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The Economic Consequences of Delay in U.S. Climate Policy

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We analyze four policy scenarios using an economic model of the U.S. economy embedded within a broader model of the world economy. The first scenario imposes an economy-wide carbon tax that starts immediately at $15 and rises annually at 4 percent over inflation. The second two scenarios impose different (and generally higher) carbon tax trajectories that achieve the same cumulative emissions reduction as the first scenario over a period of 24 years, but that start after an eight year delay. All three of these policies use the carbon tax revenue to reduce the federal budget deficit. The fourth policy imposes the same carbon tax as the first scenario but uses the revenue to reduce the tax rate on capital income.

We find that by nearly every measure, the delayed policies produce worse economic outcomes than the more modest policy implemented now, while achieving no better environmental benefits.

Keywords

fiscal policy, carbon tax, general equilibrium

JEL Classification

Q54, H2, E17

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THE ECONOMIC CONSEQUENCES OF DELAY IN U.S. CLIMATE POLICY[1]

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Abstract

The United States Environmental Protection Agency (EPA) has begun regulating existing stationary sources of greenhouse gases (GHG) using its authority under the Clean Air Act (the Act). The regulatory process under the Act is long and involved and raises the prospect that significant U.S. action might be delayed for years. This paper examines the economic implications of such a delay.

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INTRODUCTION

The United States Environmental Protection Agency (EPA) has begun regulating existing stationary sources of greenhouse gases (GHG) using its authority under the Clean Air Act (the Act).[2] The agency has begun with a proposed rule covering the one third of U.S. GHG emissions that come from electric power plants. Absent a major policy change, subsequent EPA rules will regulate GHG emissions from U.S. oil refineries, chemical plants, and other industrial facilities[3].

The regulatory process under the Act is long and involved even in the best of circumstances. For each source category (such as power plants), EPA must first regulate new sources, and only when a new source rule is final can EPA issue an "emission guideline" for existing sources in the same category. States must prepare compliance plans for approval by EPA that explain how the state will achieve EPA's emission guideline. EPA can approve or reject the state plans, and the agency can impose a federal compliance plan on states that do not submit a satisfactory plan.

President Obama laid out a timeline for the power plant rule that would finalize an emission guideline in summer 2015 and require completed state implementation plans by 2017, with possible extensions to 2018 for multi-state plans. That timeline does not include the delays that would likely arise from litigation. Even if the power plant regulation moves forward expeditiously, additional multi-year processes are necessary for all the other categories of stationary sources. Moreover, if the next president is unsupportive of climate regulation, he or she could extend the compliance schedule for states for the power plant rule and indefinitely delay promulgation of emissions guidelines for other source categories.

The protracted process is problematic for several reasons. First, yet-to-be-regulated firms face considerable policy-related uncertainties in planning long-lived investments. This both delays investment and makes it less efficient. Second, if the process is sufficiently protracted and the United States must adhere to cumulative emissions goals, future regulations may need to be more stringent than would have been necessary if a more timely policy was enacted. Because greater stringency can impose incrementally higher compliance costs, a delayed policy could be more costly even while achieving no greater cumulative environmental benefits.

On the other hand, if an emissions abatement policy imposes welfare costs (not counting the environmental benefits), the present value of those losses may be lower if the policy is adopted later, all else equal. Further, if stakeholders know the policy is coming, a delay in emissions constraints could allow for cost-reducing technological development and more gradual turnover

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[2] *See* Executive Office of the President, Presidential Memorandum—Power Sector Carbon Pollution Standards (June 25, 2013) and *Massachusetts v E.P.A.*, 549 U.S. 497, 528 (2007). See also Tarr et al (2013).

[3] A details analysis of a power sector only approach using the same model as the current paper can be found in McKibbin, Morris, and Wilcoxen (2014).

of long-lived capital in anticipation of the future constraints.[4] In other words, advance notice might actually be useful. Thus the empirical question arises of what economic consequences follow from a substantial delay in US climate policy.

To investigate this question, this study uses the G-Cubed model, an intertemporal computable general equilibrium (CGE) model of the world economy. With policy simulations, we compare a modest climate policy adopted now with more stringent policies adopted after an eight year (or two electoral cycles) delay. We hold cumulative emissions over the first 24 years of the analysis constant in all the scenarios to see how the outcomes of achieving the same environmental goal vary across different approaches to timing and stringency. We also show how the economic differences in the timing of climate policies compare to differences in other ways a climate policy can be implemented. In other words, we ask whether the consequences of delay are large or small relative to the consequences of other policy design features.

The EPA has only just begun development of emission guidelines for existing stationary sources, and the resulting abatement goals and costs will vary by source category and state[5]. Thus it is not feasible to model EPA policy directly with G-Cubed. Rather, this study focuses on the more general questions of the effects of policy delay and the degree to which delayed policies must be more stringent to make up for later implementation. We also explore how much timing matters relative to other policy design choices.

A number of earlier papers have investigated the importance of timing in climate policy. Many emphasize the cost-reducing role of "when" flexibility, i.e. the advantages of a climate treaty or regulatory program that establishes a multi-year compliance period rather than a series of annual emissions targets.[6] The logic underlying this literature derives from the fact that climate damages depend on the global concentration of the gases, not local annual emissions. Emissions goals that are expressed as cumulative emissions over a period of several years allow regulated parties to smooth their abatement over time and avoid inadvertent stringency from spikes in energy demand (for example from a harsh winter) or other transitory factors. Our analysis builds on that literature by examining the sharp change in stringency at the moment when a policy first comes into effect. Once in operation, the carbon taxes we examine all achieve a reduction in cumulative emissions via a policy with smoothly increasing stringency.

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[4] A significant literature explores the interactions between research and development (including induced technological change) and the optimal carbon pricing policy. See Gerlach et al (2009), for example.

[5] See Morris (2014) for one approach to implement state by state policy efficiently.

[6] Toman et al (1999).

1. MODELING APPROACH

As our core scenario (Scenario 1), we simulate an excise tax on the carbon content of fossil fuels in the U.S. energy sector starting immediately at $15 per ton of carbon dioxide and rising at 4 percent above inflation each year for 39 subsequent years. The tax applies to fossil fuel carbon in all sectors, including transportation fuels. One can think of this scenario as illustrating a policy that Congress could enact that would efficiently achieve abatement broadly consistent with EPA's authority under the Clean Air Act (should the agency choose concomitant emissions goals). However, our choice of the initial tax rate is essentially arbitrary; we do not mean to suggest that such a price is socially optimal or that the abatement it produces is the most likely outcome of EPA policy.

We assume all policies are adopted only in the U.S. and that other countries pursue policies consistent with baseline projections. This means that for the tax levels we model, the scenarios here maximize the potential for both emissions leakage abroad and international competitive challenges for U.S. firms.

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 (2013).[7] 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 three-letter codes will be used to identify the sectors in figures). 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.

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[7] 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.

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

No.	Code	Sector		No.	Code	Sector
1	Ele	Electric Utilities		7	Min	Other Mining
2	GaU	Gas Utilities		8	Agr	Agriculture
3	Ref	Petroleum Refining		9	Dur	Durables
4	Coa	Coal Mining		10	Non	Non-Durables
5	Crd	Crude Oil		11	Trn	Transportation
6	GaE	Gas Extraction		12	Srv	Services

The Baseline Scenario

The model's projections for future emissions and economic activity in the absence of climate policy is our business-as-usual (baseline) scenario. A detailed discussion of the baseline construction process for 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.[8] 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.

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

Along with the baseline for the United States, 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 United States and other regions over the past decade. In the baseline, neither the United States nor other countries adopt an economy-wide price on carbon.

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. For example, according to the U.S. Environmental Protection Agency, fossil fuel combustion comprised 94 percent of all U.S. CO_2 emissions in 2012, and about 78 percent of gross U.S. greenhouse gas emissions on a CO_2-equivalent basis.[9]

The Policy Scenarios

We use the G-Cubed model to analyze four policy scenarios. The first three scenarios allow us to compare a climate policy that starts immediately with ones that achieve the same cumulative emissions target over a period of 24 years, but that start after an 8 year delay. One delay scenario starts at the same carbon price as the immediate policy, but ramps up more quickly. The other starts at a higher price and ramps up at the same pace as the immediate policy. The purpose of these scenarios is to explore the relative effects of a higher initial price versus a higher rate of growth in the tax rate.

Although cumulative U.S. emissions over 24 years are the same in each of the first three scenarios, cumulative *global* emissions may not be. That is because the three scenarios have different outcomes for trade, investment, and other factors with spillovers beyond the U.S. economy, and those economic spillovers affect emissions in other countries.

In each of the first three scenarios, we use the revenue from the carbon tax to lower the federal budget deficit, and we hold federal spending on goods, services, and labor at baseline values. This means that the primary effect of the reduction in the deficit is a decline in government debt and, accordingly, the government's interest payments on the debt, relative to the baseline scenario. These deficit reduction scenarios thus have lower future tax burdens

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[9] U.S. Environmental Protection Agency (April 2014), *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2012*, p. ES-5, Table ES-2. Accessed on May 29, 2014:
http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2014-Chapter-Executive-Summary.pdf

than the baseline scenario. Rather than imposing an assumption about which tax rates a future Congress would lower, we give the revenue back to households as lump sum transfers.

A reduction in the federal deficit reduces government dissaving and will change international capital flows, influence the U.S. exchange rate, and affect the balance of trade. Because G-Cubed includes a detailed treatment of trade and financial flows between countries, we are able to examine these linkages. We explore how the debt reduction affects the U.S. economy, specifically its gross domestic product (GDP) and gross national product (GNP), different measures of the economy's size and strength. GDP is the total value of goods and services produced within the United States, and GNP is that same measure minus the net flow of funds from investments by foreigners in the United States and investments by Americans in assets abroad. In effect, GNP measures the income of the U.S. economy and GDP measures its output.

The gross receipts from the carbon tax will usually be larger than the reduction in the federal deficit because the carbon tax will tend to reduce revenues from other taxes. For example, if the carbon tax reduces employment levels or wages, revenues from labor income taxes will fall. The size of this reduction, or "offset," is of considerable interest because it will influence how fiscal authorities should score a carbon tax. In this study we determine the size of the offset by holding all tax rates other than the carbon tax (and the lump-sum rebate mentioned above) constant across the three scenarios and observing how much revenues from those taxes vary.

The extent to which economic actors can anticipate a delayed policy is an important assumption. The more efficiently the economy can transition to the new relative prices, the less costly the delay will be.[10] G-Cubed represents households and firms as mixtures of two types of agents: one group which bases its decisions on forward-looking expectations using the model as a basis for future predictions and a second group which follows simpler myopic rules of thumb using only current-year variables. The rules followed by the second group are optimal in the long run when current-year variables converge to their long run values but they are not necessarily optimal in the short run when future variables could be expected to differ from current-year values. G-Cubed assumes that 30 percent of firms and households fall into the first group and make investment and savings decisions that are fully forward-looking. The remaining firms and households invest or save according to expectations that are a moving average of past and future variables. [11] This allows the model to capture the inertia observed in empirical investment studies. In contrast, international asset traders are assumed to be fully forward-looking; we discuss this further below.

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[10] See Clarke et al (2009) for an overview of a multi-model study that explored the implications of delayed participation in an international climate agreement. In that study, Bosetti et al (2009) and Blanford (2009) showed that anticipation can greatly lower the costs of mitigation policy.

[11] The mix of rational and backward looking firms is calibrated to capture the empirical evidence on invesment behaviour. See the discussion in McKibbin and Wilcoxen (2013).

Because firms and households have a mix of foresighted and myopic behavior we expect to observe some investments consistent with a carbon price policy in the eight years leading up to the imposition of the delayed taxes, but not to the extent that would occur if all firms and households were perfectly forward looking. This is intended to be consistent with the current regulatory environment in which the ultimate U.S. climate policy, both in terms of its stringency and timing, is uncertain.

The fourth scenario imposes a carbon tax identical to the first scenario but uses the revenue to cut the current tax rate on capital income. This scenario reduces the excess burden of the tax system and offsets part of the overall economic burden of the carbon tax. This scenario allows us to compare the relative economic importance of delay versus how the tax revenue is used. In other words, we want to know which is most important: when the policy starts or how the policy is designed.

1. *Carbon tax starting now with deficit reduction*

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 carbon dioxide and rising at 4 percent above inflation each year through 39 subsequent years and then leveling out at $67 from year 40 onwards.[12] We specify the carbon tax trajectory *a priori* in this way such that it follows a Hotelling rule by increasing at the long run real interest rate of 4 percent in the model. Below we will refer to this scenario as "*S1_now*".

2. *Delayed carbon tax with higher starting price*

This scenario establishes a similar excise tax on the carbon content of fossil fuels in the US energy sector, but it starts eight years later than Scenario 1. Like Scenario 1, the tax rises at 4 percent above inflation each year until it gets to the same capped tax rate of Scenario 1. We solve for the starting price needed after the 8 year delay to achieve the same cumulative emissions as Scenario 1 over the first 24 years of the policy. We will refer to this scenario as "*S2_step*" to reflect the fact that it involves an initial carbon tax that is stepped up relative to the *S1_now* scenario.

3. *Delayed carbon tax with faster price growth*

This scenario establishes a carbon tax starting eight years later than Scenario 1, and like Scenario 1 it starts at $15 per ton of carbon dioxide. However, it rises more quickly than 4

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[12] This scenario is the same modeling scenario as the deficit reduction scenario in McKibbin, Morris, Wilcoxen and Cai (2014). All dollar values are in 2010 dollars.

percent over inflation each year so that the policy achieves the same cumulative emissions as Scenario 1 over the first 24 years of the policy. In this scenario we solve for that higher rate of increase to achieve the cumulative emissions achieved by Scenario 1. Again, we end the growth of the tax when it gets to the maximum tax rate that applies in Scenario 1. We will refer to this scenario as "*S3_rate*" since the tax grows at an accelerated rate.

4. *Carbon tax starting now with capital tax rate cut*

As in Scenario 1, 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 carbon dioxide and rising at 4 percent above inflation each year through 39 full years of the policy. Again, we hold the tax constant after 39 years. The important difference from Scenario 1 is that the revenue from the carbon tax is applied to an endogenous decrease in the tax rate on capital income rather than a reduction in the federal budget deficit. Scenario 4 holds the federal budget deficit constant relative to baseline levels. We will refer to this scenario as "*S4_taxswap*".

Although the carbon tax trajectories are identical in Scenarios 1 and 4, their U.S. and global emissions outcomes will differ. That is because the different uses of the carbon revenue drive different macroeconomic outcomes, so the carbon tax rates apply to two different macroeconomic futures.

3. RESULTS

Policy Now vs. Delay

Figures 1 through 18 show the results for the carbon tax starting now (*S1_now*) and the two delayed carbon tax scenarios (*S2_step* and *S3_rate*) over the first 24 years of the simulations**.** We show all the policy results relative to the baseline to facilitate comparison between them, so a value of zero means that the policy produced no deviation from the baseline. A positive (negative) value implies the policy raised (lowered) that variable relative to the baseline. All dollar figures are in constant 2010 dollars.

Figure 1 shows the carbon tax under the first three scenarios and includes vertical lines at years 1 and 9 to indicate the onset dates of the policies. Under *S1_now* the tax starts in year 1 at $15 per ton of CO_2 and rises by 4 percent above the rate of inflation each year until it reaches the peak of $67, after which it is held constant. Under *S2_step,* the carbon tax is delayed until year 9 but then starts at $25.50 and rises at 4 percent annually in real terms until reaching the same maximum tax rate as in *S1_now*. As expected, the initial tax in *S2_step* must be substantially higher than the initial tax in *S1_now* in order to achieve the same emissions reduction over a shorter period of time. Moreover, it is substantially higher than the year-9 tax under *S1_now*. An eight year delay thus requires a starting tax rate that is 70 percent higher than one that starts now. The tax in the third scenario, *S3_rate*, starts at $15 per ton (in constant dollars), but not until year 9. To achieve the same the cumulative emissions as *S1_now* through period 24, we find that the necessary growth rate is 10 percent per year—more than double the growth rate of the policy that starts now.

Figure 1: The Tax Rate per Metric Ton of Carbon Dioxide

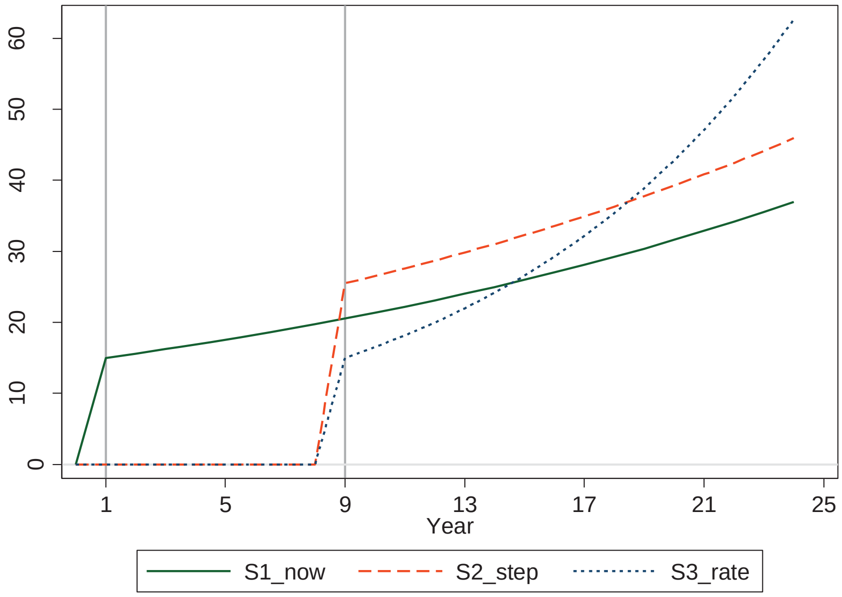


Figure 2 shows CO_2 emissions abatement under the three scenarios. Emissions fall sharply in the *S1_now* scenario in year 1 upon imposition of the carbon tax and decline steadily thereafter. In the delay scenarios, emissions fall very gradually through year 8 as some firms and households anticipate the policy coming in year 9. Interestingly, policy anticipation drives much more significant changes in other economic variables (as discussed below). From year 9 onwards, emissions fall more quickly in the two delay scenarios because they must make up for lost time to achieve the same cumulative emissions as the policy adopted now. The cumulative emissions abatement over the 24 years in all three scenarios is about 19 billion metric tons of CO_2.

Figure 2: Decline in CO_2 Emissions (Billions of Metric Tons)

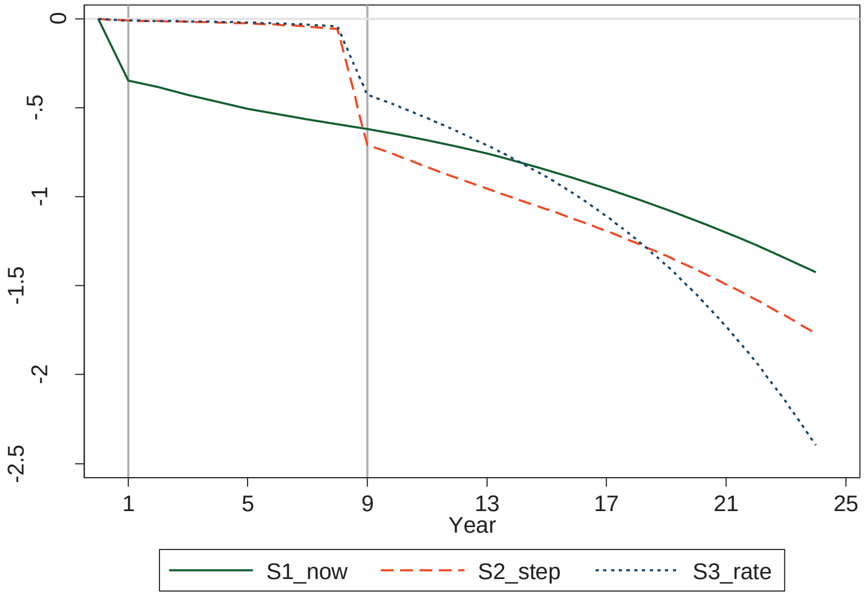


Figure 3 shows the government's annual revenue from the carbon tax in each scenario. Revenue is driven by the interaction of three factors: (1) underlying economic growth, which tends to increase carbon emissions and hence carbon tax revenue; (2) escalation of the tax rate, which also tends to increase revenue; and (3) reductions in emissions due to the higher tax, which tends to reduce revenue. In *S1_now*, the carbon tax raises $79 billion in the first year. Over years 9 through 24, the decrease in emissions due to the tax just about balances the growth in emissions in the baseline and revenue rises about 4 percent per year. The delayed policies produce no revenue until year 9, but due to their higher tax rates, both eventually produce more annual revenue than *S1_now*. However, over years 9 through 24, the higher taxes in the delayed policies cause larger reductions in emissions than under *S1_now* and revenue rises more slowly: at 3.7 and 8.4 percent per year for *S2_step* and *S3_rate*, respectively. Overall, *S1_now* produces significantly more cumulative revenue over the 24 years of the simulation: at a 4 percent interest rate, the present value of revenue in the three simulations is $2 trillion for *S1_now*, $1.6 trillion for *S2_step*, and $1.4 trillion for *S3_rate*.

Figure 4 shows how much the carbon tax reduces the federal budget deficit relative to baseline. We find there are large immediate changes in the deficit when each tax is imposed.

Figure 3: Gross Receipts from Carbon Tax (Billions of Dollars)

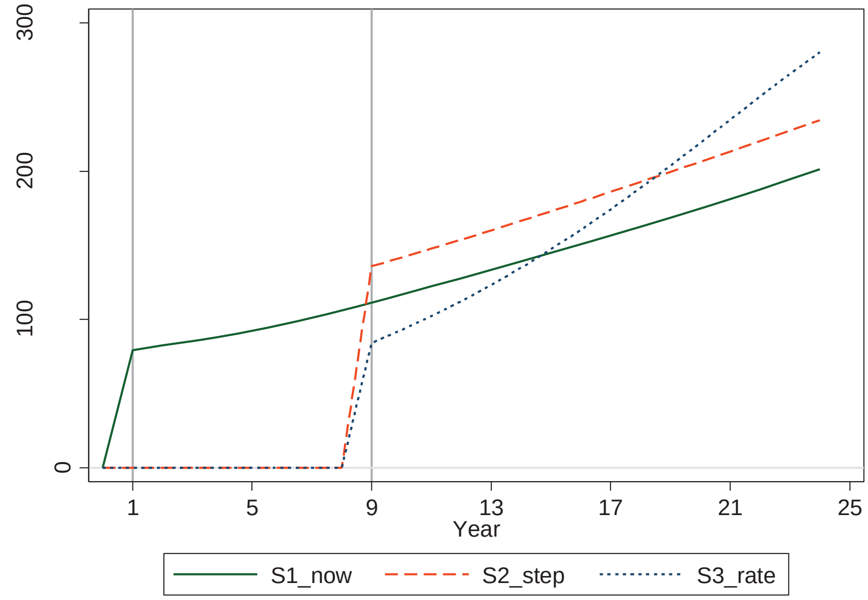
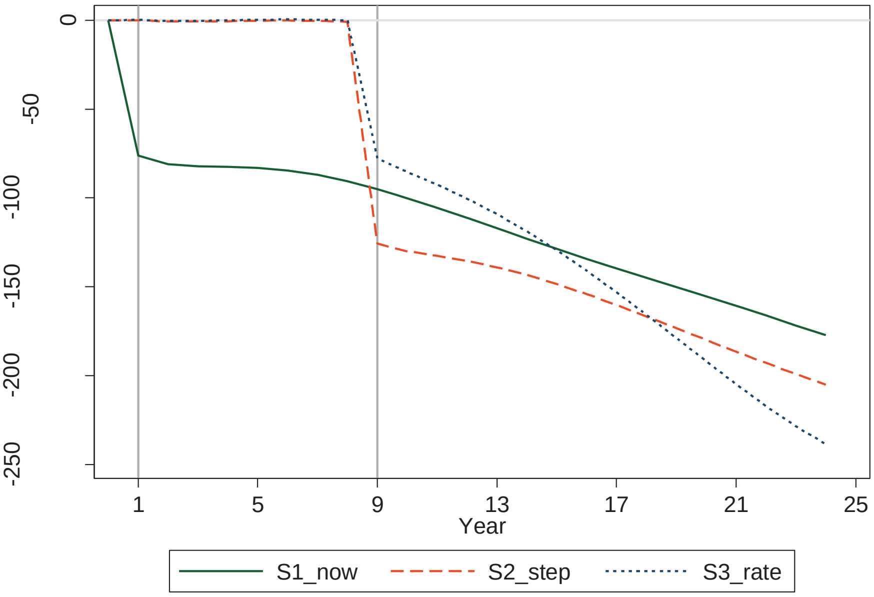
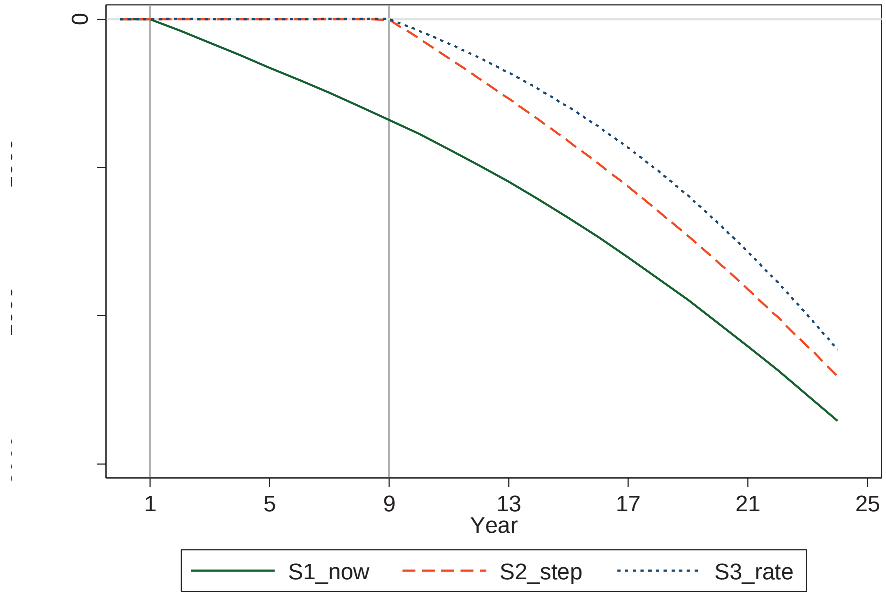


Figure 4: Decline in Annual U.S. Federal Budget Deficit (Billions of Dollars)



As the annual budget deficits fall, the federal debt also falls relative to baseline levels. The stock of government bonds (the debt) appears in Figure 5. For the same change in cumulative emission over the 24 years following the policy, *S1_now* produces more cumulative revenue and reduces the stock of U.S. debt falls by the most.

Figure 5: Decline in U.S. Debt (Billions of Dollars)



As discussed above, the gross receipts from the carbon tax in Figure 3 exceed the overall revenue changes for the federal government and resulting deficit reduction in Figure 4. That is because the carbon tax affects the broader macroeconomy and consequently changes other tax revenues. Figure 6 shows the extent of the offset due to reductions in other revenue. We find that the revenue lost from other tax instruments varies significantly over time, from about 5 percent to 15 percent of the gross carbon tax receipts. Over the 24 year period, the undiscounted cumulative offset for *S1_now* totals $335 billion or about 10 percent of the undiscounted carbon tax revenue. This is somewhat lower than the longstanding convention used by the Congressional Budget Office (CBO) of a 25 percent offset in scoring net excise tax receipts.[13] The two delay scenarios have slightly higher cumulative offsets: about 12 percent of cumulative carbon tax revenue.

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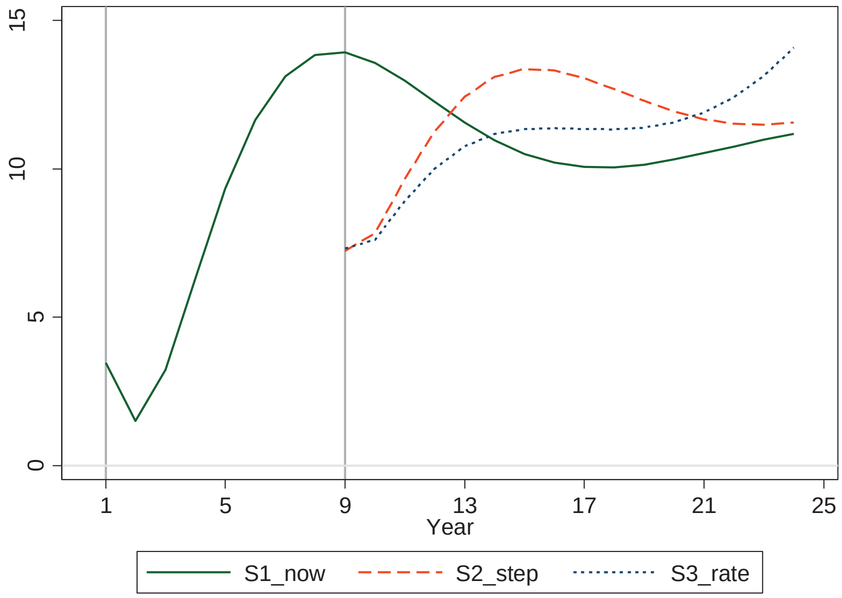
[13] CBO, "The Role of the 25 Percent Revenue Offset in Estimating the Budgetary Effects of Legislation," Economic and Budget Issue Brief, January 13, 2009. http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/96xx/doc9618/01-13-25percentoffset.pdf

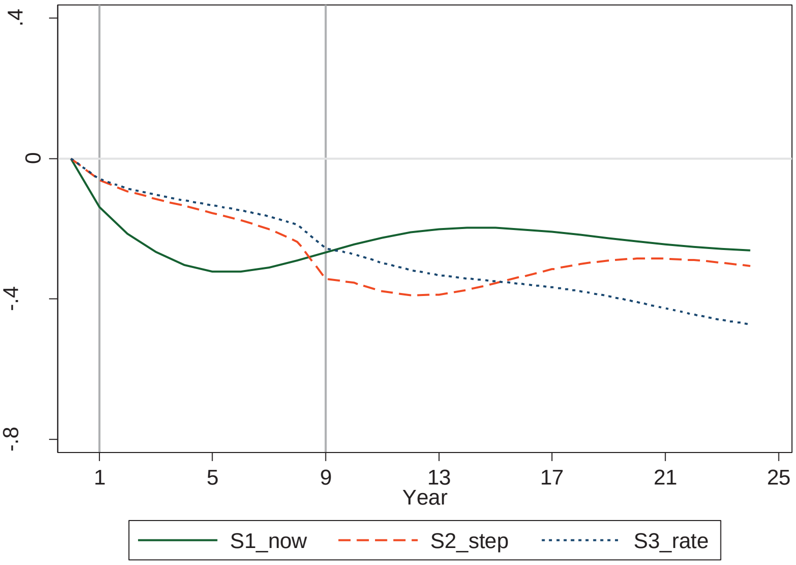
Figure 6: Loss in Other Revenues as a Percent of Gross Receipts from Carbon Tax



The macroeconomic adjustments are shown in Figures 7 through 12. The results for U.S. GDP, GNP, consumption, investment, and net exports are expressed as changes as a percent of baseline GDP. Expressing the changes relative to baseline GDP is convenient because it allows the absolute magnitudes of the changes to be compared. In addition, the change GDP will exactly equal the sum of the changes in its components.

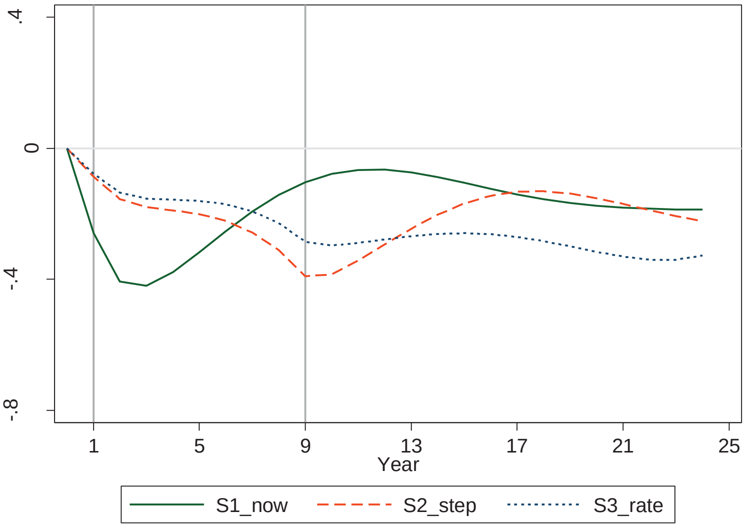
Figure 7 shows the three policy scenarios outcomes for real GDP. Under *S1_now* GDP falls by 0.3% relative to baseline after 5 years and is somewhat lower over the following decades. Interestingly, the delayed policies also reduce GDP in the early years because the forward-looking agents in the model anticipate the coming tax. To be clear, the curves show the change in GDP *relative to a growing baseline*; negative values do not imply a recession. Rather they indicate a slight lowering of the positive rate GDP growth. We discuss this more below in Figures 24 and 25.

Figure 7: Decline in U.S. Gross Domestic Product as a Percent of Baseline GDP



Of the major components of GDP, the largest impact of the carbon tax is on economy-wide investment, as shown in Figure 8. Although the sector with the greatest output and investment contraction is the coal industry, investment also falls relative to baseline in the broader economy as firms prepare for a slowdown in growth. In the delayed policy scenarios, investment falls even early on in anticipation of the tax. Moreover, the rapidly rising tax in *S3_rate* causes investment to remain further below baseline throughout the 24-year period. Again, the declines we show here are relative to a growing baseline. Investment does not fall in absolute terms.

Figure 8: Decline in U.S. Investment as a Percent of Baseline GDP



The results for real consumption are shown in Figure 9. The pattern of decline in consumption reflects both the increase in costs associated with the carbon tax and the reduction in the domestic capital stock due to the decrease in investment. Thus, consumption falls more gradually than investment but remains lower in the long run. Consumption falls only slightly through year 8 in the delayed policies, and more sharply once the tax is imposed.

Figure 9: Decline in U.S. Consumption as a Percent of Baseline GDP

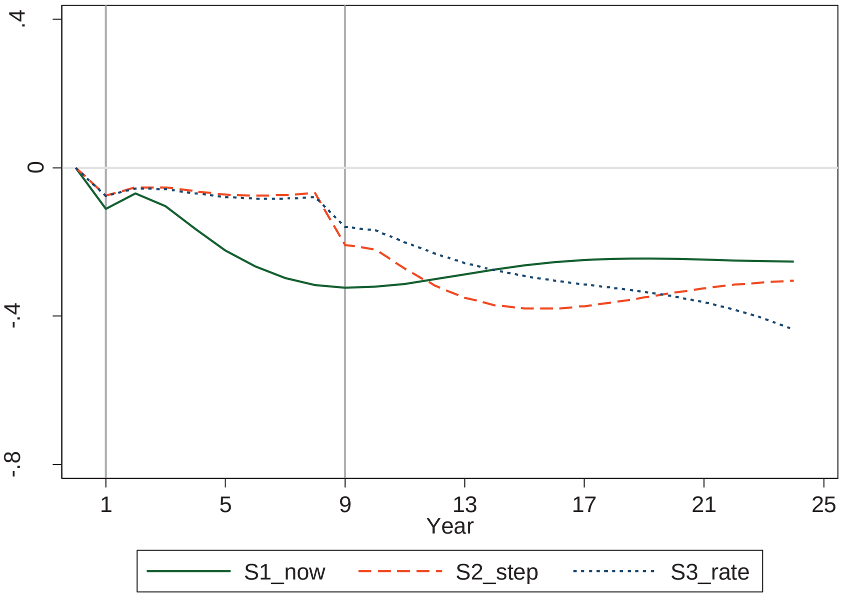


Figure 10 reports the effect of the policies on U.S. net exports (the balance of trade). Four competing mechanisms play roles in driving the results. First, the carbon tax raises input costs, which in isolation would make U.S. exports less competitive and would reduce net exports. Second, the tax reduces U.S. income slightly, reducing the demand for imports. Third, the tax reduces the return on U.S. investments, which reduces inflows of foreign capital. Fourth, the reduction in the federal deficit raises national saving, reducing borrowing from abroad and further reducing capital inflows. The reductions in capital inflows reduce demand for the U.S. dollar and cause the exchange rate to depreciate (see Figure 12), partially offsetting the impact of the carbon tax on the costs of exporting industries. Our results in Figure 10 show that the last three mechanisms—the reduction in income and depreciation of the dollar due to the capital flow effects—dominate the first. Together, these effects are sufficient to cause net U.S. exports to rise. We find that *S1_now* causes a larger increase in net U.S. exports than the delayed policies although the impact on the real exchange rate is almost as large.[14]

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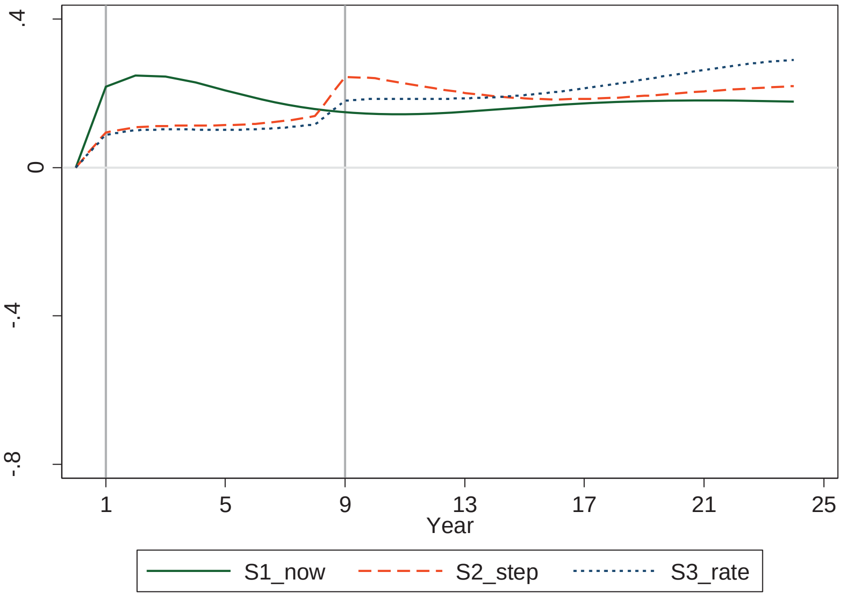
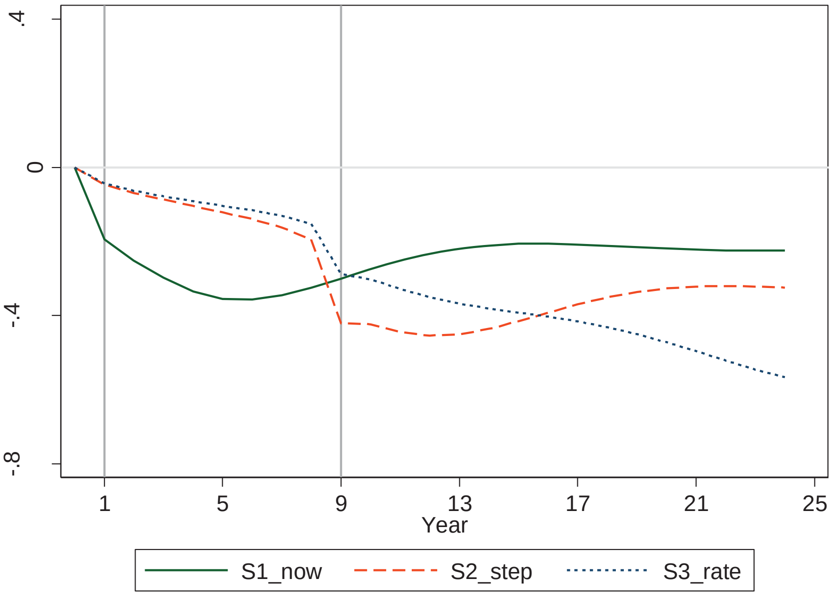
[14] Even though firms and households anticipate the imposition of the tax, many variables jump markedly in year 9, particularly asset prices like the exchange rate. This is explored in McKibbin and Wilcoxen (1998).

Figure 10: Increase in Net U.S. Exports as a Percent of Baseline GDP



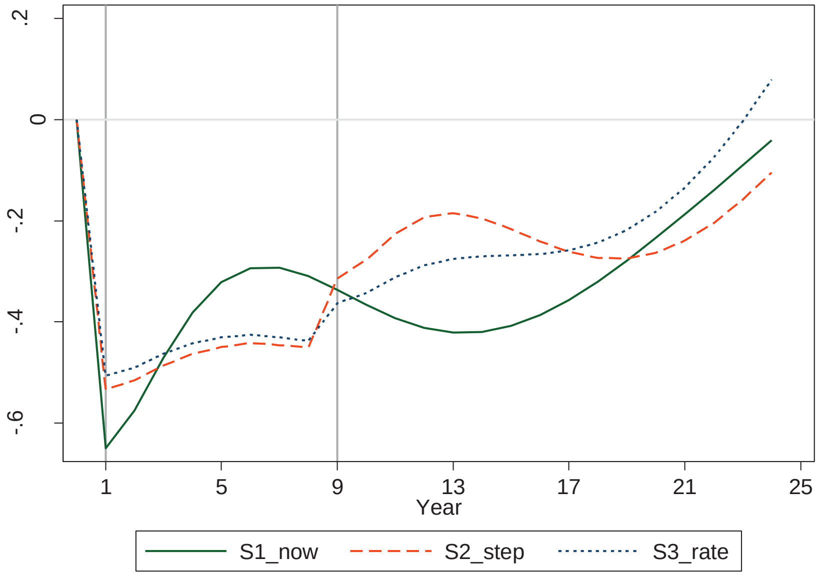
Real GNP (Figure 11) is real GDP minus net payments to foreign factors of production. In our simulations, results for GDP and GNP diverge because deficit reductions reduce payments of interest on the U.S. debt and some of that debt is held by foreigners. Thus, GNP falls less than GDP (also see Figure 19). Although GNP falls by more initially under *S1_now*, that policy provides better long term outcomes than the delayed policies. That is because it lowers the debt by more overall, as shown in Figure 5, so acting now works better to lower both future tax liabilities and future payments to foreign holders of U.S. government debt.

Figure 11: Decline in Gross National Product as a Percent Deviation from Baseline



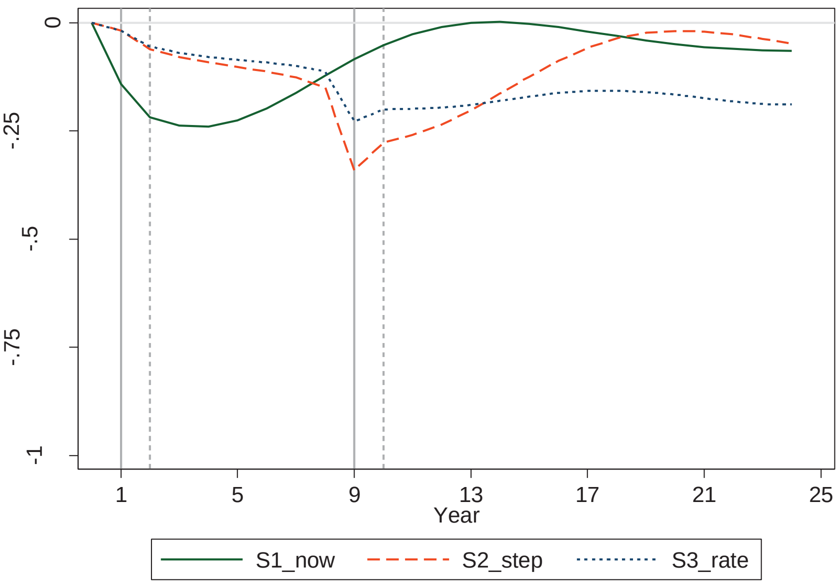
When the carbon tax arrives in year 9 under the delayed policies, much of the real exchange rate adjustment (Figure 12) is already underway since international asset holders anticipate the tax and its subsequent impact on the U.S. economy. The impact of foresight on the part of asset traders is clearest in the exchange rate results for year 1: the immediate depreciation of the U.S. dollar is almost as large under the delay scenarios as under *S1_now*.

Figure 12: Percent Change in Real Exchange Rate of U.S. Dollar



One of the unique features of G-Cubed is its incorporation of labor market dynamics. Policies can raise or lower employment levels, even over long periods, if wages are slow to adjust to new conditions. Figure 13 shows aggregate U.S. employment under the three policies, relative to a growing baseline. We find that all the policies produce a maximum negative effect on employment levels of about 0.25 percent, but employment in the "now" scenario returns to baseline levels within a decade and a half, even as the carbon tax continues increasing. Employment dynamics in the delayed policies are sharper, and the *S3_rate* scenario produces a lasting net decrease in employment relative to the other delay scenario. Employment does not fall in absolute terms in any of the carbon tax scenarios; it just grows slightly less quickly than it otherwise would.

Figure 13: Percent Change in Total U.S. Employment Relative to Baseline



We would not expect the effects of a carbon tax on employment to be equal across different sectors in the economy, even as the economy returns to baseline levels of employment. Figure 14 shows how the employment outcomes of *S1_now* vary across the 12 sectors in the U.S. economy in year 14, which is representative of the medium to long run. Declines in the coal (Coa), gas extraction (GaE) and electric utilities (Ele) sectors reduce the demand for labor in those sectors. As workers and capital move around the economy, the initial loss of jobs in those sectors is offset by the creation of new jobs in the non-energy sectors, particularly in the durable and non-durable manufacturing sectors (Dur, Non) and the service sector (Srv). By year 14, the gains in some sectors match the losses in others and the economy has returned to its overall baseline employment level.

Figure 14: Change in Employment by Sector in Year 14 (*S1_now*)

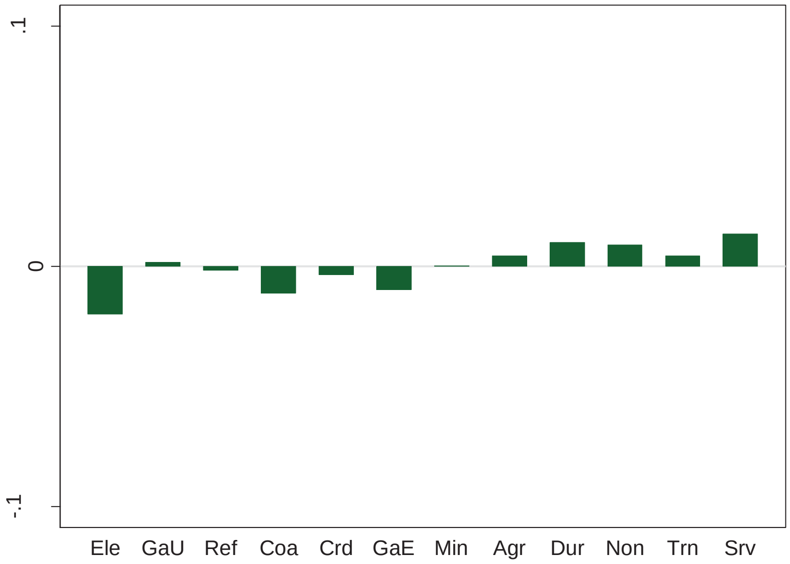
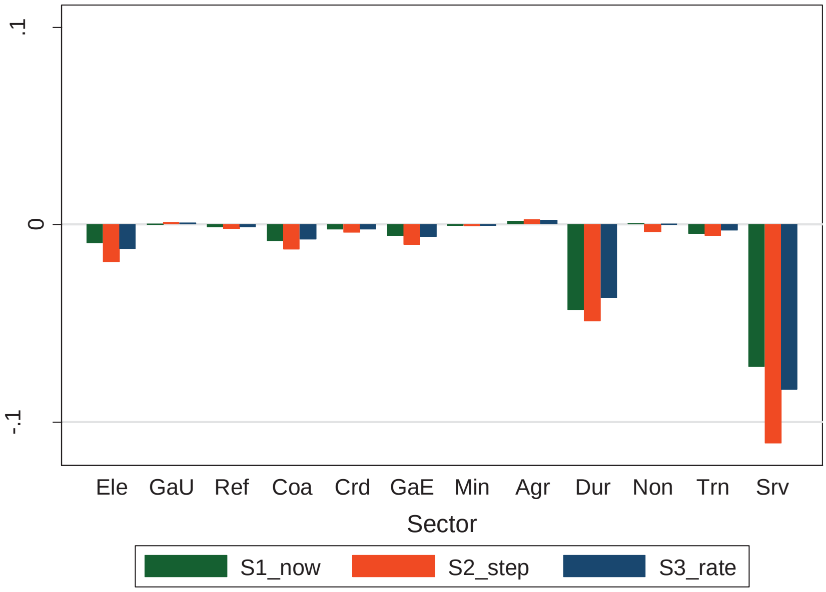


Figure 15 shows the short run employment outcomes in the second year of the carbon tax under each policy—that is, in year 2 for *S1_now* and in year 10 for the delayed policies, both of which are shown by dashed vertical lines in Figure 13. Figure 15 shows that the employment effects in the second year of the policy are smaller for *S1_now* than for the delayed policies. For example, the service sector (Srv) loss of employment (relative to baseline) is one third larger for *S2_step* compared with *S1_now*. The results in Figure 15 are expressed as changes from baseline as a percent of the total U.S. labor force, so we see that although the within-sector effects are larger for coal, natural gas and electric utilities, overall employment declines are larger in the larger sectors, particularly services.

Figure 15: Change in Employment Relative to Baseline, Second Year of Carbon Tax



Additional sector-specific results appear in Figures 16 and 17. The figures show the change in purchaser prices and domestic output, respectively, for each sector in the U.S. economy in the second year of the change in the carbon tax. This is the same kind of comparison as Figure 15, except the units are percentage changes of price and output within each sector. The largest direct impact of the carbon tax is overwhelmingly on the coal sector. We find that *S1_now* has much smaller price and output effects than the delayed policies, particularly relative to *S2_step*, which has a considerably larger carbon tax in its second year. This suggests that the large immediate tax of *S2_step* is significantly more disruptive for the coal industry (even when it is somewhat anticipated) than the policies that start more modestly.

Figure 16: Change in Purchase Prices by Sector, Second Year of Carbon Tax

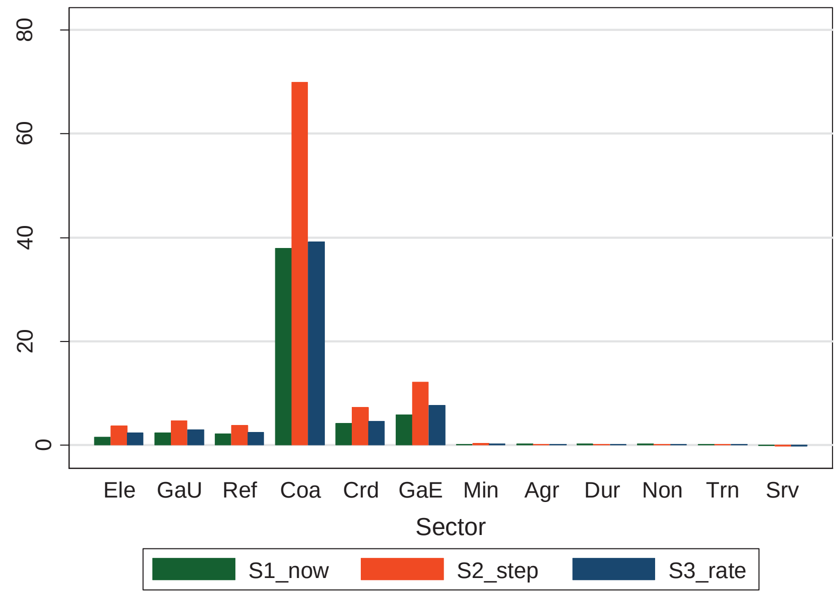
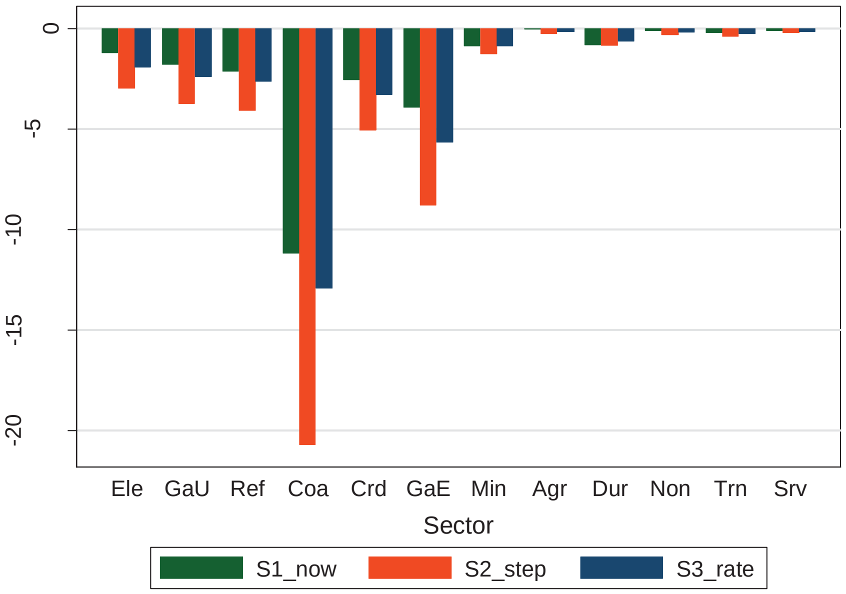
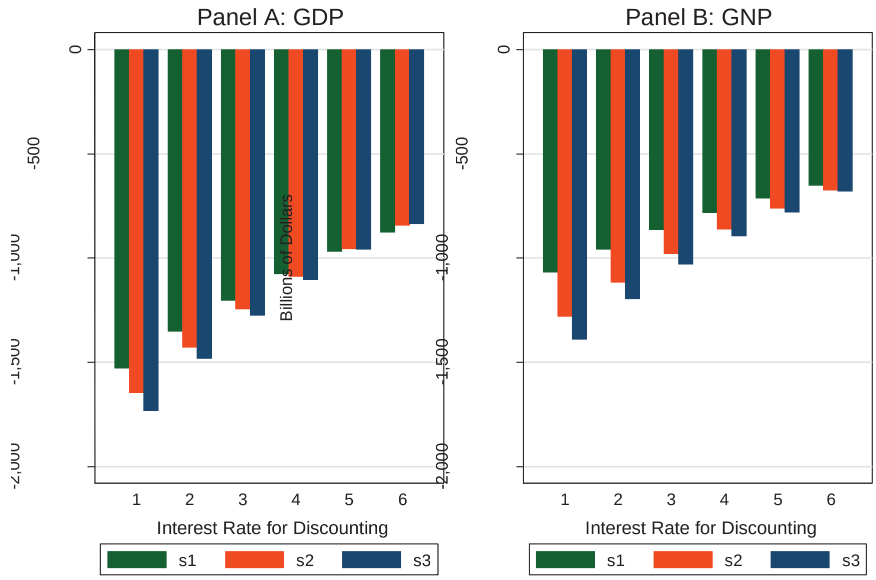


Figure 17: Change in U.S. Output by Sector, Second Year of Carbon Tax



One way to summarize the complex dynamic effects of the different policies is to calculate the net present value (NPV) of changes in variables such as GDP and GNP, discounting future values into today's dollars. In Figure 18, Panels A and B show the NPV using a range of interest rates for discounting from 1 to 6 percent (the horizontal axis). For GDP (Panel A), the NPV of loss relative to baseline is smallest under *S1_now* except when discount rates are 5 percent or greater. This is not surprising because the GDP losses in *S1_now* are earlier, followed by lower longer term costs than the delay scenarios. The results for GNP are more decisively best for *S1_now* because they reflect the benefits of faster federal debt reduction, which lowers interest payments to foreigners.

Figure 18: Net Present Value of Declines in GDP and GNP over 24 Years

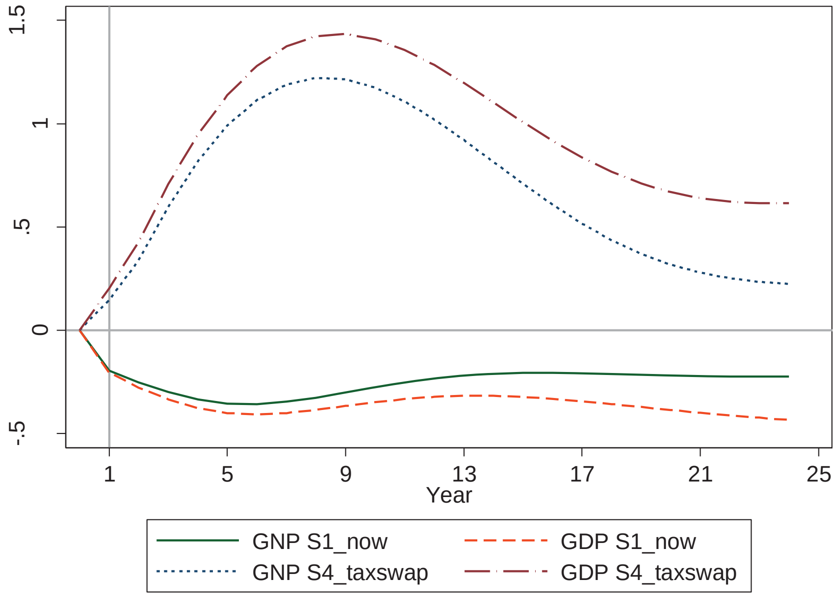


Alternative Uses of Carbon Tax Revenue

All of the carbon tax scenarios presented so far achieve the same environmental outcome (cumulative carbon emissions) and use the revenue to reduce the federal budget deficit while holding all other tax rates to baseline levels. In this section, we explore an alternative use of the carbon tax revenue with an eye to understanding the importance of the timing of the policy relative to the policy's other design features.

Accordingly, we introduce the *S4_taxswap* scenario, in which a carbon tax is implemented at the same time and trajectory as *S1_now*, but the revenue is used to reduce the tax rate on U.S. capital income, holding the federal budget deficit at baseline levels. Figure 19 shows both GDP and GNP for the *S1_now* and *S4_taxswap* scenarios. The difference in the two policies is dramatic. Recycling the revenue to reduce the tax on capital income *raises* GDP and GNP rather than lowering them.[15]

Figure 19: Changes in GDP and GNP under Alternative Revenue Uses



The mechanism driving GDP and GNP up is a sharp increase in investment in response to the cut in capital taxes. Figure 20 shows that private investment in the short to medium run rises by more than 1 percent of baseline GDP. Over time, the economy's capital stock grows substantially, producing persistently higher output in the long run.

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[15] This result is also obtained by Jorgenson, et al. (2013). For additional background on the potential for pro-growth environmental tax swaps, see Bento and Jacobsen (2007). Not all CGE models find that such tax swaps produce net increases in economic activity, but all show that a tax swap is less costly than a carbon tax with lump sum rebates. See Goulder and Hafstead (2013), for example.

Figure 20: Changes in U.S. Investment under Alterative Revenue Uses

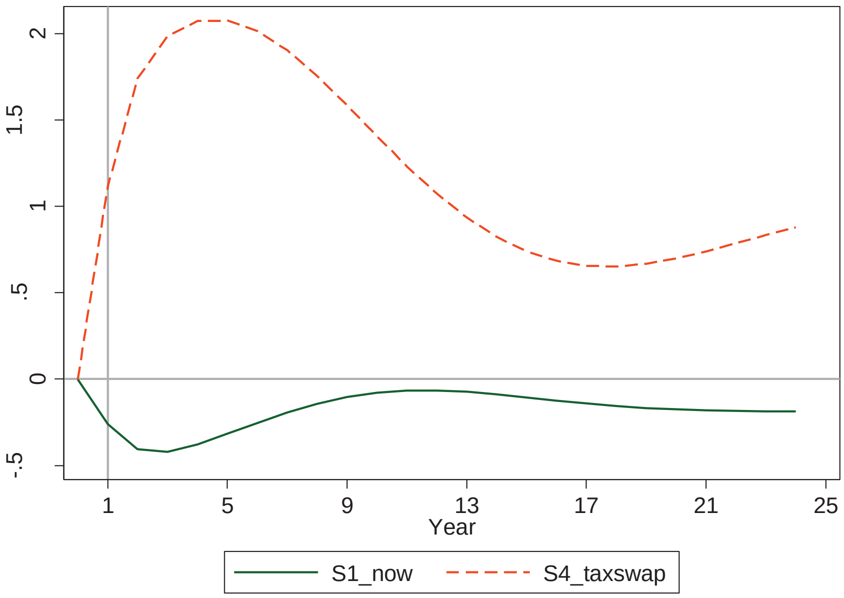


Figure 21 shows that the trade effects are also very different under the two alternative uses of revenue. The tax swap produces no change in government saving. That, along with the increase in private investment, produces an inflow of foreign capital attracted by the higher after tax returns to capital in the United States. The U.S. dollar appreciates under the pressure of greater capital inflows, reducing exports and making imports cheaper. As a result, net exports fall and the U.S. trade balance deteriorates. Because a part of the expansion in GDP shown in Figure 19 is financed by foreign investment (and borrowing from foreigners), the expansion in GNP is persistently smaller than the expansion in GDP.

Figure 21: Changes in Net U.S. Exports under Alterative Revenue Uses

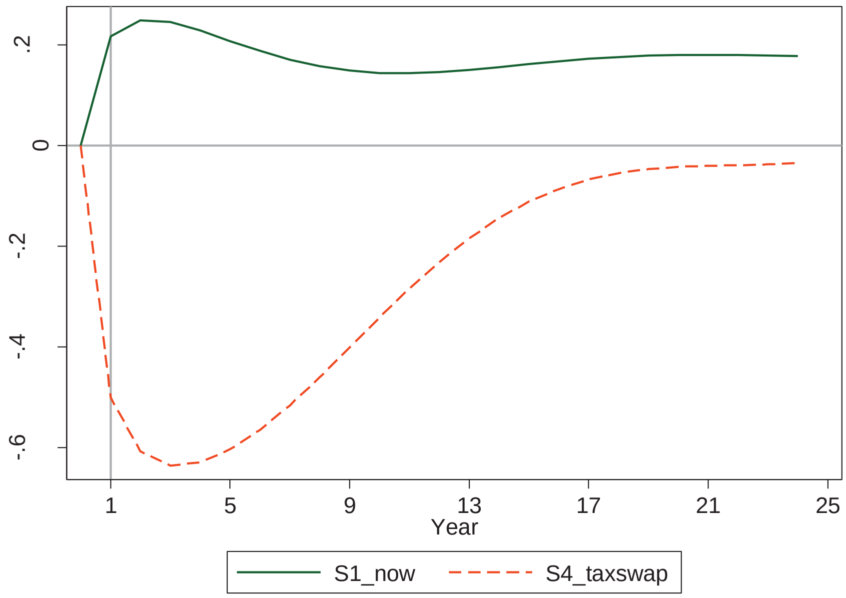


Figure 22 compares the employment outcomes from the two ways of using the carbon tax revenue. The tax swap produces a persistent and significant rise in employment, up to about one percent relative to baseline, as the policy stimulates the economy in the short term.

Figure 22: Changes in Total U.S. Employment under Alterative Revenue Uses

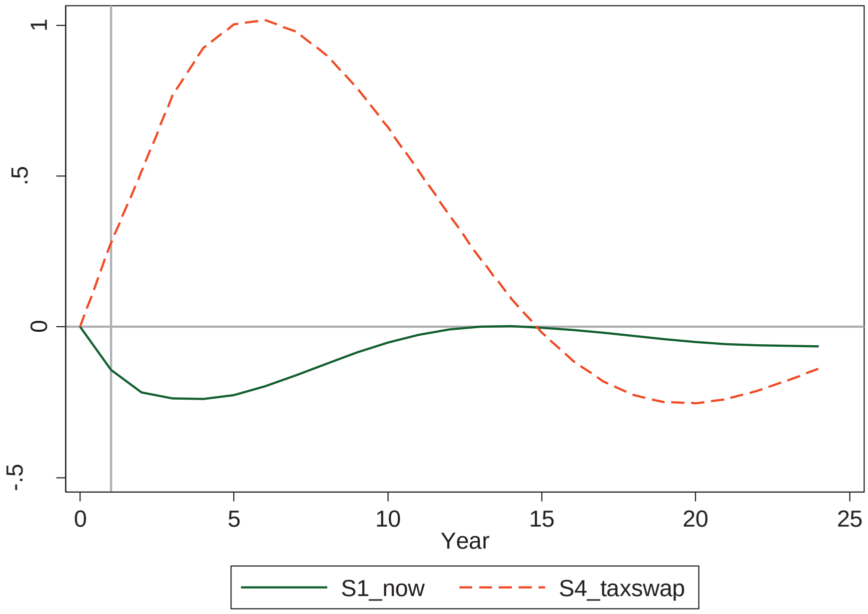
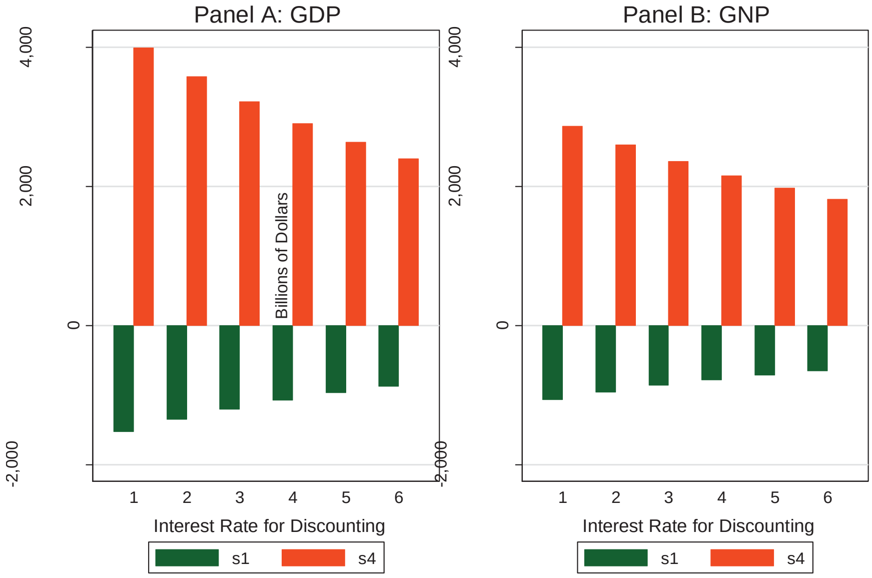


Figure 23 compares the net present values of changes in GDP and GNP over a range of discount rates. Comparing Figures 18 and 23, it is clear that the way in which revenue from the carbon tax is used is decisively more important than the timing of the policy. For example, at a 4 percent discount rate, the difference between *S1_now* and *S4_taxswap* is roughly $3 trillion while the range between the other scenarios (*S1_now* and *S3_rate*) is only about $200 billion.

Figure 23: NPV of Changes in GDP and GNP with Alternative Revenue Uses



One outcome of the stronger economic in the tax swap scenario is that the tax induces slightly less abatement through the 24 years of the policy than the scenario with the deficit reduction: 16 billion metric tons rather than 19 billion metric tons.

The Impact of Carbon Taxes on the Long Run Level of GDP

It is also useful to examine the impact of the policies on the long term level of GDP, not just how annual GDP changes relative to its baseline. Figure 24 shows GDP in levels under all four policy scenarios and the baseline. GDP under *S4_taxswap* is barely discernibly higher than the baseline. Under the other three policies, in absolute terms at this scale, GDP is nearly indistinguishable from the baseline. Figure 25 zooms in on GDP from years 22 to 24. The horizontal line shows that the level of GDP achieved in year 23 of the baseline scenario. Under *S4_taxswap* that level is achieved 6 months earlier (since grow was higher for a time) while under *S1_now* and the delayed scenarios it is achieved a month or two later that in the baseline.

Figure 24: Levels of GDP in Carbon Tax Policy Scenarios (Trillions of Dollars)

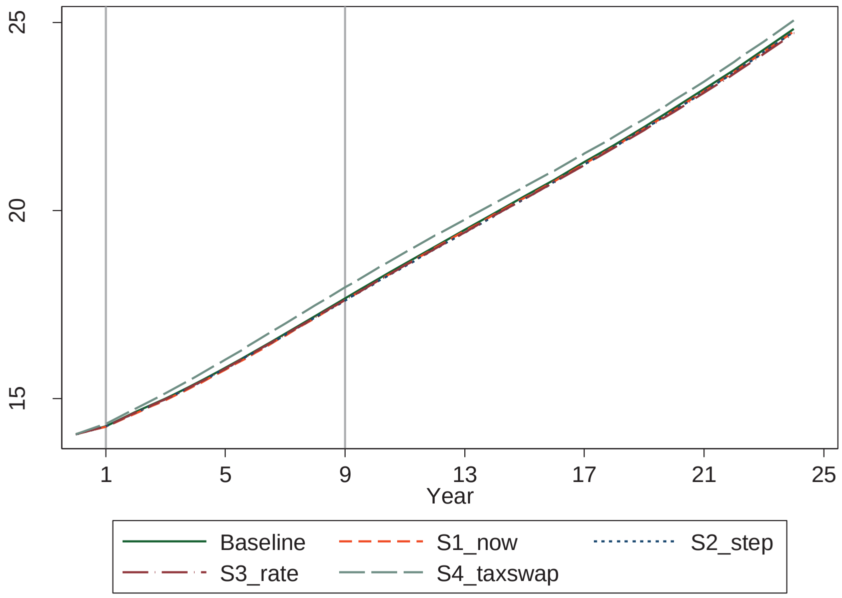
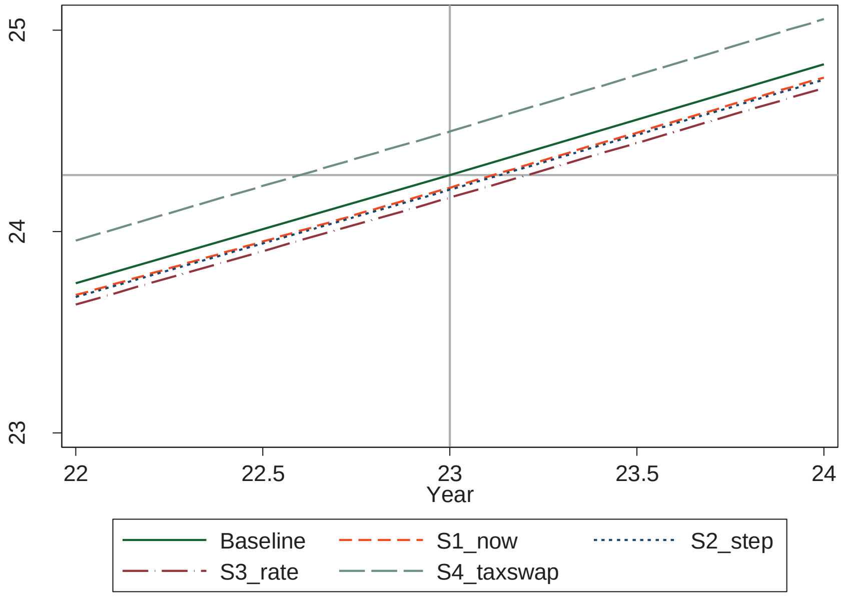


Figure 25: Long Run GDP in Carbon Tax Policy Scenarios (Trillions of Dollars)



Emissions and Leakage

As noted above, one outcome of the stronger economic growth under *S4_taxswap* is that the carbon tax induces slightly less abatement through the 24 years of the policy than it does under *S1_now*: 16 billion metric tons rather than 19 billion metric tons. That is, a somewhat larger carbon tax would be required to achieve the same abatement when revenues are recycled via a capital tax reduction.

Finally, emissions reductions in the U.S. are generally not offset by increased emissions abroad (often called "leakage"). The first three policies have cumulative leakage rates of 4-5 percent over years 1-24; that is, only about 5 percent of the U.S. reduction is offset by increases in emissions elsewhere. Under the tax swap policy, world emissions actually fall about 3 percent more than U.S. emissions as foreign capital flowing into the U.S. reduced investment slightly in other parts of the world. In other words, under *S4_taxswap* the leakage rate is -3 percent.

4. CONCLUSION

This paper explores the economic implications of a delay in U.S. climate policy. We use the G-Cubed model to analyze four policy scenarios. The first imposes a carbon tax that starts immediately at $15 and rises annually at 4 percent over inflation. The second two scenarios impose other carbon tax trajectories that achieve the same cumulative emissions reduction as the first scenario over a period of 24 years, but that start after an eight year delay. One delayed policy starts at the same carbon price as the immediate policy, but ramps up more quickly. The other starts at a higher price and ramps up at the same gradual pace as immediate policy. All three of these policies use the carbon tax revenue to reduce the federal budget deficit without changing any future tax rates. The fourth policy imposes the same tax as the first scenario, adopted now, but uses the revenue to reduce the tax rate on capital income.

We find that an eight year delay requires a starting tax rate that is 70 percent higher than one that starts now ($25.50 vs. $15) or a rate of increase that is more than twice as fast (10 percent annually vs. 4 percent). By nearly every measure, the delayed policies produce worse economic outcomes than a more modest policy implemented now, while achieving no better environmental benefits. We find that all three scenarios in which carbon tax is used solely to reduce the federal budget deficit produce declines—typically less than 0.5 percent—in U.S. GDP, investment, consumption, and employment compared to our baseline simulation. However, the declines are small compared to the annual growth of each of those variables; the policies slow growth slightly but do not cause absolute declines in at the macroeconomic level.

We find that the policy adopted now would lower the federal debt by more than the delayed policies, and it would have more muted effects on U.S. employment. Within individual industries, we find that delaying the policy causes greater disruptions throughout the economy because the carbon tax must be higher or must rise more quickly to achieve the same emissions goal. A policy adopted now has much smaller price and output effects than the delayed policies, particularly relative to the policy that starts at a higher tax rate. Of the two delay scenarios, the one with faster growth in the carbon tax rate generally produces worse economic outcomes, for example for GDP, GNP, investment, and employment. However, the policy with the sharp but delayed increase in the tax is significantly more disruptive for the energy sector (especially the coal industry) than a policy that begins with more modest taxes.

Our fourth scenario is a striking contrast to the first three scenarios. The *S4_taxswap* results show that a carbon tax can actually strengthen macroeconomic variables when the revenue is used to reduce distortionary taxes. We find that using carbon tax revenue to reduce tax rates on capital income can raise U.S. GDP, investment and employment by 0.5 to 1 percent relative to baseline. The net present value gain in U.S. GDP or GNP can be 2 trillion dollars or more, depending on the discount rate. So while the timing of the policy matters, our results show that other climate policy design features, particularly how the revenue of a carbon tax is used, can matter significantly more.

A few qualifications of these results are in order. First, by design, the deficit reduction scenarios in this study avoided imposing an assumption about which tax rates a future Congress would lower by returning excess revenues to households lump sum. Were Congress to lower future tax rates instead of providing those transfers, some of the pro-growth tax swap effects we saw in the fourth scenario could arise. They would not be as large as the effects in *S4_taxswap* because those future tax rates would only fall enough to match the decline in interest payments on the debt, not by enough to match the net carbon tax revenue.

Second, we have assumed that the delayed policies produce the same environmental benefits as our core scenario by being more stringent when they do take effect. Clearly one real world risk of delay is that delayed U.S. policies do not make up for lost time and ultimately concentrations of GHGs are irreparably higher. Further, we have abstracted from the effects of U.S. action on the incentives for other countries to act. Were the United States to delay its policies, global environmental outcomes could be worse even if the United States hits its own cumulative emissions goal.

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