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EXECUTIVE SUMMARY

This paper examines fiscal reform options in the United States with an intertemporal computable general equilibrium model of the world economy called G-Cubed. Six policy scenarios explore two overarching issues: (1) the effects of a carbon tax under alternative assumptions about the use of the resulting revenue, and (2) the effects of alternative measures that could be used to reduce the budget deficit. We examine a simple excise tax on the carbon content of fossil fuels in the U.S. energy sector starting immediately at $15 per metric ton of carbon dioxide (CO_2) and rising at 4 percent above inflation each year through 2050. We investigate policies that allow the revenue from the illustrative carbon tax to reduce the long run federal budget deficit or the marginal tax rates on labor and capital income. We also compare the carbon tax to other means of reducing the deficit by the same amount.

We find that the carbon tax will raise considerable revenue: $80 billion at the outset, rising to $170 billion in 2030 and $310 billion by 2050. It also significantly reduces U.S. CO_2 emissions by an amount that is largely independent of the use of the revenue. By 2050, annual CO_2 emissions fall by 2.5 billion metric tons (BMT), or 34 percent, relative to baseline, and cumulative emissions fall by 40 BMT through 2050.

The use of the revenue affects both broad economic impacts and the composition of GDP across consumption, investment and net exports. In most scenarios, the carbon tax lowers GDP slightly, reduces investment and exports, and increases imports. The effect on consumption varies across policies and can be positive if households receive the revenue as a lump sum transfer. Using the revenue for a capital tax cut, however, is significantly different than the other policies. In that case, investment booms, employment rises, consumption declines slightly, imports increase, and overall GDP rises significantly relative to baseline through about 2040. Thus, a tax reform that uses a carbon tax to reduce capital taxes would achieve two goals: reducing CO_2 emissions significantly and expanding short-run employment and the economy.

We examine three ways to reduce the deficit by an equal amount. We find that raising marginal tax rates on labor income has advantages over raising tax rates on capital income or establishing a carbon tax. A labor tax increase leaves GDP close to its baseline, reduces consumption very slightly and expands net exports slightly. Investment remains essentially unchanged. In contrast, a capital tax increase causes a significant and persistent drop in investment and much larger reductions in GDP. A carbon tax falls between the two: it lowers GDP more than a labor tax increase because it reduces investment. However, its effects on investment and GDP are more moderate than the capital tax increase, and it also significantly reduces CO_2 emissions. A carbon tax thus offers a way to help reduce the deficit and improve the environment, and do so with minimal disturbance to overall economic activity.

1. INTRODUCTION

Either a carbon pollution tax or a cap-and-trade system can "price carbon."[1] Of the two approaches, a tax may have the better prospects in the United States since Congressional debates over cap-and-trade collapsed in 2010. One option for pricing carbon in the United States would embed a carbon pollution tax within a broader tax reform or budget deficit reduction package. Such an approach could use the revenue from the carbon tax to improve the economic efficiency of the tax system and/or reduce the federal budget deficit, while also reducing the need for costlier regulatory measures to reduce climate-disrupting greenhouse gases.[2] A carbon tax might also allow reductions in subsidies for clean energy technologies since a price on carbon alone can make low-carbon technologies more competitive with their conventional alternatives.

When economists talk about a greenhouse gas (GHG) or carbon tax, they generally have several canonical features in mind. The tax would fall on the carbon content of fossil fuels broadly across the economy and possibly other non-CO_2 GHG emissions. The price signal would start modestly and ramp up gradually in real terms. And the tax program itself would be relatively simple, with few exemptions, complications, and ancillary policies.

In the long run, a tax on the carbon in energy sector fossil fuels will be largely passed forward to consumers through higher prices on energy and higher prices on other goods and services that use energy as an input. Those higher overall real price levels depress the returns to working and investing by shrinking the basket of goods people can buy with their earnings. Because income is already taxed (for example through income, payroll, and capital taxes), the carbon pollution tax introduces another distortion on top of the existing ones. Research suggests this piling on of distortions, known as the "tax interaction effect," can be even more costly than the direct abatement costs.[3]

Policymakers may be able to offset the tax interaction effect by using the carbon tax revenue to reduce other taxes, either now (by lowering marginal tax rates) or in the future (by reducing the federal deficit). In addition to raising revenue, taxes cause "excess burden" or "deadweight loss." These are costs that arise from distortions in behavior that result from the tax. For example, income taxes reduce the returns to working and create a disincentive to work. The higher the marginal tax rate on labor income, the greater the incremental disincentive to work. This tax-induced disincentive to work results in a lower-than-efficient amount of labor supply in

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[1] A hybrid approach, such as that proposed by McKibbin and Wilcoxen (2002), could also price carbon.

[2] This paper focuses on a carbon tax, but versions of a cap-and-trade program or hybrid that raise revenue could offer fiscal reforms analogous to the carbon tax scenarios in this paper.

[3] For example, see Goulder et al (1997).

the economy, and that inefficiency is costly. Likewise, taxes on capital income (like the corporate income tax), lower investment which in turn reduces future consumption below what it would have otherwise been.

The deadweight loss produced by the last dollar of revenue that a tax instrument collects is called its "marginal excess burden," and the size of the excess burden can vary significantly across different kinds of taxes. Using carbon pollution tax revenue in a way that reduces marginal tax rates could reduce the excess burden of the fiscal system. This is called "revenue recycling," and some estimates suggest that using carbon pollution tax revenue to lower the deficit or other taxes can lower the overall costs of the program by 75 percent.[4]

The proposition that revenue from an environmental tax could improve the efficiency of the tax system and lower overall costs if it is used to lower other tax rates is called the "weak double dividend" hypothesis. The first dividend is lowering damaging emissions. The second dividend is the potential welfare improvement from revenue recycling relative to a scenario in which the pollution tax revenue is given back to households in a lump sum fashion.[5] The argument is that lump sum rebates don't reduce any of the existing distortions in the tax system, so they don't provide any efficiency gains. Using the carbon tax revenue to reduce the budget deficit could also be a form of efficiency-enhancing revenue recycling because it lowers the tax burdens necessary to support the federal debt.

Feldstein (2006) argues that the distortions from the tax system are greater than most people realize, resulting in costs of about $0.76 for every dollar the federal government raises. Thus in theory, the most efficient form of revenue recycling would offset the most distortionary taxes, meaning the ones that have the highest marginal deadweight loss, now or in the future. Parry and Bento (2000) and Parry and Williams (2011) find that efficiency gains are particularly large when revenue recycling lowers taxes that favor some kinds of consumption (such as housing or health insurance) over others.

Two obvious options are to use the carbon tax revenue to reduce labor income taxes and to reduce capital income taxes. Such tax reforms can substantially offset the regressiveness of the carbon tax and improve the returns to working and saving. For example, a carbon tax could finance a reduction in payroll taxes. Metcalf (2007a) analyzes such a tax swap. He finds that a carbon tax of $15 per metric ton (MT) of CO_2, imposed in 2005, would have raised $78.5 billion and allowed a rebate of the employer and employee payroll taxes on the first $3,660 of earnings per worker, or a maximum rebate if $560 per covered worker. Given payroll tax collections of about $727 billion in 2005, the carbon tax could lower payroll tax burdens on

[4] Parry (1997)

[5] A number of studies have examined the potential for revenue recycling in pricing carbon. For example: Goulder et al. (1999), Parry et al. (1999), Parry and Oates (2000), Parry and Bento (2000), and CBO 2007.

average by just under 11 percent. Metcalf shows this can more than offset the regressivity of the carbon tax.

Revenue from a carbon tax could allow lower marginal tax rates on corporate income. The 2012 President's Framework for Business Tax Reform notes that the U.S. corporate income tax, as a result of its relatively narrow tax base and high statutory tax rate, is "uncompetitive and inefficient." [6] By taxing dividends at both the corporate and personal levels, the current tax code encourages corporations to finance themselves with debt rather than equity, increasing the risk of financial distress, according to the report. The relatively high marginal tax rates encourage corporations to shift their activities out of the United States to a lower tax jurisdiction.

Analyzing a 15 percent cut in emissions from a cap-and-trade program, the U.S. Congressional Budget Office (CBO) estimates that the downward effect on GDP from the program could be reduced by more than half if the government sold allowances and used the revenues to lower corporate income taxes rather than to provide lump-sum rebates to households or to give the allowances away.[7] Metcalf (2007b) analyzes a scenario in which the revenue from a small carbon tax funds corporate tax integration, a reform in which corporate income is taxed only at the personal level. He finds that not only would the tax swap enhance the overall efficiency of the tax system, the corporate tax reform could blunt the consumer price impacts of the carbon tax.

This paper examines tax reform options with an intertemporal computable general equilibrium (CGE) model of the world economy called G-Cubed. We investigate policies that allow the revenue from an illustrative carbon pollution tax to reduce the long run federal budget deficit or the rates of distortionary taxes on labor and capital income. We establish a simple excise tax on the carbon content of fossil fuels in the U.S. energy sector starting immediately at $15 per ton of CO_2 and rising at 4 percent above inflation each year through 2050.[8] We specify the U.S. carbon tax trajectory *a priori* in this way such that it follows a path that minimizes the cost of the cumulative abatement of emissions through 2050. To isolate the effects of the U.S. climate and fiscal policy on the United States, we assume other countries adhere to their baseline emissions trajectories.

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[6] Joint Report by the White House and the Department of the Treasury, February, 2012. Downloaded July 23, 2012, from http://www.treasury.gov/resource-center/tax-policy/Documents/The-Presidents-Framework-for-Business-Tax-Reform-02-22-2012.pdf

[7] Elmendorf (2009)

[8] The choice of a tax that begins at $15 per ton of CO_2 is arbitrary; the authors do not mean to suggest that such a price point is socially optimal.

2. MODELING APPROACH

A brief technical discussion of G-Cubed appears in McKibbin et al. (2009) and a more detailed description of the theory behind the model can be found in McKibbin and Wilcoxen (1999) and in McKibbin and Wilcoxen (2012).[9] We use a version of the model that includes the nine geographical regions listed in Table 1 below and the 12 industrial sectors listed in Table 2. The United States, Japan, Australia, and China are each represented by a separately modeled region. The model aggregates the rest of the world into five composite regions: Western Europe, the rest of the OECD (not including Mexico and Korea); Eastern Europe and the former Soviet Union; OPEC oil exporting economies; and all other developing countries.

Table 1: Regions in the G-Cubed Model (Country Aggregation E)

Region Code	Region Description
USA	United States
Japan	Japan
Australia	Australia
Europe	Western Europe
ROECD	Rest of the OECD, i.e. Canada and New Zealand
China	China
EEFSU	Eastern Europe and the former Soviet Union
LDC	Other Developing Countries
OPEC	Oil Exporting Developing Countries

Table 2: Industry Sectors in the G-Cubed Model

Sector Number	Sector
1	Electric Utilities
2	Gas Utilities
3	Petroleum Refining
4	Coal Mining
5	Crude Oil & Gas
6	Mining
7	Agriculture
8	Forestry & Wood

[9] The type of CGE model represented by G-Cubed, with macroeconomic dynamics and various nominal rigidities, is closely related to the dynamic stochastic general equilibrium models that appear in the macroeconomic and central banking literatures.

9	Durables
10	Non-Durables
11	Transportation
12	Services

The Government's Budget Constraint

To describe the baseline and policy scenarios, we first specify G-Cubed's representation of the federal government's budget constraint, which matches the government's outlays to its revenue. In the analysis in this study, government outlays include purchases of goods, services, and labor, along with interest payments on government debt. The first simulation also includes lump sum transfers to households. Government revenue comes from sales taxes, corporate and labor income taxes, and sales of new government bonds. We also include an additional lump sum tax that satisfies a condition called the "no Ponzi game" (NPG) condition. It prevents per capita government debt from growing faster than the interest rate forever, in which case the government would be unable to pay interest on the debt.[10] In addition, some of the simulations include a tax on the carbon content of fossil fuels used in the energy sector.

Mathematically, in any given year the following equates government expenditure to government revenue:

$$G_G + wL_G + R_{LS} + rB = T + t_C Q_C + T_{LS} + D$$

The left hand side sums outflows from the government in value terms:

- G_G government spending on goods and services
- wL_G government spending at (tax inclusive) wage w on quantity of labor wL_G
- R_{LS} lump sum transfers to households
- rB interest payments on the stock of federal bonds B at interest rate r

The right hand side sums sources of income to the government:

- T tax revenue from all taxes other than carbon taxes
- $t_C Q_C$ carbon pollution tax revenue on emissions Q_C
- D net government borrowing via the fiscal deficit

[10] Implicitly we assume that agents will not hold government bonds unless they expect the bonds to be paid off eventually. The binding NPG condition means that at any point in time the current level of debt will always be exactly equal to the present value of future budget surpluses. McKibbin and Wilcoxen (1999) present the equivalent intertemporal constraint: the transversality condition on the stock of debt.

The Baseline Scenario

In the baseline, exogenous variables include the deficit *D*, and the tax rates included in *T*. The baseline scenario includes no lump sum transfers to households, so R_{LS} is identically zero. The stock of bonds *B* is determined by the accumulation of past deficits. Wages, prices of goods and services, and the interest rate on government debt are all endogenous. Each region's real government spending on goods and services is exogenous and allocated across inputs in fixed proportions according to their values in 2010. Government labor demanded, L_G, is also exogenous in the baseline.

A model's assumptions (or in the case of G-Cubed, its endogenous projections) about future emissions and economic activity in the absence of climate policy is called the baseline scenario. A detailed discussion of the baseline in G-Cubed appears in McKibbin, Pearce and Stegman (2009). The baseline in this study is broadly consistent with the emissions and GDP growth in the Department of Energy's Updated *Annual Energy Outlook* Reference Case Service Report from April 2011.[11] It sets G-Cubed's projected productivity growth rates so that the model's baseline results approximate the report's forecasts for U.S. real gross domestic product (GDP) and other key variables.

Along with the baseline for the U.S., we construct a baseline scenario for the other regions in the world that reflects our best estimate of the likely evolution of each region's economy without concerted climate policy measures. To generate this scenario, we begin by calibrating the model to reproduce approximately the relationship between economic growth and emissions growth in the U.S. and other regions over the past decade. In the baseline, neither the U.S. nor other countries adopt an economy-wide price on carbon through 2050.

The Policy Scenarios

We use the G-Cubed model to analyze six policy scenarios that allow us to compare deficit reductions via a carbon tax and increases in labor and capital taxes as well as deficit neutral tax shifts.

In all the policy simulations, we hold the real value of government spending on goods, services, and labor ($G_G + wL_G$) at baseline levels. As we discuss later in this paper, assumptions about how government spending changes (or not) as a result of a carbon tax have important implications for consumption-based measures of household welfare. That's because a carbon tax can lower wages. If government labor quantity demanded is exogenous (as is typically

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[11] The report appears at the DOE's Energy Information Administration website: http://www.eia.doe.gov/oiaf/servicerpt/stimulus/index.html.

assumed) and wages fall, then the carbon tax induces lower government spending on labor and lower total government consumption. Thus lower wages in the policy simulation effectively shrink the burden of the government and expand consumption by households. This particular beneficial outcome for household welfare doesn't arise directly from the carbon tax but rather by its indirect effects on the overall size of government. To isolate the effect of the carbon tax on welfare independent of changes in the overall burden of supporting government, we hold government spending in these simulations to its baseline by imposing an endogenous lump sum tax that is just the right size to finance baseline government spending.

The first policy scenario imposes a carbon tax whose revenue is rebated lump sum to households. It includes essentially no other important fiscal changes. The second scenario applies the carbon tax revenue to deficit reduction. The third and fourth scenarios achieve the same deficit reductions as the second, but do it with increases in the labor income tax and the capital income tax, respectively. The fifth and sixth scenarios use carbon tax revenues to fund deficit neutral decreases in taxes on labor and capital income, respectively. Here are the details:

1. Carbon tax with lump sum rebate.

This scenario establishes a simple excise tax on the carbon content of fossil fuels in the U.S. energy sector starting immediately at $15 per ton of CO_2 and rising at 4 percent above inflation each year through 2050. We specify the carbon tax trajectory *a priori* in this way such that it follows a path that minimizes the cost of emissions abatement.

In each year of the simulation, government spending, the federal budget deficit, and tax rates on sales, corporate income, and labor income are held at the same levels as in the baseline. The government returns the revenue from the carbon tax to households with the lump sum rebate.

Each year's total rebate to households will be slightly different than the carbon tax revenue due to the general equilibrium effects of the carbon tax. For example, if the carbon tax slows economic activity and lowers the revenue from other taxes, some of the carbon tax revenue the government must retain some of the carbon tax revenue to finance government spending (held at baseline levels) without increasing the deficit.

The carbon tax can also induce a change in the composition of economic activity across categories with different tax treatment and change the relative prices of different inputs to government spending.

2. Carbon tax with deficit reduction.

This scenario imposes the same tax on carbon emissions as Scenario 1, but applies the revenue towards deficit reduction. As in Scenario 1, we hold total government spending and noncarbon tax rates at their baseline levels. A key difference in outcomes between this simulation and Scenario 1 is that this scenario produces lower government deficits and debt owing to the revenue of the carbon tax. It means that the interest payments on the debt fall, and the NPG tax embedded in *T* will be smaller than in Scenario 1.

There are no lump sum rebates to households; all of the carbon tax revenue applies towards deficit reduction. However, the decline in the deficit relative to baseline will differ slightly from the carbon tax revenue due to general equilibrium effects.

3. Deficit reduction via an increase in tax rates on labor income

4. Deficit reduction via an increase in tax rates on capital income

Scenarios 3 and 4 allow us to compare deficit reductions via a carbon tax with other ways to reduce the deficit by the same amount. These simulations exogenously set the deficit to the lower-than-baseline trajectory achieved in Scenario 2.

Scenario 3 endogenously determines the (larger than baseline) tax rate on labor income each year such that the increase in labor income tax revenue produces exactly the same (lower than baseline) deficit that obtained in Scenario 2.

Scenario 4 does the same thing as Scenario 3 with the tax rate on capital income rather than the tax rate on labor income.

There are no carbon taxes or lump sum rebates in Scenarios 3 and 4.

Because these simulations determine tax rates on labor and capital endogenously each year to hit a particular deficit target, they are best thought of as diagnostic scenarios rather than realistic policy scenarios.

5. Carbon tax with reduction in tax rates on labor income.

6. Carbon tax with reduction in tax rates on capital income.

Scenarios 5 and 6 apply revenue from a carbon tax to finance reductions in the tax rates on labor and capital income. The deficit and government spending are held exogenously to baseline levels. The same carbon tax as Scenario 1 applies.

Scenario 5 endogenously determines the (lower than baseline) tax rate on labor income each year such that net result of the decrease in labor income tax revenue and the increase in revenue from the carbon tax produces exactly the deficit in the baseline for that year. Scenario 6 does the same thing as Scenario 5 with decreases in the tax rates on capital income instead of the tax rates on labor income.

In these simulations the deficits and debt are the same as in the baseline and Scenario 1. There are no lump sum rebates to households. As in the other simulations, the revenue from the carbon tax and the reduction in other tax revenues would differ slightly due to general equilibrium effects.

Table 3 below summarizes the key features of the scenarios.

Table 3: Summary of Baseline and Policy Scenarios

Scenario	Carbon Tax	Deficit	Labor tax rate	Capital tax rate	Lump Sum Rebate
Baseline	no	exogenous	exogenous	exogenous	no
1	Yes, tax on the carbon in fossil fuels in the U.S. energy sector, starting immediately at $15 per ton of CO_2, rising at 4% real each year through 2030	baseline	baseline	baseline	yes
2	same as Scenario 1	falls relative to baseline	baseline	baseline	no
3	no	same decline as Scenario 2	Higher than baseline	baseline	no
4	no	same decline as Scenario 2	baseline	Higher than baseline	no
5	same as Scenario 1	baseline	Lower than baseline	baseline	no
6	same as Scenario 1	baseline	baseline	Lower than baseline	no

The comparative general equilibrium effects of these scenarios are of particular interest. For example, the tax swap scenarios (5 and 6) use the carbon tax revenue to reduce other distortions in the economy. This raises the question of whether the net effect of these fiscal reforms on employment, consumption, and GDP will be positive or negative.

The carbon tax in Scenarios 1, 2, 5, and 6 increases at the long term real interest rate, a trajectory known as a "Hotelling path" after the work of Harold Hotelling. Hotelling (1931) showed that the price of an exhaustible resource grows at the real interest rate when owners maximize the value of their resource over the extraction period. A Hotelling path has the property that it minimizes the present value of the abatement cost of achieving a specified reduction in cumulative emissions. In each year, polluters will reduce emissions whenever the marginal cost of doing so is less than the carbon price. If the carbon price rises at the real interest rate, then present value cost of the last unit abated in each future period will be equal, which is precisely the condition required for minimizing the present value cost of a fixed quantity of abatement.

The greenhouse gas emissions included in G-Cubed comprise only CO_2 from energy-related fossil fuel consumption including combustion of coal, natural gas, and oil. This represents a large majority of total U.S. greenhouse gas emissions and the vast majority of emissions growth since 2000. For example, according to the U.S. Environmental Protection Agency, fossil fuel combustion comprised 94 percent of all U.S. CO_2 emissions in 2008, and over 80 percent of gross U.S. greenhouse gas emissions on a CO_2-equivalent basis.[12]

3. RESULTS

The six policy scenarios explore two overarching issues: (1) the effects of a carbon tax under alternative assumptions about the use of the resulting revenue, and (2) the effects of alternative measures that could be used to reduce the budget deficit. Simulations 1, 2, 5 and 6 address the first issue and share a common carbon tax. Simulations 2, 3 and 4 address the second issue and share a common reduction in the deficit. Each issue will be discussed in turn below. The labels for the scenarios in the figures below abbreviate the scenarios according to Table 4. The figures also label the baseline scenario as "Base."

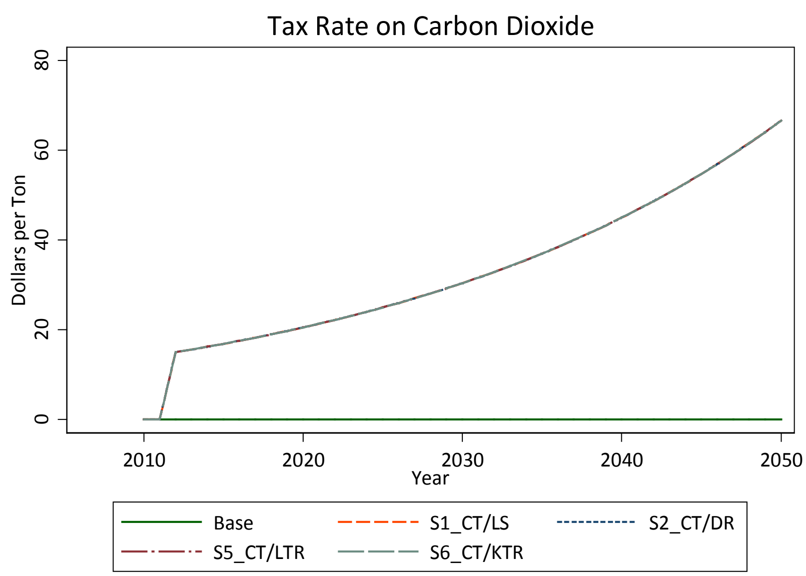
[12] U.S. Environmental Protection Agency (2010), *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2008*, p. ES-4, Table ES-2. Accessed on July 8, 2010: http://epa.gov/climatechange/emissions/downloads10/US-GHG-Inventory-2010_ExecutiveSummary.pdf.

Table 4: Policy Scenario Abbreviations in Figures

Scenario	Scenario Description	Abbreviation
1	Carbon tax (CT) with lump sum (LS) rebates	S1_CT/LS
2	Carbon tax (CT) with deficit reduction (DR)	S2_CT/DR
3	Deficit reduction (DR) via increase in labor tax (LT)	S3_LT/DR
4	Deficit reduction (DR) via increase in capital tax (KT)	S4_KT/DR
5	Carbon tax (CT) with reduction in labor tax rates (LTR)	S5_CT/LTR
6	Carbon tax (CT) with reduction in capital tax rates (KTR)	S6_CT/KTR

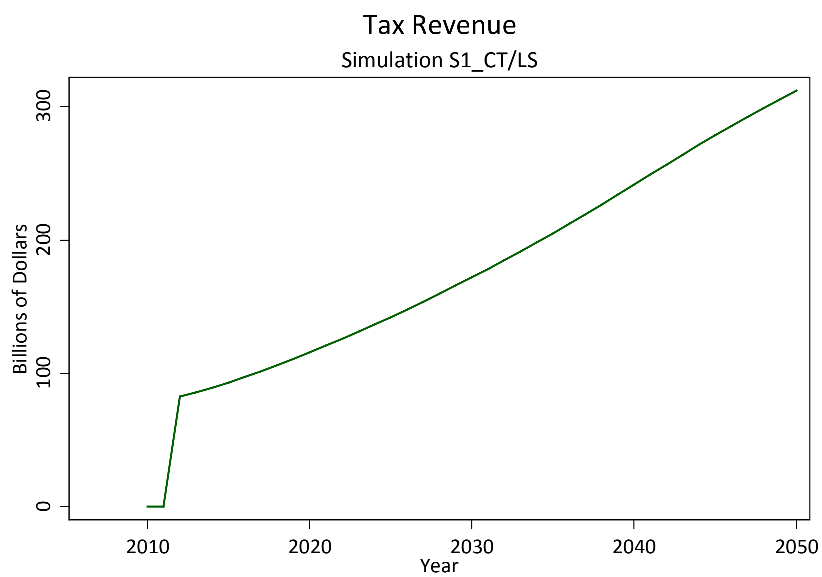
Scenarios 1, 2, 5 and 6 all include a tax on CO_2 emissions that begins in 2012 at $15 per metric ton and rises at a real rate of 4 percent per year. Figure 1 shows the constant-dollar tax rate through 2050.

Figure 1



As shown in Figure 2 for Scenario 1, the tax raises considerable revenue: $80 billion at the outset rising to $170 billion in 2030 and $310 billion by 2050.

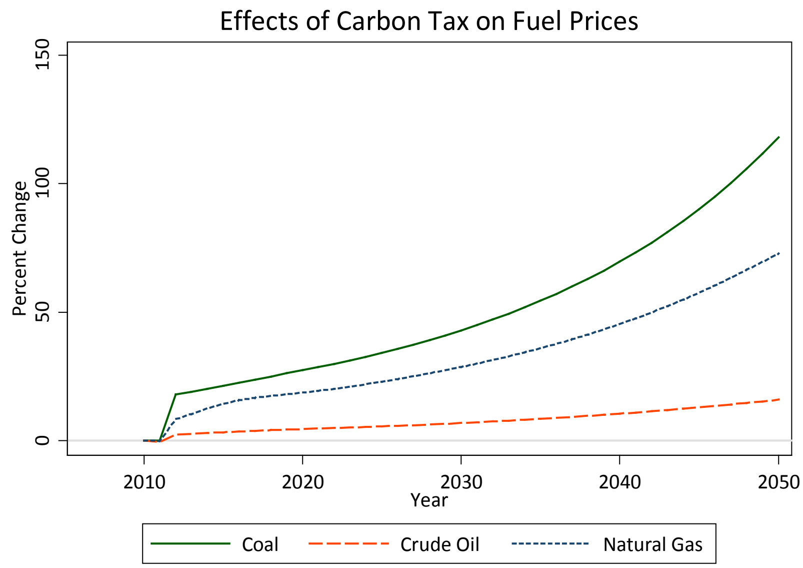
Figure 2



Carbon Tax Policies: Lump Sum Rebates

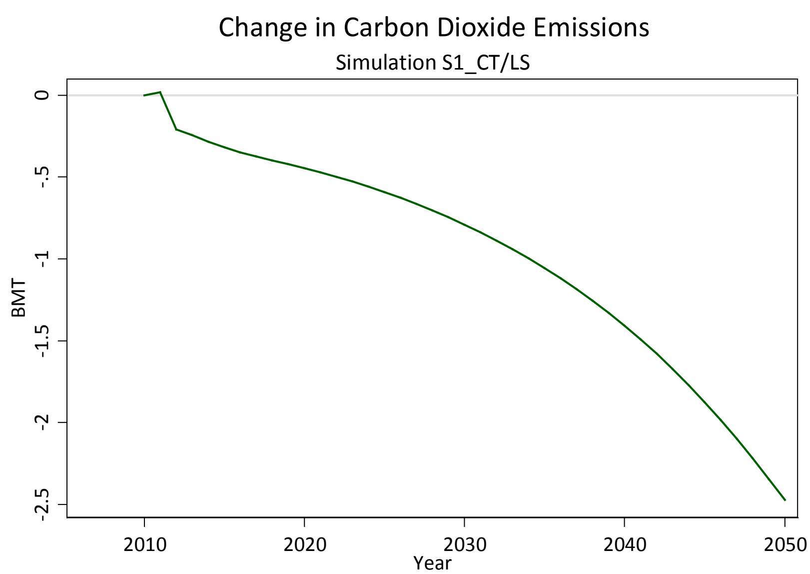
To keep the discussion concise, we will present Scenario 1 in detail and then discuss the key differences that arise with alternative uses of the revenue in simulations 2, 5 and 6. The immediate effect of the carbon tax is to raise purchaser's prices of coal (sector 4), crude oil (sector 5), and natural gas (sector 6). Figure 3 shows the effect of the tax on the prices of the three fuels to domestic buyers. Each curve shows the percentage change in the price of the fuel relative to its value in the base case. The price of coal rises most in percentage terms due to its high carbon content and low price per unit of energy. In contrast, crude oil prices change least in percentage terms. Although oil has higher carbon content per unit of energy than natural gas, its pre-tax price per unit energy is higher. That means that as a percentage of its pre-tax price, the carbon tax is smaller for oil than natural gas.

Figure 3



The tax reduces annual CO_2 emissions significantly, as shown in Figure 4. By 2050, annual emissions fall by 2.5 billion metric tons (BMT) of CO_2, or 34 percent, relative to baseline. The cumulative reduction in emissions relative to the base case through 2050 is 40 billion metric tons (BMT).

Figure 4



The effects of the tax on prices at the industry level for a representative year, 2030, are shown in Figure 5. For each sector, three prices are shown: in green are producer prices, which exclude any tax on the producer's output; in red are domestic purchaser's prices, the producer's price plus the carbon tax; and in blue are the final supply prices, which are a composite of domestic and import purchaser's prices.

As noted above, the immediate effect of the tax is to raise purchaser's prices for coal (sector 04), crude oil (05) and natural gas (06). Supply prices for crude oil and natural gas rise slightly less than domestic prices because the exchange appreciates (discussed further below). Downstream, the increase in purchaser's prices raises costs for electricity (01) and refined petroleum (03) and prices rise as a result. There is little change in the price of gas utilities (02), because it includes pipeline and delivery costs but not the value of the gas itself. Costs and prices rise slightly for transportation (11) as a result of higher refined oil prices. Prices in the remaining sectors fall very slightly due to declines in real wages and appreciation of the dollar. The percentage change in the exchange rate relative to the base case is shown in Figure 6; a positive value corresponds to strengthening of the U.S. dollar.

Figure 5

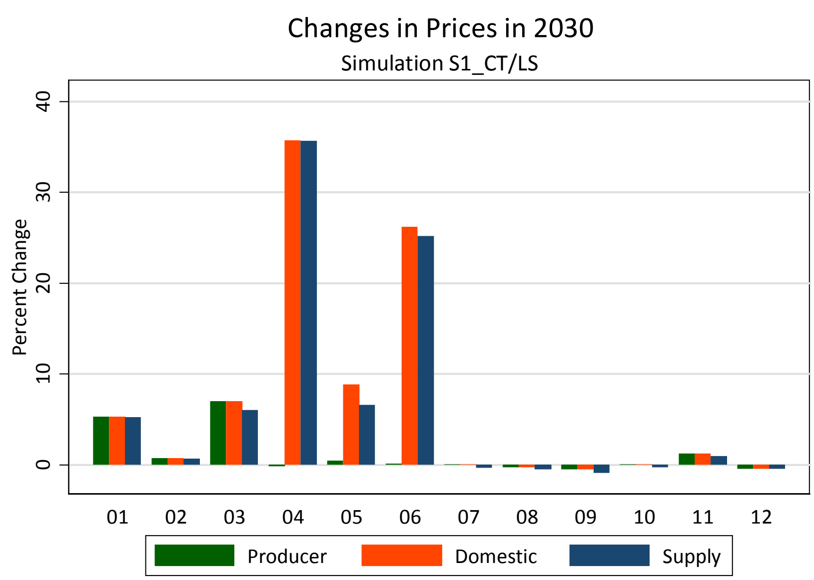
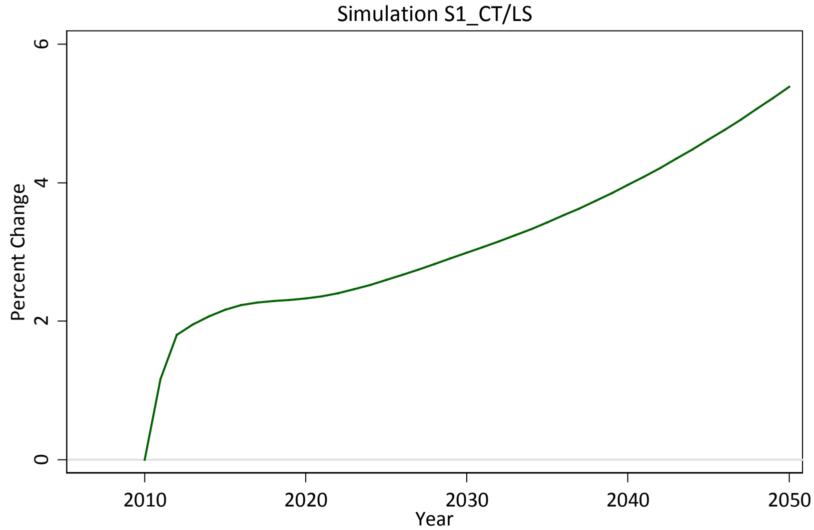


Figure 6

Changes in Real Exchange Rate
Simulation S1_CT/LS



Changes in 2030 domestic production and total supply of each good are shown in Figure 7. Primary energy production falls by more than 10 percent for coal (04) and natural gas (06). Production of crude oil (05) falls by about 7 percent and production of refined oil falls about 6 percent (03). Due to the appreciation of the exchange rate, imports of crude oil and natural gas are reduced by more than domestic production. As a result, total supply (shown in red) falls by more than domestic output for those sectors. Outside the energy sectors, reductions in output are modest, with the largest effect occuring in transportation (11).

Figure 7

Changes in Quantities in 2030
Simulation S1_CT/LS

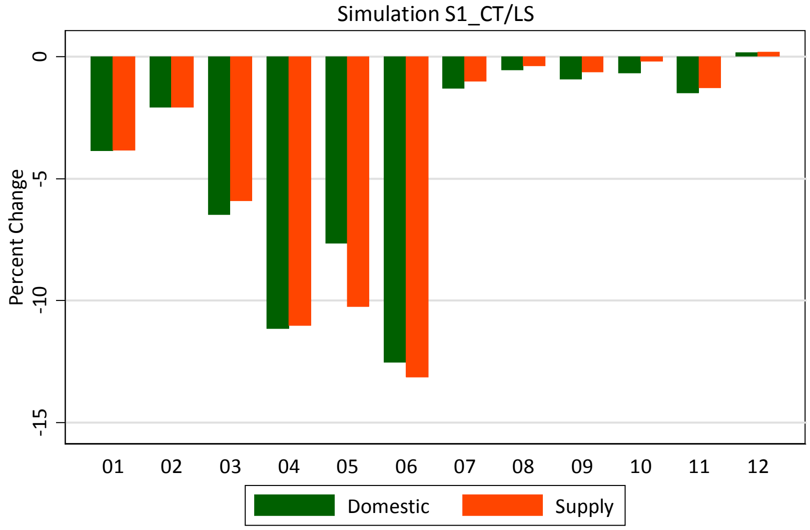


Figure 8 shows the impact of the price and quantity changes on total revenue to producers (shown in green) and total payments by buyers (shown in red for domestic production and blue for total supply). Revenue falls by 8 to 10 percent for producers of coal (04), crude oil (05) and natural gas (06). Expenditure on those goods, inclusive of the tax, rises by more than 20 percent for coal (04) and by more than 10 percent for natural gas (06). Expenditure on the total supply of crude oil (05) actually falls slightly (blue bar) because appreciation of the exchange rate offsets a significant part of the tax increase.

Figure 8

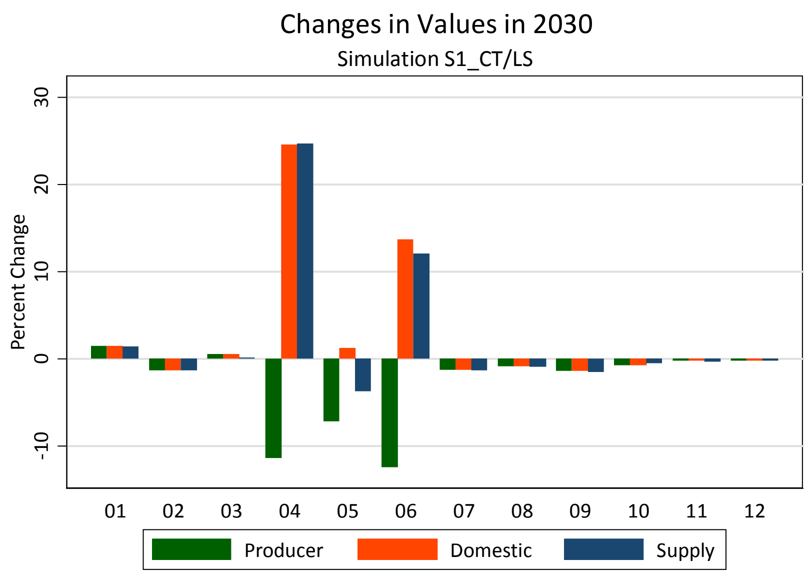
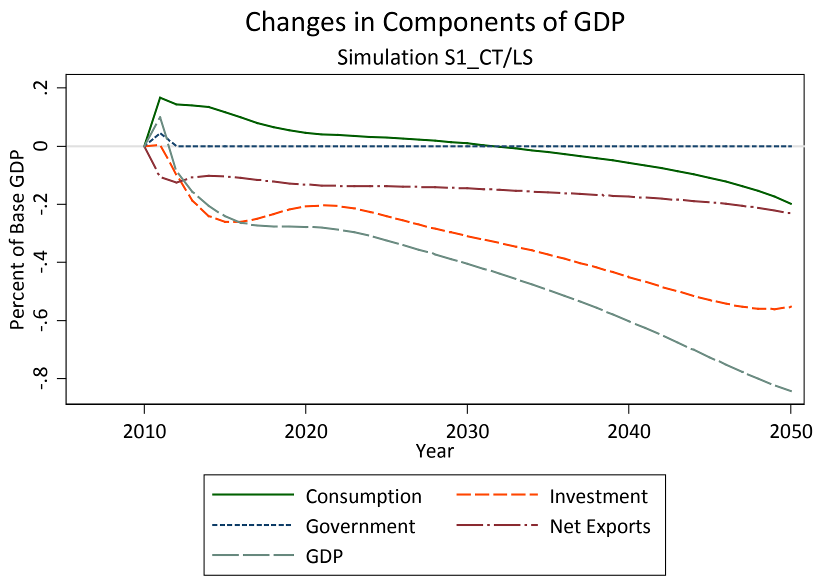


Figure 8 turns to the economy as a whole by showing the change the policy produces in real GDP and its four components: consumption, investment, government spending, and net exports. The figure shows the GDP component variables as percentages of baseline GDP, which allows straightforward comparisons of their magnitudes and easy decomposition of the overall GDP effect. The carbon tax lowers GDP slightly relative to the baseline by reducing investment and net exports in every year. In the early years of the simulation, those reductions are partly offset by an increase in consumption. Government spending is fixed to baseline levels by design in all of the policy scenarios.

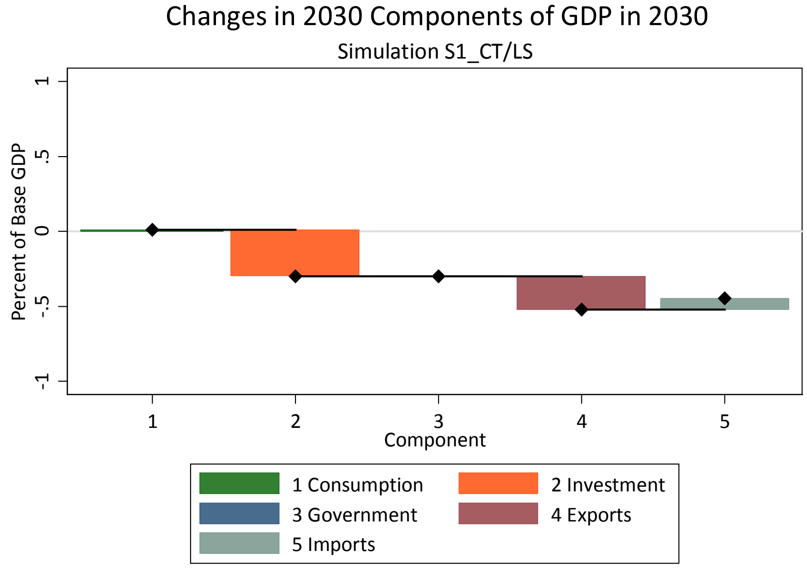
Figure 9



Other than in the earliest years, the change in GDP is dominated by declines in investment and net exports. Figure 10 uses a cumulative sequence of bars to illustrate the composition of changes in real 2030 GDP. The short green bar at the left shows the decline in consumption in terms of baseline 2030 GDP. The effect is very small: real consumption in 2030 is essentially unchanged from the base case. Each subsequent bar begins at the end of the previous bar, which is marked by a small black diamond and horizontal line. The bar shows the *additional* increase or decrease attributable to the indicated component. For example, investment falls relative to the base case, so the red bar for component 2 starts where the change in consumption ended (shown by the black line at the top of the investment bar) ends lower, with the black diamond on the investment bar indicating a reduction of 0.3 percent of base GDP.

Moving further to the right, real government spending is held constant by construction, and exports fall relative to the base case by 0.2 percent of GDP. Imports fall as well (indicated by an upward movement of GDP with the light blue bar), and this increases GDP by 0.1 percent of its baseline value. The overall change in GDP is indicated by the black diamond on the right most bar, and is a reduction of about 0.4 percent.

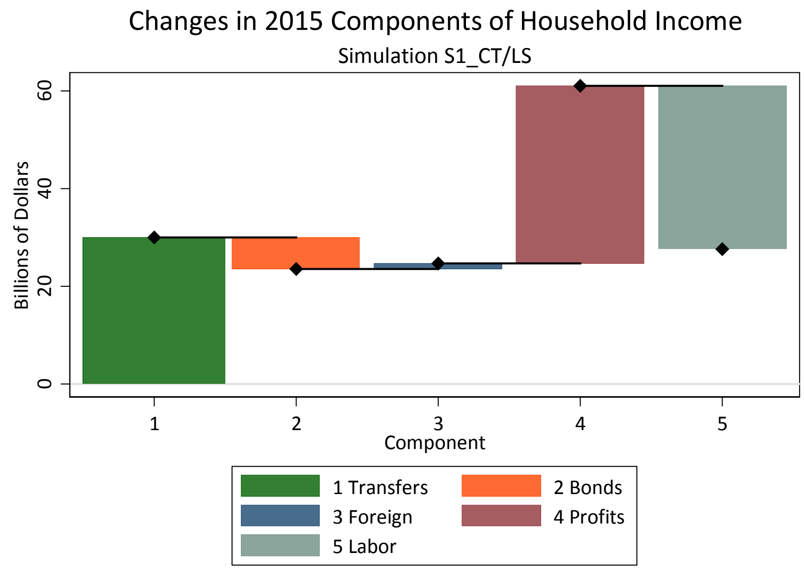
Figure 10



Through about 2025 real consumption is slightly above its baseline because net household income rises slightly and the liquidity-constrained households consume more. Figure 11 shows how the policy affects the components of real household income in 2015: transfers (including in Simulation 1 the lump sum rebates from the carbon tax); income from government bonds; net income from foreign bonds; profits; profits; and labor income.

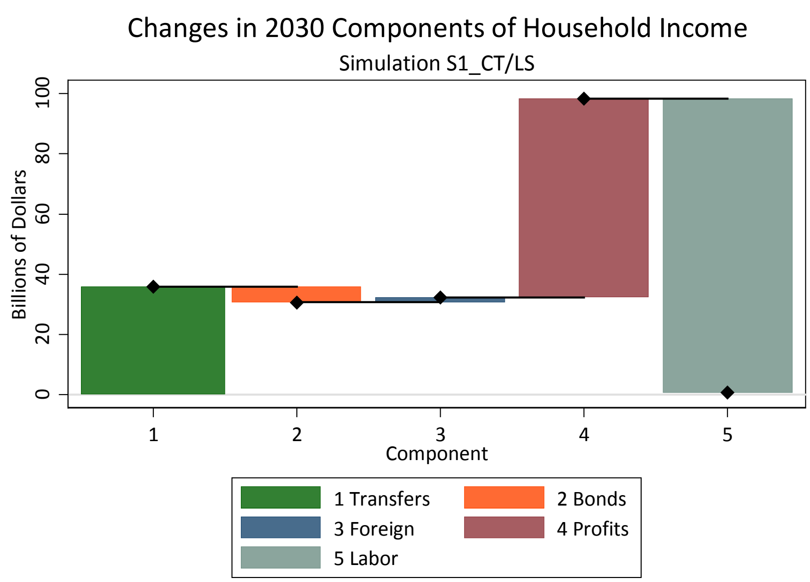
Transfers increase relative to the base case by about $30 billion. Income from government bonds falls modestly and income from net holdings of foreign bonds increases very slightly. Profits, in contrast, rise by more than $30 billion (discussed in more detail below). The top of the profits bar indicates that if there been no further effects, household income would have risen by $60 billion relative to the base case. However, the final component, labor income, falls by almost as much as income from profits rises. Thus, the four components other than transfers largely balance out. The overall change in income, shown by the black diamond on the right-most bar, is essentially the same height as the transfer alone.

Figure 11



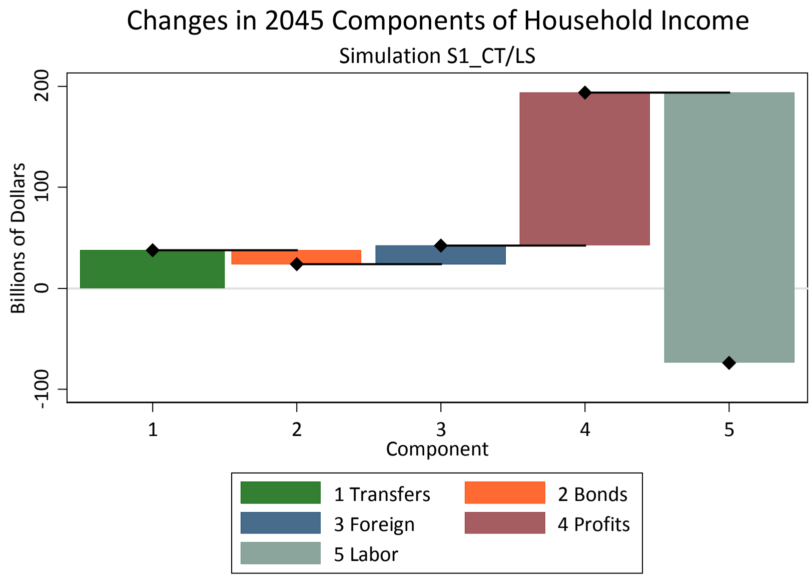
By 2030, the magnitude of each effect increases but the changes are not proportional. As shown in Figure 12, the reduction in labor income increases significantly relative to the others. In fact, the reduction in labor income relative to the base case is large enough to completely offset the transfer as well as the increase in profits. As a result, real income in 2030 is essentially unchanged from its base case value (the right-most diamond lies very close to 0).

Figure 12



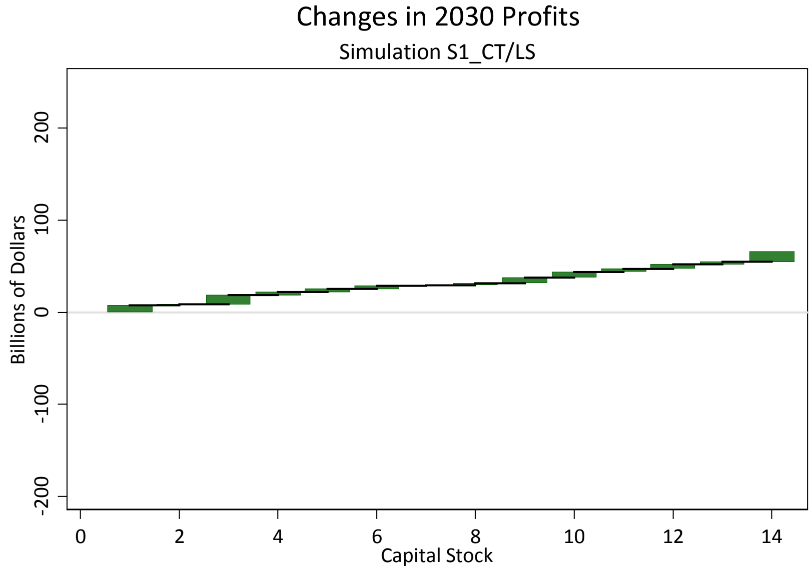
By 2045, reduced labor income exceeds the increases in other components and overall income falls, as shown in Figure 13. As indicated in Figure 9, the real value of consumption falls as a result.

Figure 13



The overall increase in profits across the U.S. economy is the sum of small increments in the returns to capital associated with each sector's capital stock. Profits in each sector are its revenues minus its costs of energy, labor, materials, and investment. Figure 14 is a cumulative sequence of bars showing increases in real returns in 2030 in 14 sectors. The first 12 are the producing sectors listed in Table 2, followed by the capital stock associated with the capital goods industry (13) and the household capital stock (14). For clarity, the black diamonds used to mark the top of each bar in previous graphs have been omitted but the horizontal lines connecting the end of one bar to the beginning of the next are shown. Also, the vertical scale is set to allow convenient comparisons with other simulations discussed later.

Figure 14



The reasons for the increase in profits that result from the policy vary by sector. For example, Figure 15 decomposes the change in 2030 profits for electric utilities (sector 1) into revenues and the four cost categories. As shown in Figure 8, the real value of electricity sales in 2030 rises slightly relative to the base case. The increase in revenue appears in Figure 15 as the green bar at the left. The cost of energy inputs rises, reducing profits by the amount shown by the orange bar. The change in energy costs is more than double the increase in revenue so in the absence of other changes, profits would have fallen by about $7 billion (the diamond on the energy bar). However, labor and materials costs both fall as output drops, and this partly offsets the decline in profits due to higher energy costs. Finally, as shown by the gray bar at the far right, short-run profits also rise because real spending on new investment declines. Labor and investment costs decline in part because the policy reduces real wages and the price of new capital goods, as shown in Figure 16. In addition, investment costs also decrease because the sector grows more slowly and fewer new capital goods are needed. Overall, the increase in revenue and the reductions in labor, materials, and investment costs more than offset the increase in costs associated with energy inputs and real profits rise.

Figure 15

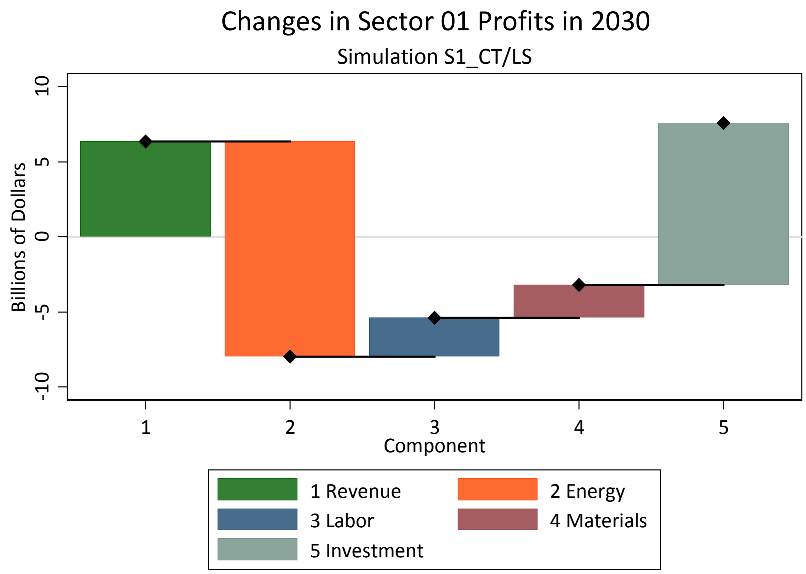
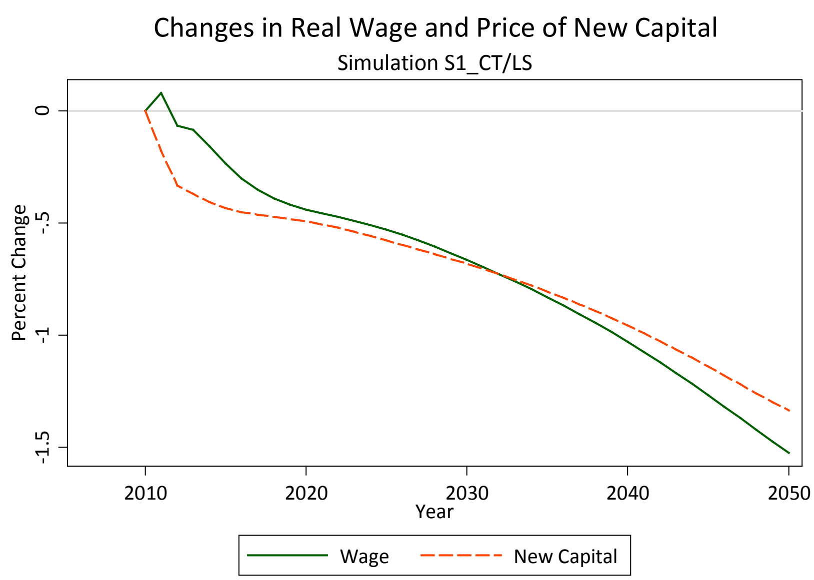
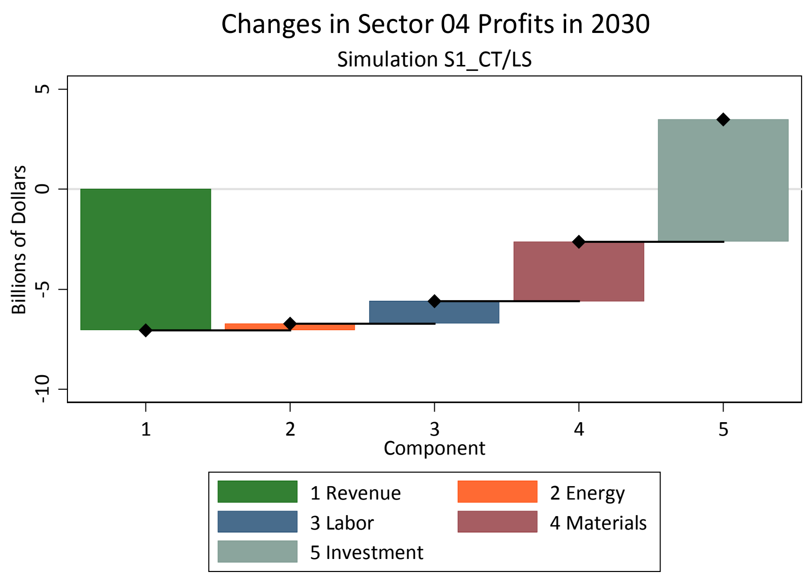


Figure 16



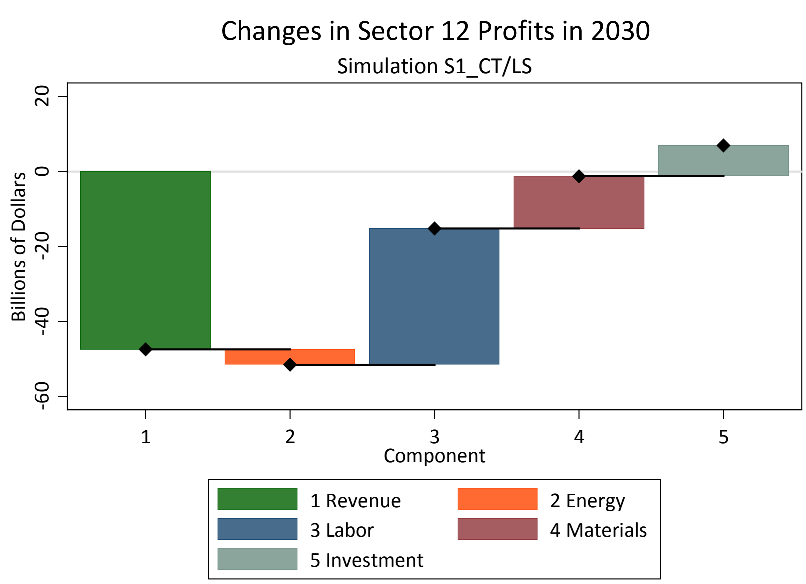
The results for the primary energy sectors differ from the electricity sector but investment costs play a key role there, too. Figure 17 decomposes the change in 2030 profits for the coal industry (sector 4). As shown earlier in Figure 8, revenue falls significantly. Reductions in spending on energy, labor and materials partially offset the drop. However, investment spending drops sharply and short run profits rise slightly overall.

Figure 17



In the service sector, shown in Figure 18, reductions in labor costs driven by a decline in the real wage play a more important role. Investment spending is slightly lower due to a drop in the price of new investment goods but it is a much smaller contribution.

Figure 18



Percentage changes in real 2030 spending on energy, labor and investment are shown for all sectors in Figure 19 through Figure 21. Energy expenses increase for electric utilities and most of the non-energy sectors. Labor and investment costs fall for all sectors, with the largest percentage decrease in the energy sectors directly affected by the carbon tax. Investment spending in coal, crude oil and natural gas extraction falls by more than 60 percent relative to the base case.

Figure 19

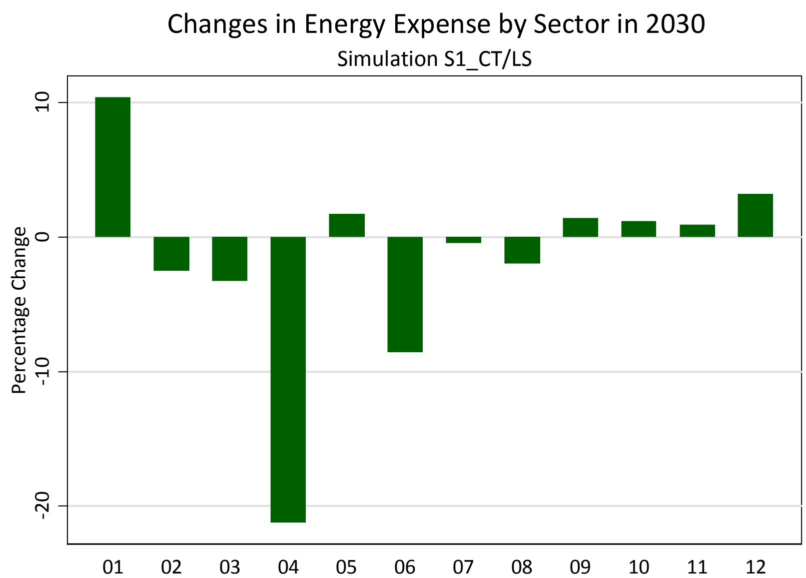


Figure 20

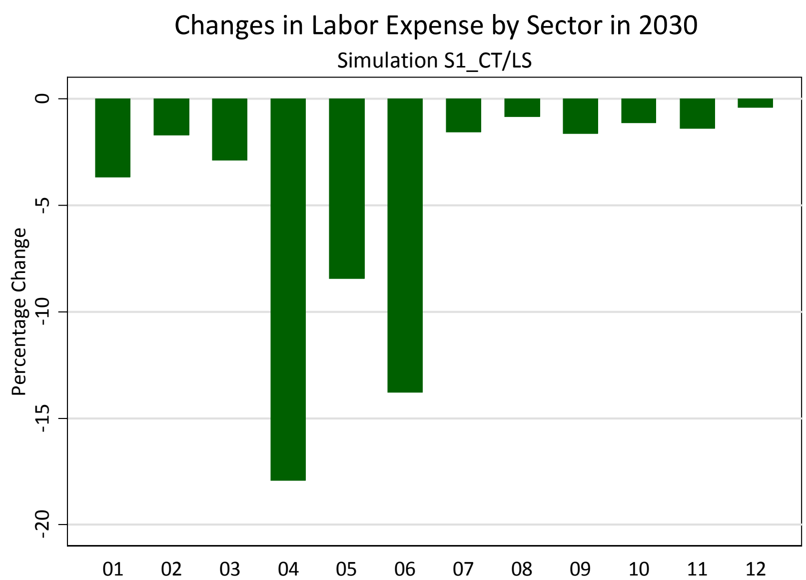
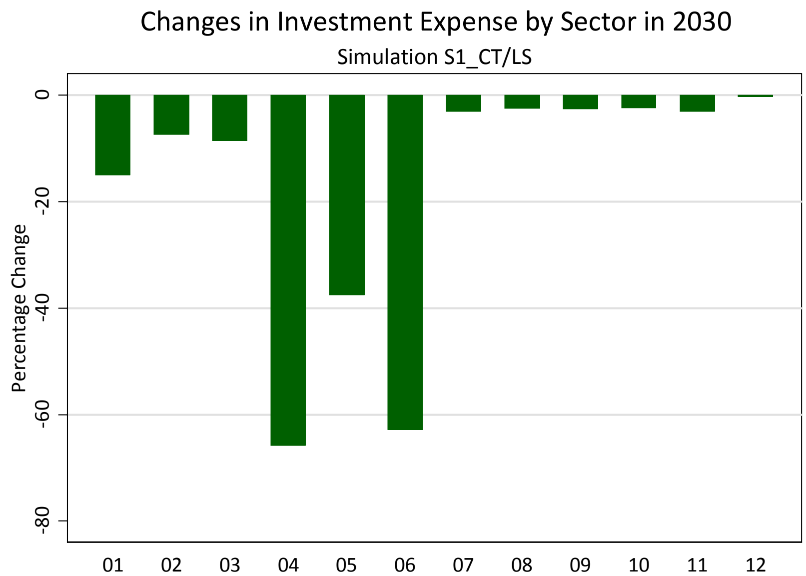


Figure 21

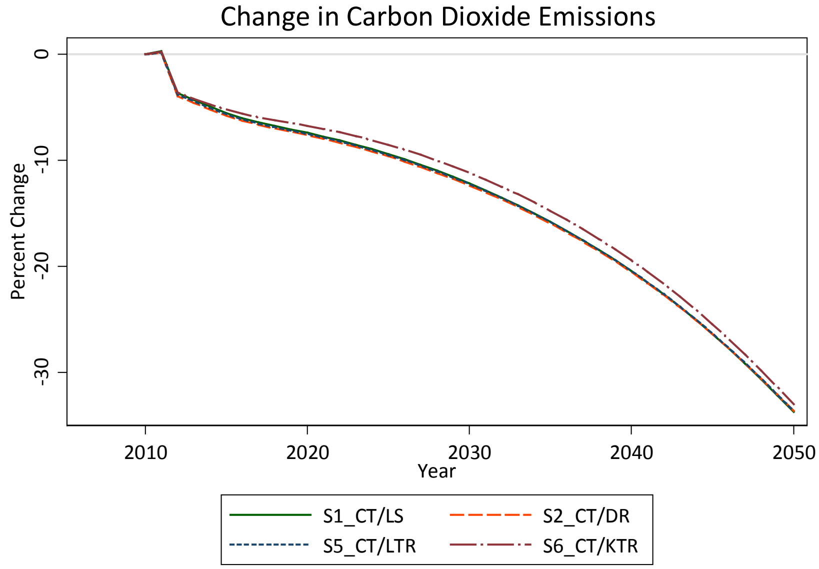


Overall, the carbon tax with a lump-sum rebate reduces GDP slightly and shifts its composition away from investment and net exports and toward consumption.

Alternative Uses of Carbon Tax Revenue: Comparing Scenarios 1, 2, 5 and 6

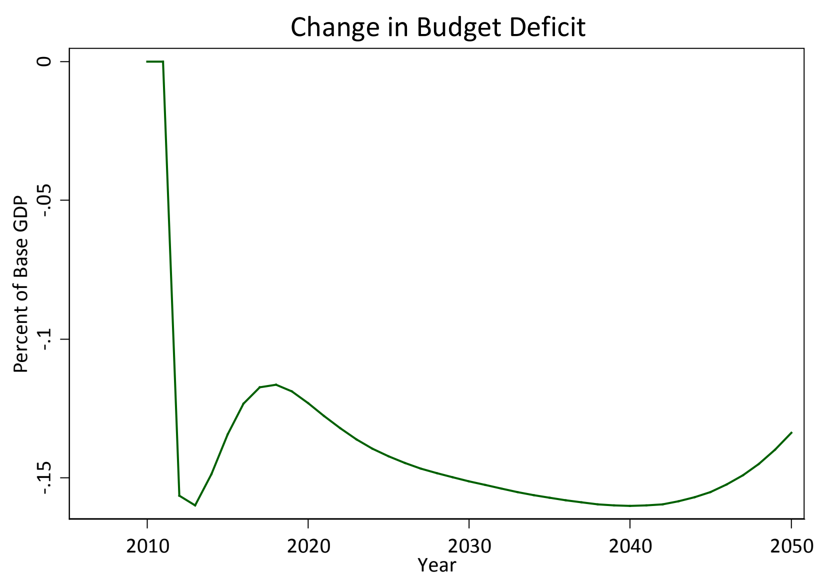
Figure 22 shows that all four of the carbon tax scenarios (Scenarios 1, 2, 5, and 6) achieve similar annual reductions in emissions, suggesting that the management of the revenue has little effect on the environmental performance of the policy. By 2050, cumulative emissions in scenarios 1, 2 and 5 are all 40 billion metric tons lower than the base case. Under scenario 6, the expansion in economic activity from the capital tax swap causes the cumulative reduction to be slightly less—38 billion metric tons.

Figure 22



A carbon tax of the magnitude used in Scenario 1 could allow significant reductions in the budget deficit or modest reductions in the tax rates on labor or capital income. As shown in Figure 23, the budget deficit under Scenario 2 is lower by about 0.15 percent of baseline GDP. The decrease is immediate and relatively constant for the duration of the policy.

Figure 23



As shown in Figure 24, the carbon tax allows the labor tax rate under Scenario 5 to be reduced by about 0.3 percentage points while holding the deficit constant. Under Scenario 6, the capital tax rate could be reduced by almost 6 percentage points in the long run, as shown in Figure 25.

Figure 24

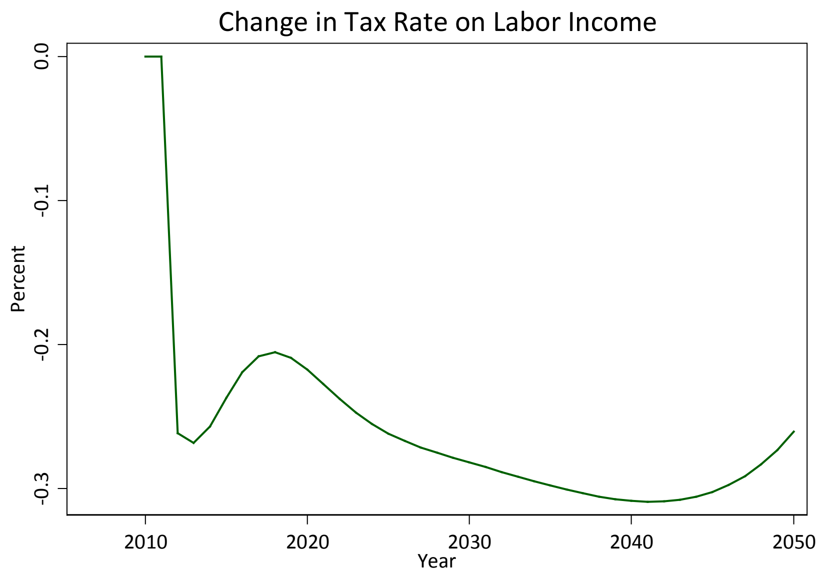
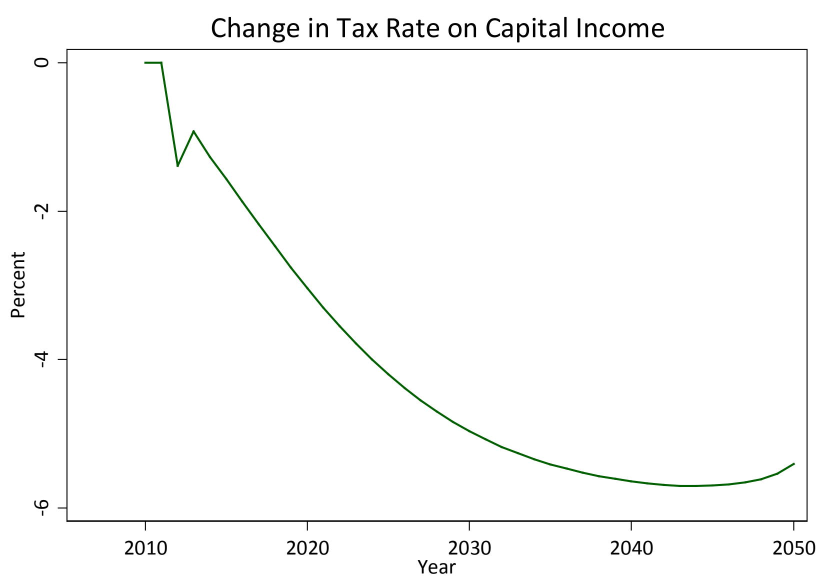
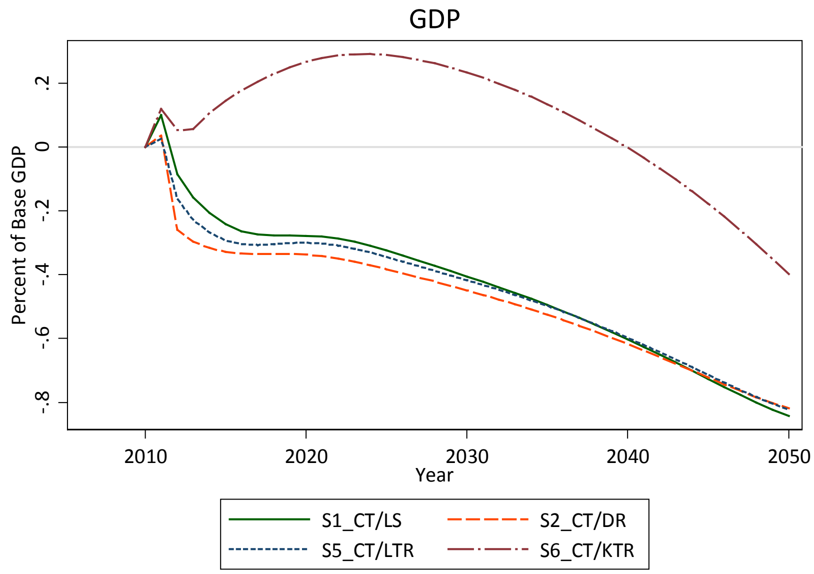


Figure 25



Using the revenue from the carbon tax for deficit reduction or tax reform affects the pattern of changes in GDP and its components. Figure 26 shows the change in GDP relative to baseline under all four of the carbon tax scenarios: the lump sum case in green, the deficit reduction case in red, the labor tax reduction in blue, and the capital tax reduction in brown. The first three simulations are similar overall, although deficit reduction and the labor tax rebate lower GDP slightly more than the lump sum rebate in the early years. The capital tax reduction stands in sharp contrast: it raises GDP above the baseline for several decades.

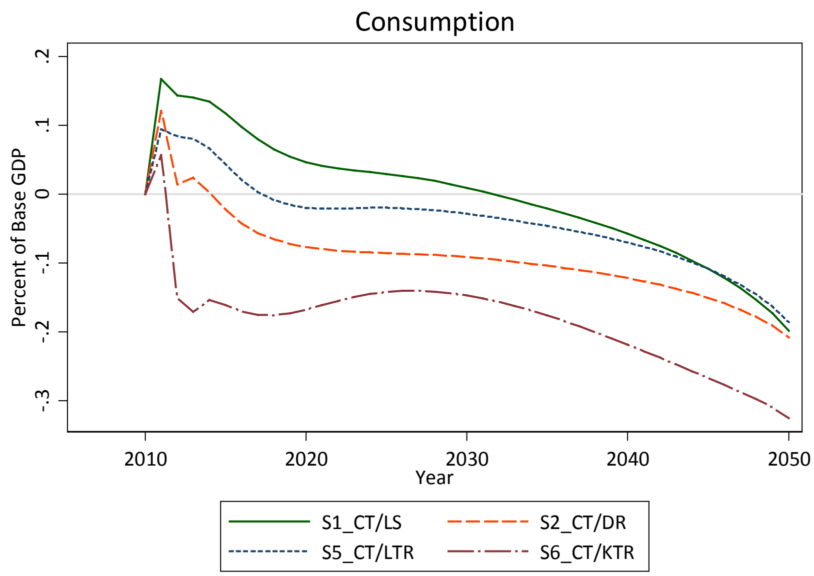
Figure 26



In terms of GDP, then, the capital tax swap appears to produce a double dividend, i.e. both emissions reductions and an increase in economic activity.

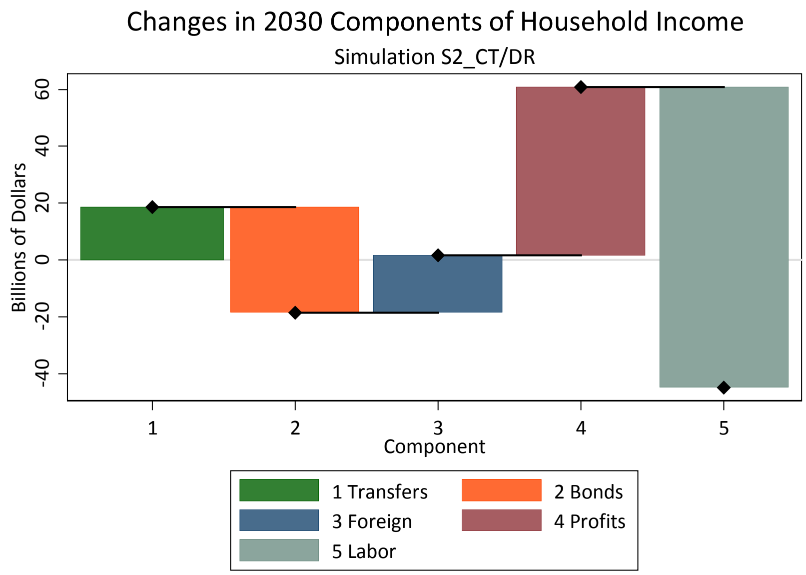
The components of GDP vary across scenarios as well, and there the differences between the first three simulations become more pronounced. Figure 27 shows the effects of the policies on real consumption, one measure of the welfare effects of the policies. All three of the alternatives to lump sum rebates are less positive for consumption. Under deficit reduction or the labor tax reduction, initial consumption rises less than under the lump sum case and quickly falls below its baseline (although by a small amount: less than 0.1 percent of GDP). Under the capital tax rebate, consumption drops sharply and remains lower than all of the other scenarios.

Figure 27



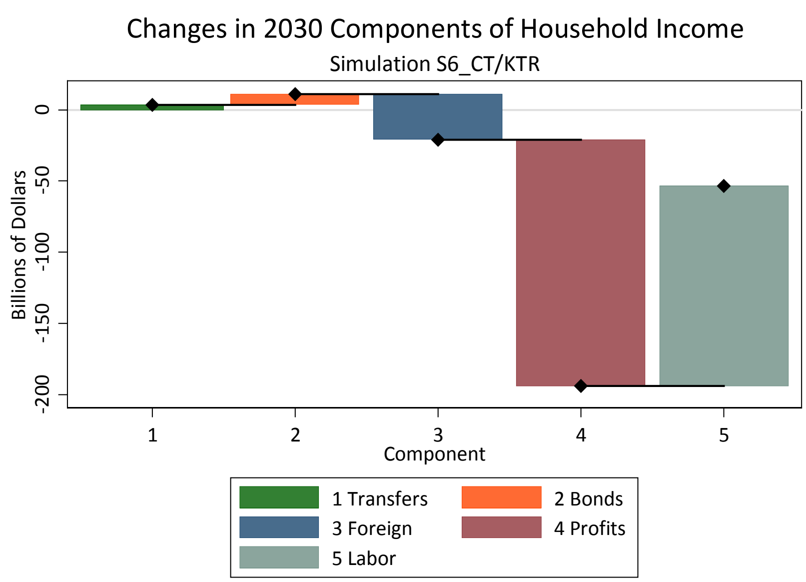
Consumption is lower under Scenarios 2, 5 and 6 in part because households do not receive the large lump sum transfer of income that occurs in Scenario 1. For example, Figure 28 shows the composition of changes in real income in 2030 under the deficit reduction scenario. Transfers rise slightly due to reductions in the cost of servicing government debt. Income from government bonds falls as the stock of debt declines relative to the base case, and income from foreign assets rises slightly. Together, the first three changes roughly balance: the diamond on the third bar is very close to 0. However, the changes in profits and real wages induced by the carbon tax are largely unaffected and result in a net drop of about $40 billion. As a result, overall income falls and consumption declines.

Figure 28



The mechanisms at work in the capital tax swap scenario are quite different. Figure 29 shows the corresponding changes in the components of income in 2030. The policy induces small increases in transfers and income from bonds, and a modest decrease in income from foreign assets. The main effects, however, are a large reduction in profits and an accompanying increase in labor income. Overall, household income falls.

Figure 29



Labor income in Scenario 6 rises largely because the real wage rises, and to a lesser extent because employment rises. Figure 30 shows the effects of the scenarios on real wages over time, and Figure 31 shows effects on employment; both are measured as percentage changes from their base case values. The first three scenarios are very similar to one another but boom in investment under scenario 6 drives up the demand for labor significantly.

Figure 30

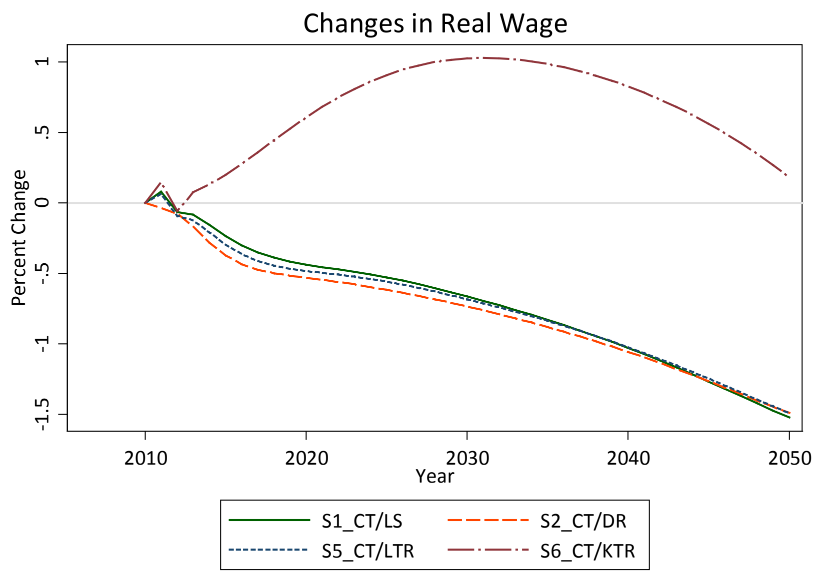
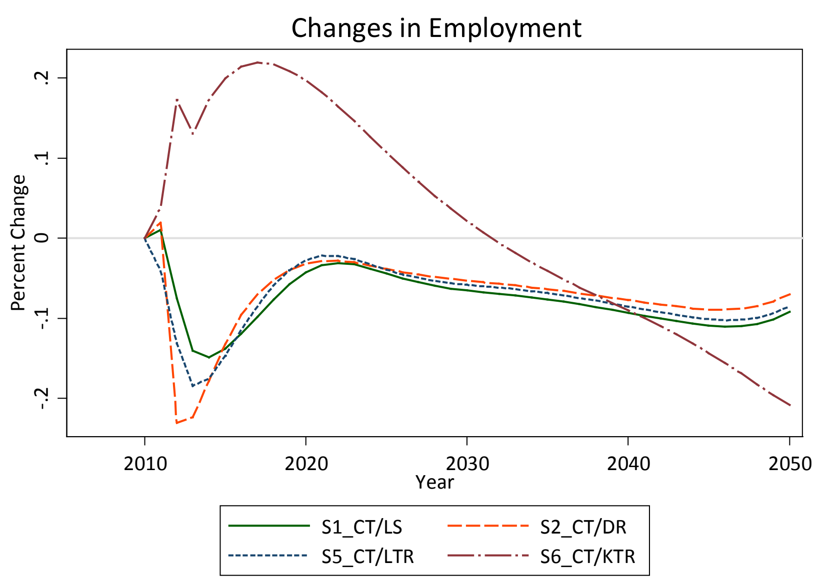
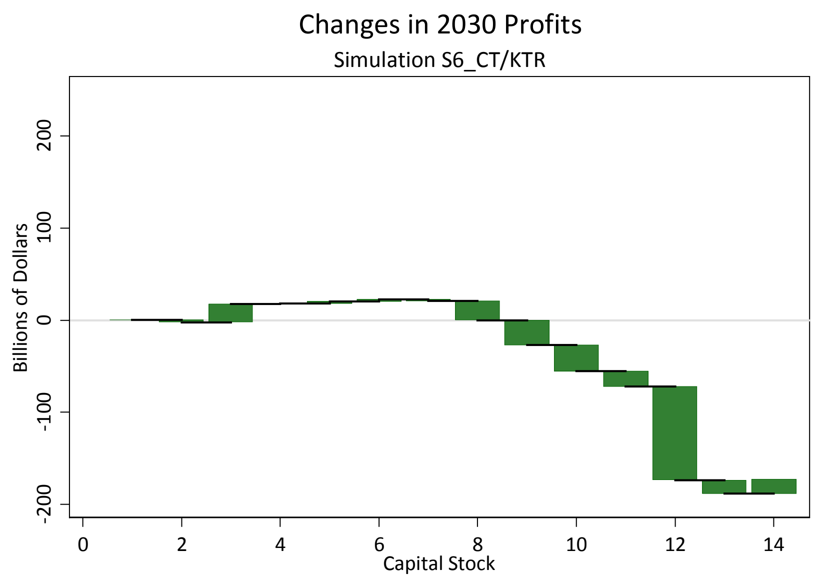


Figure 31



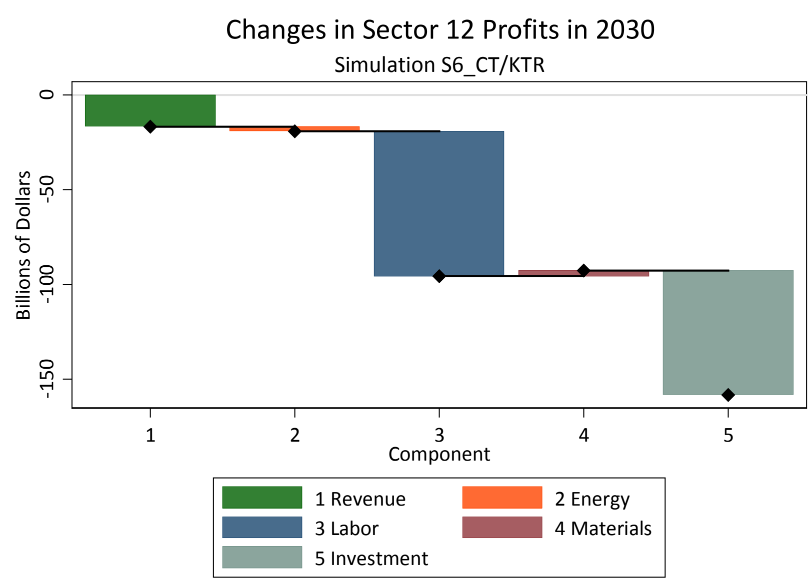
The decline in profits can be decomposed by capital stock as shown in Figure 32. There is a modest increase in the profitability of petroleum refining (sector 3) but declines in profits in sectors 8-12, as well as in the production of new capital goods (13).

Figure 32



The largest decline in profits occurs in the service sector. As shown in Figure 33, the drop results largely from increases in labor costs and increases in spending on investment.

Figure 33



Investment increases in the other sectors as well and, as shown in Figure 34, total investment rises relative to the base case by about 0.5 percent of baseline GDP for about the first 20 years of the policy.

Figure 34

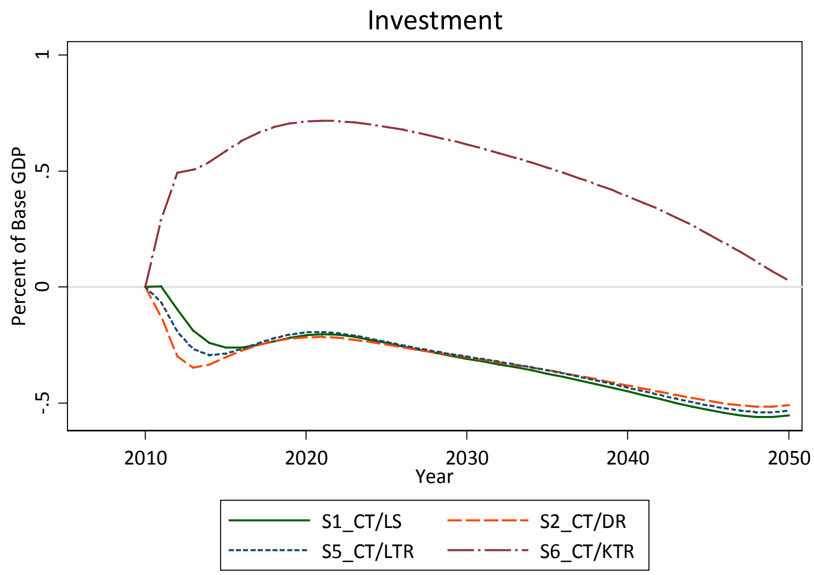
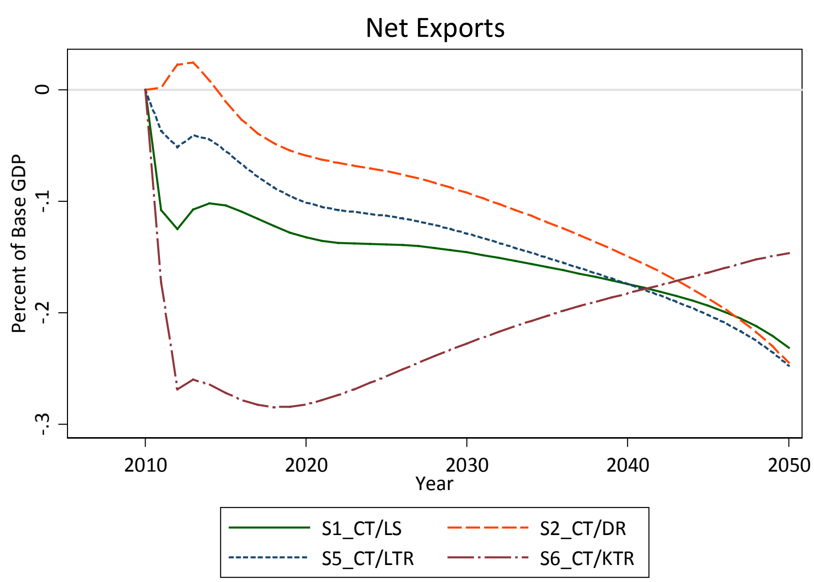


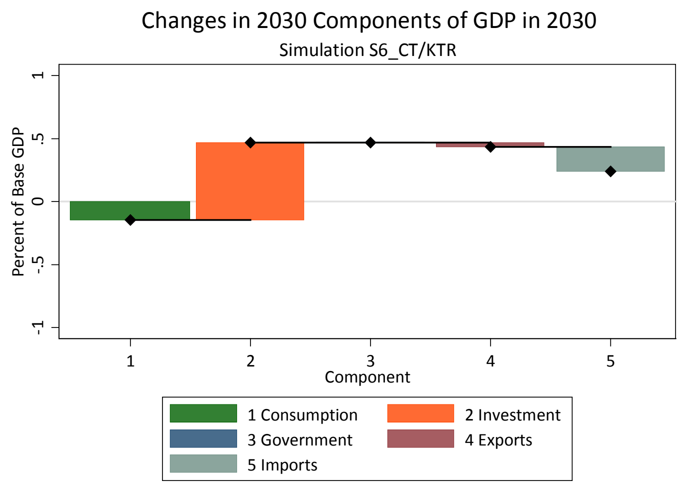
Figure 35 shows the policies have pronounced differences in their effects on net exports. Under rebates, deficit reduction, and labor tax reduction, exports and imports both fall, and the drop in imports partially offsets the fall in exports, as Figure 10 illustrates for Scenario 1.

Figure 35



Under the capital tax, however, imports rise substantially, augmenting the fall in GDP associated with the drop in exports. In fact, Figure 36 shows that the increase in imports (shown by the light blue decline in GDP) can be significantly larger than the decrease in exports. In essence, the capital tax reduction causes a boom in investment and a significant rise in the demand for imports.

Figure 36



In sum, a carbon tax will significantly reduce CO_2 emissions, and the environmental performance of the policy is largely independent of the use of the revenue. However, how the revenue is used has important effects on the economy broadly and the allocation of GDP across consumption, investment and net exports. For most of the simulations, the carbon tax tends to lower GDP slightly, reduce investment and exports, and increase imports. The effect on consumption varies by policy and can be positive if household receive the revenue as a lump sum transfer. Using the revenue for a cut in tax rates on capital income, however, is substantially different than the other revenue policies. In that case, investment booms, employment rises, consumption declines slightly, imports increase, and overall GDP rises significantly relative to baseline levels. Thus, adopting a carbon tax and using the revenue to reduce capital taxes would achieve two goals: reducing CO_2 emissions significantly and expanding short-run employment and the economy.

Deficit Reduction Policies

Scenarios 2, 3 and 4 all reduce the budget deficit by the amount achieved via the carbon tax in Scenario 2 (shown in Figure 23). The carbon tax in Scenario 2 is shown in Figure 1. Figure 37 and Figure 38 show the increases in the marginal tax rates on labor and capital income (Scenarios 3 and 4) that reduce the deficit by the same amount. Figure 37 shows the labor tax must about 0.3 percentage points higher, while Figure 38 shows the capital tax rate would need to be about 6 percentage points higher in the long run than in the baseline.

Figure 37

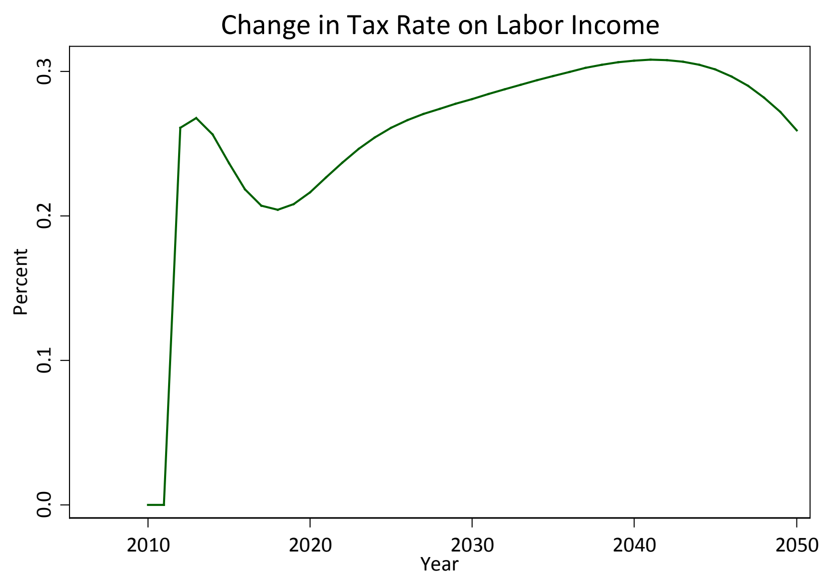
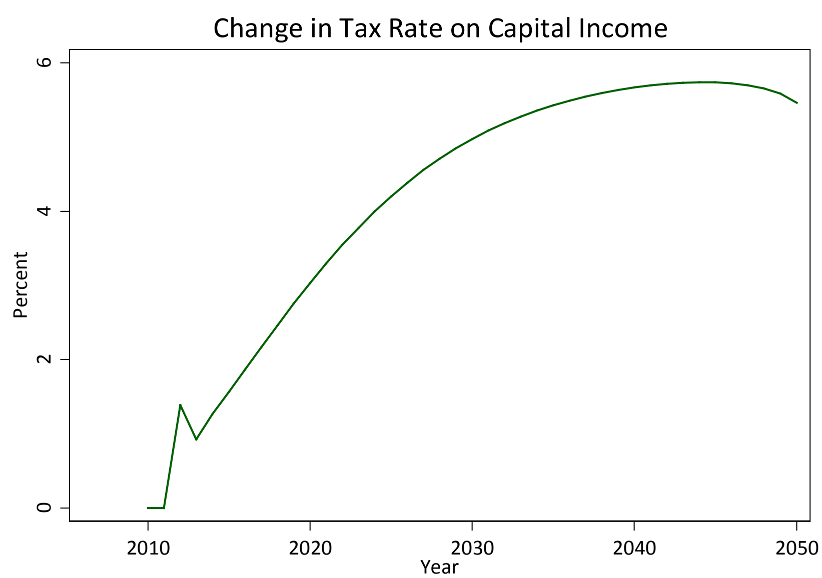
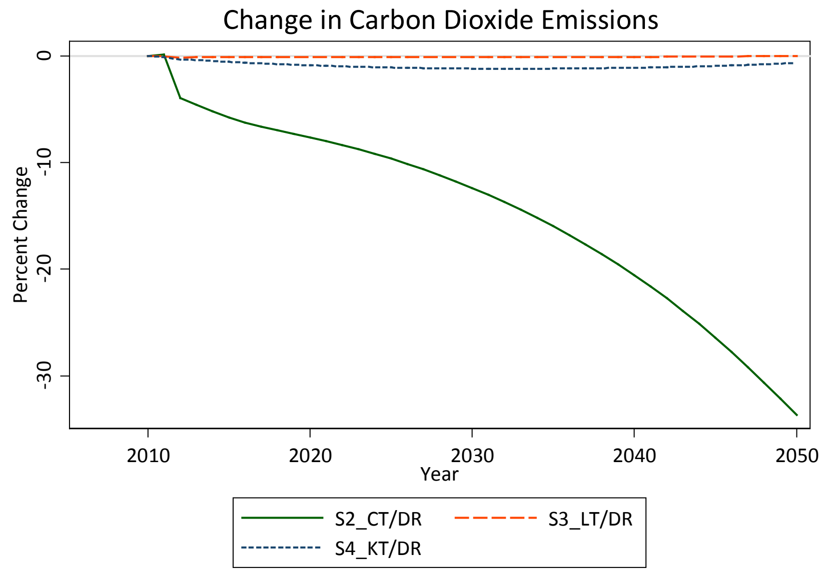


Figure 38



Of the three policies, only the carbon tax has a meaningful effect on CO_2 emissions. As shown in Figure 39, annual emissions under the capital tax increase fall very slightly relative to the base case, and emissions under the labor tax increase are essentially unchanged.

Figure 39



As shown in Figure 40, the effects of the deficit reduction scenarios on GDP differ significantly. The carbon tax, shown in green, reduces GDP by about 0.3 percent of its baseline level in the short run and by about 0.7 percent in the long run. In contrast, an equivalent reduction via an increase in the labor tax produces almost no drop in GDP. The capital tax causes a significantly larger drop in GDP than either of the other policies in the short run but long run effect is smaller than the carbon tax.

An interesting feature of the results is that none of the policies improve long term GDP. The reasons are threefold: (1) the risk premium on government securities in the model is unaffected by reductions in the deficit; (2) international capital in-flows limit crowding out of private investment; and (3) a large share of households are forward-looking and exhibit Barro-neutrality. [13]

The risk premium is unaffected due to two interlocking features of the simulations. First, our baseline scenario does not include explosive growth in transfer payments under federal entitlement programs. As a result, baseline government debt stabilizes as a share of GDP. Second, and consistent with the first point, we treat the risk premium associated with U.S.

[13] Barro (1974)

government debt as exogenous and constant. Thus, deficit reduction has only minor general equilibrium effects on the interest rate paid by the government. Future work will relax both of these assumptions to raise baseline transfers sharply and to adjust the risk premium on U.S. government debt accordingly. Under those circumstances, deficit reduction will have an additional benefit to the economy and may raise GDP above its baseline.

A related issue arises with international capital flows. G-Cubed includes risk premia on foreign debt but the rates are exogenous. As a result, both the U.S. government and the private sector have access to a very elastic supply of international capital. Relatively high borrowing by the government does little to crowd out private investment.

Finally, the forward-looking households in the model are Barro-neutral and regard deficit spending as equivalent to the present value of future payments required to finance it. Thus, they are generally indifferent to deficit reductions matched by reductions in future taxes. This neutrality would change if the risk premium on debt were endogenous; in that case, the combination of deficit reduction and lower future taxes would produce a gain in present value wealth for households.

Figure 40

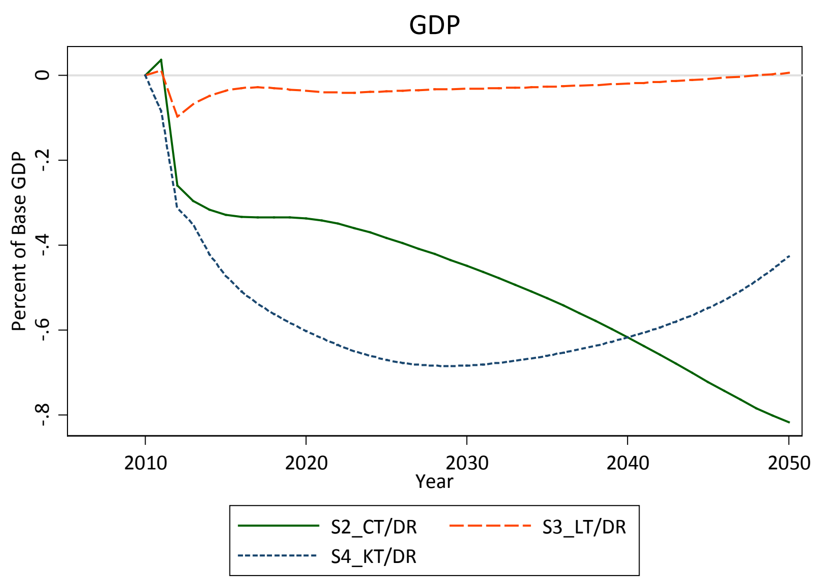


Figure 41 decomposes Scenario 2's GDP results in 2030. The largest effect is a decline in investment of 0.3 percent of baseline GDP. Augmenting that are declines of 0.2 and 0.1 percent of GDP in exports and consumption, respectively. The declines are partially offset by a fall in imports, which raises GDP by about 0.1 percent of its baseline level. Figure 40 shows, on the same vertical scale, that the labor tax increase has a similar effect on consumption but almost no effect on other components of GDP.

Figure 41

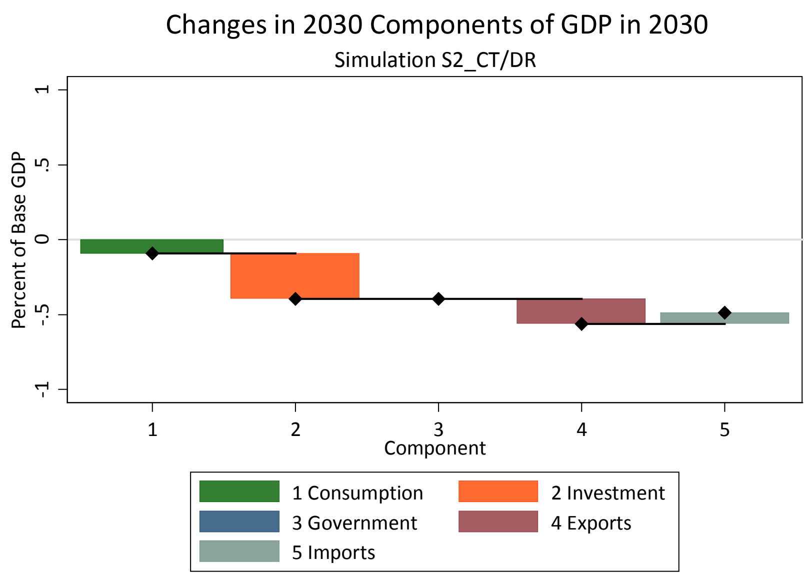
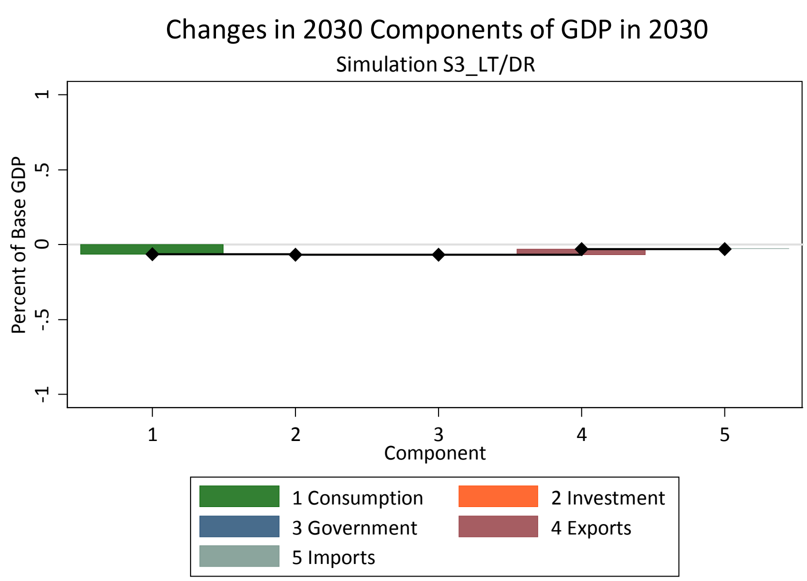
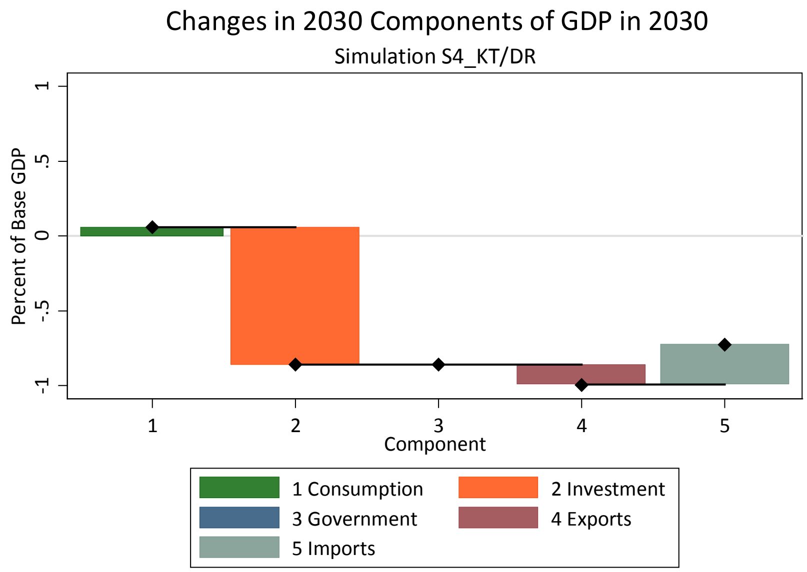


Figure 42



The capital tax, shown in Figure 43 (also using the same vertical scale), reduces GDP largely because it discourages investment which is lower by almost 1 percent of baseline GDP. It also lowers exports by about 0.1 percent of GDP but that is more than offset by a reduction in imports that raises GDP by almost 0.3 percent. Consumption also rises but by less than 0.1 percent of base GDP.

Figure 43



The evolution of consumption, investment and net exports over time are shown in Figure 44, Figure 45, and Figure 46. Consumption is persistently slightly above its baseline value under the capital tax scenario while it is lower in most years under the carbon and capital taxes. The effects on investment are also roughly comparable over time: there is little effect under the labor tax, a large decline under the capital tax, and a modest decline under the carbon tax. Finally, in the short run the capital tax causes a boom in net export s by lowering imports significantly. In the long run, however, exports decline and offset part of the gain.

Figure 44

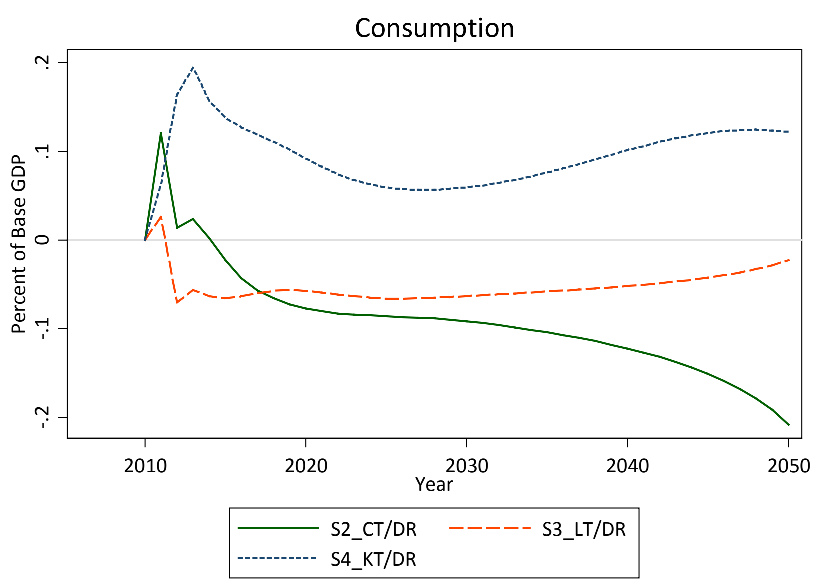


Figure 45

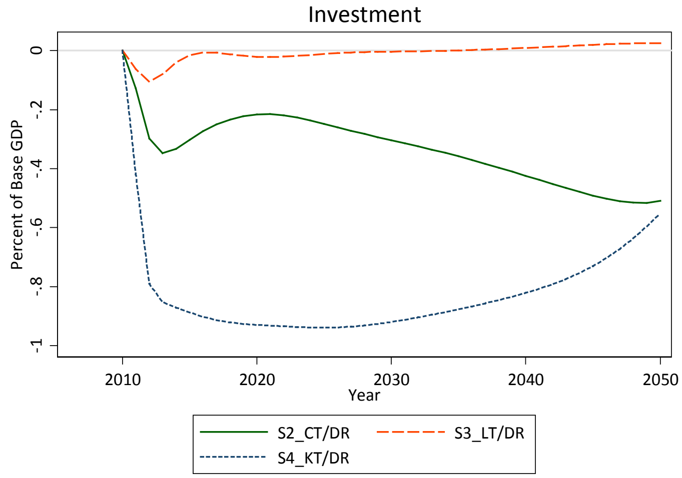
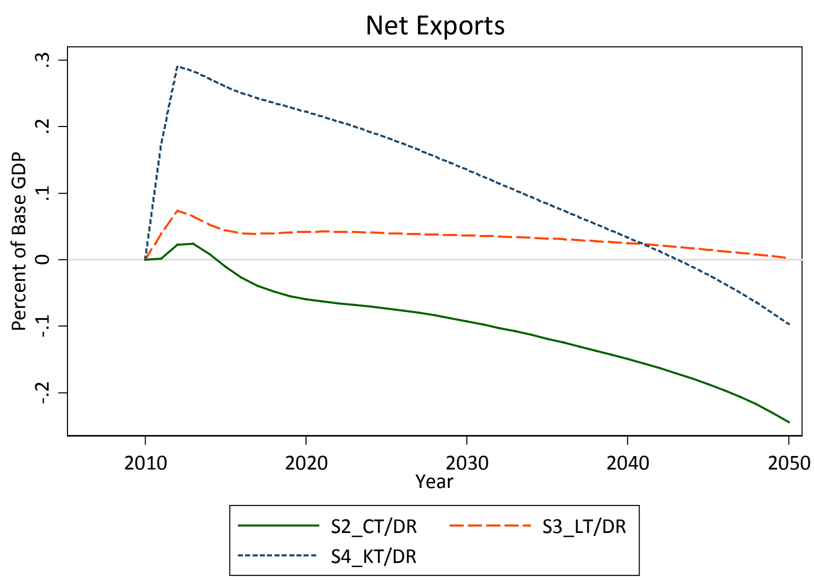


Figure 46



In sum, we find that raising taxes on labor is the best approach for reducing the deficit with minimal disturbance to the overall economy. GDP remains very close to its base case level, consumption is reduced very slightly and net exports expand slightly. Investment remains essentially unchanged. In contrast, increasing tax rates on capital income to reduce the deficit causes a significant and persistent drop in investment and much larger reductions in GDP. A carbon tax falls between the two: it produces a larger decline in GDP than a labor tax increase since (as discussed above) it reduces investment. However, it has much more moderate effects on investment and GDP than the capital tax increase, and it also provides a very significant reduction in CO_2 emissions. A carbon tax offers the option to help reduce the deficit and improve the quality of the environment, and to do so with minimal disturbance to overall economic activity.

4. CONCLUSION

This paper examines fiscal reform options in the United States with an intertemporal computable general equilibrium model of the world economy called G-Cubed. The six policy scenarios explore two overarching issues: (1) the effects of a carbon tax under alternative assumptions about the use of the resulting revenue, and (2) the effects of alternative measures that could be used to reduce the budget deficit. We examine a simple excise tax on the carbon content of fossil fuels in the U.S. energy sector starting immediately at $15 per metric ton of CO_2 and rising at 4 percent above inflation each year through 2050. We investigate policies that allow the revenue from the illustrative carbon tax to reduce the long run federal budget deficit or the marginal tax rates on labor and capital income. We also compare the carbon tax to increases in labor and capital income taxes that reduce the deficit by the same amount.

We find that the carbon tax will significantly reduce CO_2 emissions, and the environmental performance is largely independent of the use of the revenue. By 2050, annual emissions fall by 2.5 billion metric tons (BMT) of CO_2, or 34 percent, relative to baseline. The cumulative reduction in emissions relative to the base case through 2050 is 40 BMT.

The use of the carbon tax revenue affects the policy's broad economic impacts as well as the composition of GDP across consumption, investment and net exports. For most of the scenarios, the carbon tax tends to lower GDP slightly, reduce investment and exports, and increase imports. The effect on consumption varies across policies and can be positive if households receive the revenue as a lump sum transfer.

Using the revenue for a cut in the marginal tax rates on capital income, however, is significantly different than the other policies. In that case, investment booms, employment rises, consumption declines slightly, imports increase, and overall GDP rises significantly relative to baseline through about 2040. Thus, adopting a carbon tax and using the revenue to reduce capital taxes would achieve two goals: reducing CO_2 emissions significantly and expanding short-run employment and the economy.

We examine three ways to reduce the deficit: a carbon tax, an increase in tax rates on labor income, and an increase in tax rates on capital income. We find that raising marginal tax rates on labor income has advantages over the other two approaches. With the labor tax increase, GDP remains very close to its base case level, consumption is reduced very slightly and net exports expand slightly. Investment remains essentially unchanged. In contrast, using a capital tax to reduce the deficit causes a significant and persistent drop in investment and much larger reductions in GDP. A carbon tax falls between the two: it has a larger effect on GDP than a labor tax increase since (as discussed above) it reduces investment. However, it has much more moderate effects on investment and GDP than the capital tax increase, and it also provides a very significant reduction in CO_2 emissions. A carbon pollution tax thus offers a way to help reduce the deficit and improve the quality of the environment with minimal disturbance to overall economic activity.

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