A Sustainable Economy: Analysis of a Comprehensive Approach to Climate Change and Energy Policy[1]

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ABSTRACT: With the volatility in crude oil prices of the last few years, the increasing dependence of the U.S. economy on imported crude oil has become more apparent. Carbon emissions in the U.S. have been on the rise since 1990, making the adoptions of the recommendations of the Kyoto Protocol more difficult. Furthermore, there is no long-term policy plan to guide public and business decision makers as to how climate change and energy policy may evolve. Although a consensus is emerging that the U.S. needs to improve energy efficiency and diversify sources of energy supply, suggested policies that would reduce energy consumption and emissions are viewed as having painful economic impacts.

This paper describes our study which used the Inforum LIFT model of the U.S. to investigate the economic results of an energy policy which is designed to protect the environment, yet not harm the economy, or result in unfair burdens for affected workers and firms. We incorporate technology and energy efficiency assumptions from the Clean Energy Futures (CEF) study. The policy package examined has these four main components:

1. *Market mechanisms to reduce consumption of energy (carbon/energy tax) with the revenues used to stimulate employment by lowering the costs of labor, without decreasing wages.*
2. *Energy efficiency improvements indicated in the CEF report, including private investment and government spending necessary to achieve these improvements.*
3. *Border adjustment applied to each industry with a carbon/energy tax burden of 2% or more of the total cost of production.*
4. *Compensation for lost jobs and community transition assistance.*

We find that U.S. carbon emissions can be reduced significantly by 2020, with a slight increase in GDP and employment. Oil imports fall significantly. The effect on income distribution is slightly progressive. While the results are conditional on certain energy efficiency assumptions, the assumptions result from technologies that are deemed feasible and not prohibitively expensive.

1. Issues and Goals of Global Climate Change Policy

The U.S. is the largest economy and also has a fairly high fossil fuel/GDP ratio, making it the largest energy consuming economy by a wide margin. Since carbon emissions and other greenhouse gases are roughly proportional to fossil fuel consumption, the U.S. is responsible for a large share of total world emissions. While there is some agreement that emissions should be reduced, there is little agreement on how that policy goal should be achieved. A common proposal, that has received a lot of attention, is a carbon or Btu tax. However, there are many who would argue that a carbon tax is unacceptable. Spokesmen for the energy industries, and industries heavily reliant on energy have argued that the economy would suffer as a result of such a tax, and that they would bear the brunt of the suffering. Labor and consumer groups have raised concerns about the effect on employment in the affected industries, and

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about the possible adverse impacts on low-income households. Indeed, many of the economic studies that have been made show significantly negative economic impacts, both on GDP and employment.[2]

However, the current study is unique in a number of respects. It attempts to combine the best elements of a market-based approach (a carbon tax with revenue recycling), policies to promote investment and technology, competitiveness policies (border tax adjustments), and equity concerns (transition assistance). Many other studies of a carbon tax have used only the carbon tax without revenue recycling, and have not addressed the technology, competitiveness or equity issues. This study also incorporates engineering-based analysis of the implications of the potential of specific technologies. These technology assumptions are taken primarily from Department of Energy models and studies.[3]

The modeling framework is also unique in the use the Inforum LIFT model, an input-output based macroeconomic model that can capture the interplay between industry and macroeconomic impacts. The LIFT model operates at a level of detail of 97 industries, which allows for the implementation of emissions coefficients reflecting the broad range of energy and emissions intensities observed. The industry detail available is also crucial in the modeling of technology assumptions, border tax adjustments as well as worker transition assistance.

The goals of a reasonable energy policy that inform this study are: protecting the environment, improving energy security, strengthening the economy, preserving competitiveness, and distributing burdens and benefits as fairly as possible. Protecting the environment is addressed through the mechanism of reducing carbon emissions. The vast majority of the world's leading scientists agree that the emissions of greenhouse gases are the primary cause of global warming. The U.S. has an important responsibility to assume if the reduction of worldwide emissions is to occur. Energy security relates to the dependence of the U.S. upon the world oil market, and the economic instability that arises from fluctuations in world oil prices. Strengthening the economy is a particularly important goal, that is often seen as in conflict with the goal of protecting the environment. Previous studies have suggested that approaches used to reduce carbon emissions or increase energy efficiency would reduce GDP, wages and employment. If a policy can be designed that satisfies both goals, it will certainly be more politically acceptable. The goal of preserving competitiveness of domestic industries in the world economy is another one that is often seen as conflicting with environmental policy. If a policy imposes costs on domestic producers that are not borne by foreign competitors, they will be at a competitive disadvantage. Finally, a policy which reduces carbon emissions is likely to affect energy producers and energy-intensive industries the most, particularly reducing employment and incomes in those industries. To the extent this is not offset by other policies, workers and firms in these industries should receive assistance from the revenues forthcoming from environmental taxes.

2. A Policy Package Satisfying These Goals

The policy package examined in this paper has these four main components:

- Market mechanisms to reduce energy consumption, while at the same time stimulating employment. This would consist of a carbon/energy tax[4], that serves to increase the costs of using fossil fuels, and a mechanism that lowers the costs of labor without reducing wages.

[2] See the Energy Information Administration (1998), WEFA (1998), Consad Research Corp. (1998) and Charles River Associates (1997).
[3] In particular, the Interlaboratory Working Group (2000) *Scenarios for a Clean Energy Future* (CEF). Additional policies were included using estimates made by the Tellus Institute. These estimates were made using the National Energy Modeling System (NEMS), the same model used in the CEF report.
[4] This is not strictly a tax on carbon content only, due to the equalizing charge on nuclear and hydro power described below. We will refer to it simply as 'carbon tax' in the body of the paper. An equivalent policy mechanism would be a system of tradeable carbon emissions permits.

- Policies to promote and hasten the adoption of clean energy technologies, as outlined in the *Clean Energy Futures* (CEF) report, including private investment and government spending necessary to achieve energy efficiency using these technologies.
- Policies to preserve competitiveness of fossil fuel and energy-intensive industries, primarily implemented as a border tax adjustment, described below.
- Policies to ensure a just transition for workers in affected industries and residents of affected communities.

Market Mechanisms

The first component of the policy package is a tax on the carbon content of fuels, with the revenue returned through a cut in labor taxes. This type of tax places the highest burden on coal, followed by oil, then natural gas. An equalizing charge is placed on electricity produced from nuclear and hydroelectric power. Although at first blush such a charge goes against the goal of reducing carbon emissions, without the charge there would be regional inequities for both residential and industrial consumers. The tax would be phased in over a five-year period. The final tax is $50 per ton of carbon emitted. (This amounts to about $0.13 per gallon for gasoline.) This tax raises $70 to $80 billion after it has been fully phased in.

The majority of the revenues from the carbon/energy tax would then be returned to households through reductions in taxes on labor.[5] In the policy scenario we examine, the labor tax cut would take the form of a refundable credit against income taxes for part of the payroll taxes paid by workers. This would effectively exempt the first $6,044 of earnings from the payroll tax, but have no effect on Social Security collections and disbursements. The exemption would be phased out for earnings above $65,000. While most of the revenues from the carbon tax are used to reduce payroll taxes, a portion of the revenue is used to fund the energy efficiency and just-transition programs described below.

Clean Energy Technologies

The second component of the package is a set of policies to promote research, development and commercialization of existing energy efficiency and clean energy technologies. Energy efficiency promotion policies are by their nature diverse and sector specific. In order to identify a credible package of technology initiatives, we have adopted, with some modifications the technology policy package from *Scenarios for a Clean Energy Future* (CEF). The CEF report is the result of a massive multi-year effort by the national laboratories of the U.S. Department of Energy to develop a consensus national energy strategy based on sound science and consistent economic assumptions. The CEF report includes more than 50 individual policies to promote energy efficiency and renewable energy. The policy package analyzed in this paper is based on CEF's "advanced scenario", including the corporate average fuel economy (CAFE) "sensitivity case".[6] **Table 1** shows the highlights of the technology and policy set.

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[5] Meyer and Ewerhart (1998) assumed a similar recycling mechanism in a study of the German economy, using an Inforum model with enhanced energy and emissions detail. They found a positive employment effect in their policy scenario. Surveys of the economic impact of environmental taxation have generally found a positive or neutral, effect when environmental tax revenue is recycled include Hoerner and Bosquet (2001); Repetto and Austin (1997) and Majocci (1996).

[6] Appendix B in Hoerner and Barrett (2002) details the CEF assumptions, and modifications thereof, that were used in the policy scenario for this study.

Competitiveness

We may fail to meet the goal of competitiveness if U.S. firms do not have a level playing field with respect to international competitors. Since these competitors may not have to pay the same energy taxes as U.S. firms, the policy package includes a border tax adjustment, on fossil fuels and energy-intensive goods.

The border tax adjustment works as follows. Importers of fossil fuels and energy-intensive goods are required to pay whatever taxes would have been required had the products been produced domestically. In addition, taxes associated with U.S. production of energy-intensive exports would be rebated to the producer. These border adjustment taxes are commonly used in conjunction with value added taxes (VATs) in Europe and are explicitly allowed under GATT and WTO.

Many industries are not energy-intensive, and the labor tax cut is generally sufficient to offset the burden of the carbon tax for them. In addition, the border tax adjustments can be complicated to administer. For this reason, we limit the border tax adjustment to products for which the carbon/energy tax has a significant impact on price (set at 2% for the purposes of this study). This includes fossil fuels themselves, electricity and a handful of energy-intensive industries, including primary metals, cement, paper and certain chemicals.

Just Transition

As shown below, the overall effects on GDP and total employment of the policy package considered here are on balance slightly positive. Nevertheless, in some industries, most notably coal mining, some job loss appears unavoidable under any effective carbon abatement policy. Thus, the policy package includes items designed to provide these workers with new skills or a bridge to retirement. The policies are intended to provide economic compensation for workers in industries that lose employment as a result of the carbon tax.

A number of alternative packages were modeled. Two are described here. The first package includes two years of full, unconditional income replacement, up to four years of full-time training or educational benefits, and living stipends for an additional two years for those who remain in training. It includes replacement of health insurance and contributions to retirement plans. Workers within five years of retirement would have the option of foregoing training and receiving additional income replacement as a bridge to retirement. The average cost of this program is approximately $122,000 per worker. For workers in the coal mining sectors, whose salaries average just over $62,000 per year, the average cost of the total benefit package would equal about $196,000.

The alternative package would simply make a cash payment to eligible workers equal to their after-tax wages at layoff for up to five years. If a worker finds a new job within five years, for every dollar earned the payment would be reduced by 50 cents. This package is slightly more expensive than the first package.

Large-scale layoffs can affect not only the individual worker but also the communities in which they live. The policy package also provides funds from the carbon tax revenues equal to $10,000 per job lost, for investment in local community development

3. The Modeling Approach

The modeling approach required for this study is one that accounts for industry behavior, yet also provides full macroeconomic results. For this reason, the Inforum LIFT model[7] was chosen. At its core,

7 A more complete description of LIFT can be found in McCarthy (1991) and Meade (2001).

LIFT is a 97-sector interindustry (input-output) model. Econometric equations are used to forecast categories of final demand at the industry level. Output, imports and inventory change are solved jointly within the input-output solution. Hours and employment are based on the solution for output. Wage rate equations explain labor compensation per hour, from which total labor compensation by industry is derived. Other categories of value added, such as corporate profits, business transfer payments, and capital consumption allowances are also forecast by industry, using econometric equations. The price solution is based on intermediate input costs and value added. Over 800 macroeconomic variables round out the model. Many of these are formed as aggregates of industry variables, whereas others, such as the interest rate variables, have their own equations. Personal income is calculated as the sum of its component parts, many of which are industry level components of value added. Disposable income is formed by removing personal taxes and contributions to social insurance. The personal savings rate is calculated by an econometric equation. Total personal consumption is roughly equal to disposable income less personal savings. Real income can increase either through a rise in nominal income or through a fall in the consumer deflator, which is formed as an implicit price index of personal consumption by detailed category.

The consumption system is estimated jointly, with 92 categories of consumption goods and services, grouped into 9 major functional groups.[8] Consumption for each good is based on relative prices of the good and its group, real income, demographic and other factors. Within this system, substitution and complementarity are explicitly estimated. Equipment investment for each industry is estimated using a two-stage, three equation system that relates equipment investment to industry output, and the relative cost of capital with respect to labor and energy. Industry wages are determined by expected inflation and labor productivity. The model has a rich array of tax and fiscal policy levers and a highly detailed government sector.

The LIFT model is capable of determining the impact on the price of any good based on changes in the prices of its inputs, or of changes in input requirements. Prices also respond to changes in unit labor cost, whether it be due to a change in labor requirements (labor productivity) or the hourly compensation rate.

For this study, LIFT was enhanced to include explicit accounting for carbon emissions by industrial sector and in personal consumption, based on use of coal, petroleum products, electricity and natural gas.[9] A carbon tax accounting module was developed to calculate the amount of carbon tax collected by source and establish carbon taxes as a component of indirect taxes flowing to the federal government.

A baseline simulation was developed that was calibrated to GDP growth rates and energy use patterns contained in the 2001 *Annual Energy Outlook* of the Energy Information Administration. GDP growth was calibrated by adjusting labor productivity growth. Energy use by industry was calibrated on the production side by adjusting the technical (input-output) coefficients as well as by calibrating the consumer demand system.

For the alternative, or "policy" simulation, the following items were incorporated:

- A carbon tax was imposed that ramps up linearly from $10/ton in 2001 to $50/ton in 2005, remaining at $50/ton thereafter, in 1997 constant dollars. Part of the revenue was recycled using the labor tax cut described above.
- Energy efficiency improvements from the CEF report as well as several additional energy efficiency policies were implemented by adjusting input-output coefficients downward.

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[8] The personal consumption system is more fully described in Almon (1996).

[9] The carbon emissions were estimated from the official U.S. carbon emission estimates by sector and fuel type published by the Energy Information Administration (EIA) of the U.S. Department of Energy, as described in Hoerner (2000), pp 21-25.

- Private investment and government spending sufficient to achieve these energy efficiencies were added to the current investment and spending levels.[10] The investment requirements were taken from the CEF report, which projects how much investment would be forthcoming due to the policy packages adopted.
- Compensation for lost jobs and community transition assistance were implemented as an increase in unemployment insurance expenditures and general state and local government spending.
- Border adjustments were applied to each industry with a carbon tax burden of 2% or more of the total cost of production. This was done by reducing the effective export price of the affected industries by the percentage increase caused by the carbon tax, and increasing the effective import price of the competing import industries.
- In a few cases, more specific adjustments were made in the model, such as to capture the increased cost and labor requirements for the production of more fuel-efficient vehicles.

4. Results

To summarize in advance, our simulations find that a carbon tax with revenue recycling, coupled with a reduction in carbon emissions deriving from increased energy efficiency can result in a small increase in GDP, income and total employment.

Aggregate effects

Table 2 is a summary of the policy versus the base scenario, with a snapshot comparison for 2010 and 2020. Although the impact of the policy we have examined on GDP, income and employment is small, the environmental benefits are quite substantial. Carbon emissions are cut sharply relative to the baseline, by 31 percent in 2010, and 55 percent in 2020.

Reductions in refined petroleum coefficients lead indirectly to a large reduction in the total use of crude oil (-22.4 percent by 2020), and an even larger percentage reduction in imported crude oil (-34 percent by 2020). These positive findings are tempered by the finding of significant employment declines in a few industries. In particular, coal mining loses 72.4 percent of its jobs by 2020, a reduction of 33 thousand jobs of a total of 46 thousand. Total employment increases by 0.85 percent, an increase of 1.4 million jobs over the base by 2020.

Table 3 shows a breakdown of the GDP differences by major component of final demand. By 2020, of the total increase in GDP of 103 billion (in 1997$) in the policy scenario, by far the largest contributor to that increase is equipment investment, which is higher by 151 billion. Government purchases are also higher in the policy scenario by 26 billion by 2020. Exports are lower than the base by 24 billion in the policy scenario by 2020. Imports increase by 67 billion, primarily as a result of increased domestic final demand. (Since imports are subtracted in the calculation of GDP, they serve to counteract the contribution of government spending and equipment investment.) Although oil imports decline by 28 billion, other imports increase by 95 billion.[11] The GDP changes, though positive, are quite small in comparison with the reduction in emissions achieved.

Some of the increase in equipment investment is comprised of the investment calculated to flow from several of the technologies and policies in the CEF report that were implemented in the policy scenario. The CEF policies contributed to about $100 billion of the total increase. The government spending

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[10] In order to maintain budget neutrality, the government program expenditures are deducted from the carbon tax receipts before payroll taxes are cut.

[11] The increase in imports is typical of a scenario which includes increases in components of final demand. For each increment of final demand, some share of that demand is satisfied by imports. This share is of course different for each sector in the LIFT model.

increase results from increases in federal R&D expenditures, costs of information and technical assistance, and investment in promoting alternative fuels and efficiency in the government fleet program.[12]

Besides the assumptions about incremental private and public investment spending, the results are also sensitive to the behavior of prices. **Table 4** summarizes the behavior of aggregate prices, wages and productivity in the policy case with respect to the base case. The GDP deflator and the personal consumption deflator are higher by .68 percent and .60 percent, respectively in the policy scenario. This is partly the result of the demand pressures induced by higher real GDP, but is also the result of the carbon tax. The tax figures into the price of every good and service produced in the economy, either directly or indirectly. Note that the exports deflator, while higher in the policy case, has not increased as much as the GDP or consumption deflators. This is because of the border adjustments that were made on those goods most affected by the carbon tax. The fact that it is still higher than in the base is due to the fact that we made the border tax adjustments only on those goods who paid at least 2 percent of the total value of output for the tax. The behavior of the import deflator is mixed, with import prices increasing in several industries and decreasing in others, relative to the base. Like the GDP changes, the price deflator changes are small, especially considering the time frame of these scenarios.

Carbon emissions

Carbon emissions are cut significantly in the policy scenario. This is due both to the reduction in demand for those commodities whose relative price rises, as well as technological coefficient changes deriving from the CEF report. The policy package of course will also reduce other pollutants, besides carbon based emissions. Carbon emissions are a reasonable proxy for the combined sum of air pollution from the burning of fossil fuels. We can safely assume that most other pollutants will be reduced proportionately.

The next few tables present the change in carbon emissions by major sector and by fuel. **Table 5** shows the change in carbon emissions by major sector of the economy. By 2010, total carbon emissions have been reduced by 490 mmt (millions of metric tons). By 2020, the total reduction is more than double this amount, a total of 1035 million mmt. Of that total, the largest component arises from households, which is also the largest source of carbon emissions. The second largest reduction comes in the commercial sector. The policy package includes substantial increases in the energy efficiency of buildings, as well as significant advances in the carbon efficiency of electricity generation, which explains much of the carbon reduction in the household and commercial sectors. The third largest reduction occurs in manufacturing. Changes in manufacturing emissions are driven by a variety of technology and conservation programs identified in CEF. Economy-wide, there is also a certain amount of carbon reduction caused by substitution away from sectors whose price has increased due to the carbon tax, but we have not quantified which portion of the total change is due to this effect.

Table 6 shows a simple accounting of the change in carbon emissions by fuel. Note that in this table we have allocated the carbon emissions due to electricity consumption back to the energy input used to generate that electricity. The largest reduction by far is in coal. Carbon emissions from coal are reduced from the baseline by 308 mmt in 2010 and 568 mmt in 2020. This is more than half of the total reduction of 1035 mmt in 2020. One reason for this decline is the relatively high carbon content of coal-fired electricity. We have assumed a significant level of penetration of new combined-cycle natural gas plants, replacing the existing coal-steam generators. Not only does gas replace coal as an input, but it delivers Btus with less carbon emitted. The second largest decline, 303 mmt in 2020, is in petroleum based energy products. This is due to increased efficiencies in manufacturing processes, buildings and transportation. Reductions in carbon emissions from natural gas are smaller. Although we have assumed

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[12] Private and public investment cost estimates for the CEF policies were calculated by Steve Bernow and Bill Dougherty of the Tellus Institute under contract with the Center for a Sustainable Economy. They are described in greater detail in Appendix B of Hoerner and Barrett (2002).

increased efficiencies in natural gas usage, gas actually increases significantly in the electricity generating sector.

Carbon tax: sources and disposition

The carbon tax is assumed to ramp up gradually, starting at $10/mt in 2001, and reaching $50/mt ton in 2005, in 1997 dollars. **Table 7** shows that after adjusting for inflation, the actual level of the tax is $63.8/mt in 2010 and $77.9/mt in 2020 (but remaining at $50/mt in 1997 dollars). This table also shows that the total carbon tax revenue collected is $88.6 billion current dollars in 2010, and falls somewhat to $79.6 billion current dollars by 2020. About a third of the total is paid by households. By 2020, manufacturing and transportation each pay roughly one quarter of the total. The largest decline in share is in the commercial sector. The disposition of the tax revenue is divided between just transition assistance to workers and communities, federal program costs (R&D, administrative cost, grants, etc.) and the payroll tax reduction. The payroll tax reduction is the largest component, nearly 70 percent in 2010, falling to 51 percent by 2020.

Prices

How are industry prices affected? **Table 8** shows the change in domestic producers' prices for the top 15 industries, ranked by the percentage change from baseline in 2010. Industries at the top of the list either pay a large amount of carbon tax directly or indirectly. Motor vehicles (industry 49) and motor vehicles parts (industry 50) have relatively large price increases due to the increased labor, capital and intermediate requirements assumed for the development of more fuel-efficient vehicles. The positive changes in prices by industry explain the higher level of the GDP deflator that was shown in **table 1.** The extra labor requirements in the motor vehicle industry in large part explain the slight decline in aggregate productivity and potential GNP that were shown in that table. **Table 9** lists the industries which were selected for border tax adjustments on imports and exports. This selection is related to the degree of price change. Using input-output calculations outside the LIFT model, we determined which tradeable goods had at least a 2 percent price change to be expected from the carbon tax. To a large extent, the industries in **table 9** comprise the list of industries for which prices increased the most. However, the dynamic behavior of the model causes certain prices to increase by more or less than the static calculation indicated. For this reason, the border tax adjustments are not exact.

Employment

The sharpest drop in employment occurs in the Coal mining industry, as shown in **table 10**. This industry suffers a 54 percent reduction in employment by 2010, and a 72 percent reduction by 2020. This employment reduction is a direct result of a decline in coal use throughout the economy, but particularly in the electric utilities sector, as well as declines in the output of Electric utilities. In fact, in terms of the number of jobs lost, the Electric utilities sector fares much worse than coal. Although it has a 46 percent reduction in employment by 2020, the actual number of jobs lost compared to the base case is 145 thousand, compared to 33 thousand in coal mining.

In absolute terms, the Crude petroleum and natural gas sector loses the most jobs, a loss of 202 thousand in 2020. The top 6 industries ranked by percentage of jobs lost are all energy sectors. Railroads comes next, not because it is a large energy consumer (it is), but because the demand for railroad transportation is strongly affected by transportation of many of the energy products and industrial commodities that will be experiencing decreases in output relative to the base case,. Outside of the energy producing sectors and railroads, jobs declines are found in Stone, clay and glass (-4.2%), Non-metallic mining (-3.1%) and Metal mining (-1.8%). All other industries had either increases in employment or small reductions.

In contrast to the energy-producing sectors, the energy-intensive industries suffer negligible losses or have small gains under the policy scenario. The case of Ferrous metals (which includes steel) is fairly typical in this regard. It experiences rather mild impacts, with small employment losses in the early years, but fully recovers by 2020. The relatively benign impacts are due to three causes. The first is the border tax adjustment which mitigates the erosion of competitiveness relative to international markets. The second is the assumed improvements in energy efficiency. Although the carbon tax increases the price per unit of energy consumed, the efficiency improvements allow steel producers to make steel with less energy, so the price of steel only rises by 3.25 percent relative to the base by 2020. Finally, there is a slight stimulus resulting from the higher GDP in the policy scenario.

Many sectors, such as Construction, Motor vehicles, Trucking and Paper see modest gains in employment relative to the base. Trucking is an interesting case. Also the price of truck transportation rises slightly, the demand for trucking services is relatively insensitive to price, and depends mainly on the volume of goods shipped by truck, which increases. (Contrast this with the experience of railroads, described above.) Taken together, the modest improvements in many sectors yield increased employment in the policy scenario for the economy as a whole. Employment increases in the service sector are slightly greater in percentage terms than those for manufacturing. However, the absolute number of jobs created in the service sector is much larger.

The job declines shown in **table 10** provide the basis for the estimation of transition assistance to workers. However, we also make an estimate of normal job turnover, to adjust for workers who would have normally retired, quit voluntarily, or left their job for other reasons. **Table 11** shows our estimates for average annual layoffs in excess of normal turnover[13] that would result from the policies described in this paper. These are only those energy industries or energy-intensive industries that have positive layoffs. Note that some industries, such as Primary metals, Chemicals, Paper and Stone, clay and glass do not appear because their employment levels do not decline by more than the normal turnover amount.

Energy Prices, Demand and Expenditures

One concern of many critics of carbon/energy taxes is that they will impose hardships on consumers. Our modeling finds that, despite increases in energy prices, quantities of energy purchased by consumers decline enough that family budgets are not adversely affected by rising energy bills. **Figures 1 to 3** summarize the prices and total expenditures of petroleum products, electricity and natural gas.

Petroleum prices in the baseline case are projected to fall somewhat from their current levels, and then rise steadily until they are about 29 percent higher than their 2000 levels by 2020. Relative to the baseline, gasoline prices in the policy case are about 1.4 percent higher in 2010 and 3.4 percent higher in 2020. Despite the higher price, total expenditures in nominal terms are actually below the baseline in every year. Furthermore, while expenditures increase in every year in the baseline, expenditures actually fall throughout much of the policy case.

Electricity prices grow almost uniformly through 2020 in both the baseline and the policy case, with prices in the policy case about 6.5 percent higher than the baseline by 2020. However, by 2020, nominal expenditures on electricity are about 54 percent of the baseline value. Results for natural gas are similar, but prices rise higher and expenditures fall less than for gasoline and electricity. By 2020, prices are about 10 percent higher in the policy case, and expenditures 25 percent lower than the baseline. Part of the reason that natural gas expenditures do not decline as much is the extensive substitution of natural gas for coal in the electric utilities sector.

[13] We use a fairly conservative estimate of the value of turnover -- 3% per year -- equal to the average rate of voluntary turnover due to retirement alone, based on available data. Use of this conservative value implies that our estimates of the cost of transition assistance probably err on the high side. We also used a low threshhold for eligibility, in that we assumed that everyone laid off was covered, regardless of whether this was due to the carbon tax policy or not.

Conclusion

We have indicated in this study a scenario in which carbon emissions and energy consumption could be cut dramatically, yet with no significant loss of GDP or employment -- in fact, we find a slight increase in both GDP and employment. One might reasonably wonder what are the main factors driving our results, and why are they different from many of the previous studies that have examined the impacts of a carbon tax policy?

One important component is certainly revenue recycling. We have crafted a policy where the extra tax revenue from the carbon tax is allocated to:

- transition assistance for affected workers and communities;
- public spending on R&D, public investment in energy saving equipment, and programs to assist firms to adopt more energy-efficient production techniques; and
- payroll tax reductions that serve both to reduce the cost of labor as well as increase after-tax incomes of workers.

Results of studies that do not implement some form of revenue recycling will of course be heavily influenced by the simple Keynesian effects of higher taxes with no concomitant increase in expenditures,[14] finding a reduction in GDP. In addition, one could argue that such recycling is an appropriate use of the carbon tax revenues, since they not only neutralize the deficit impact, but enhance the policy goals of the tax and help to achieve fairness for those negatively affected.

Another important component of our study is the adoption of improved technologies and conservation measures by government, private firms and consumers. This adoption is crucial to the achievement of significant reductions in energy consumption. It is also important to the finding of increased GDP, as this is due in part to the private and government investment necessary to achieve the reductions. However, it is supported by many engineering and economic studies that indicate that energy savings yield cost savings that more than pay for the initial investments in new equipment and technologies. The fact that this study finds that there are economic gains to be had by the increased pace of adoption of existing technologies might seem to imply that businesses and consumers are ignoring or unaware of potentially profitable investments. However, this is not the case. Rather, the primary source of the economic benefits we find from technology policy is an acceleration of the currently occurring rate of energy efficiency and productivity improvement through additional research and coordination of private efforts.

Our approach is also unique in the use of the Inforum LIFT model, which allows for the simultaneous modeling of industry energy consumption, carbon emissions, carbon tax revenues, revenue recycling, border adjustments, and just transition assistance. No other model that we know of has the ability to analyze all of these components of the policy framework we have laid out, nor does any other model have the interindustry structure of the economy integrated with macroeconomic results.

While this study suffers from some limitations common to studies of this sort, and while the policy package modeled here may not be ideal, the results strongly indicate that a comprehensive approach is required to address the problems posed by dependence on fossil fuels. Our findings suggest that the appropriate direction for both research and policy development lies in the exploration of comprehensive policy packages. In fact, similar packages have already been pursued in other countries that have adopted stronger carbon reduction policies.

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[14] Most macro models, including the LIFT model, will show positive impacts on GDP from increasing the deficit, and negative impacts from reducing the deficit, i.e., they don't display Ricardian equivalence.

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TABLE 1

Major Policies in the CEF advanced scenario*

Buildings	Efficiency standards for equipment Labeling and deployment programs
Industry	Voluntary programs Agreements with individual industries and trade associations
Transportation	Tax incentives for super-efficient vehicles Increased CAFE standards "Pay-at-the-pump" auto insurance
Electric Generation	Renewable energy portfolio standards and production tax credits Electric industry marginal cost pricing**
Cross-sector policies	Doubled federal research and development Domestic carbon market mechanism (auctioned permit or tax, $50/ton of carbon)

* The scenarios are defined by approximately 50 policies; the 11 listed here are the most important ones in the advanced scenario. Each policy is specified in terms of magnitude and timing. For instance, "efficiency standards for equipment" comprises 16 new equipment standards introduced in various years with specific levels of minimum efficiencies. For details, see the CEF report.

** Note that the cEF assumes that marginal cost pricing will be implemented through electric utility industry restructuring. We do not make this assumption, as the same policies could also be implemented through regulatory reforms.

TABLE 2

Impact of the policy package for GDP, income, emissions and employment

		Baseline		Policy scenario		Percent change from baseline	
	2000	2010	2020	2010	2020	2010	2020
GDP	9,557	12,930	16,852	12,961	16,955	0.24	0.61
Disposable income	6,667	9,353	12,488	9,403	12,591	0.53	0.82
Carbon emissions	1,538	1,814	2,054	1,325	1,019	-26.99	-50.40
Industrial	1,057	1,199	1,355	873	698	-27.17	-48.50
Personal consumption	481	615	698	451	321	-26.65	-54.09
Total coal use	27,900	33,627	36,736	12,097	4,710	-64.03	-87.18
Total crude petroleum use	83,707	102,559	116,266	92,284	90,215	-10.02	-22.41
Petroleum imports	57,846	67,413	82,104	56,402	54,184	-16.33	-34.01
Total employment	142,726	157,572	167,456	158,233	168,872	0.42	0.85
Agriculture, mining, construction	12,448	13,527	14,689	13,518	14,534	-0.07	-1.05
Coal mining	87	53	46	24	13	-54.15	-72.41
Manufacturing	19,798	19,082	18,210	19,129	18,454	0.25	1.34
Ferrous metals	426	425	354	425	356	-0.08	0.53
Services	91,535	102,504	109,665	103,005	110,853	0.49	1.08

Note: GDP and Disposable income are in billions of 1997$, use and imports figures are in millions of 1997$, carbon emissions are in millions of metric tons, and employment is in thousands of jobs.

TABLE 3

Components of GDP

	2000	Baseline 2010	Baseline 2020	Policy scenario 2010	Policy scenario 2020	Change from baseline 2010	Change from baseline 2020
GDP	9,557	12,930	16,852	12,961	16,955	31	103
Personal consumption expenditures	6,399	8,669	11,439	8,685	11,450	15	11
Residential structures	364	477	556	479	558	2	2
Nonresidential structures	291	402	491	403	495	2	5
Equipment investment and software	1,297	1,797	2,473	1,816	2,624	20	151
Inventory change	53	22	5	22	4	0	-1
Exports	984	1,799	2,482	1,790	2,458	-9	-24
Imports	1,401	2,141	2,975	2,157	3,042	15	67
Oil imports	58	67	82	56	54	-11	-28
Other imports	1,344	2,074	2,893	2,100	2,988	26	95
Government	1,570	1,905	2,383	1,922	2,408	17	26

Note: GDP and its components are in billions of 1997$.

TABLE 4

Prices, wages and productivity

	2000	Baseline 2010	Baseline 2020	Policy scenario 2010	Policy scenario 2020	Percent change from baseline 2010	Percent change from baseline 2020
GDP deflator	1.05	1.27	1.55	1.28	1.56	0.21	0.68
Consumption deflator	1.05	1.26	1.54	1.27	1.55	0.55	0.60
Exports deflator	1.04	1.18	1.14	1.18	1.14	0.17	0.09
Imports deflator	1.00	1.10	1.23	1.10	1.22	0.23	-0.18
Aggregate wage index	1.16	1.77	2.68	1.77	2.69	-0.01	0.34
Real wage index	1.11	1.40	1.74	1.39	1.73	-0.55	-0.25
Aggregate productivity	27.03	33.74	41.41	33.69	41.32	-0.16	-0.22
Potential GNP	6,953	9,692	12,762	9,677	12,726	-0.15	-0.28

All deflators and wage indexes are normalized to 1.0 in 1997, aggregate productivity is defined as GNP divided by total hours worked; potential GNP is based on smoothed values of labor force, labor productivity and average hours worked.

TABLE 5

Carbon emissions by sector

		Baseline		Policy scenario		Change from Baseline	
	2000	2010	2020	2010	2020	2010	2020
Agriculture, mining, construction	56	66	74	36	25	-29	-50
Manufacturing	443	464	512	343	285	-122	-227
Transportation	253	310	366	274	268	-36	-98
Commercial	306	359	403	220	120	-139	-283
Households	481	615	698	451	321	-164	-378
Total	1,538	1,814	2,054	1,325	1,019	-490	-1035

Note: Carbon emissions are in millions of metric tons.

TABLE 6

Carbon emissions by fuel

		Baseline		Policy scenario		Change from Baseline	
	2000	2010	2020	2010	2020	2010	2020
Coal	548	636	659	328	91	-308	-568
Petroleum	722	759	873	643	570	-115	-303
Natural gas	269	420	522	353	357	-66	-164
Total	1,538	1,814	2,054	1,325	1,019	-490	-1035

Note: Carbon emissions are in millions of metric tons. Carbon generated in the use of electricity has been allocated back to the primary fuel used to generate that electricity.

TABLE 7

Carbon taxes and revenue recycling: policy scenario

	Levels		Percent	
	2010	2020	2010	2020
Carbon tax rate ($/mt)	63.8	77.9		
Agriculture, mining, construction	2.6	2.0	3%	2%
Manufacturing	23.5	22.3	27%	28%
Transportation	17.5	20.9	20%	26%
Commercial	16.2	9.4	18%	12%
Households	28.8	25.0	33%	31%
Total	88.6	79.6		
Total tax collected	88.6	79.6		
Just transition assistance	12.3	14.5	14%	18%
Program costs	14.8	24.5	17%	31%
Payroll tax reduction	61.5	40.6	69%	51%

Note: Carbon tax revenue and recycling is in billions of current dollars (BCD). Carbon tax rate is specified as dollars per metric ton.

TABLE 8

Effects on domestic producers' prices

		Base		Policy		Percent change from baseline	
	2000	2010	2020	2010	2020	2010	2020
6 Non-metallic mining	1.092	1.269	1.453	1.379	1.650	8.7	13.6
49 Motor vehicles	1.098	1.220	1.404	1.309	1.615	7.3	15.0
2 Metal mining	1.095	1.273	1.466	1.363	1.609	7.1	9.7
3 Coal mining	1.082	1.343	1.573	1.411	1.765	5.0	12.2
66 Electric utilities	1.041	1.320	1.663	1.374	1.766	4.0	6.2
67 Gas utilities	1.419	1.364	1.858	1.416	2.050	3.8	10.4
31 Stone, clay & glass	1.071	1.234	1.427	1.270	1.530	2.9	7.2
61 Water transport	1.125	1.306	1.521	1.340	1.559	2.6	2.5
90 Miscellaneous tiny flows	0.065	0.288	0.543	0.295	0.556	2.4	2.5
33 Primary nonferrous metals	0.988	1.091	1.213	1.114	1.249	2.1	2.9
32 Primary ferrous metals	1.064	1.162	1.292	1.185	1.336	2.0	3.4
20 Agricultural fertilizers and chemicals	1.052	1.216	1.388	1.236	1.417	1.6	2.1
50 Motor vehicle parts	1.149	1.292	1.524	1.313	1.575	1.6	3.3
24 Petroleum refining	1.134	1.238	1.464	1.257	1.512	1.5	3.3
13 Alcoholic beverages	1.025	1.203	1.389	1.220	1.432	1.5	3.1

Note: prices are based to equal 1.0 in 1997.

TABLE 9

Industries with border tax adjustments

2	Metal mining
3	Coal mining
5	Crude petroleum
6	Non-metallic mining
11	Canned and frozen foods
12	Bakery and grain mill products
13	Alcoholic beverages
14	Other food products
18	Paper
20	Agricultural fertilizers and chemicals
21	Plastics and synthetics
23	Other chemicals
24	Petroleum refining
31	Stone, clay and glass
32	Primary ferrous metals
33	Primary nonferrous metals
59	Railroads
60	Trucking and highway passenger transit
62	Air transport
66	Electric utilities
67	Gas utilities

TABLE 10

Employment: Top 10 losers ranked by percentage change in 2020

		Base		Policy		Percent change from baseline	
	2000	2010	2020	2010	2020	2010	2020
3 Coal mining	87	53	46	24	13	-54.1	-72.4
66 Electric utilities	308	401	314	304	169	-24.1	-46.1
67 Gas utilities	115	147	187	138	142	-6.0	-23.7
24 Petroleum refining & fuel oil	125	139	97	125	76	-9.8	-21.5
63 Pipeline	12	7	3	6	3	-7.3	-16.3
5 Crude petroleum & natural gas	803	800	1,608	780	1,406	-2.5	-12.5
59 Railroads	229	177	140	171	132	-3.3	-5.5
31 Stone, clay & glass	601	592	576	588	552	-0.8	-4.2
6 Non-metallic mining	117	129	139	127	135	-1.4	-3.1
2 Metal mining	51	54	36	53	35	-1.8	-1.8

Note: Employment is measured in thousands of jobs.

TABLE 11

Program-induced layoffs in impacted industries

		2001-10		2011-20	
Industry number	Industry	Average annual layoffs	% average layoffs	Average annual layoffs	% average layoffs
2	Metal mining	-	-	355	0.78
3	Coal mining	4,715	6.78	657	1.38
5	Crude petroleum	31	-	-	-
6	Non-metallic mining	5	-	-	-
24	Petroleum refining	658	0.51	2,124	1.80
35	Engines and turbines	27	0.04	50	0.08
59	Railroads	281	0.14	35	0.02
61	Water transport	-	-	-	-
63	Pipelines	261	2.78	258	5.47
66	Electric utilities	402	0.12	6,255	1.76
67	Gas utilities	42	0.04	-	-

Figure 1. Petroleum Products

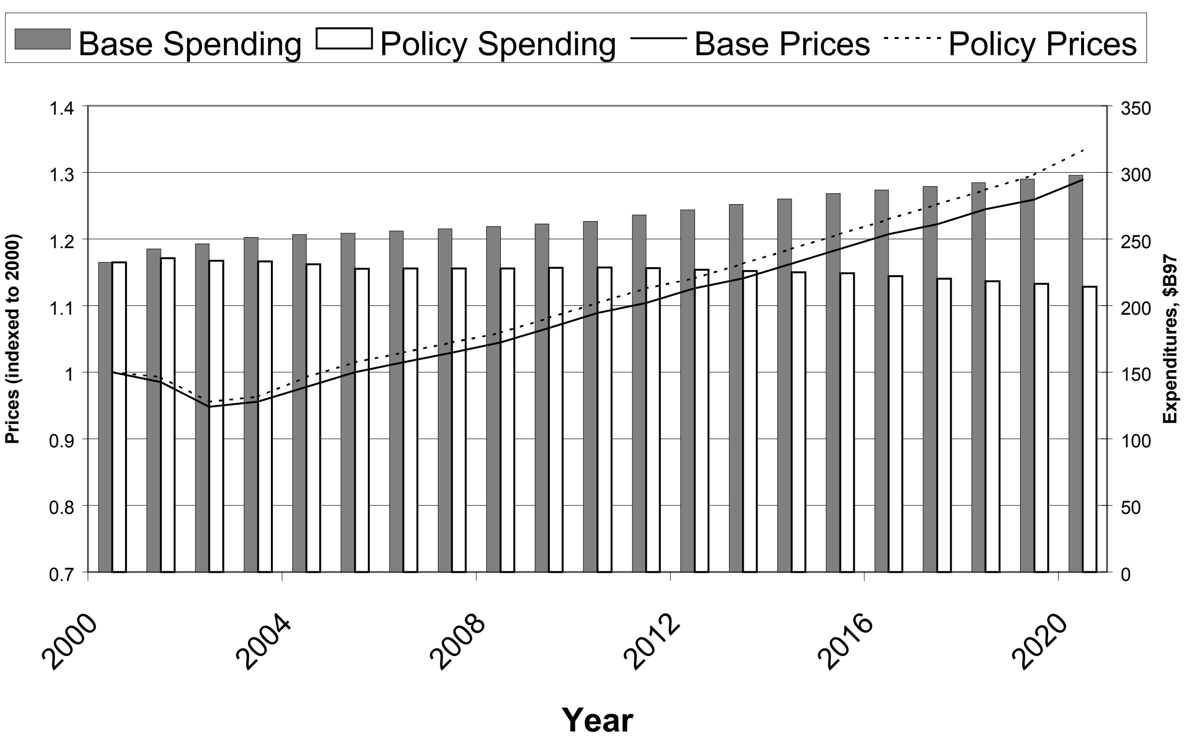

Figure 2. Electricity

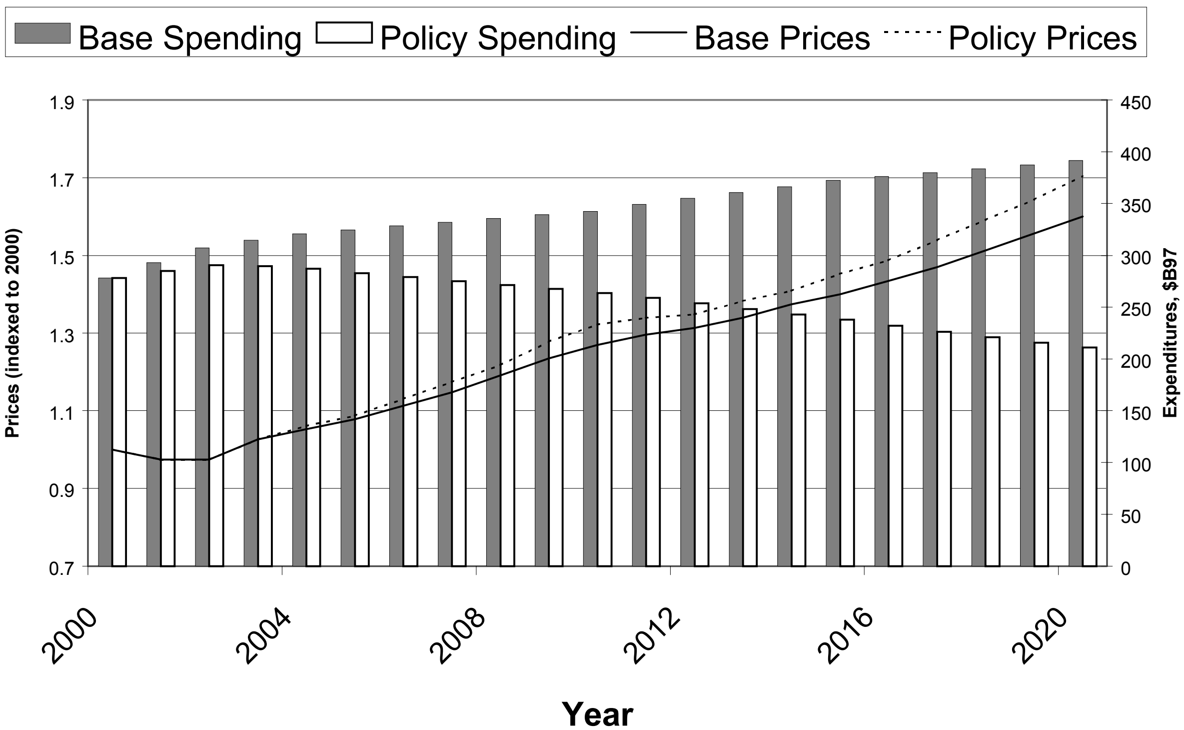

Figure 3. Natural Gas