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Tax Reform and Environmental Policy

Options for Recycling Revenue from a Tax on Carbon Dioxide

Lawrence H. Goulder and Marc A.C. Hafstead

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RESOURCES FOR THE FUTURE

Tax Reform and Environmental Policy: Options for Recycling Revenue from a Tax on Carbon Dioxide

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Abstract

Carbon taxes are a potential revenue source that could play a key role in major tax reform. This paper employs a numerical general equilibrium model of the United States to evaluate alternative tax reductions that could be financed by the revenues from a carbon tax. We consider a carbon tax that begins at $10 per ton in 2013 and increases at 5 percent per year to the year 2040. The net revenue from the tax is substantial, and the GDP and welfare impacts of the tax depend significantly on how this revenue is recycled to the private sector. Under our central case simulations (which do not account for beneficial environmental impacts) over the period 2013–2040, the tax reduces GDP by .56 percent when revenues are returned through lump-sum rebates to households, as compared with .33 and .24 percent when the revenues are recycled through reductions in personal and corporate tax rates, respectively. Introducing tradable exemptions to the carbon tax reduces or eliminates the negative impacts on the profits of the most vulnerable carbon-supplying or carbon-using industries. The GDP and welfare impacts are somewhat larger when such exemptions are introduced.

Key Words: carbon tax, tax reform, climate

JEL Classification Numbers: Q50, Q58, H23

Contents

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Lawrence H. Goulder and Marc A.C. Hafstead*

1. Introduction

Carbon taxes address the externality represented by the contribution of carbon dioxide (CO_2) emissions to global climate change. In addition to yielding environmental benefits, carbon taxes generate revenues that can be put to useful purposes. The revenues can finance reductions in current distortionary taxes and/or reduce the federal deficit.

This report assesses the economic impacts of a U.S. carbon tax under alternative methods of recycling the tax revenues. These impacts stem from policy simulations from the Goulder–Hafstead Energy-Environment-Economy (E3) computable general equilibrium model of the U.S. economy. The model simulates a range of revenue-neutral carbon tax policies, including policies in which the revenues are used to finance reductions in personal and corporate income taxes. The policy outcomes considered include effects on welfare (according to the equivalent variation measure), gross domestic product (GDP), consumption, and investment, as well as on industry profits and prices.

2. The Numerical Model

The E3 model is an intertemporal general equilibrium model of the U.S. economy with international trade. Agents of the model include producers of goods and services, an infinitely lived representative household, and a representative federal-state-local government. A complete description of the model is in Goulder and Hafstead (2013).

The model's features are particularly well suited to an analysis of alternative methods for recycling revenue generated by a tax on CO_2. First, it contains a detailed representation of domestic energy production and demand. This is important for gauging both the industry-specific and aggregate impacts of a tax on CO_2. Table 1 indicates the 24 industry classifications in the model. Electricity produced by natural gas–fired generators represents over 95 percent of total

* Goulder, Standford University and Resources for the Future; Hafstead, Resources for the Future.

generation within the "other fossil electricity generation" category. Nonfossil generation includes generation from solar, wind, geothermal, and hydroelectric power.

Another key feature is the model's realistic treatment of the U.S. tax system. Specifics of the tax system are important for capturing the interaction of the tax system and environmental policies, and they provide several avenues through which policy-generated revenues can be recycled back to the agents of the model.

3. Data and Parameters

3.1 Data

The model splits industrial production into 24 sectors, including 8 sectors that produce energy-related goods.[1] Industry input and output flows were obtained primarily from the 2010 input-output tables from the U.S. Department of Commerce's Bureau of Economic Analysis (BEA). These tables were also the source for consumption, investment, government spending, employment, import, and export values by industry. Data on capital stocks by industry derive from BEA tables on the net stock of structures and equipment for each industry.[2]

3.2 Parameters

3.2.1 Production Parameters

The model employs production function elasticities of substitution derived from estimates in Jorgenson and Wilcoxen (1996). We translate the Jorgenson–Wilcoxen estimates of parameters for translog cost functions into elasticities of substitution parameters to make them compatible with the Constant Elasticity of Substitution (CES) form of our model. The capital adjustment cost parameters are based on Summers (1981).[3] For the retail sector that purchases

[1] The energy industries are oil and gas extraction, coal mining, natural gas distribution, petroleum refining, and the electricity sector. The electricity sector is divided into four industries: a retail electricity sector that sells electricity to consumers (industrial, commercial, and residential) and three types of wholesale electricity generators that sell their electricity to the retail electricity sector. Wholesale electricity generators are divided into coal-fired electricity generators, other fossil electricity generators, and nonfossil electricity generators.

[2] Readers may refer to Goulder and Hafstead (2013) for a complete description of the data and the aggregation/disaggregation process.

[3] Goulder, Houde, and Timmins are currently in the process of jointly estimating the elasticities of substitution and the level of capital adjustment costs.

electricity from the three distinct wholesale parameters, we impose an elasticity of substitution of 3, recognizing that because of geographic disparities in sources of electricity perfect substitution cannot occur between electricity generators across the country.

3.2.2 Household Parameters

The elasticity of substitution in consumption between goods and leisure is set to yield a compensated elasticity of labor supply of 0.4.[4] The intertemporal elasticity of substitution in consumption equals 0.5.[5] The leisure intensity parameter is set to generate a ratio of labor time to the total time endowment equal to 0.44. These parameters imply a value of 0.19 for the interest elasticity of savings between the current period and the next.

3.2.3 Emissions Parameters

CO_2 emissions coefficients are set to match the distribution of emissions from energy consumption by source in 2010 (Table 2). The emissions coefficients (or "carbon coefficients") indicate the emissions of CO_2 associated with the use of fossil fuels. Due to differences between the aggregation of reported emissions sources by end-user (electric power, transportation, commercial, residential, and transportation) and the industrial aggregation of our model, we make the following assumptions: (a) the coal coefficient for all industries except coal-fired electricity generators is equal, and (b) the oil coefficients for all industries except petroleum refining, other fossil electricity generation, and natural gas distribution are equal. Importantly, we assume that the carbon coefficients converting inputs of the backstop technology for the oil and gas sector into emissions are the same as the carbon coefficients for the oil and gas sector.

3.2.4 Tax Parameters

Marginal income tax rates in the model are taken from the TAXSIM model (of the National Bureau of Economic Research) for 2010. The rates are the sum of federal and state dollar-weighted average marginal income tax rates. The rates are 0.2582, 0.2806, 0.2344, and 0.1949 for labor income, interest income, dividend income, and long-term capital gains.[6] The

[4] This lies in the middle of the range of estimates displayed in the survey by Russek (1996).

[5] This value falls between the lower estimates from time-series analyses (e.g., Hall (1988) and the higher ones from cross-sectional studies (e.g., Lawrance (1991).

[6] The dividend income marginal tax rate is a 50-50 weighted average of the ordinary and qualified dividend tax rates.

corporate tax rate is 0.46, equal to the federal rate of 0.35 plus a weighted average of 2010 state rates equal to 0.11.

4. The Baseline (Reference Case)

Our reference case simulation assumes business-as-usual conditions and yields outcomes against which we compare the impact of policy shocks. In the reference case (and in most of the policy cases we consider), the real price of oil and gas is specified as increasing by a fixed amount—$1.92 in 2010 prices—each year. This increment is 2.41 percent of the 2010 price. This estimate approximately matches the reference case projections of oil prices from the U.S. Energy Information Administration's 2011 *Annual Energy Outlook*. A "backstop technology" for the oil and gas extraction industry is introduced beginning in the year 2020. The backstop is a perfect substitute for output from the oil and gas industry. Because the real price of oil and gas grows over time, eventually the backstop technology replaces imported oil as the marginal source of supply. In the reference case, this occurs in the year 2040.

In the model, technological change is labor-augmenting (Harrod-neutral). The rate of technological change is exogenous and constant at a rate of one percent.[7]

Table 1 shows the levels of real output of each industry in the reference case in 2013, in billions of 2012 dollars and as a percentage of the economy-wide total. Figure 1 displays the time profile for total CO_2 emissions from energy consumption over the interval 2013–2050. Figure 2 displays the reference case time profiles of GDP, consumption, investment, and government spending (federal, state, and local combined).[8]

[7] This contrasts with models that allow for policy-induced technological change. The direction of the bias from our purely exogenous treatment of technological change is an empirical matter. To the extent that a carbon tax generates investments in R&D with a social rate of return exceeding the market return, our estimates of the costs of a carbon tax will be biased upward.

[8] The model yields trade balance in each period. An exchange rate variable adjusts so that the value of exports equals the value of imports.

5. Carbon Taxes and Tax Reform

5.1 Defining the Carbon Tax

In the model, carbon tax policies are defined by (a) the tax time profile, (b) the point of regulation, (c) the scope of sectoral coverage, (d) the method of revenue recycling, and (e) the level of tax exemptions. In the simulations here, we consider policies that differ in terms of the method of revenue recycling and the level of tax exemptions.

The carbon tax is introduced in 2013. The units of the tax are dollars per ton of carbon dioxide equivalent. For our central case, the tax rate is initially $10 (in 2012 dollars). It rises at a rate of 5 percent per annum until 2040, after which the tax rate remains $37.37 (in 2012 dollars).[9] The point of regulation in the central case carbon tax is the industrial user's gate. Industrial users face a tax on the fossil fuel input according to the CO_2 emissions that will be released from the burning of said fossil fuel by the industrial user (or the users' customers). The industry coverage of the policy is set to cover all industrial users of fossil fuels. The resulting policy covers all but 0.02 percent of all emissions in 2013. The only emissions not covered by this policy are those resulting from the direct burning of coal and coal-related products by households. Figure 3 displays the time profile of the central case carbon tax.

By considering alternative uses of the revenues from the carbon tax, we investigate the role the carbon tax policy can play in tax reform. We focus on four types of revenue recycling: (a) lump-sum rebates, (b) cuts in personal income taxes (both wage income and capital income), (c) corporate income tax cuts, and (d) a combination of (b) and (c).

In exploring alternative recycling approaches, one must distinguish between gross and net revenue. The carbon tax's gross revenue is the aggregate value of the carbon tax payments by producers. The revenue available for recycling to households falls short of this gross revenue for two reasons. First, to the extent that the carbon tax reduces the level of economic activity, the tax base of other taxes declines, implying a reduction in revenues generated by these other taxes. In addition, the government's revenue needs are affected by the imposed condition that real government purchases and transfers remain the same as in the reference case. To the extent that

[9] We do not claim that the time-profile is optimal. Economic theory indicates that the optimal time profile involves a continually increasing tax rate. The overall rate of increase is equal to the sum of the market interest rate and the "removal" rate, where the latter is the rate at which carbon naturally decays from the atmosphere. See, for example, Nordhaus (1982).

the carbon tax leads to an increase in the overall price level, maintaining constant real government purchases requires additional revenues for these purchases, and nominal spending on transfers must increase as well.[10] We define the net revenue from a carbon tax policy as the gross revenue minus the revenue loss associated with the lowered tax base and minus any additional revenue needed to maintain constant government purchases and transfers. It is this net revenue that is returned to households (either as a lump sum or via reductions in tax rates) in our revenue-recycling experiments.

We also consider a policy in which firms in certain industries receive permits that exempt some emissions from the carbon tax. Each permit allows for the exemption of one ton of CO_2. The permits are allocated to the ten industries that would experience profit losses of at least one percent (relative to the reference case) in the previously described policy of a carbon tax with net revenues devoted to cuts in the personal income tax. Firms in some of these industries (e.g., the coal mining industry and the water utilities industry) pay no carbon taxes under the previous described policy since they do not purchase fossil fuels directly. However, they experience losses of profits as a result of the changes in price and demand occasioned by the carbon tax. For these firms the permits are valuable because we specify them as tradable.

Under this additional policy, emissions permits with a value representing 15 percent of the potential net carbon tax revenue (the revenue that would apply if no permits were issued) are given out each year. The permits are allocated to the ten industries in proportion to the profit losses under the previously described policy. The remainder of the carbon tax revenue is used to finance marginal tax rate cuts in personal income taxes. Table 3 displays the level of exemptions as a percent of annual aggregate emissions as well as the value of exemptions in 2020 and 2040.

5.2 CO_2 Emissions and Carbon Tax Revenue

Figure 4a displays the time profile for CO_2 emissions in the baseline and under the central case carbon tax, when the carbon tax revenues are recycled as lump-sum rebates (and

[10] Social Security payments are an example of transfers that are tied to changes in the price level.

where there are no exemptions).[11] In the first year of the policy, emissions fall approximately 9.2 percent relative to 2012 emissions. The time profile features declining CO_2 emissions until 2040. In 2040, emissions are 72.3 percent of 2012 emissions. Starting in that year, the carbon tax rate is kept constant. Consequently, emissions begin to grow, consistent with the continued growth of the economy. Cumulatively, emissions are reduced by 20.9 billion tons CO_2 from 2013 to 2040, a 35 percent reduction relative to cumulative emissions in the baseline over the same time period.

Figure 4b displays the time profile of gross and net revenue in the central case carbon tax with lump-sum rebates and zero exemptions. In 2013, gross revenue from the carbon tax is approximately $50 billion (2012$), and the level of annual gross revenue rises to approximately $151 billion (2012$) in 2040. For comparison, the level of federal nondefense consumption expenditures was $356 billion in 2012. Net revenue, the amount that is refunded to the household, is considerably lower, as indicted in the figure.

5.3 Carbon Tax Impacts under Alternative Recycling Approaches

5.3.1 Financing Rate Cuts

In the simulations involving cuts in marginal tax rates, the net revenues are used to finance permanent reductions in the marginal rates such that, in present value, the revenue loss from these reductions equals the present value of the net revenue from the carbon tax.[12] Table 4 indicates the original tax rates as well as the lowered rates that apply in the different cases. The numbers in parentheses indicate the size of the rate reduction, in percentage points.

5.3.2 GDP and Welfare Costs

Figure 5 shows the impacts on GDP, consumption, and investment for the policies involving recycling via lump-sum rebates, cuts in personal income tax rates, and cuts in corporate income tax rates. Note that these impacts do not account for the beneficial impacts to the economy from avoided climate change.

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[11] The emissions time profile is similar under the other recycling cases. For example, in 2030, emissions in the lump-sum recycling case are reduced by 21.6 percent relative to 2012 emissions. By comparison, the emissions reductions in that year are 21.5, 21.2, 21.5, and 21.4 percent in the cases involving personal tax cuts, corporate tax cuts, a combination of personal and corporate tax cuts, and personal tax cuts with carbon tax exemptions, respectively. Emissions are slightly higher (and emissions reductions slightly smaller) when revenues are used to finance rate cuts because lower tax rates lead to greater economic activity.

[12] The present value calculations are over the finite time horizon 2013–2040.

Figure 5a indicates that the GDP costs expand over time, in keeping with the rising carbon tax rate. With lump-sum rebates, the initial GDP cost in 2013 is 0.15 percent of the reference case GDP. The GDP costs level off starting around 2040, when the carbon tax rate becomes constant. In the very long run (steady state) the GDP cost is 1.5 percent of the long-run GDP in the reference case.

Figure 5a shows that the GDP cost depends importantly on the type of revenue recycling. The distortionary cost or excess burden of taxes is a function of marginal tax rates. When carbon tax revenues are devoted to marginal rate cuts, some of this distortionary cost is avoided. This benefit is not enjoyed when revenues are recycled through lump-sum rebates. The results in Figure 5a show that using the revenues to finance cuts in marginal tax rates significantly reduces the costs relative to the case in which revenues are recycled through lump-sum rebates. In the year 2030, for example, the GDP cost under personal and corporate tax rate recycling is 40 and 67 percent smaller, respectively, than under lump-sum recycling. In the model, the marginal excess burdens of the personal and corporate tax are $0.17 and $0.77, respectively.[13] Because the corporate tax is more distortionary (has a larger marginal excess burden) than the personal tax, it produces larger cost savings when carbon tax revenues are devoted to cutting the marginal rates of this tax.

Figures 5b and 5c reveal the impacts on consumption and investment. These time profiles have a shape similar to that of the time profile of GDP impacts. Again the impacts expand over time and begin to level off when the carbon tax rate stops rising.

Table 5 provides further information on the policy costs. The top panel expresses the GDP costs as a percentage of baseline GDP and per ton of CO_2 reduced. The bottom panel shows the aggregate welfare cost, as measured by the equivalent variation measure. As with GDP, welfare costs are considerably smaller when revenues are recycled via cuts in marginal rates.[14] Using revenues from a carbon tax to reduce marginal personal income tax rates reduces the welfare cost of the cap and trade by 26.2 percent, but using the revenues to cut marginal corporate tax rates reduces the welfare cost by over 55 percent.

[13] Marginal excess burden is defined as the welfare costs per marginal dollar of gross revenue (personal or corporate income) raised over the period 2013–2040.

[14] Gross domestic product costs are measured over the time horizon 2013–2040. The welfare costs are measured over an infinite horizon.

5.4 Industry Impacts

5.4.1 Profits

Table 6 displays the impacts on profits. First consider the recycling approaches other than the one involving tradable exemptions to the carbon tax. The most significant losses are experienced by the coal mining industry and the coal-fired electricity generators. This is in keeping with the high carbon intensity of these industries. Although the coal mining industry does not directly pay the carbon tax, it bears a significant burden from the tax as a result of the policy-induced reduction in demand for coal. Significant profit losses also occur in the retail electricity and petroleum refining industries, which rely significantly on carbon-intensive fuels. Our simulations indicate that “other fossil” (principally natural gas) and nonfossil generators enjoy higher profits as a result of the carbon tax. The tax raises coal prices considerably more than the price of natural gas, leading to substitutions of natural gas for coal by utilities. The increased demand helps boost profits and more than offsets the adverse impact associated with the higher natural gas prices induced by the carbon tax.

Introducing tradable exemptions to the carbon tax significantly alters the pattern of profit impacts. By design, exemptions are offered only to the ten industries that would suffer the greatest profit losses. In these industries, the losses of profit are reduced considerably. In fact, industries that receive exemptions enjoy higher profits under this policy than under the one in which carbon tax revenues are used to finance cuts in corporate income tax rates.

5.4.2 Prices

Table 7 displays the impacts on producers’ output prices. For producers that rely significantly on fossil fuels, the price changes reflect the higher costs of production associated with the carbon tax that applies to fuel inputs.[15] The figures in the table are percentage changes from the reference case for the years 2020 and 2035. The price impacts are largest for the coal-fired generation, other fossil (principally natural gas) generation, and electricity transmission/distribution industries—industries that rely significantly on fuel inputs. The higher fuel costs prompt reductions in demands for fossil fuels (especially coal), leading to reduced producer prices for coal. As indicated in the table, electricity prices paid by consumers rise by about 6 percent relative to baseline in 2020, and by about 13 percent in the longer run. Retail

[15] The price paid by industries for oil and gas or coal is equal to the producer price plus the carbon tax.

prices of gasoline (not shown in the table) rise by about 4 percent in 2020 and 8 percent in the long run.

5.5 Sensitivity Analysis

Table 8 shows results from an alternative policy design in which the carbon tax rate is a constant $30 per ton from the start. This is the same as the central case carbon tax rate employed in the model developed by Jared Carbone and Roberton Williams III. The table also displays outcomes under different values for the elasticity of labor supply (ε_{ls}).

Compared with our previously described policies, the policy involving a constant carbon tax leads to larger emissions reductions in the short term and smaller reductions in the longer term, and yields larger overall cumulative reductions over the time period 2013–2040. As a result, overall GDP costs (measured over the time period 2013–2040) are somewhat higher. However, the welfare costs (measured over the infinite horizon) are lower because the carbon tax is lower in the long run ($30, as compared with $37.4 in our central case). Additionally, the revenue raised from such a carbon tax is much greater than in our central case. As a result, the opportunity to reduce welfare losses using personal income tax reductions is greater. In this case, using revenues to cut personal income taxes reduces the welfare loss by 54.8 percent, nearly double the offset (26.5 percent) that applies under the central-case carbon tax profile.

A higher (lower) value for the consumption-leisure elasticity implies a higher labor supply elasticity, which in turn implies that the carbon tax will cause greater (smaller) distortions in the labor-leisure choice. Thus, increasing (lowering) the elasticity of labor supply from its central case value of 0.4 implies larger (smaller) GDP and welfare costs.

The far-right column of the table shows results when gross, rather than net, revenues from the carbon tax are used to finance personal tax cuts. Because this policy allows for larger marginal rate cuts than in the case involving net revenues, the GDP and welfare costs are substantially different. In this policy, welfare costs are significantly reduced and GDP costs are eliminated almost completely.[16]

[16] When the tax cuts are financed through gross carbon tax revenues, preserving revenue neutrality requires additional revenues from some other source since, in this case, the *net* revenues from the carbon tax fall short of the revenue loss associated with the cuts in personal income tax rates. To maintain revenue neutrality, in this policy simulation, the needed additional revenues are obtained through lump-sum increases in personal taxes. If the needed revenue were obtained through increased distortionary taxes, the policy costs would be higher than those reported here.

6. Conclusion

A carbon tax can contribute to tax reform by financing cuts in existing taxes. Using a numerical general equilibrium model with detail on the energy and tax systems, we consider the impacts of several types of tax reductions that can be financed through the carbon tax.

We focus on a carbon tax introduced at a rate of $10 per ton in 2013 and increasing by 5 percent per year until it reaches a terminal price of $37.37 per ton in 2040. The gross revenues from this tax are substantial. By 2020, they amount to about $67 billion (2012$). The carbon tax reduces the tax revenue that is generated by other, existing taxes. In order to maintain constant government expenditures in real terms, some additional revenues need to be devoted to higher nominal government spending to compensate for increases in the price level. Hence, net revenues – the revenues that can be devoted to cuts in pre-existing personal or corporate taxes – are considerably lower than the carbon tax's gross revenues.

Over the interval 2013–2040, the present value of the GDP costs of the revenue-neutral carbon tax ranges from 0.24 to 0.56 percent of GDP. Recycling the net revenues through marginal rate cuts lowers significantly the costs of the carbon tax relative to the costs when revenues are returned through lump-sum rebates. Compared with lump-sum recycling, the GDP costs are 42 percent lower when revenues are recycled via cuts in personal income tax rate, and 58 percent lower when revenues are recycled through cuts in the corporate income tax rate.

There is considerable variation in the costs of revenue-neutral carbon taxes across industries. Under policies that do not include carbon tax exemptions, coal-fired generators experience significant profit losses, while natural gas-fired generators are likely to enjoy a boost in profits, a reflection of substitutions of natural gas for coal. Introducing tradable exemptions to the carbon tax reduces or eliminates the negative impacts on profits in the most vulnerable carbon-supplying or carbon-using industries. However, exemptions lower the cost-effectiveness of revenue recycling by reducing the level of revenue that can be used to finance marginal rate cuts.

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Tables and Figures

See following pages.

Table 1. Output in 2013 by Industry in Reference Case

Industry	Output[a]	Pct. of Total Output
Coal-Fired Electricity Generation	104.4	0.3
Other Fossil Electricity Generation	60.2	0.2
Nonfossil Electricity Generation	66.9	0.2
Electric Transmission/Distribution (Retail)	459.9	1.2
Oil and Gas Extraction	283.9	0.7
Coal Mining	82.9	0.2
Natural Gas Distribution	151.1	0.4
Petroleum Refining	597.9	1.5
Agriculture and Forestry	528.5	1.4
Noncoal Mining	72.6	0.2
Water Utilities	50.7	0.1
Construction	5,552.9	14.4
Food, Tobacco, and Beverages	1,011.6	2.6
Textiles	194.7	0.5
Wood and Paper Products	475.9	1.2
Chemicals and Misc. Nonmetal Products	1,592.8	4.1
Primary Metals	325.0	0.8
Machinery	2,343.3	6.1
Motor Vehicle Production	750.6	1.9
Transportation	838.1	2.2
Railroads	149.2	0.4
Information and Communication	1,156.6	3.0
Services	16,656.1	43.1
Owner-Occupied Housing	5,128.2	13.3

[a] In billions of 2012 dollars.

Table 2. Emissions by Fuel and Source

	Source				
Fuel	Electric Power	Transportation	Residential	Commercial	Industrial
Coal	1,828	0	1	6	154
Natural Gas	399	38	259	168	401
Motor Gasoline	0	1,124	0	4	19
Other Petroleum	33	712	78	45	333

Note: Emissions in millions of tons of carbon dioxide (U.S. Energy Information Administration, 2012).

Figure 1. Reference Case CO_2 Emissions, 2013–2050

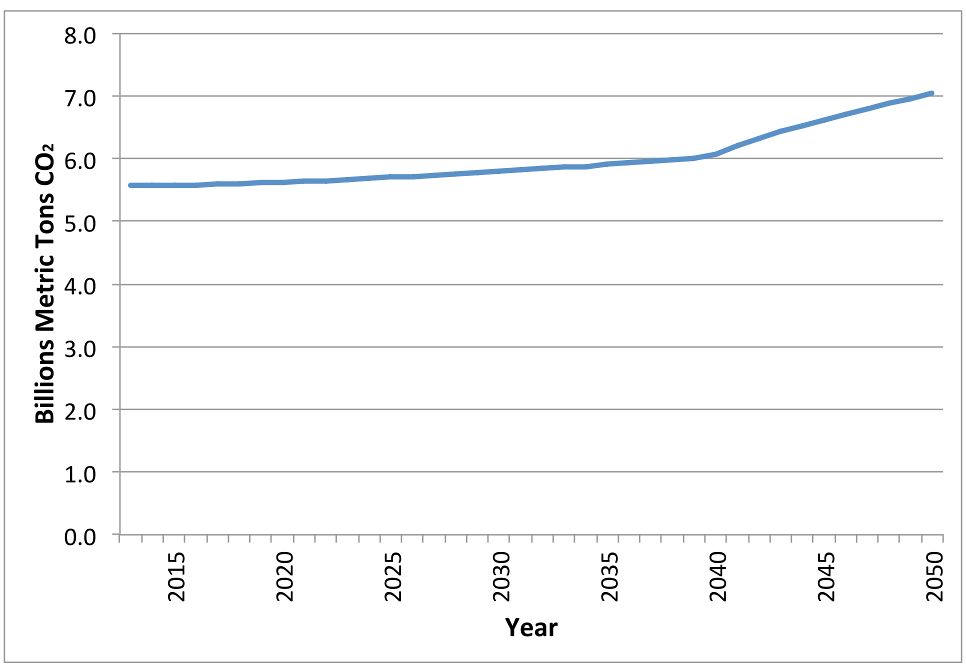


Figure 2. Reference Case GDP and Components

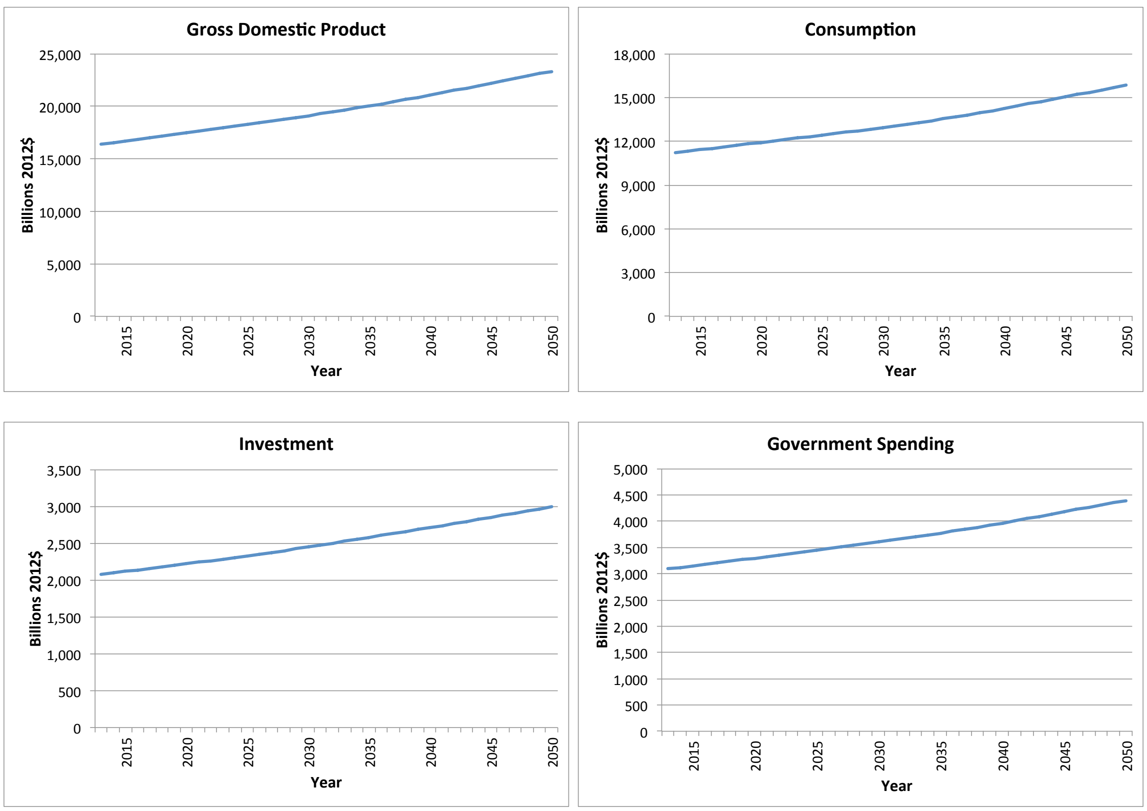


Figure 3. Carbon Tax ($/ton CO_2) Time Profile

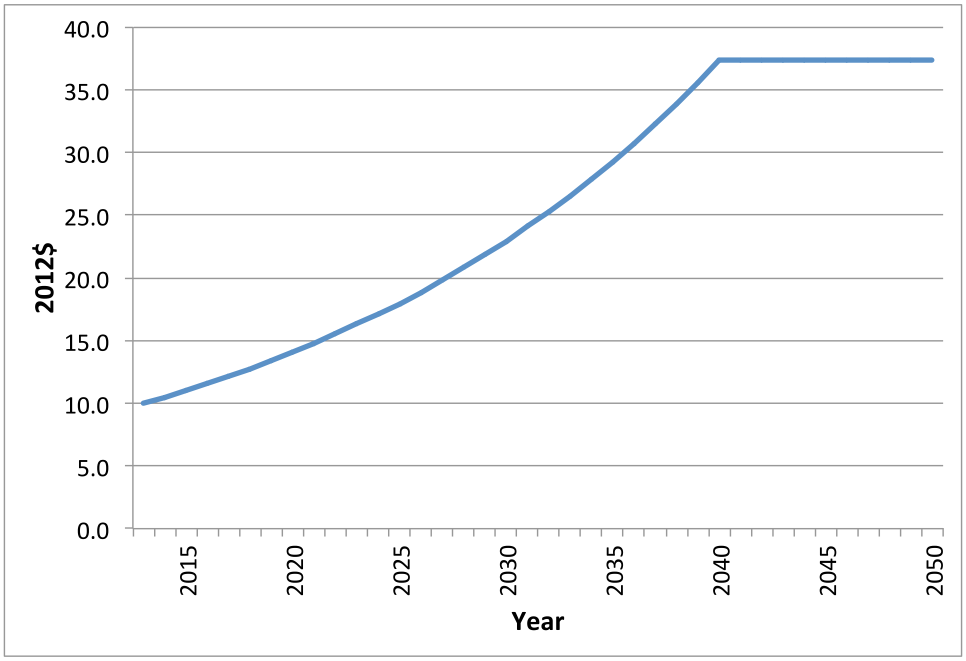


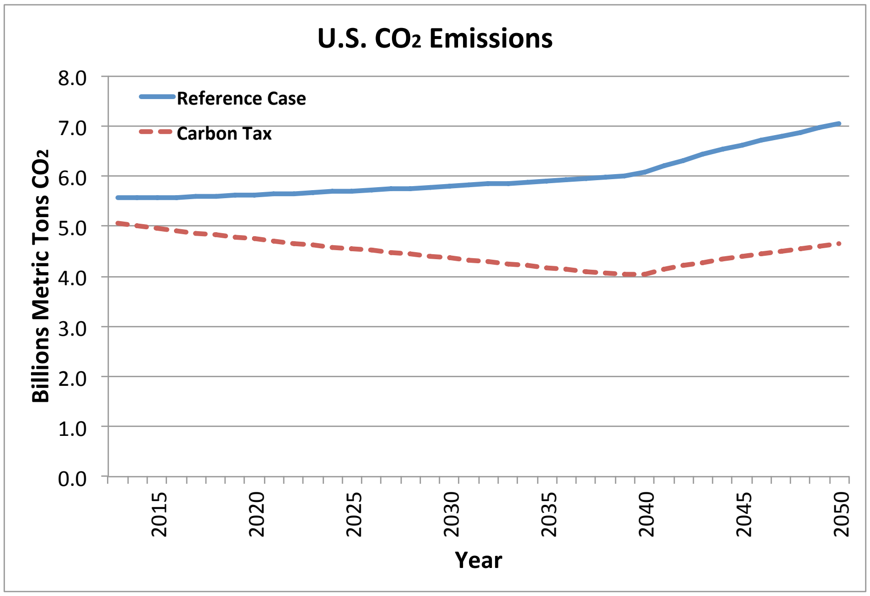
Table 3. Tradable Carbon Tax Exemptions by Industry

Industry	Total Exemptions[a]	Value of Exemptions[b] 2020	Value of Exemptions[b] 2040
Coal-Fired Electricity Generation	5.2	3.14	6.91
Coal Mining	3.5	2.13	4.68
Electric Transmission/Distribution (Retail)	2.7	1.64	3.60
Railroads	0.9	0.54	1.19
Natural Gas Distribution	0.8	0.50	1.10
Chemicals and Misc. Nonmetal Products	0.7	0.44	0.96
Petroleum Refining	0.5	0.29	0.64
Primary Metals	0.3	0.19	0.42
Noncoal Mining	0.1	0.09	0.19
Water Utilities	0.1	0.05	0.11

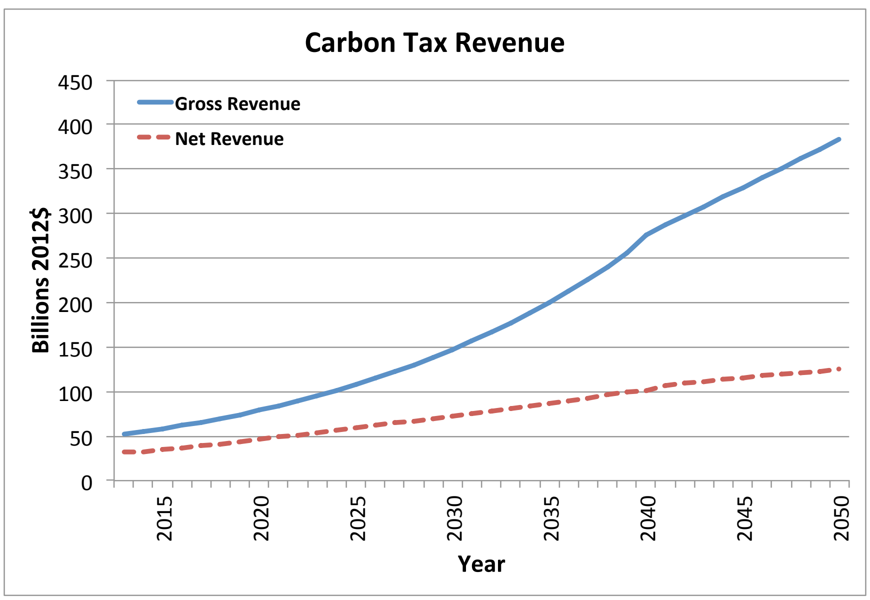
[a] Measured as a percentage of annual aggregate emissions.

[b] In billions of 2012 dollars.

Figure 4. Emissions and Revenue Time Profiles



(a)



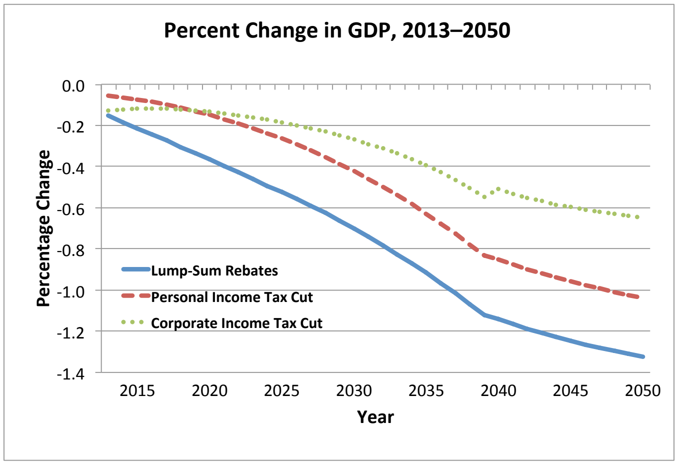
(b)

Table 4. Carbon Tax Revenue and Tax Rate Cuts

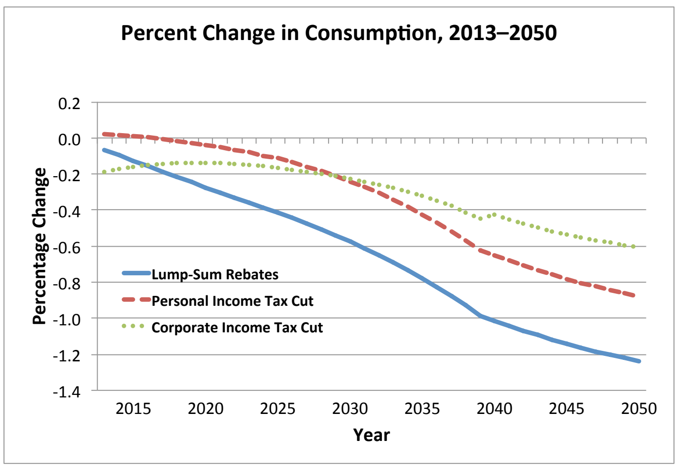
Marginal Tax Rates	*Lump-Sum Rebates*	*Personal Income Tax Cuts*	*Corporate Income Tax Cuts*	*Personal and Corporate Income Tax Cuts*	*Personal Income Tax Cuts w/ Carbon Tax Exemptions*
Labor	25.82	25.46 (–0.36)	25.82	25.58 (–0.24)	25.55 (–0.27)
Dividends	23.44	23.11 (– 0.33)	23.44	23.22 (–0.22)	23.20 (–0.24)
Interest	28.06	27.67 (–0.39)	28.06	27.80 (–0.26)	27.77 (–0.29)
Capital Gains	19.49	19.22 (–0.27)	19.49	19.31 (–0.18)	19.29 (–0.20)
Corporate	46.00	46.00	44.71 (–1.29)	45.57 (–0.43)	46.00

Note: Number in parentheses represents percentage point change in tax rates from baseline.

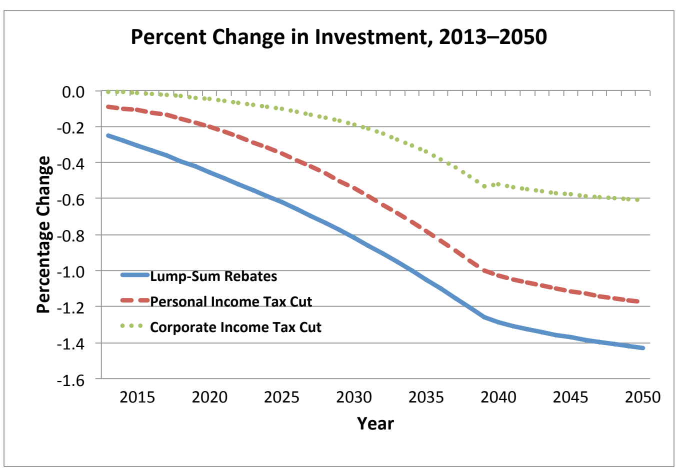
Figure 5. Impacts on GDP, Consumption, and Investment



(a)



(b)



(c)

Table 5. GDP and Welfare Costs
under Alternative Revenue-Recycling Methods

	Lump-Sum Rebates	*Personal Income Tax Cuts*	*Corporate Income Tax Cuts*	*Personal and Corporate Income Tax Cuts*	*Personal Income Tax Cuts w/ Tradable Exemptions*[a]
GDP					
GDP Costs[b]					
- as Pct of Baseline GDP	0.564	0.329	0.236	0.295	0.403
- per Ton of CO_2 Reduced[c]	\$97.79	\$57.68	\$41.77	\$51.79	\$70.79
Welfare					
EV (2012\$ Billions)	–\$4095.5	–\$3024.2	–\$1835.2	–\$2618.2	–\$3254.4
- as Pct of Wealth	–0.39	–0.28	–0.17	–0.25	–0.31
- per Dollar Gross Revenue[d]	–\$0.73	–\$0.53	–\$0.32	–\$0.46	–\$0.61
- per Ton of CO_2 Reduced[c]	–\$52.47	–\$39.02	–\$24.09	–\$33.96	–\$42.07

Note: EV = equivalent variation.

[a] Total annual exemptions equal to 15 percent of annual aggregate emissions.

[b] GDP costs measured as present value of real GDP loss, 2013 – 2040.

[c] Cumulative tons reduced, discounted at reference case real interest rate.

[d] Present value of gross revenue, 2012$.

Table 6. Percentage Change in Present Value of Profits, 2013–2040

Industry	*Lump-Sum Rebates*	*Personal Income Tax Cuts*	*Corporate Income Tax Cuts*	*Personal and Corporate Income Tax Cuts*	*Personal Income Tax Cuts w/ Tradable Exemptions*[a]
Coal-Fired Electricity Generation	–25.9	–25.7	–24.7	–25.4	–7.0
Coal Mining	–26.7	–26.7	–25.5	–26.3	–7.3
Electric Transmission/Distribution (Retail)	–5.0	–4.7	–3.6	–4.4	–1.1
Railroads	–1.8	–1.8	–0.3	–1.3	–0.4
Natural Gas Distribution	–2.6	–2.4	–1.2	–2.0	–0.5
Chemicals and Misc. Nonmetal Products	–1.2	–1.1	0.2	–0.7	–0.2
Petroleum Refining	–3.6	–3.6	–2.1	–3.1	–0.9
Primary Metals	–1.9	–1.9	–0.5	–1.4	–0.5
Noncoal Mining	–1.1	–1.1	0.6	–0.5	–0.3
Water Utilities	–4.0	–3.7	–2.7	–3.3	–0.8
Other Fossil Electricity Generation	12.4	12.7	14.2	13.2	12.7
Nonfossil Electricity Generation	32.4	32.7	34.7	33.4	32.5
Oil and Gas Extraction	0.5	0.2	2.6	1.0	0.3
All Industries Above[b]	–2.4	–2.3	–0.9	–1.9	–0.0
Other Industries[b]	–0.3	–0.2	0.8	0.1	–0.2
All Industries[b]	–0.6	–0.5	0.6	–0.1	–0.2

[a] Total annual exemptions equal to 15 percent of annual aggregate emissions.

[b] Weighted average (2010 output).

Table 7. Impacts on Producer Prices
Percentage Change from Reference Case

	2020		2035	
	Lump-Sum Rebates	*Personal Income Tax Cuts*	*Lump-Sum Rebates*	*Personal Income Tax Cuts*
Coal-Fired Electricity Generation	20.03	20.16	52.44	52.26
Coal Mining	–1.89	–1.82	–0.16	–0.22
Electric Transmission/Distribution (Retail)	6.14	6.24	13.29	13.12
Railroads	–0.33	-0.25	0.47	0.36
Natural Gas Distribution	3.83	3.92	9.21	9.04
Chemicals and Misc. Nonmetal Products	0.73	0.79	1.92	1.85
Petroleum Refining	4.36	4.42	8.43	8.24
Primary Metals	0.75	0.81	2.39	2.32
Noncoal Mining	0.52	0.58	1.80	1.72
Water Utilities	0.29	0.37	1.21	1.14
Other Fossil Electricity Generation	10.57	10.67	20.24	20.04
Nonfossil Electricity Generation	7.14	7.24	7.17	6.92
Oil and Gas Extraction	0.53	0.58	0.28	0.05
All Industries Above [a]	2.65	2.72	5.85	5.71
Other Industries[a]	0.16	0.21	0.64	0.59
All Industries (PPI)	0.43	0.49	1.26	1.20
Price of Consumption Bundle	0.35	0.41	1.05	1.00

Note: PPI = Laspeyres producer price index.
[a] Weighted average (2010 output).

Table 8. Sensitivity Analysis

	Central Case		Constant Carbon Tax[a]		$\varepsilon_{ls} = 0.3$		$\varepsilon_{ls} = 0.5$		*Personal Income Tax Cuts Financed with Gross Revenue*
	Lump-Sum Rebates	*Personal Income Tax Cuts*	*Lump-Sum Rebates*	*Personal Income Tax Cuts*	*Lump-Sum Rebates*	*Personal Income Tax Cuts*	*Lump-Sum Rebates*	*Personal Income Tax Cuts*	
Emissions									
Emissions Reductions[b]									
- 2020	14.7	14.6	24.1	23.8	14.7	14.6	14.8	14.7	14.3
- 2040	27.2	26.9	24.2	23.6	27.0	26.8	27.3	27.0	26.5
Cumulative Reductions[c]									
- as Pct of Baseline	35.0	34.8	45.2	44.9	35.0	34.8	35.0	34.8	34.5
Revenue									
Gross Revenue[d]	\$1,700.5	\$1,704.6	\$2,519.7	\$2,533.5	\$1,702.0	\$1,705.6	\$1,698.9	\$1,703.2	\$1,711.6
GDP Costs[e]									
- as Pct of Baseline GDP	0.56	0.33	0.79	0.25	0.54	0.34	0.59	0.38	0.03
- per Ton CO_2 Reduced[f]	\$97.79	\$57.68	\$104.99	\$33.13	\$93.22	\$59.28	\$103.12	\$65.64	\$4.49
Welfare Costs									
EV (2012\$ Billions)	–\$4095.5	–\$3024.2	–\$3919.2	–\$1771.7	–\$3831.9	–\$2870.1	–\$4310.6	–\$3121.4	–\$1230.6
- as Pct of Wealth	–0.39	–0.28	–0.37	–0.17	–0.36	–0.27	–0.41	–0.29	–0.12
- per Dollar Gross Revenue	–\$0.73	–\$0.53	–\$0.67	–\$0.30	–\$0.68	–\$0.50	–\$0.77	–\$0.54	–\$0.21
- per Ton CO_2 Reduced[f]	–\$52.47	–\$39.02	–\$49.18	–\$22.55	–\$49.15	–\$37.05	–\$55.19	–\$40.28	–\$16.09

Note: EV = equivalent variation.

[a] \$30/ton CO_2 (2012\$) in every period.

[b] Percentage Reduction from 2012 Emissions.

[c] Annual emissions reductions, 2013–2040.

[d] Present value of real gross revenue, 2013–2040, 2012\$ billions.

[e] GDP costs measured as present value of real 2012\$ GDP loss, 2013–2040.

[f] Cumulative tons reduced, discounted at reference case real discount rate.