6. Assessment of Economic Impacts

Objectives of the Macroeconomic Analysis

Because energy resources are used to produce most goods and services, higher energy prices can affect the economy's production potential. Since the energy crisis of the 1970s, economic research has led to a better understanding of the potential adverse economic consequences of rising real energy costs, in terms of both long-run equilibrium costs and short-run adjustment costs. Long-run equilibrium costs are associated with reducing reliance on energy in favor of other factors of production—including labor and capital, which become relatively cheaper as energy costs rise. Short-run adjustment costs, or business cycle costs, can arise when price increases disrupt capital or employment markets. Long-run costs are considered unavoidable. Short-run costs might be avoidable if price changes can be accurately anticipated or if appropriate compensatory monetary and fiscal policies can be implemented.

This chapter assesses possible impacts on the economy associated with attaining the alternative carbon mitigation targets presented earlier in this report, focusing on three target cases—the 3-percent-below-1990 (1990-3%), the 9-percent-above-1990 (1990+9%), and the 24-percent-above-1990 (1990+24%) cases—and comparing them with a reference case that does not include the Kyoto Protocol. In evaluating these alternative targets, three key questions are posed:

- What would be the unavoidable minimum impact on the economy?
- With rising energy prices and inflation, what cyclical reactions could the economy face, and how would the Federal Reserve Board implement accommodating monetary policy?
- What would be the impact of fiscal policy on economic output and inflation?

EIA used the Data Resources, Inc. (DRI) model of the U.S. economy to assess these issues.[78] The DRI model is a representation of the U.S. economy with detailed output, price, and financial sectors incorporating both long-term and short-term properties. In the DRI model, the concept of *potential* GDP reflects the trajectory of the long-term growth potential of the economy at full employment, while *actual* GDP is a measure of the transition effects as the economy adjusts to its long-run path. Energy end-use demands and prices for fuels are the key energy inputs to the DRI model.[79] In addition, for this analysis, assumptions were made about the domestic flow of funds that would result from a U.S. system of carbon permits sold by the Federal Government, and about the international flow of funds that would result from international trading of permits. These assumptions were based on the results of the energy market analyses described in the preceding chapters of this report.

This chapter first presents a discussion of the U.S. permit system and the potential role of international trading of permits. A summary of the macroeconomic effects is presented next, focusing on the definition and measurement of *potential GDP*, *actual GDP*, and the *value of the purchased international permits* as key elements. The chapter then discusses in detail two topics. The first addresses the unavoidable loss to the economy that would result from a reduction in available energy resources. The unavoidable loss has two components: the loss in potential GDP and the value of the purchased international permits. The chapter concludes with a discussion of the possible transitional impacts on the aggregate economy that might occur as energy prices increase in response to carbon emission constraints. The critical roles of monetary and fiscal policy are highlighted. Two fiscal policies are considered as alternative methods of returning carbon permit revenues to the economy: through a lump sum personal income tax rebate and through a social security tax rebate that would pass funds back to both employers and employees.

[78]The version of the model used is US97A95.

[79]This macroeconomic analysis of the costs of implementing the Kyoto Protocol is limited to the consideration of investment costs that are comparable in magnitude to those in the reference case, as well as direct fuel costs. No consideration is given to the potential incremental costs of investment in technology and infrastructure that would be necessary in each of the specific cases analyzed. Business investments above reference case levels may be required to reduce energy costs in response to increasing energy prices.

The U.S. Permit System and International Trading of Permits

Two key features shape the discussion in this chapter—first, the characterization of the carbon permit trading system as an auction run by the Federal Government; and second, the international trading of carbon permits. Both of these issues have important implications for the assessment of the potential macroeconomic impacts of carbon mitigation policies.

The U.S. Permit System

When a system is developed for the trading of carbon permits within the United States, a number of initial decisions must be made: How many permits will be available? Will they be freely allocated or sold by competitive auction? If they are allocated, how will the initial allocations be made? If they are sold, what will be done with the revenues? How many permits will be bought in international markets? If the permits are traded in a free market, holders of permits who can reduce carbon emissions at a cost below the permit price will sell their permits, and those with higher costs of reduction will buy permits, resulting in a transfer of funds between private parties. If the permits are sold by competitive auction, there will be a transfer of funds from emitters of carbon to the Federal treasury.

This analysis makes the explicit assumption that carbon permits will be sold in a competitive auction run by the Federal Government.[80] To illustrate the importance of recycling the funds back to the economy, two fiscal policy approaches are considered: first, returning collected revenues to consumer through personal income tax rebates and, second, lowering the social security tax rate as it applies to both employers and employees. The two policies are meant only to be representative of a set of possible fiscal policies that might accompany an initial carbon mitigation policy.

International Trading of Permits

In the energy market assessments described earlier in this report, the projected carbon prices reflect the price the United States would be willing to pay to achieve a given emissions reduction target. The more stringent the carbon target, the higher the carbon price. The energy market analysis in this report does not address the international implications of achieving a particular target at the projected carbon price. In the absence of modeling international trade of emissions permits, the energy market assessment makes no link between the U.S. carbon price and the international market-clearing price of permits, or the price at which other countries would be willing to offer permits for sale in the United States.

The macroeconomic analysis in this chapter departs from the above interpretation in order to facilitate an evaluation of the role of the purchase of permits in an international market. The analysis first assumes that the U.S. State Department's assessment of the accounting of carbon-absorbing sinks and offsets from reductions in other greenhouse gases will reduce the binding U.S. emissions target to 3 percent below the 1990 level of emissions. Then, if the United States is to meet a target that is less stringent, the difference in emissions is assumed to be made up through the purchase of permits on the international market. Moreover, the United States is assumed to purchase international permits at *the marginal abatement cost in the United States*. Thus, the domestic carbon price would be the same as the international permit price under the alternative targets considered. If unrestricted international trading among Annex I countries is allowed, the international carbon price could fall below the levels projected here for domestic permits. If this were to occur, to achieve equilibrium in an unconstrained market for carbon permits, the domestic carbon price would fall to the international carbon price.

The above assumptions imply that different international supplies of permits would be available in the alternative cases considered. This is an important simplifying assumption, and the value placed on the overseas transfer of funds to purchase international permits is subject to considerable uncertainty. However, this element must be considered a key factor in performing any assessment of the impacts on the economy, and therefore it is explicitly factored into the analysis. Table 25 shows the assumed carbon reductions, carbon prices, and number and value of carbon emission permits purchased on the international market in the 1990-3%, 1990+9%, and 1990+24% cases.

Summary of Macroeconomic Impacts

In the long run, higher energy costs would reduce the use of energy by shifting production toward less energy-intensive sectors, by replacing energy with labor and

[80] A permit auction system is identical to a carbon tax as long as the marginal abatement reduction cost is known with certainty by the Federal Government. If the target reduction is specified, as in this analysis, then there is one true price, which represents the marginal cost of abatement, and this also becomes the appropriate tax rate. In the face of uncertainty, however, the actual tax rate applied may over- or undershoot the carbon reduction target. Auctioning of the permits by the Federal Government is evaluated in this report. The costs of administering the program are not considered. To investigate a system of allocated permits would require an energy and macroeconomic modeling structure with a highly detailed sectoral breakout beyond those represented in the NEMS and DRI models. For a comparison of emissions taxes and marketable permit systems, see R. Perman, Y. Ma, and J. McGilvray, *Natural Resources and Environmental Economics* (New York, NY: Longman Publishing, 1996), pp. 231-233.)

Table 25. Energy Market Assumptions for the Macroeconomic Analysis of Three Carbon Reduction Cases, Average Annual Values, 2008 through 2012

Analysis Case	Binding Carbon Emissions Reduction Target (Million Metric Tons)	Average U.S. Carbon Emissions Reductions (Million Metric Tons)	U.S. Purchases of International Permits (Million Metric Tons)	Carbon Price		Value of Purchased International Permits (Billion 1992 Dollars)
				1996 Dollars per Metric Ton	1992 Dollars per Metric Ton	
1990-3%	485	485	0	290	263	0
1990+9%	485	325	160	159	144	23
1990+24%	485	122	363	65	59	21

Source: Office of Integrated Analysis and Forecasting, National Energy Modeling System, runs FD24ABV.D080398B, FD09ABV.D080398B, and FD03BLW.D080398B.

capital in specific production processes, and by encouraging energy conservation. Although reflecting a more efficient use of higher-cost energy, this gradual reduction in energy use would tend to lower the productivity of other factors in the production process. The derivation of the long-run equilibrium path of the economy can be characterized as representing the "potential" output of the economy when all resources—labor, capital, and energy—are fully employed. As such, potential gross domestic product (GDP) in the DRI model is equivalent to the full employment concept calculated in a number of other models that focus on long-run growth while abstracting from business cycle behavior.[81]

The ultimate impacts of carbon mitigation policies on the economy will be determined by complex interactions between elements of aggregate supply and demand, in conjunction with monetary and fiscal policy decisions. As such, cyclical impacts on the economy are bound to be characterized by uncertainty, possibly significant. Raising energy prices and, as a result, downstream prices in the rest of the economy could introduce cyclical behavior in the economy, resulting in employment and output losses in the short run. The measurement of losses in actual output for the economy, or actual GDP, incorporates the transitional cost to the aggregate economy as it adjusts to its long-run path. Resources may be less than fully employed, and the economy may move in a cyclical fashion as the initial cause of the disturbance—the increase in energy prices—plays out over time.

The possible impacts on the economy are summarized in Table 26, which shows average changes from the reference case projections over the period from 2008 through 2012 in the three carbon reduction analysis cases.[82] The *loss of potential GDP* measures the loss in productive capacity of the economy directly attributable to the reduction in energy resources available to the economy. It represents part of the long-run, unavoidable impact on the economy. The *macroeconomic adjustment cost* reflects frictions in the economy that may result from the higher prices of the carbon mitigation policy. It recognizes the possibility that cyclical adjustments may occur in the short run. The *loss in actual GDP* for the economy is the sum of the loss in potential and the adjustment cost. The *purchase of international permits* represents a claim on the productive capacity of domestic U.S. resources. Essentially, as funds flow abroad, other countries have an increased claim on U.S. goods and services. The *total cost to the economy* is represented by the loss in actual GDP plus the purchase of international permits (Figure 110). These costs need to be put in perspective relative to the size of the economy, which is projected to average $9,425 billion between 2008 and 2012 in the reference case.

Another way to view the macroeconomic effects is by looking at the effects of the carbon reduction cases on the growth rate of the economy, both during the period of implementation and during the early part of the commitment period, from 2005 through 2010, and then over the entire period from 2005 through 2020 (Figures 111 and 112). In all instances, the economy continues to grow, but growth is slower than projected in the reference case. In the reference case, potential and actual GDP grow at 2.0 percent per year from 2005 through 2010. In the 1990+9% case, the growth rate in potential GDP slows to 1.9 percent per year, and the growth rate in actual GDP slows to 1.6 percent per year when the

[81] In the DRI model, the aggregate production function (the potential GDP equation) uses the following concepts as important variables: energy, labor, capital stocks of equipment and structures, and research and development expenditures. The aggregate supply is estimated by a Cobb-Douglas production function that combines factor input growth and improvements in total factor productivity. Factor input equals a weighted average of energy, labor, fixed capital (outside the energy-producing sector), and public infrastructure. Factor supplies for the non-energy sector are defined by estimates of the full-employment labor force, the full-employment capital net of pollution abatement equipment, domestic energy consumption, and the stock of infrastructure. Total factor productivity depends on the stock of research and development capital and a technological change trend.

[82] The output measures presented in this chapter are expressed in constant 1992 chain-weighted dollars. The DRI macroeconomic model uses National Income and Products Accounts (NIPA) as an estimating framework. Expressing these output measures in 1992 dollars maintains consistency with the NIPA framework and facilitates comparison with results from other macroeconomic models. For the purposes of recycling the funds, collections and rebates are expressed in nominal dollars, to be consistent with the Federal Government's tax accounting system.

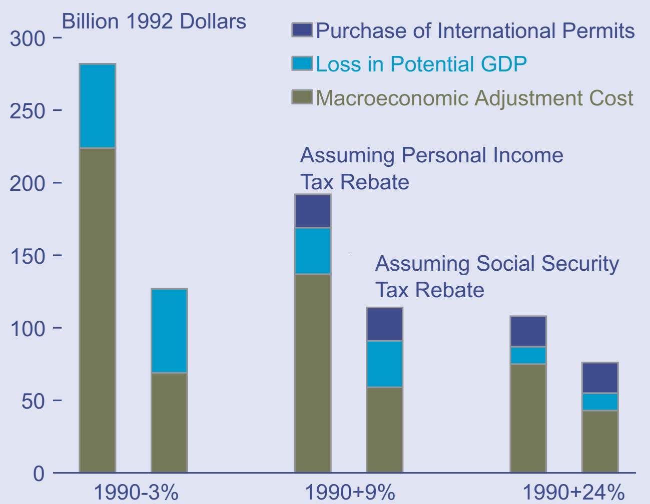
Table 26. Macroeconomic Impacts in Three Carbon Reduction Cases, Average Annual Values, 2008-2012 (Billion 1992 Dollars)

Analysis Case	Loss in Potential GDP	Macroeconomic Adjustment Cost	Loss in Actual GDP	Purchases of International Permits	Total Cost to the Economy
1990-3%					
Personal Income Tax Rebate.	58	225	283	0	**283**
Social Security Tax Rebate	58	70	128	0	**128**
1990+9%					
Personal Income Tax Rebate.	32	137	169	23	**192**
Social Security Tax Rebate	32	59	91	23	**114**
1990+24%					
Personal Income Tax Rebate.	12	76	88	21	**109**
Social Security Tax Rebate	12	44	56	21	**77**

Note: Loss in potential GDP plus the macroeconomic adjustment costs equals the loss in actual GDP. The actual GDP loss plus purchases of international permits equals the total cost to the economy.

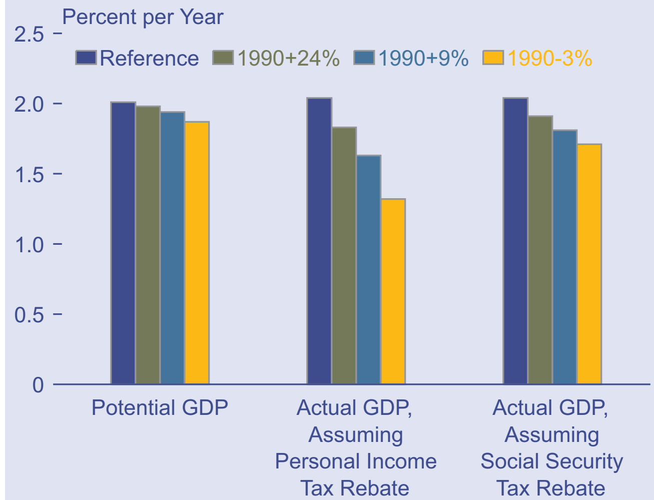
Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Figure 110. Projected Annual Costs of Carbon Reductions to the U.S. Economy, 2008-2012



Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Figure 111. Projected Annual Growth Rates in Potential and Actual GDP, 2005-2010

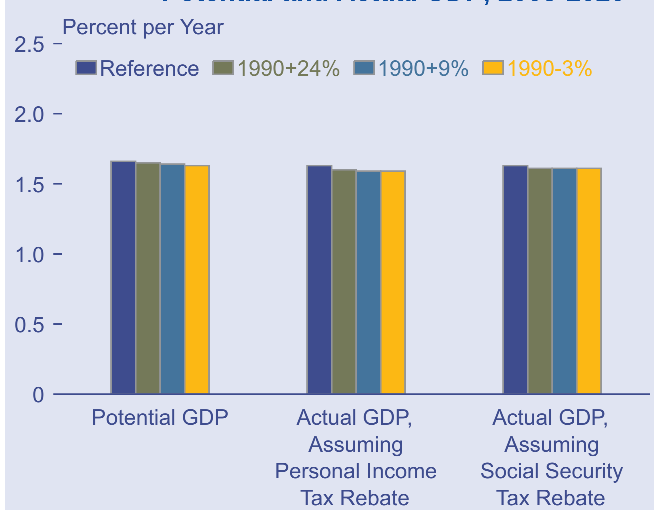


Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

personal income tax rebate is assumed or 1.8 percent per year when the social security tax rebate is assumed. However, through 2020, with the economy rebounding back to the reference case path, there is no appreciable change in the projected long-term growth rate. The results for the 1990+24% and 1990-3% cases are similar.

Aggregate impacts on the economy, as measured by actual GDP, are shown in Table 27 in terms of losses in actual GDP per capita. In the 1990+9% case, the loss in potential GDP per capita is $106; however, the loss in actual GDP for in the 1990+9% case is $567 assuming the personal income tax rebate and $305 assuming the social security tax rebate. Again, the lower value (loss in potential GDP) represents part of the unavoidable loss per person, and the higher values (loss in actual GDP) reflect the highly uncertain, but significant, impacts that individuals could experience as the result of frictions

Figure 112. Projected Annual Growth Rates in Potential and Actual GDP, 2005-2020



Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Table 27. Projected Losses in Potential and Actual GDP per Capita, Average Annual Values, 2008-2012
(1992 Dollars per Person)

Analysis Case	Loss in Potential GDP per Capita	Loss in Actual GDP per Capita, Personal Income Tax Rebate	Loss in Actual GDP per Capita, Social Security Tax Rebate
1990-3%	193	947	428
1990+9%	106	567	305
1990+24	40	294	187

Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

within the economy. Again, to provide scale, actual GDP per capita averages $31,528 in the reference case from 2008 through 2012.

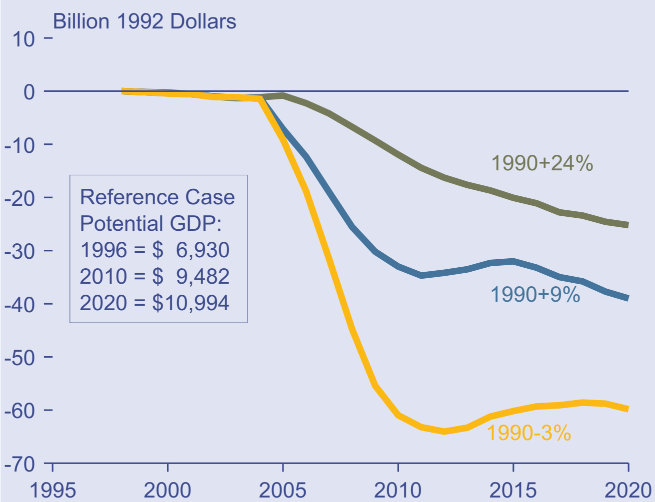
Estimating The Unavoidable Impact on the Economy

Figure 113 shows the losses in the potential economic output, as measured by potential GDP, for the three carbon reduction cases. The shapes of the three trajectories mirror the carbon price trajectories. In the 1990-3% case, potential GDP declines relative to the reference case from 2005 through 2008, reaching a maximum loss of $64 billion (in 1992 dollars) in 2012 and then leveling off at just under $60 billion a year through 2020. In the 1990+9% case, the loss in potential GDP declines to $35 billion by 2011 and reaches $39 billion in 2020. In the 1990+24% case, with steadily increasing carbon prices, potential GDP declines relative to the reference case projections throughout the period and is $26 billion lower than the reference case levels in 2020.

These three potential GDP trajectories represent a valuation of the possible loss in output in the economy in the absence of any cyclical influences brought on by price changes. As shown in Table 25, the three cases considered in this chapter reduce U.S. carbon emissions by 122, 325, and 485 million metric tons a year on average between 2008 and 2012. Figure 114 shows the relationship between the projections of carbon emission reductions and carbon prices. When the carbon reduction target is more stringent, the carbon price is higher; and for the most stringent targets, the projected carbon prices are disproportionately higher than those in the less stringent cases (i.e., the relationship is nonlinear). This curve can be used to measure losses to the aggregate economy by calculating the integral under the curve up to the level of the specified target case. Results for the 1990-3%, 1990+9%, and 1990+24% cases are shown in Table 28.

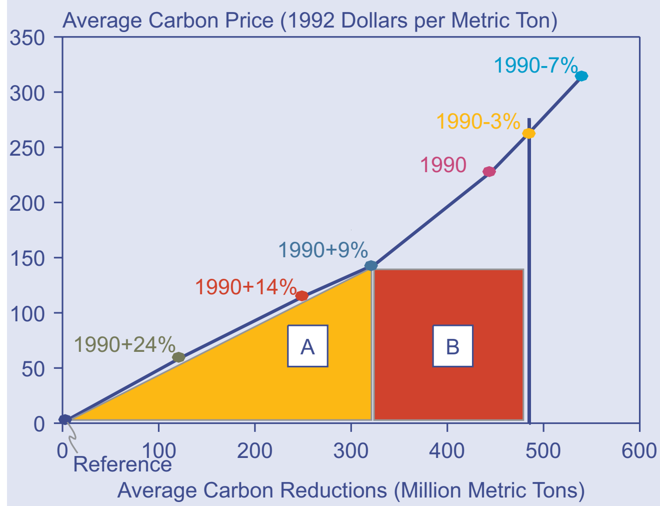
The 1990+9% case results in an average reduction in carbon emissions of 325 million metric tons per year during the period from 2008 to 2012. The average carbon price projected for the same period is $144 per metric ton (in 1992 dollars) (Table 25). The triangular area under the curve in Figure 114, labeled A, represents the value of the carbon reduction to the economy—i.e., the value of reduction in economic output that would result from higher energy prices. In the 1990+9% case, the economic loss projected by the NEMS model totals $25 billion (Table 28). In comparison, the loss in potential GDP

Figure 113. Projected Dollar Losses in Potential GDP Relative to the Reference Case, 1998-2020



Note: Carbon permit revenues are assumed to be returned to households through personal income tax rebates.
Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Figure 114. Average Carbon Reductions and Projected Carbon Prices, 2008-2012



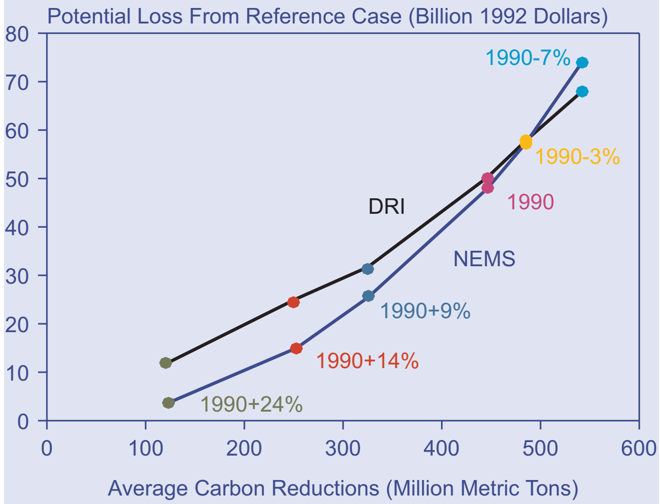
Source: Office of Integrated Analysis and Forecasting, National Energy Modeling System runs KYBASE.D080398A, FD24ABV.D080398B, FD1998. D080398B, FD09ABV.D080398B, FD1990.D080398B, FD03BLW.D080398B, and FD07BLW.D080398B.

Table 28. Average Projected Annual Losses in Economic Output, 2008-2012

Analysis Case	Value of Lost Output: NEMS Valuation (Billion 1992 Dollars)	Value of Lost Output: DRI Potential GDP Loss (Billion 1992 Dollars)	U.S. Purchase of International Permits (Billion 1992 Dollars)
1990-3%	57	58	0
1990+9%	25	32	23
1990+24%	4	12	21

Sources: Office of Integrated Analysis and Forecasting, National Energy Modeling System, runs FD24ABV.D080398B, FD09ABV.D080398B, and FD03BLW.D080398B, and simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Figure 115. Comparison of Average U.S. Economic Losses Projected by the NEMS and DRI Models, 2008-2012



Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

calculated by the DRI model over the same period is $32 billion. As a first approximation, this value closely matches the estimate of the value of the lost output calculated independently using the energy model results (Figure 115).

The curve shown in Figure 114 can also be used to estimate the international value of traded permits. The carbon prices calculated in the NEMS model can be characterized as the particular penalties that the United States would be willing to pay to achieve a given carbon mitigation target. For example, in the 1990+9% case, U.S. carbon emission reductions average 325 million metric tons per year during the period 2008 to 2012. The difference between that reduction and the binding target of 485 million metric tons under the Kyoto Protocol (as reflected by the 1990-3% case) is assumed to be made up through purchases of international permits abroad. The value of those purchases is shown as the rectangle B under the curve in Figure 114. For the 1990+9% case, this represents a transfer of $23 billion dollars (1992 dollars) to purchase permits abroad. For the 1990+24% case, the transfer is $21 billion (Table 25). Even though more permits are purchased abroad, the purchases occur in the context of greater permit availability in the 1990+24% case, and the international price at which they are bought is projected to be dramatically lower, as shown in Table 25.

Focusing on the last two columns of Table 28 highlights the role of international permit trading. Potential GDP is a measure of the level of the output of the economy, but as the last column indicates, there now is a cost to the economy reflected in the transfer of funds abroad to buy permits. Although the direct cost to the U.S. economy in terms of lost potential GDP as a result of lower energy consumption would be less in the 1990+24% and 1990+9% cases than in the 1990-3% case, there would be additional losses of output available to the U.S. economy in those cases. Funds transferred abroad for purchases of international carbon emissions permits would, in effect, reduce the amount of potential GDP available for domestic use.

Energy Prices and the Role of Monetary and Fiscal Policy

This following analysis focuses on the possible transitional impacts on the aggregate economy that would result from efforts to reduce U.S. carbon emissions. The measurement of *actual* output for the economy, or actual GDP, is the key concept used in the examination of changes in the aggregate economy as it adjusts to its long-run path. In addition to internal frictions caused by wage-price interactions and capital stock obsolescence, losses in domestic income may occur as funds are transferred out of the United States to purchase international carbon permits. Resources may be less than fully employed, and the economy will move in a cyclical fashion as the initial cause of the disturbance—the increase in energy prices—plays out over time. Shifts in the sectoral composition of the economy would also accompany the adjustment process.

Here, a single fiscal policy is assumed to accompany the carbon mitigation policy—the revenues collected from the domestic permit auction are returned to consumers through personal income tax rebates. This is a stylized analysis in that it represents only one of a wide range of possible combinations of monetary and fiscal responses.

Impacts of Higher Energy Prices on the Economy

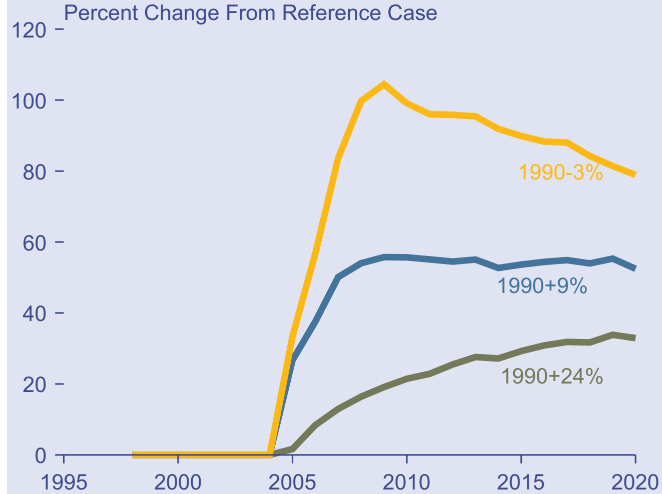
As a direct consequence of the carbon price, aggregate energy prices in the U.S. economy are expected to rise. One way to measure this effect is to look at the percentage change in the *level* of prices in the economy. One measure that can be used is the calculated wholesale price index for fuel and power (Figure 116). In the 1990-3% case, aggregate energy prices are projected to double by 2010 and then decline to 79 percent above reference case price levels in 2020. In the 1990+9% case, energy prices are 56 percent higher than the reference case projection in 2010 and remain more than 50 percent above the reference case over the rest of the forecast period. Prices in the 1990+24% case are 22 percent higher than the reference case in 2010 and continue to rise to 33 percent in 2020.

These changes can also be expressed as rates of change. In the reference case, overall energy prices rise by 3.9 percent per year between 2005 and 2010; however, in the 1990+9% case, aggregate energy prices rise at a rate of 13.5 percent per year, a difference of 9.6 percentage points. The 1990-3% case shows a more dramatic rise, at 19.2 percent per year, and the 1990+24% case shows a rise of 8.0 percent per year. Over the longer run, measured between 2005 and 2020, the rise in energy prices is less dramatic, with the reference case growth at 4.2 percent per year and the 1990+9% case at 7.2 percent per year, a difference of 3.0 percentage points. For the 2005-2020 period, the 1990-3% case shows energy prices rising by 8.3 percent and the 1990+24% case by 6.2 percent per year.

The projected energy price increases would also affect downstream prices for all goods and services in the economy. An intermediate measure is the producer price index (Figure 117), which reflects price impacts on intermediate goods and services. The projected increase in producer prices relative to the reference case in 2010 is 16 percent in the 1990-3% case, 9 percent in the 1990+9% case, and 4 percent in the 1990+24% case. By 2020, the prices in the three carbon reduction case begin to converge, as the differences in projected carbon prices narrow.

Final prices for goods and services in 2009, as shown by the consumer price index (CPI) series (Figure 118), are more than 6.6 percent higher in the 1990-3% case than in the reference case, 3.7 percent higher in the 1990+9% case, and 1.4 percent higher in the 1990+24% case. Again, by 2020, the differences narrow considerably. In the reference case the CPI rises by 3.6 percent per year between 2005 and 2010, but in the 1990+9% case, it rises at a rate of 4.3 percent per year, a difference of 0.7 percentage points. The 1990-3% case shows a more dramatic rise, at 4.8 percent per year, and the annual

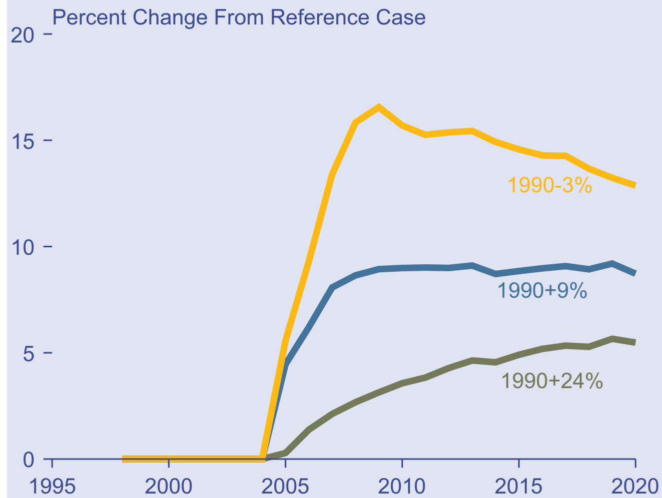
Figure 116. Projected Changes in Wholesale Price Index for Fuel and Power Relative to the Reference Case, 1998-2020



Note: Carbon permit revenues are assumed to be returned to households through personal income tax rebates.

Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Figure 117. Projected Changes in Producer Price Index Relative to the Reference Case, 1998-2020



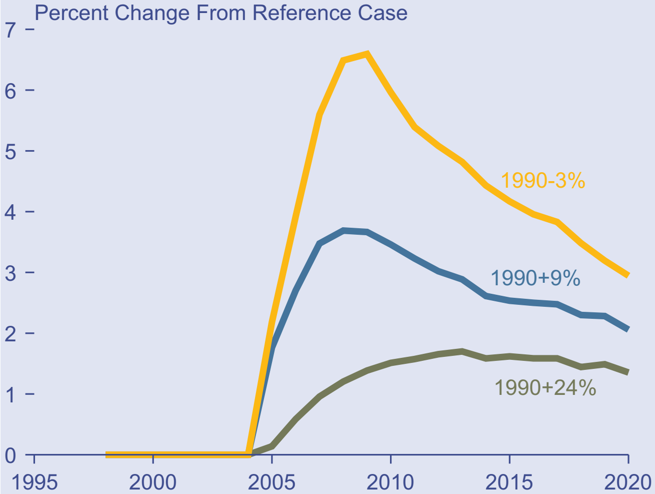
Note: Carbon permit revenues are assumed to be returned to households through personal income tax rebates.

Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

increase in the 1990+24% case is 3.9 percent. In the long term, between 2005 and 2020, the increase in the aggregate price for all goods and services is less dramatic: 3.8 percent per year in the reference case and 3.9 percent per year in the 1990+9% case, a difference of only 0.1 percentage points. Over the same period, the 1990-3% case projects a 4.0-percent annual increase in the CPI and the 1990+24% case a 3.9-percent annual increase.

One aspect of the CPI is particularly noteworthy. The CPI measures the prices that consumers face, regardless

Figure 118. Projected Changes in Consumer Price Index Relative to the Reference Case, 1998-2020



Note: Carbon permit revenues are assumed to be returned to households through personal income tax rebates.

Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

of the country of origin of the product. Import prices, to the extent that they do not rise at the rate of domestic prices because non-Annex I countries do not face carbon constraints, would dampen the price effects as lower priced imports found their way into U.S. markets.

These figures suggest the following rule of thumb for the year 2010. Each 10-percent increase in the level of aggregate prices for energy may lead to a 1.5-percent increase in producer prices and a 0.7-percent increase in consumer prices.

Revenues Flows With International Permit Purchases

The process of auctioning emissions permits would raise large sums of money. If permits were purchased from other countries, as is assumed in both the 1990+9% and 1990+24% cases, there would actually be two revenue flows—domestic and international. The carbon permit revenues remaining within U.S. borders for each case are calculated as the carbon permit price for that case times the level of carbon emissions in the 1990-3% case. Thus, the number of carbon permits purchased domestically remains constant; only the price at which they are available varies across cases. Permits are assumed to be purchased abroad in order for U.S. carbon emissions to continue above the 1990-3% level. Therefore, the international revenue flow equals the difference between actual emissions in the 1990+9% (or 1990+24%) case and those in the 1990-3% case, times the carbon permit price in the 1990+9% (or 1990+24%) case.

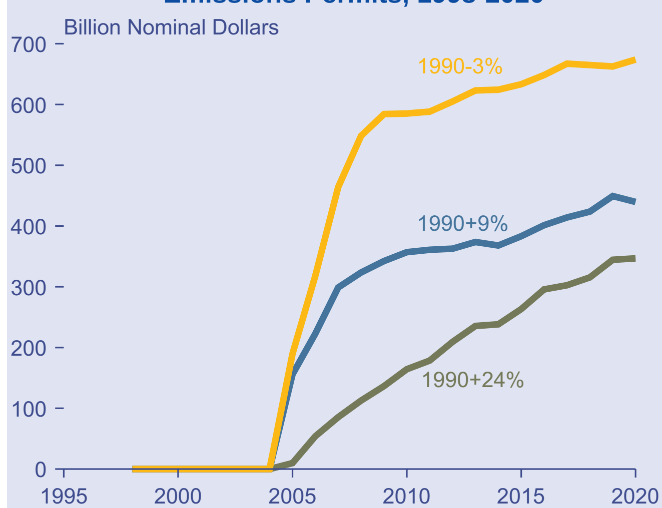
In the 1990-3% case the United States attains the binding target level, and all the funds collected are kept within U.S. borders. The revenue collected in 2010 is projected to total $585 billion nominal dollars, calculated as the level of carbon emissions (1,305 million metric tons) times the carbon permit price ($266 in 1992 dollars), adjusted to nominal dollars. In contrast, in the 1990+9% case, U.S. emissions are reduced to 1,467 million metric tons, or 162 million metric tons short of the binding target. The domestic portion of the collected revenues is equal to the binding target value of 1,305 million metric tons times the new, lower carbon permit price of $148 per metric ton in 1992 dollars. The remaining 162 million metric tons must be offset by permits purchased abroad, again valued at $148 per metric ton. Figure 119 shows total U.S. expenditures for carbon permits in the three carbon reduction cases, and Figure 120 shows the projected split between domestic and international flows for the years 2010 and 2020.

The total projected payments for carbon permits become substantially lower as the carbon reduction target moves from 1990-3% to 1990+9% to 1990+24%. And, although the flow of funds overseas represents an increasing *proportion* of the total collected funds from the 1990+9% case to the 1990+24% case, the actual level of the transfers is relatively stable. Under the domestic-only program of the 1990-3% case, the revenue from permits is assumed to be returned to U.S. households through income tax rebates. In the 1990+9% and 1990+24% cases, only the domestic portion of the funds would be recycled back to consumers. The international flow of carbon permit revenue is considered an increase in the purchase of imported services.

Dynamics of Adjustment in an Economy With Frictions

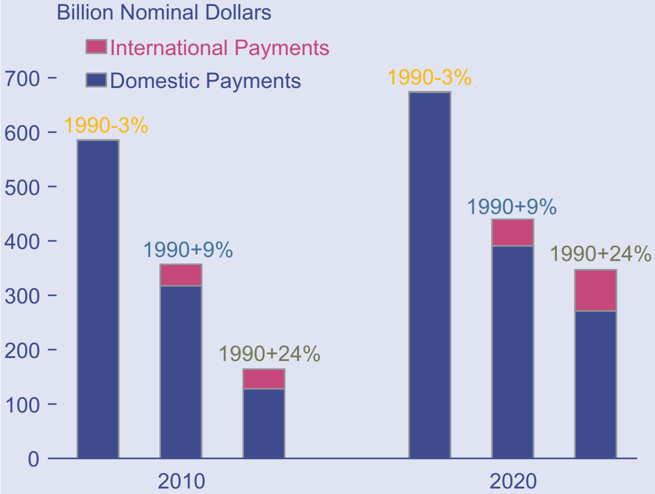
The ultimate impacts of carbon mitigation policies on the economy will be determined by complex

Figure 119. Total Projected U.S. Payments for Domestic and International Carbon Emissions Permits, 1998-2020



Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Figure 120. Projected Destinations of Funds Paid for Carbon Emissions Permits, 2010 and 2020



Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

interactions between elements of aggregate supply and demand, in conjunction with monetary and fiscal policy decisions. As such, any discussion of possible cyclical impacts on the economy is bound to be characterized by uncertainty and controversy. It should be recognized, however, that the process of raising the price of energy and downstream prices in the rest of the economy by the magnitudes shown in Figure 116, 117, and 118 could introduce cyclical behavior in the economy resulting in employment and output losses beyond those associated with the projected impacts on potential GDP.

The introduction of carbon emission limits would affect both consumers and businesses. Households would be faced with higher prices for energy and the need to adjust spending patterns. Nominal energy expenditures would rise, taking a larger share of the family budget for goods and service consumption and leaving less for savings. Higher prices for energy would cause consumers to try to reduce spending not only on energy, but on other goods as well. Thus, changes in energy prices would tend to disrupt both saving and spending streams.

Energy services also represent a key input in the production of goods and services. As energy prices increase, the costs of production rise, placing upward pressure on the nominal prices of all intermediate goods and final goods and services in the economy, with widespread impacts on spending across many markets. The ultimate effect will depend on opportunities for substitution away from higher-cost energy to other goods and services and the effectiveness of compensatory fiscal and monetary policy.

The transitional adjustment of the economy can be captured by calculations of the actual GDP of the economy. The impacts on actual GDP represent a measure of the loss of output from the economy, recognizing that adjustments are not frictionless and that all resources may not be fully employed in the near term. The output of the economy as reflected by actual GDP can cycle around the measure of potential GDP.

The Role of Monetary Policy

Monetary policy can moderate or intensify the ultimate impacts on the economy; however, trying to predict the response of monetary authorities to large increases in energy prices is a difficult task. The emphasis on controlling inflation relative to concerns about rising unemployment has changed over the past 20 years, and using history as a guide does not remove the large amount of uncertainty about the response of monetary authorities. In addition, the types of financial instruments available have become more numerous and more interdependent, and the task of monitoring the Nation's money supply has become more complex.

The monetary authorities could concentrate on increased inflation resulting from higher energy prices and choose not to increase the money supply in order to moderate the resulting inflation. In this instance, output and employment losses would be larger than they would if the money supply were expanded when energy prices increased. Another option would be to allow the money supply to increase in order to remove the unemployment impacts while allowing substantial additional price inflation. This analysis uses neither extreme of these assumptions about the response of the Federal Reserve. The discussion that follows represents a middle path that the Federal Reserve might follow.

In the setting that has been described—returning funds in the form of personal income tax rebates—higher prices in the economy would place upward pressure on interest rates. The Federal Reserve Board would then seek to balance the consequences of higher energy prices on the economy with possible adverse effects on output and employment. The Federal Reserve would respond to changes in inflation and unemployment brought on by the initial carbon mitigation policy by making adjustments to influence the Federal funds rate.[83] The adjustments would be designed to moderate the possible impacts on both inflation and unemployment, and to return the economy toward its long-run growth path. The characterization of monetary policy reactions to inflation and unemployment used in these simulations is based on a DRI reaction function that has been estimated to reflect the historical relationship between the

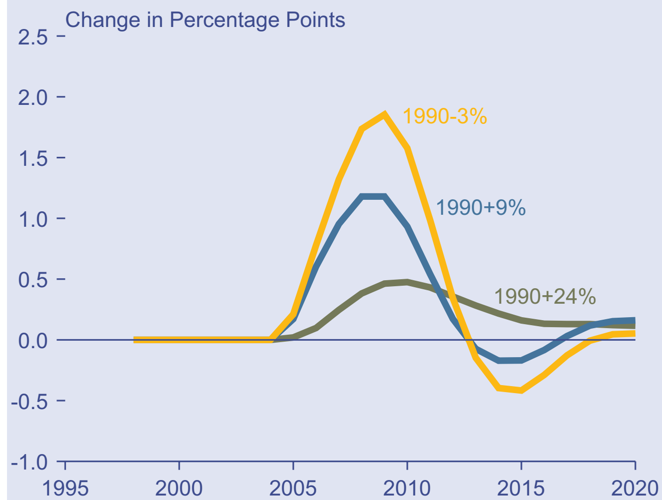
[83]The Federal funds rate is the rate charged by a depository institution on an overnight sale of Federal funds to another depository institution. This rate influences the trend in behavior for other interest rates in the economy.

Federal funds rate and changes in inflation and unemployment. As such, the reaction function is a reflection of how the Federal Reserve may react to changes in the economy caused by the carbon price, based on past behavior.

If the rate of inflation increases, but unemployment does not increase, the Federal Reserve may choose to let the nominal interest rate rise in an attempt to cut the rise in inflation. However, if this is accompanied by an increase in the unemployment rate, the Federal Reserve may consider a cut in the rate to stimulate economic expansion and the demand for labor. In essence, there is a balancing game between the two factors—inflation and unemployment—as the initial originating policy initiative has uneven impacts on the two over time. Figures 121, 122, and 123 show the interrelationship between the projected inflation rate, unemployment rate, and Federal funds rate in the 1990+24%, 1990+9%, and 1990-3% cases. This assessment combines the monetary policy formulation described above with a fiscal policy that returns collected carbon permit revenues back to consumers. An alternative combination of fiscal and monetary policy is considered later in this section.

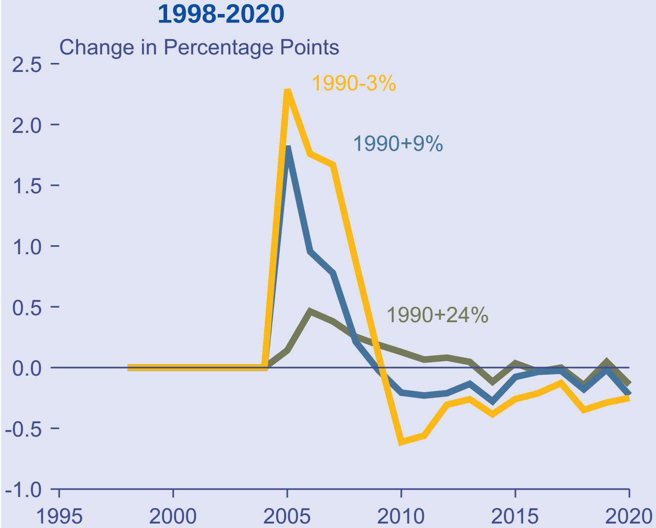
Focusing first on the 1990+9% case, the inflation rate jumps from 3.3 percent per year to 5.1 percent per year, a difference of 1.8 percentage points in 2005, the first year of the energy price rise, and continues to remain high for the first 4 years of the carbon reduction program. In the same 4-year period, the unemployment rate first responds slowly and then accelerates to a peak in 2009 that is more than a full percentage point above the reference case unemployment rate, rising from 5.6 percent in the reference case to 6.8 percent in the 1990+9% case. The key point here is that the responses of inflation and unemployment are not symmetric over time. There is a lag between the two effects with output and employment effects lagging behind price effects. Prices rise in the economy in response to the initial energy price increase and then to secondary price effects as the costs of intermediate goods and services rise. Business, in response to rising prices and lower aggregate demand, absorbs the near-term output loss but eventually reduces its use of labor. The lag from initial price effects to ultimate output and employment losses can be a year or so.

Figure 122. Projected Changes in U.S. Unemployment Rate Relative to the Reference Case, 1998-2020



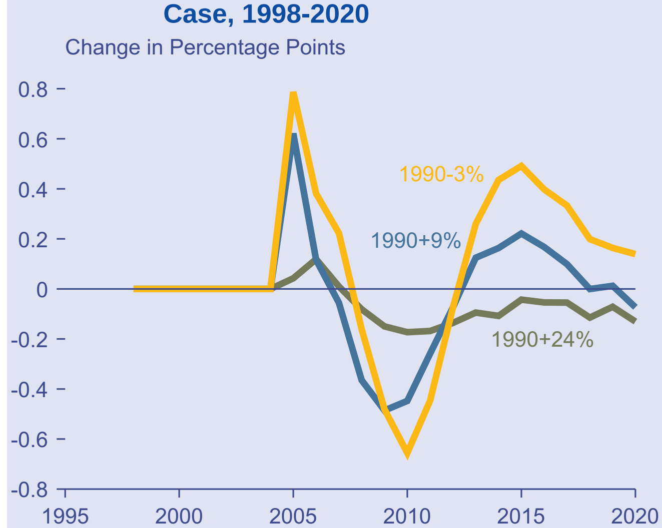
Note: Carbon permit revenues are assumed to be returned to households through personal income tax rebates.
Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Figure 121. Projected Changes in U.S. Inflation Rate Relative to the Reference Case, 1998-2020



Note: Carbon permit revenues are assumed to be returned to households through personal income tax rebates.
Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Figure 123. Projected Changes in U.S. Federal Funds Rate Relative to the Reference Case, 1998-2020



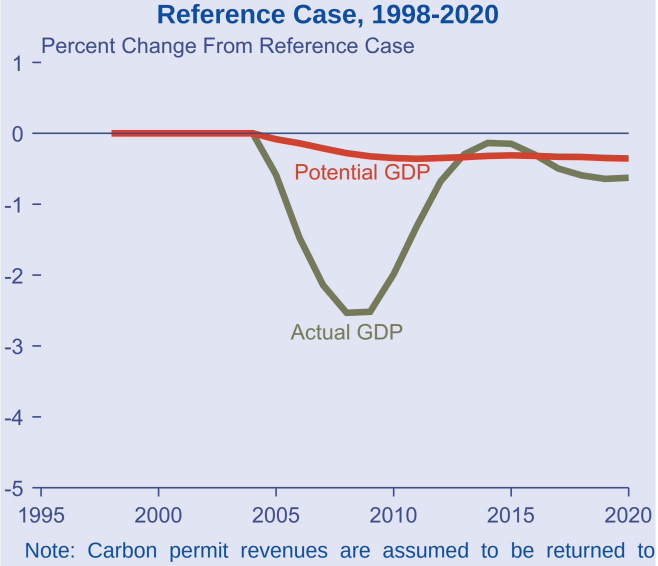
Note: Carbon permit revenues are assumed to be returned to households through personal income tax rebates.
Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

As a result of the differential effects projected for inflation and unemployment during the years from 2005 to 2008, the Federal Reserve is assumed to allow a modest rise in the Federal funds rate in the short term, when concern over inflation outweighs concern over GDP losses and unemployment. After the initial rise in energy prices, with the carbon price actually projected to fall after 2009, the inflation rate reverts to that projected in the reference case; however, aggregate output is still depressed, and unemployment in the economy remains above the reference case value. During this period, the Federal Reserve reacts by reducing the Federal funds rate, in order to combat the loss in output and employment in the economy. After 10 years, by 2015, both inflation and unemployment have returned to at or about reference case levels. The Federal Reserve again allows interest rates to rise to bring the economy back to its long-run growth path.

Impacts on Actual Output and Consumption

In the 1990+9% case, potential GDP is projected to decline smoothly over time, leveling off to a steady-state value of approximately 0.35-percent loss in output for the economy (Figure 124). In contrast, actual GDP is buffeted about as the economy adjusts to the significant price pressures brought on by higher energy prices, losing approximately 2.5 percent in real output by 2009. The loss in actual output can also be described in terms of the impacts on the growth rate for actual GDP. Between 2005 and 2010, actual GDP is projected to grow by 2.0 percent per year in the reference case. In the 1990+9% case, the growth rate slows to 1.6 percent per year, reducing growth in the economy over the same period by 0.4 percentage points.

Figure 124. Projected Changes in Potential and Actual U.S. Gross Domestic Product in the 1990+9% Case Relative to the Reference Case, 1998-2020



Note: Carbon permit revenues are assumed to be returned to households through personal income tax rebates.

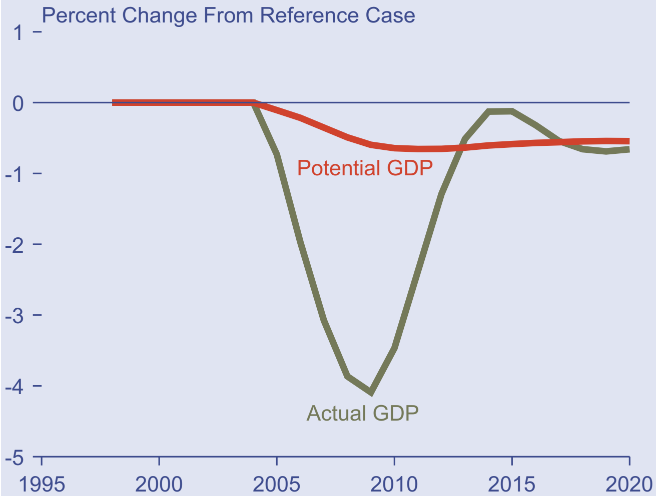
Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

After 2010, although the economy is still below the reference case, actual GDP begins to cycle in response to energy prices. The economy cycles for two fundamental reasons. First, output effects lag price effects in the economy as consumers and businesses adjust to the price changes. Also, in the case considered, the rise in energy prices levels off dramatically by 2010, and inflation rates are actually lower than in the reference case, as shown in Figure 121. The interesting property of the two output concepts, actual and potential, is that they begin to converge by 2015, 10 years after the beginning of the initial impacts on the economy. By 2020 they have merged into a steady-state path. This suggests that while the economy may very well be on a long-run path that could yield a loss to the economy of about 0.3 percent if its potential output, there is the possibility that near-term impacts may be larger as the economy adjusts to its long-run trajectory.

The projected impacts on actual GDP in the 1990-3% case peak at a loss of 4.1 percent in 2009, but again rebound back toward and merge with the ultimate potential GDP impact measure of 0.55 percent (Figure 125). The growth rate between 2005 and 2010 slows to 1.3 percent per year, a reduction of 0.7 percentage points from the reference case growth rate of 2.0 percent. In the 1990+24% case, actual GDP shows a peak loss of 1.0 percent relative to the reference case in 2010, with no significant impact on the growth rate, then begins to return to its long-run potential GDP path. In this case, however, because the carbon price is still rising, the economy continues to show a slight divergence between actual and potential GDP in 2020, although the gap is significantly narrowed (Figure 126).

Beyond the aggregate impact on GDP, a significant change in the composition of final demand is projected in the carbon reduction cases (Table 29). In the 1990+9% case, consumption in 2009 is projected to be 1.9 percent lower than projected in the reference case (Figure 127). Returning the carbon permit revenues to households through personal income tax rebates moderates the impacts on disposable income in the economy, which, in turn moderates the adverse impact on purchases of consumer goods and services, and therefore the impact on the aggregate economy measured by actual GDP. Investment is more severely affected, with rising interest rates and a general loss in demand in the economy projected in the years immediately after the imposition of the carbon price (Figure 128). In 2007, investment in the 1990+9% case is projected to be 5.9 percent below the reference case projection. After 2008, with lower interest rates, the economy begins to rebound as investment expands rapidly. By 2013, investment is above the reference case by 3.2 percent and is leading the recovery.

Figure 125. Projected Changes in Potential and Actual U.S. Gross Domestic Product in the 1990-3% Case Relative to the Reference Case, 1998-2020

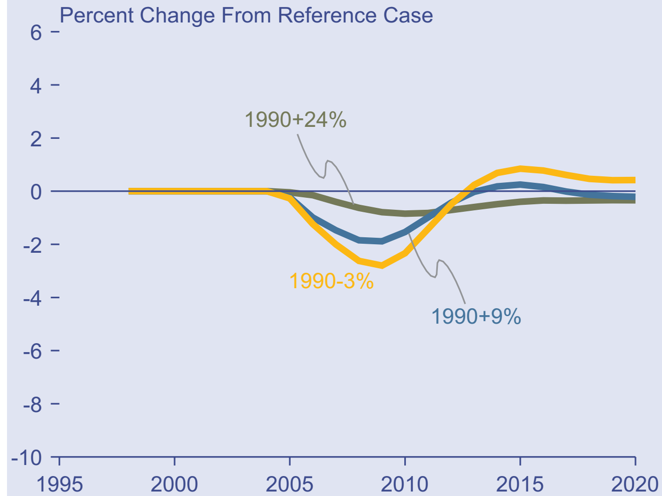


Note: Carbon permit revenues are assumed to be returned to households through personal income tax rebates.
Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Figure 126. Projected Changes in Potential and Actual U.S. Gross Domestic Product in the 1990+24% Case Relative to the Reference Case, 1998-2020

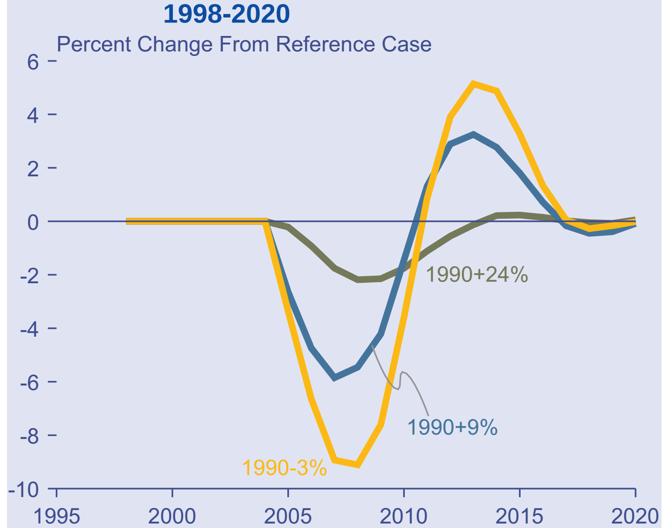
Note: Carbon permit revenues are assumed to be returned to households through personal income tax rebates.
Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Figure 127. Projected Changes in Real Consumption in the U.S. Economy Relative to the Reference Case, 1998-2020



Note: Carbon permit revenues are assumed to be returned to households through personal income tax rebates.
Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Figure 128. Projected Changes in Real Investment in the U.S. Economy Relative to the Reference Case, 1998-2020



Note: Carbon permit revenues are assumed to be returned to households through personal income tax rebates.
Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

The 1990-3% case shows a pattern of adjustment similar to that projected in the 1990+9% case, except that the reaction in terms of both consumption and investment is more extreme, given the higher carbon price. Consumption reaches its lowest point in the year 2009 at 2.8 percent below the reference case. Thereafter, consumption returns to the reference case level in 2013 and by 2015 is 0.8 percent above the reference case level. Investment is more volatile, falling to 9.1 percent below reference case levels by 2008. Again, with interest rates declining relative to the reference case after 2010, investment recovers rapidly and by 2013 is 5.1 percent above the reference case.

The 1990+24% case reflects a much smoother path for both consumption and investment. Consumption remains below the reference case throughout the period, but with a maximum loss of only 0.8 percent in 2010. The impact on investment, likewise, is more moderate than in the 1990-3% and 1990+9% cases, falling to 2.2 percent

Table 29. Projected Economic Impacts of Carbon Reduction Cases Assuming Personal Income Tax Rebate
(Changes From Reference Case)

Analysis Case	2010	2015	2020
1990-3%			
Collections (Billion Nominal Dollars)	585	633	674
Wholesale Price Index for Fuel and Power (Percent Change)	99.1	89.9	78.9
Producer Price Index (Percent Change)	15.7	14.6	12.9
Consumer Price Index (Percent Change)	6.0	4.2	2.9
Unemployment Rate (Difference in Rate)	1.6	-0.4	0.1
Federal Funds Rate (Difference in Rate)	-0.7	0.5	0.1
Potential GDP (Percent Change)	-1.2	-0.8	-0.6
Real GDP (Percent Change)	-3.5	-0.1	-0.7
Real GDP (Billion 1992 Chain-Weighted Dollars)	-327	-12	-72
Consumption (Percent Change)	-2.3	0.8	0.4
Investment (Percent Change)	-3.6	3.3	-0.0
Industrial Output (Percent Change)	-5.8	-2.5	-3.6
1990+9%			
Collections (Billion Nominal Dollars)	317	340	391
Wholesale Price Index for Fuel and Power (Percent Change)	55.7	53.7	52.5
Producer Price Index (Percent Change)	9.0	8.8	8.7
Consumer Price Index (Percent Change)	3.5	2.5	2.1
Unemployment Rate (Difference in Rate)	0.9	-0.2	0.2
Federal Funds Rate (Difference in Rate)	-0.4	0.2	-0.1
Potential GDP (Percent Change)	-0.7	-0.4	-0.4
Real GDP (Percent Change)	-2.0	-0.1	-0.6
Real GDP (Billion 1992 Chain-Weighted Dollars)	-187	-15	-68
Consumption (Percent Change)	-1.5	0.2	-0.2
Investment (Percent Change)	-1.5	1.8	-0.1
Industrial Output (Percent Change)	-3.0	-1.6	-3.1
1990+24%			
Collections (Billion Nominal Dollars)	128	206	271
Wholesale Price Index for Fuel and Power (Percent Change)	21.5	29.3	32.9
Producer Price Index (Percent Change)	3.6	4.9	5.5
Consumer Price Index (Percent Change)	1.5	1.6	1.4
Unemployment Rate (Difference in Rate)	0.5	0.2	0.1
Federal Funds Rate (Difference in Rate)	-0.2	-0.0	-0.1
Potential GDP (Percent Change)	-0.2	-0.3	-0.3
Real GDP (Percent Change)	-1.0	-0.5	-0.5
Real GDP (Billion 1992 Chain-Weighted Dollars)	-96	-54	-49
Consumption (Percent Change)	-0.8	-0.4	-0.3
Investment (Percent Change)	-1.8	0.2	0.1
Industrial Output (Percent Change)	-1.3	-1.3	-2.0

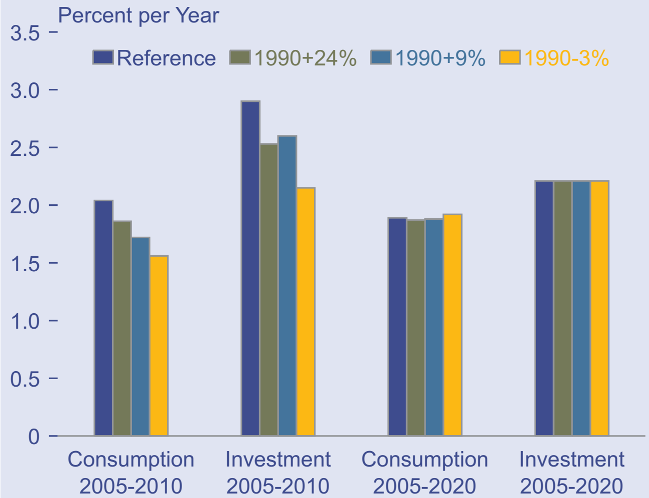
Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

below the reference case in 2008. Thereafter, investment returns to the reference case level and essentially remains at that position for the remainder of the forecast period.

Figure 129 shows the projected impacts on consumption and investment in terms of growth rates between 2005 and 2010 and between 2005 and 2020. Between 2005 and 2010, consumption growth rates fall from 2.0 percent per year in the reference case to 1.9 percent in the 1990+24% case, 1.7 percent in the 1990+9% case, and 1.6 percent in the 1990-3% case. Investment shows a similar, but more pronounced profile, with growth declining from 2.9 percent per year in the reference case to 2.5 percent, 2.6 percent, and 2.2 percent in the respective carbon reduction cases. Slight variations in the order of the impacts—the 1990+24% case at 2.5 percent and the 1990+9% case at 2.6 percent—can be explained by the highly cyclical effects on investment, as shown in Figure 128. In the long run, as indicated by the projected growth rates between 2005 and 2020, growth in both consumption and investment returns to the reference case rates.

These results indicate that, as a result of higher energy prices, the economy may absorb a near-term loss in output in response to higher inflation and a rise in the unemployment rate. However, with appropriate action

Figure 129. Consumption and Investment Growth Rates



Note: Carbon permit revenues are assumed to be returned to households through personal income tax rebates.

Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

on the part of the monetary authorities, these impacts could be mitigated, and in the long-term the economy could rebound.

The Role of Fiscal Policy

This analysis assumes that revenues from carbon permits would be collected by the Federal Government, which would have a number of alternatives with regard to their disposition. The producers of carbon-intensive fuels could keep the permit revenues; or the Government could either use the revenues to reduce the national debt, return them to businesses through reductions in corporate income tax rates or increased business tax credits, return them to consumers through personal income tax rebates, or return them to both consumers and businesses through social security tax rebates. Each method of using the collected permit revenue is plausible, and each method would have a different economic impact.

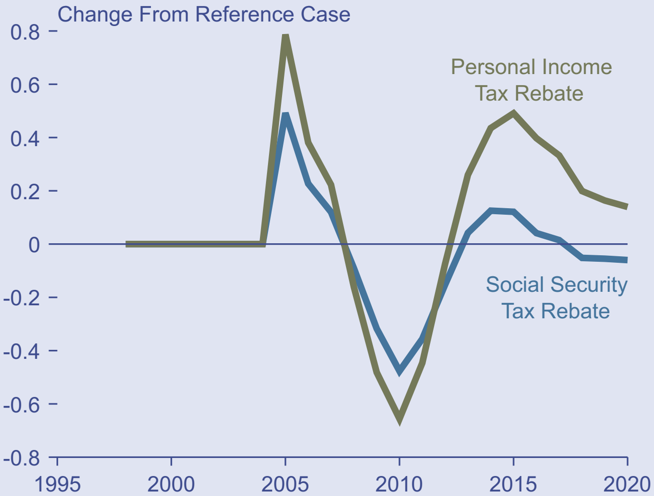
Returning the funds to consumers through personal income tax rebates or returning them to consumers and businesses through social security tax rebates would work to ameliorate the short-term impacts on the economy by bolstering disposable income. Alternative fiscal policies, such as having the Federal Government use the funds to lower the Federal debt level, or a corporate income tax rebate, probably would result in larger near-term impacts, because disposable income and therefore consumption would fall by greater amounts. Conversely, policies that serve to shift the economy away from consumption toward investment may have greater long-term benefits in terms of expansion of the aggregate capital stock.

All the projections discussed so far in this chapter have assumed a policy of returning carbon permit revenues to households through personal income tax rebates, using a lump sum transfer.[84] To highlight the potential significance of an alternative fiscal regime this chapter next reviews the potential effects of a rebate of social security taxes that passes funds back to both employees and employers in equal amounts. The analysis of a hypothetical rebate of the social security tax is meant only to be descriptive of a tax measure that could have the effect of reducing price pressures in the economy by lowering business costs, while also accomplishing a partial compensation to consumers for the higher energy bills they would face. The two policies considered in this analysis—the personal income tax rebate and the social security tax rebate—are only meant to be representative of a set of possible fiscal policies that might accompany an initial carbon mitigation policy.

The fundamental difference between the two policies is in their treatment of business. On the employer side, the reduction in employer contributions to the social security system would lower costs to the firm and, thereby, moderate the near-term price consequences to the economy. Since it is the price effect that produces the predominately negative effect on the economy, any steps to reduce inflationary pressures would serve to moderate adverse impacts on the economy. The smaller impact on aggregate prices would also moderate the monetary policy reaction, as shown in Figures 130, 131, and 132. In all the carbon reduction cases, the reaction of the Federal funds rate to the economic effects of higher energy prices would be less pronounced than projected under the assumption of a personal income tax reduction. Similarly, the social security tax option would moderate the potential impact on actual GDP in the carbon reduction cases (Figure 133), largely because of the cost-cutting aspects of lowering of the employer portion of the tax. Similar moderating effects would be seen for consumption (Figure 134) and investment (Figure 135). Under both policies, the economy would eventually revert to a long-run path consistent with the path of potential output.

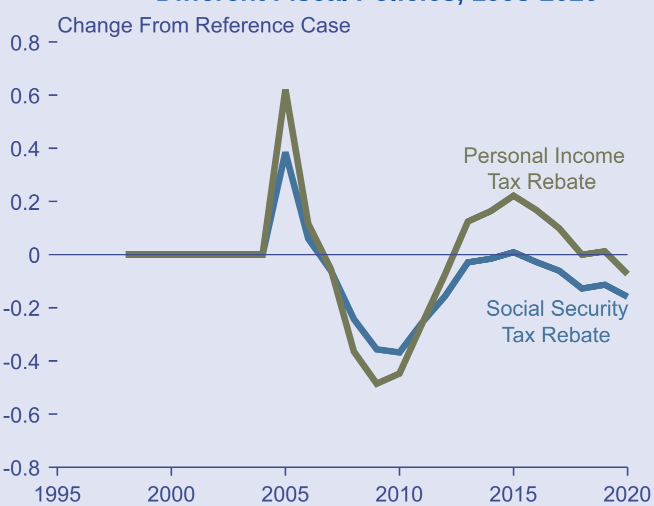
[84] In the DRI model for personal taxes only, a lump sum transfer produces the same effects as a cut in the personal income tax rate.

Figure 130. Projected Changes in U.S. Federal Funds Rate in the 1990-3% Case Relative to the Reference Case Under Different Fiscal Policies, 1998-2020



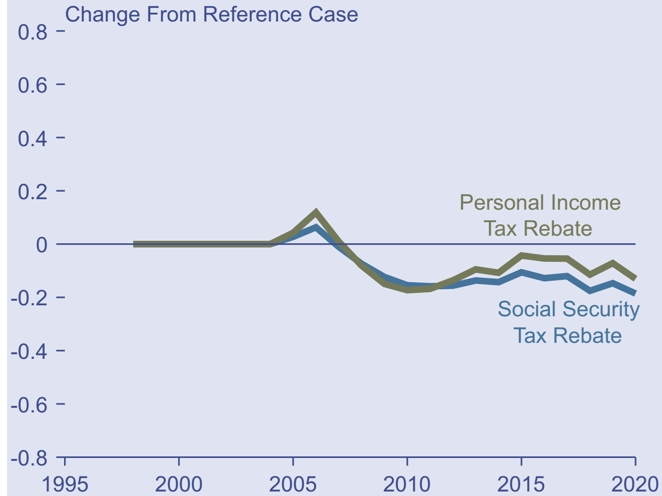
Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Figure 131. Projected Changes in U.S. Federal Funds Rate in the 1990+9% Case Relative to the Reference Case Under Different Fiscal Policies, 1998-2020



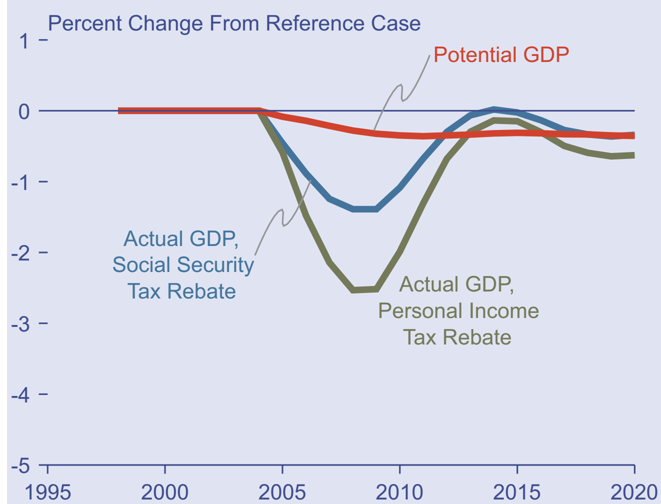
Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Figure 132. Projected Changes in U.S. Federal Funds Rate in the 1990+24% Case Relative to the Reference Case Under Different Fiscal Policies, 1998-2020



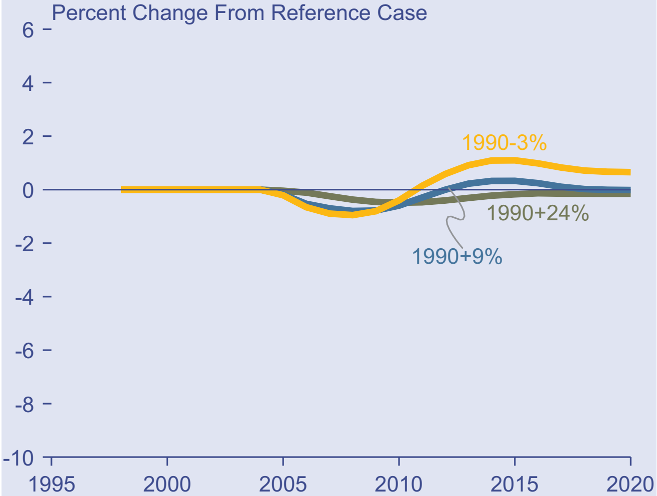
Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Figure 133. Projected Changes in Potential and Actual U.S. Gross Domestic Product in the 1990+9% Case Relative to the Reference Case Under Different Fiscal Policies, 1998-2020



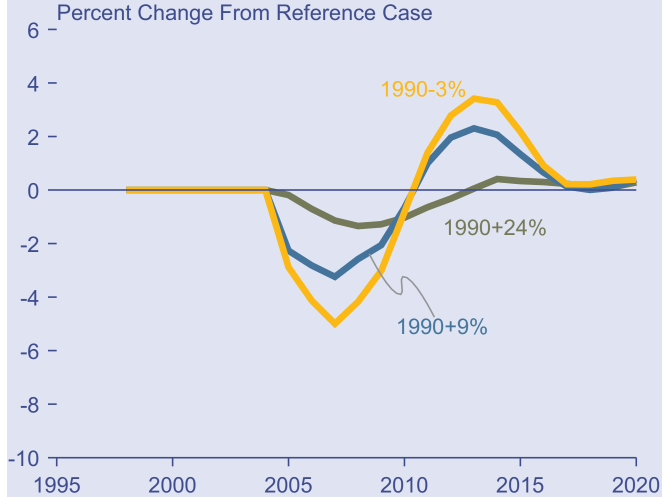
Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Figure 134. Projected Changes in Real Consumption in the U.S. Economy Relative to the Reference Case, 1998-2020, Assuming a Social Security Tax Rebate



Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Figure 135. Projected Changes in Real Investment in the U.S. Economy Relative to the Reference Case, 1998-2020, Assuming a Social Security Tax Rebate



Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Energy Investment

This macroeconomic analysis of the costs of the Kyoto Protocol includes the direct fuel costs and only those investment costs that are comparable in magnitude with those in the reference case. Business investments above reference case levels may be required to reduce energy costs in response to increasing energy prices. The potential incremental costs of investment in technology and infrastructure that may be necessary to obtain the emissions reductions specified in each of the cases analyzed are not included, either because they are not available or, in cases where they are available, because there is no direct mapping to the National Income and Product Accounts.

Full investment costs would include: (1) fuel and equipment costs, including the cost of capital and the cost of premature obsolescence; (2) research and development costs; (3) infrastructure costs, including equipment maintenance, supply, and distribution; (4) regulatory monitoring and enforcement costs; (5) the costs for manufacturers to retool prematurely; and (6) the costs of lost investment opportunities. This macroeconomic analysis, like all others, does not include all of these investment costs. The premature obsolescence of capital—when a firm is forced to retire equipment before the end of its physical or economic life—is typically ignored or assumed to be costless, because estimates of the amount of capital retired early are difficult to make. Estimates of the full cost of developing new technologies, particularly the associated research and development costs, are generally unavailable. In addition, certain new technologies may require a considerable amount of additional investment in infrastructure in order to be widely adopted. For example, widespread adoption of carbon-free vehicles (such as hydrogen fuel cell automobiles) may require substantial investment to guarantee consumers that hydrogen refueling stations are conveniently located and that the development of hydrogen stations does not present safety risks. Estimates of these costs are difficult to obtain and are at best uncertain.

In NEMS, capital costs are included for newly constructed technologies in the electricity generation sector, for major appliances and technologies in the residential and commercial sectors, for new vehicles in the transportation sector,[a] and for new natural gas pipelines and new oil refineries. The investment costs in buildings include new equipment costs but do not include costs attributable to improving the energy efficiency of structures, such as insulation and thermal windows. For generators, the investment costs include additional expenditures on both equipment and structures required for generation, transmission, and distribution of electricity. The NEMS representations of investment costs for generators probably are the most detailed estimates available from any energy modeling system; however, the financial accounting categories available from the electricity sector do not map directly into the National Income and Product Accounts included in macroeconomic models. The mapping difficulties are even greater for the end-use sectors. Reconciling and meaningfully incorporating investment information from energy models into macroeconomic models is a research area that still needs to be studied. As a result, this analysis includes only the direct cost of fuels when evaluating the macroeconomic impacts of the Kyoto Protocol.

[a]While infrastructure costs are not directly included for the transportation model, the rate at which infrastructure can expand is included in the adoption of new alternative-fuel vehicles.

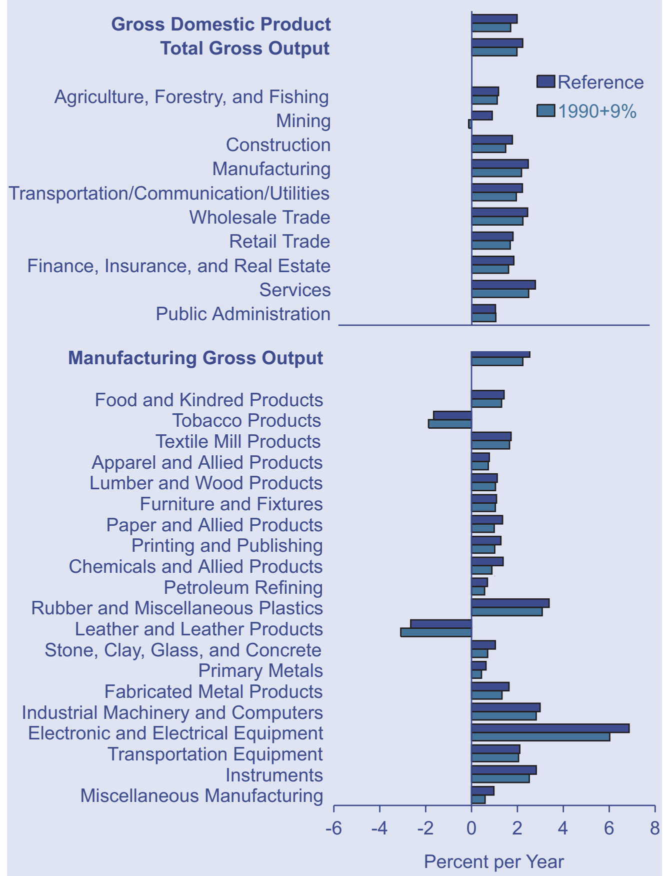
Sectoral Impacts

Regardless of the effects of carbon mitigation policies on the ultimate level of the aggregate economy, there are likely to be impacts on the configuration of the sectoral output of the economy. This section describes one possible set of outcomes. While the results are very uncertain, they indicate the potential for differential impacts among industries, primarily as the result of four key factors:

- First, the direct impact of higher energy prices is a reduction in energy demand, particularly for coal with its high carbon content. The consequences are reductions in output from the mining sector and from all services connected to the production and distribution of coal.
- Second, higher energy prices disproportionately increase the cost of production for energy-intensive industries. As energy price increases are passed along by industry through higher prices for their products, consumers will tend to substitute away from the relatively expensive energy-intensive products to less energy-intensive products and services. The consequences are reductions in gross output from the energy-intensive sectors of the economy, principally, chemicals and allied products; stone, clay, glass, and concrete; and primary metals.
- Third, the changing composition of macroeconomic final demand will alter the composition of sectoral output. In the cases considered here, all the carbon permit revenues are assumed to be returned to consumers through personal income tax rebates, moderating the projected impacts on disposable income. Consequently, in percentage terms, consumer spending falls by less than GDP, while investment falls by more. This change in the composition of final demand decreases the output from consumer-related sectors, such as services and retail trade, by less than the average drop for all economic output, while decreasing the output from the construction and manufacturing sectors by more than the average.
- Finally, because the carbon emissions restrictions are placed only on Annex I countries, industries with high levels of imports, particularly those with imports from non-Annex I countries, will see larger reductions in domestic output than industries with low import penetration. If imports are already competitive, increasing the cost of production for the domestic industry and not for non-Annex I importers will tend to increase imports, leading to a drop in domestic output. For this reason, output from manufacturing sectors such as leather and leather products, electronic and other electrical equipment, and miscellaneous manufacturing will fall by more than the output for the manufacturing sector as a whole.

It is difficult, *a priori*, to predict the degree and rate of change of such effects. Figure 136 shows the disaggregated impacts of restricting carbon emissions in the 1990+9% case. The upper part of the graph shows the projected growth rates for GDP, total gross output, and sectoral gross output for the major SIC divisions between 2005 and 2010. The GDP and total gross output growth rates provide an economy-wide frame of reference against which the sectoral growth rates can be compared. The lower part of the graph shows the growth rates for total manufacturing gross output and sectoral gross output by 2-digit SIC breakdown between 2005 and 2010, with the growth rate for total manufacturing gross output as a reference. Figures 137 and 138 show the results for the 1990-3% and 1990+24% cases, respectively.

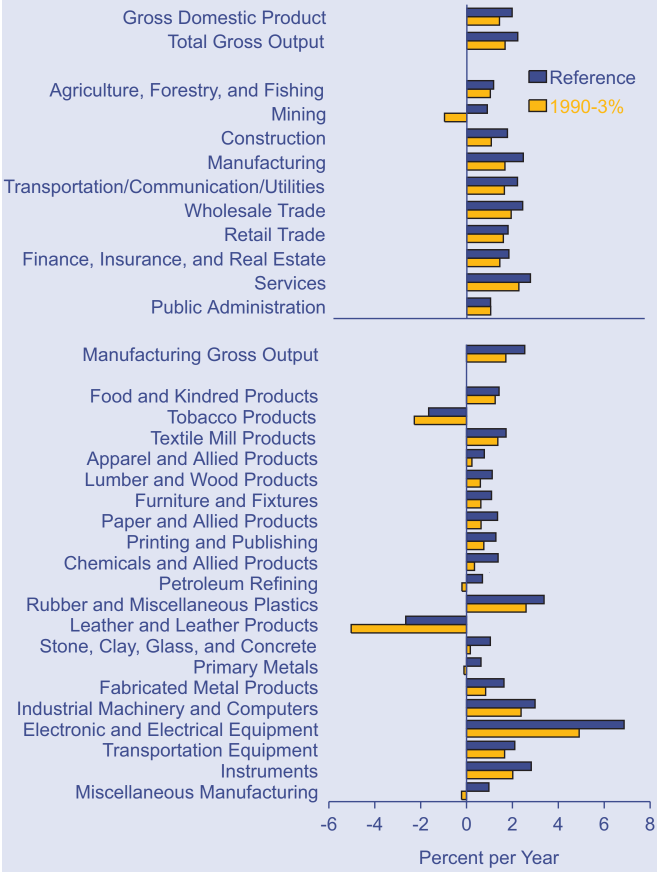
Figure 136. Projected Sectoral Growth Rates in Real Economic Output in the 1990+9% Case, 2005-2010



Note: Carbon permit revenues are assumed to be returned to households through personal income tax rebates.

Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

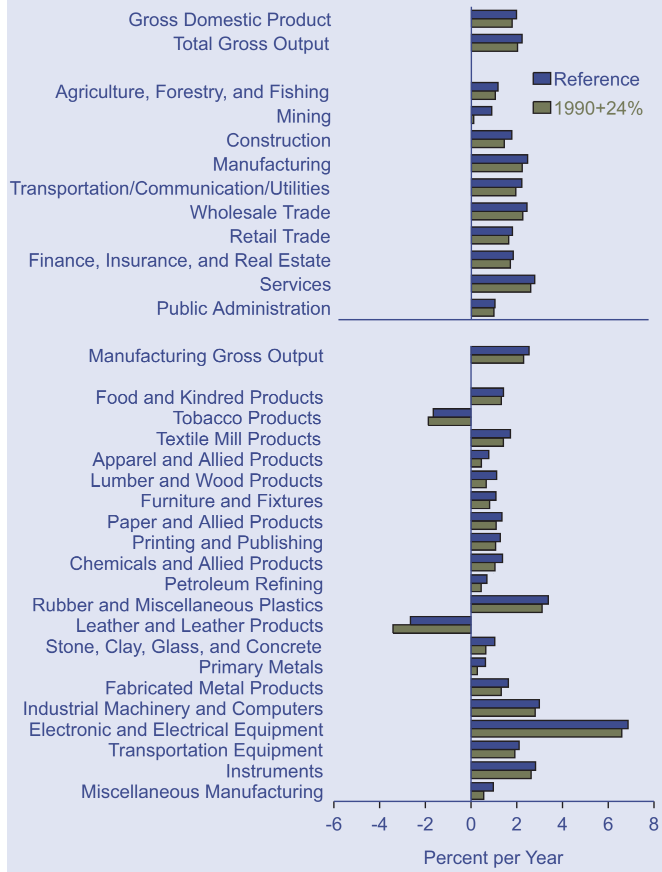
Figure 137. Projected Sectoral Growth Rates in Real Economic Output in the 1990-3% Case, 2005-2010



Note: Carbon permit revenues are assumed to be returned to households through personal income tax rebates.

Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.

Figure 138. Projected Sectoral Growth Rates in Real Economic Output in the 1990+24% Case, 2005-2010



Note: Carbon permit revenues are assumed to be returned to households through personal income tax rebates.

Source: Simulations of the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy.