able to take advantage of emissions trading. On the one hand, WEFA's point about the uncertainties involved in implementing an international emissions trading mechanism and its timing is justified. On the other hand, though, it is highly unlikely that the full commitment would be made by the United States, a major player in the negotiations, and several other developed countries to reduce their carbon dioxide emissions without any mechanism to trade emissions internationally.

EIA's macroeconomic cost projections are even higher than the WEFA estimates (see Table 4). For its macroeconomic analysis, EIA uses the Data Resources, Inc. model of the U.S. economy, a large econometric model with detailed accounts of the output, price, and financial sectors. This model incorporates gradual adjustment of the economy to policy changes, a feature to its advantage compared to the model used by WEFA. The analysis assumes that to achieve the Kyoto targets in the United States, carbon permits are traded at an auction run by the federal government. A serious weakness of the model used by the EIA is that it does not have global coverage and thus does not provide the capability to analyze impacts of international emissions trading.

EIA estimates of the macroeconomic impacts of meeting Kyoto target emissions in the United States are summarized in Table 4. U.S. GDP is projected to fall by 4.2 percent, consumption by 2.9 percent, and investment by 4.8 percent, relative to the 2010 business-as-usual case. Projected price increases are very large—gasoline prices are forecasted to increase by more than 50 percent and electricity prices by more than 80 percent.

Both WEFA, Inc. and EIA make their forecasts of the U.S. economic costs of reducing carbon emissions under the assumption of no international emissions trading. Given that this is a highly unlikely scenario of implementing the Kyoto agreement, WEFA and EIA cost predictions are to be viewed as the pessimistic extreme. Their analysis is nonetheless valuable as it reveals the potentially large adverse effects on the U.S. economy of imposing carbon dioxide emission restrictions without any market incentives built into the mechanism for implementing climate policies.

Table 4

EIA Forecast of the Impact of Reducing Carbon Dioxide Emissions to the Kyoto Target Level in the United States in 2010 under No International Trading

	Business as Usual Case	Kyoto Target Case
Carbon Permit Price (per ton)	NA	$348
Electricity Price (per kWh)	5.9¢	11.0¢
Gasoline Price (per gallon)	$1.25	$1.91
Natural Gas Price (per 1000 cubic feet)	$3.87	$9.57
GDP (billion $1992)	$9,429	$9,032
Investment (billion $1992)	$1,745	$1,662
Consumption (billion $1992)	$6,347	$6,160

Source: Energy Information Administration, *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*, 1998.

Forecasts under Varying Degrees of Trading Flexibility: Estimates by CRA, Inc. and Manne and Richels

CRA, Inc. uses a more aggregated multi-sector, multi-regional trade (MS-MRT) model to analyze the impacts of emissions reduction on the United States and other countries. A positive feature of the model is that it allows for investigation of the international trade effects resulting from emission-reduction policies under different trading schemes. One weak feature of the MS-MRT model is that it makes the assumption that future changes in markets

Table 5

CRA, Inc. Forecast of the Impact of Reducing Carbon Dioxide Emissions in the United States to the Kyoto Target Level in 2010

	Scenario I: No Trading	Scenario II: Annex I Trading	Scenario III: Full Global Trading
Decrease in U.S. Welfare (% change from baseline)	-1.3	-0.8	-0.4
Carbon Permit Price	$274	$84	$36
Increase in Energy Prices (% change from baseline)	113.9	42.1	15.8
Petroleum Price* (per gallon)	$3.26	$1.94	
Electricity Price* (per kWh)	8.3¢	6.6¢	
Natural Gas Price* (per thousand cubic feet)	$8.74	$5.17	

Source: Bernstein, Montgomery, and Rutherford, *Trade Impacts of Climate Policies: The MS-MRT Model*, CRA, Inc., 1998.

* Data taken from Tables C2 and C3 of EIA, *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*, 1998.

are perfectly anticipated and taken into account by firms and consumers when current decisions are made. This assumption is unrealistically strong for any analytical purpose, but even more so in the case of the Kyoto agreement, given the fundamental uncertainties surrounding its implementation. Another weak feature of the model is that its global coverage requires certain simplifications in the presentation of each geographical region, leading to somewhat understated estimates of the costs of reducing emissions.

The main virtue of the MS-MRT model is that it allows for analysis of different trading scenarios. Bernstein, Montgomery, and Ruth-

erford (1998) provide results under no emissions trading, trading only among Annex I countries, and full global trading (see Table 5 for a summary of the results). They consistently find that reducing carbon emissions with no international emissions trading adversely impacts the economies of all industrial countries and of some developing countries. Limited trading between Annex I countries is shown to reduce the negative impact on developed countries. Global trading is worse for some developing countries than no trading, because it eliminates distortions, such as carbon leakages, that would benefit those countries under limited emissions trading scenarios.

It is consistently found that reducing carbon emissions with no international emissions trading adversely impacts the economies of all industrial countries and of some developing countries.

Another model that allows for analysis of climate policy impacts under different trading scenarios is the one used by Manne and Richels (1998), called MERGE (a model for evaluating the regional and global effects of greenhouse emission reduction policies), in which the world is divided into nine geopolitical regions. Similarly to the model used by CRA, Inc., MERGE assumes that decision makers have perfect foresight about future market conditions. This assumption again leads to lower projections for the economic costs of reducing emissions, as in the CRA cost estimates.

Manne and Richels explore the consequences of meeting the Kyoto target level of emissions under three scenarios: no trading of emissions, Annex I trading plus Clean Development Mechanism, and full global trading. The projected annual U.S. GDP loss in 2010 is $87 billion under no trading, $50 billion under Annex I trading plus CDM, and $21 billion under full global trading. The value of carbon emission rights under the three scenarios is $240 per ton, $100 per ton, and $70 per ton, respectively.

The results from Manne and Richels's formal analysis provide several important insights for policymakers. One is that, as some of the other studies have shown, international trading of emission rights is essential to reducing the economic costs of emissions reductions. When limits are imposed on the purchase of emissions rights, GDP losses increase substantially. In the United States, for

example, if purchases of emissions are limited to one-third of the country's obligations in 2010, U.S. GDP losses could triple, according to Manne and Richels. This result implies that, in order to minimize costs of reducing carbon emissions, it is not sufficient just to have developing countries participate in the trading mechanism. It is also important to not limit or cap the amount of carbon emissions that countries can trade.

Other important insights drawn from the analysis of Manne and Richels concern the issue of carbon leakage. They show that when non-Annex I countries face no mandatory constraints on their emissions, energy-intensive industries, such as steel, paper, and chemicals, would tend to migrate from Annex I countries to non-Annex I countries, such as China, India, Brazil, and Mexico. If carbon leakage occurs, then the reductions in emissions from Annex I countries would be offset, at least partially, by increases in emissions from non-Annex I countries.

What Would It Cost Other Countries to Comply with Climate Policy Restrictions?

The predictions of the economic impact of carbon emission policies on other countries are not as numerous as the ones available for the United States. Bernstein, Montgomery, and Rutherford (1997) of CRA, Inc. estimate the economic impact of policy commitments to reduce carbon emission for individual countries. One of the scenarios under which they make the cost projections is called "Reduction Proposal." This proposal requires a decrease in carbon emissions of participating countries to 10 percent below their 1990 levels by the year 2010—a more stringent requirement than the provisions of the Kyoto Protocol agreement.

The major macroeconomic impacts on individual industrialized and developing countries, estimated by CRA under the Reduction Proposal, are discussed below.

Cost Estimates of Reducing Emissions in Developed Countries

To reduce carbon emissions to 10 percent below 1990 levels by 2010 would require participating countries to decrease their projected emissions under business as usual between 21 percent (for Germany and the United Kingdom) and 34 percent (for Australia). For the individual countries, the range of the projected decline in total production that emission restrictions would cause in 2010 is fairly wide (see Table 6). Canada, the United States, and Italy are

Table 6

CRA, Inc. International Forecast: Percent Change from Business as Usual under a 10 Percent below 1990 Carbon Dioxide Target by 2010

Country	Carbon Emissions	GDP	Unemployment Rate
Canada	-31.0	-2.8	3.4
United States	-32.1	-1.9	2.45
Italy	-28.5	-1.9	3.5
Japan	-30.2	-1.5	2.5
France	-29.2	-1.4	2.9
Australia	-33.8	-1.3	1.0
United Kingdom	-20.6	-0.9	1.5
Germany	-21.5	-0.7	1.3

Source: Bernstein, Montgomery, and Rutherford, *World Economic Impacts of U.S. Commitments to Medium-Term Carbon Emissions Limits*, CRA, Inc., 1997.

projected to suffer the highest economic costs, with GDP falling 2.8 percent, 1.9 percent, and 1.9 percent, respectively. The United Kingdom and Germany would bear the least cost, with GDP falling only 0.9 percent and 0.7 percent, respectively.

The notable differences in the estimated economic costs of reducing carbon emissions in developed countries are largely due to country-specific factors. Germany, for example, will not suffer big losses from carbon-restricting policies because of the changes in its economy after unification in 1990 and the choice of the same year as the benchmark for emission reductions. In former East Germany, energy production used to be based largely on coal, and energy efficiency was very low. Over the last decade the East German economy has been undergoing massive structural adjustments. Since 1990,

production there has contracted, driving total carbon emissions in unified Germany down. These changes, not related to climate policies, make it relatively easy for the German economy to meet the emission limits under the Reduction Proposal.

In the case of the United Kingdom, energy deregulation and a decrease in the subsidies for coal producers have encouraged substitution of natural gas for coal. Many old steel plants have been closed down for economic reasons. This has contributed to a decline in 1995 U.K. total carbon emissions to 9 percent below 1990 levels—a change that helps explain the low cost forecast for emission reductions to reach the Reduction Proposal target.

In Canada, on the other hand, a combination of factors related to its trade characteristics and industrial structure is expected to contribute to major economic losses under the Reduction Proposal. One factor is that exports are a big share of Canada's GDP and a large portion of its trade is with developed countries. This, in turn, makes the Canadian economy particularly susceptible to the decreases in total income and demand other developed economies will undergo as a result of climate policy restrictions. Another factor is that Canada exports oil and hence will suffer losses from the decrease in world oil demand. Finally, the relatively high energy-intensity of the Canadian economy implies higher costs to reduce emissions there than in countries with less energy-intensive economies.

Economic Impact on Eastern European and Developing Countries

CRA projections for the impact on Eastern European economies is based on the assumption that these countries will not agree to carbon emission constraints. Under this assumption, the impact on their GDP is not very large. In 2010, under the Reduction Proposal, GDP losses range between virtually no loss for Poland to about 0.7 percent for Russia and the former Soviet Union. The losses that former centrally-planned economies are expected to suffer stem from worsening conditions of trade as the prices of imports from developed countries rise due to the higher costs of energy.

The developing countries face mixed prospects—some countries are predicted to benefit from emission restrictions in the developed economies, others would suffer losses. The most important factors that determine whether a developing country benefits or loses are 1) whether it is an oil exporter or an oil importer, 2) what portion of its trade is with developed countries, and 3) how energy-intensive its economy is. Countries that export oil will be hurt by

the fall in world demand for oil, while oil importers will benefit from the fall in world oil prices. The more actively the developing country trades with countries subjected to emission constraints, the more it will suffer from the shrinking demand for imports in these countries and the rising prices of exports out of these countries. And finally, the higher the energy-intensity of production in the developing country, the more it will benefit from the fall in world oil prices.

The projections that CRA makes for individual developing countries show that oil-exporting countries will be hurt the most, with the United Arab Emirates, Kuwait, and Oman at the top of the list, losing more than 2.1 percent of their GDP in 2010. China, India, and Brazil are projected to suffer small negative impacts from the emission restrictions in developed countries. Projected GDP losses in these countries are below 0.3 percent. A small number of countries will be marginally better off in 2010. The list includes Jamaica (0.6 percent increase in GDP), Jordan (0.2 percent), South Korea (0.1 percent) and a few others.[8]

Summary and Conclusions

Fundamental issues regarding the use of flexible mechanisms and the participation of developing countries in the implementation of the Kyoto Protocol agreement remain unresolved. This introduces a high degree of uncertainty and makes it very difficult to have consistent estimates of the economic costs to the United States and other countries of reducing emissions to the Kyoto target levels.

International data on carbon dioxide emissions show that emissions in developing countries are growing faster than emissions in the developed world, largely because of the lower base levels in the developing countries. The industrial economies, however, currently emit much more carbon per capita than the developing countries. The United States is the world's largest carbon dioxide emitter in terms of total emissions and emissions per capita. The growth of U.S. emissions has also been relatively high compared to that in other developed economies, suggesting that it would be more burdensome for the U.S. economy to accommodate its Kyoto target level.

Data on the consumption of energy per unit of production show that among the developed economies, Canada and the United States have relatively high energy intensity of production. Comparison of the energy intensity of production in developed and some developing countries indicates that there is a substantial potential to increase

the efficiency of energy use in the developing countries, China in particular. Realizing this potential through energy source restructuring and diffusion of advanced energy-saving technology would be vital to an attempt to achieve the goal of reducing global carbon emissions in the future.

All of the macroeconomic analyses examined in this report show that restricting carbon emissions pushes energy prices, inflation, and interest rates up and leads to lower consumption, investment, and net exports, thus reducing total production and income. However, there is no consensus among forecasters on the magnitude of these impacts. The results from various models used to predict the U.S. economic costs of reducing emissions to the Kyoto target display a wide range of estimates—from a negligible less than one-tenth of 1 percent decrease in GDP in the administration's forecast to a severe impact of a more than 4 percent decrease in the Energy Information Administration's forecast.

A comparison of the models shows that cost predictions are sensitive to a number of assumptions. One of the crucial factors yielding differences in cost predictions is the degree of flexibility in international emissions trading incorporated in the model. The most dramatic increase in energy prices and fall in production is projected under the scenario of no international trading of emissions. Since it currently appears that the most likely scenario for implementing the Kyoto agreement is some limited degree of international trading, models that allow for analysis of this scenario have an advantage over models that do not.

Under international emissions trading allowed for Annex I countries, a highly likely scenario, the estimates of the decrease in U.S. GDP are slightly below 1 percent compared to business as usual (according to results from models used by CRA, Inc. and Manne and Richels). However, these cost estimates appear to somewhat understate costs because of the simplified model structure and the assumption of perfect knowledge about future market conditions.

Country-specific factors play a key role for the magnitude of the predicted economic impact of carbon reduction policies on individual participating countries. CRA, Inc. forecasts that, among the developed economies, Germany and the United Kingdom will bear the least cost of reducing emissions because of recent restructuring and regulatory changes not related to climate policies. Canada is shown to suffer the highest losses of production because of its established industrial structure and trade characteristics. The U.S. economy is projected to have the second-highest percent decrease in GDP from reducing emissions.

Notes

1. For detailed discussion of the flexible mechanisms provided in the Kyoto Protocol, see Sparber and O'Rourke, *Flexible Mechanisms: How Environmental Protection Authorities Intend to Control Greenhouse Gases,* National Legal Center for the Public Interest, 1999.
2. Department of Energy, Energy Information Administration, *International Energy Outlook 1998.*
3. *Ibid*
4. *Ibid.*
5. See W. David Montgomery, "Commentary on Obstacles to Global CO_2 Trading: A Familiar Problem," *Climate Change Policy: Practical Strategies to Promote Economic Growth and Environmental Quality,* American Council for Capital Formation Center for Policy Research, 1999, pp. 141-50.
6. The United States, Western Europe, the former Soviet Union, Eastern Europe, Japan, Canada, Australia.
7. Data from the *Household Energy Consumption and Expenditures*, EIA, show that households with annual income between $5,000 and $10,000 spend 9.8 percent to 19.5 percent of their income on major fuels, while households with income of $50,000 and more spend less than 3 percent.
8. Bernstein, Montgomery, and Rutherford, *World Economic Impacts of U.S. Commitments to Medium-Term Carbon Emissions Limits,* CRA, Inc., 1997, Table 7 .

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