Carbon regulations vs. a carbon tax: A comparison of the macroeconomic impacts

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Executive summary

This report compares the economic impact of replacing a fully implemented version of existing US carbon emission regulations with a carbon tax. The regulatory approach would reduce carbon emissions 22% relative to a baseline that includes no carbon emissions policies. The report finds that placing a uniform price on carbon emissions is a less costly means of achieving the same reduction in carbon emissions.

Specifically:

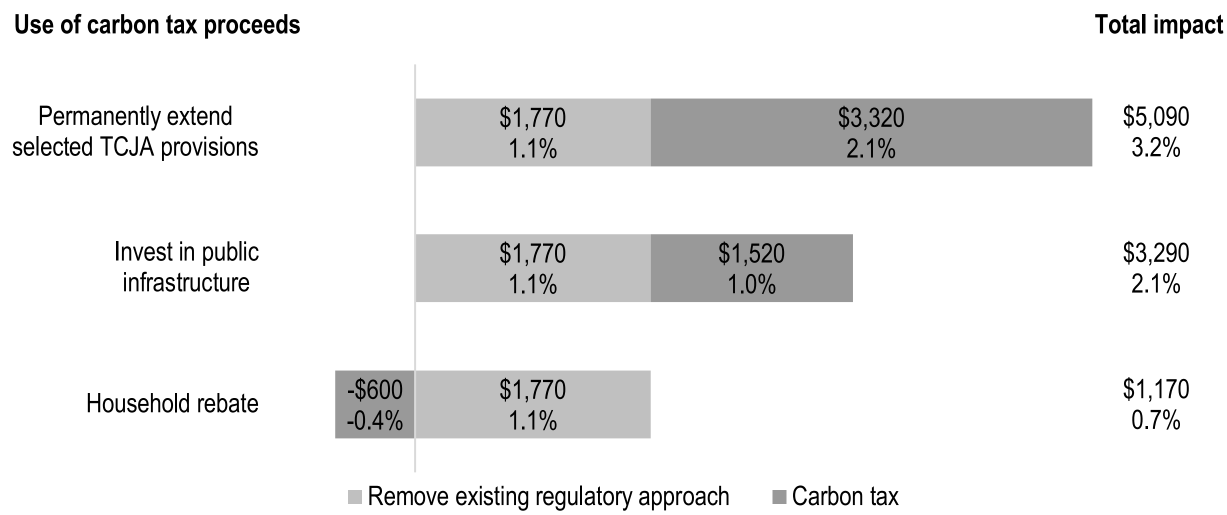
1. The existing regulatory approach is estimated to reduce gross domestic product (GDP) in the long-run by, on average, $1,770 per household annually.
2. A revenue-neutral carbon tax could increase GDP in the long-run by, on average, as much as $5,090 per household annually, relative to the existing regulatory approach.

A key determinant of the long-run economic impact of a carbon tax is the use of the revenue. This analysis estimates three alternatives:

1. Permanent extension of the Tax Cuts and Jobs Act (TCJA), which would produce the largest estimated GDP impact, a 3.2% increase in long-run GDP.
2. Investment in public infrastructure, which would yield an estimated 2.1% increase in long-run GDP.
3. Rebate to households, which would result in an estimated 0.7% increase in long-run GDP.

The total macroeconomic impact of each policy package computes the combined effect from (a) removing the existing regulatory approach (the lighter bar in Figure ES-1) and (b) imposing the carbon tax paired with one of the three specified revenue uses (the darker bar in Figure ES-1).

Figure ES-1. Long-run change in annual per-household GDP from emissions-equivalent carbon tax relative to existing regulatory approach, by use of carbon tax proceeds



Note: Economic impacts are scaled to the size of the 2018 US economy. The long-run is defined as when the US economy has fully adjusted to the change in policy. The estimated impacts from an increase in public infrastructure could differ depending on the details of a specific policy proposal but the stylized scenario modeled here assumes an increase in physical capital (e.g., highway spending). The provisions included in the permanent extension of selected TCJA provisions are the expiring individual income tax provisions and expensing of equipment investment. Figures are rounded.
Source: EY analysis.

Existing regulations targeting carbon abatement

To reduce carbon emissions, the United States relies primarily on regulations that target specific sectors or types of activities and that mandate the use of different technologies and processes. In one form or another, the regulatory approach places restrictions on or limits the choices of consumers and producers. This analysis includes a stylized modeling of the following regulations:

- **Corporate Average Fuel Economy (CAFE) standards.** CAFE standards require that a manufacturer's model year of vehicles meet a fleet-wide average fuel-efficiency level. CAFE standards apply to light-, medium-, and heavy-duty vehicles.
- **Clean Power Plan (CPP).** The CPP aims to reduce carbon emissions in the power sector. It requires that states choose one of three approaches: (1) a national emissions rate for each electricity-generating unit (in CO_2/MWh), (2) a state-specific emissions rate for the state's overall electricity portfolio (in CO_2/MWh), or (3) state-specific mass-based limits (in CO_2/year).
- **Renewable Fuel Standards (RFS).** The RFS require that motor fuel distributors include a specific percentage of renewable fuels in their total sales.
- **Appliance and equipment efficiency standards (AEES).** AEES regulate more than 60 categories of appliances and equipment in both the residential and commercial sectors. The program sets energy efficiency standards for appliances and equipment to reduce energy consumption.

While the CPP explicitly targets carbon emissions, CAFE standards, RFS, and AEES instead target reduced fossil fuel consumption, thus reducing carbon emissions indirectly. None of these regulations reflects a comprehensive, economy-wide approach to reducing carbon emissions.

Some of these policies are, to date, only partially implemented, and some may never go into effect. But, to fully capture the potential effect of the existing regulatory approach, this analysis models each policy and any recently planned expansion as if it were in full force. This report estimates that regulatory carbon controls, if fully phased in, would reduce carbon emissions by approximately 22%, while also reducing GDP in the long-run by 1.1%, or approximately $1,770 per household annually. More than 90% of this impact is attained within 10 years. These impacts are primarily driven by CAFE standards and the CPP.

Emissions-equivalent carbon tax

This analysis also models the impact of a carbon tax, a market-based alternative to the regulatory approach. The carbon tax is set to achieve the same absolute reduction in carbon emissions as the regulatory approach by imposing an economy-wide, uniform price on carbon emissions.[1]

[1] The long-run carbon price is $55/ton when the carbon tax revenue is used to fund the permanent extension of expiring individual income tax provisions in the TCJA and permanent 100% bonus depreciation. It is $52/ton when the carbon tax revenue is used to fund public infrastructure investment, and $48/ton when the carbon tax revenue is used to fund a household rebate. Generally, an increase in the size of the economy results in an increase in carbon emissions, so an increase associated with the use of carbon tax revenue then requires a higher carbon price to achieve the same amount of carbon emissions reduction as under the existing regulatory approach.

To illustrate the range of potential benefits associated with the use of revenue from the emissions-equivalent carbon tax, this analysis considers three alternatives:

1. *Permanent extension of expiring individual income tax provisions in the TCJA and permanent expensing of investment in equipment*. This use of carbon tax revenue would (1) increase the after-tax reward to work, resulting in higher real wages and/or increases in the US workforce, and (2) increase the after-tax return on savings and investment, which would encourage more capital investment and contribute to higher labor productivity.

2. *Investment in public infrastructure*. This use of carbon tax revenue would boost private-sector productivity and, consequently, increase private-sector output.

3. *Rebate to households.* This use of carbon tax revenue would, on average, offset the impact of the carbon tax on household incomes.

This report finds that, relative to the existing regulatory approach, a carbon tax with the same emissions reduction would increase annual GDP by $1,170–$5,090 per household in the long-run (depending on the use of the revenue, as seen in Figure ES-1).

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Carbon regulations vs. a carbon tax: A comparison of the macroeconomic impacts

I. Introduction

The United States relies primarily on an extensive set of rules and regulations to reduce CO_2 emissions. These rules and regulations typically target specific sectors or types of activities and mandate the use of particular technologies and processes or otherwise place restrictions on the choices of consumers and producers. This approach contrasts to the market-based approach of a carbon tax, which would place a uniform price on emitting CO_2 across the entire US economy. A uniform carbon price would leverage the knowledge and behavior of consumers and producers to find where it is least costly to reduce emissions, as compared to regulatory CO_2 controls that may be less flexible and can mandate more costly ways to reduce CO_2 emissions.

This report uses the EY General Equilibrium Model of the US Economy ("EY GE Model") to compare the economic impact of regulatory CO_2 controls with a revenue-neutral carbon tax that achieves the same reduction in CO_2 emissions. Specifically, the analysis separately models the economic impact of two alternative paths for CO_2 abatement: (1) a regulatory-focused CO_2 abatement approach that is a stylized representation of the regulatory abatement approach in the United States, and (2) an economy-wide, emissions-equivalent carbon tax with a carbon price set such that it achieves the same CO_2 reductions as the regulatory-focused CO_2 abatement approach.

To fully reflect a comprehensive, regulatory-focused CO_2 abatement approach, the stylized representation includes policies that may or may not go into effect (e.g., the Clean Power Plan). Additionally, the stylized representation of recent regulatory policies assumes that any future increases in the stringency of these recent regulatory policies are immediately in effect to highlight the difference in approach instead of policy timing.

This report finds that a revenue-neutral, emissions-equivalent carbon tax would reduce the same amount of CO_2 for significantly less cost in terms of gross domestic product (GDP) than regulatory CO_2 controls. That is, the results suggest that relying on the market-based approach of a revenue-neutral, emissions-equivalent carbon tax instead of regulatory CO_2 controls would result in a much more efficient and less costly reduction of CO_2 emissions with significant net benefits for the US economy depending on the use of the carbon tax revenues.

Regulatory CO_2 controls

The regulatory CO_2 controls analyzed by this report include the following rule-based policies:

- **Corporate Average Fuel Economy (CAFE) standards.** CAFE standards require that a manufacturer's model year of vehicles meet a fleet-wide average fuel efficiency level. CAFE standards apply to light-, medium-, and heavy-duty vehicles.
- **Clean Power Plan (CPP).** The CPP aims to reduce CO_2 emissions in the power sector. The CPP requires that states choose one of three approaches: (1) a national emissions

rate for each electricity-generating unit (in CO_2/MWh), (2) a state-specific emissions rate for the state's overall electricity portfolio (in CO_2/MWh), or (3) state-specific mass-based limits (in CO_2/year).

- **Renewable Fuel Standards (RFS).** The RFS require that motor fuel distributors include a specific percentage of renewable fuels in their total sales.
- **Appliance and equipment efficiency standards (AEES).** AEES regulate more than 60 categories of appliances and equipment in both the residential and commercial sectors. The program sets energy efficiency standards for appliances and equipment to reduce energy consumption.

While the CPP explicitly targets reduced CO_2 emissions, CAFE standards, RFS, and AEES instead target reduced fossil fuel consumption through greater fuel efficiency (CAFE), increased renewable fuel usage (RFS), and reduced energy consumption through greater energy efficiency (AEES). In this way, most of the regulatory-focused policies reduce CO_2 emissions by targeting economic activity related to CO_2 emissions rather than explicitly targeting emissions reductions or, as in the case of the CPP, include only a portion of CO_2-producing economic activity.

This report models the economic impact of these policies in their entirety. That is, while some of these policies are only partially implemented or may never go into effect, this report fully reflects a comprehensive, regulatory-focused CO_2 abatement approach by modeling the entirety of each policy and any recently planned expansion.

Revenue-neutral, emissions-equivalent carbon tax

After estimating the impact of the regulatory CO_2 controls, this report then compares the economic impact of the regulatory CO_2 abatement approach to a market-based alternative in the form of a revenue-neutral, emissions-equivalent carbon tax. The carbon price is set to achieve the same level of CO_2 emissions reduction as the regulatory CO_2 abatement approach. The market-based approach of a carbon tax would place a uniform price on emitting CO_2 across the entire economy. A uniform CO_2 price would leverage the knowledge and behavior of consumers and producers to find where it is least costly to reduce emissions, as compared to the regulatory-focused approach that is often less flexible and can mandate more costly ways to reduce emissions.

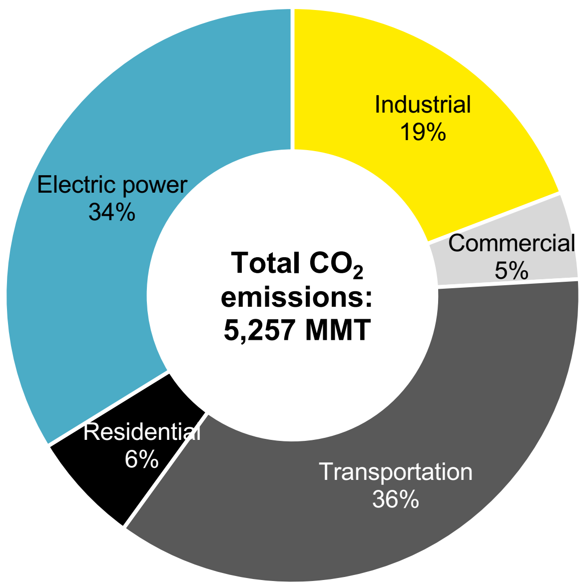
An important element of a revenue-neutral carbon tax is that it generates revenue, which creates opportunities inherent with the use of these revenues. The revenue could be used, for example, to reduce preexisting taxes, to fund additional government spending or transfers, or to reduce the federal deficit. To contrast the potential benefits associated with the use of revenue from the revenue-neutral, emissions-equivalent carbon tax analyzed by this report, three alternative uses for the revenue are considered:

1. Permanent extension of expiring individual income tax provisions in the Tax Cuts and Jobs Act (TCJA) and permanent 100% bonus depreciation
2. Investment in public infrastructure (highways, bridges, etc.)
3. Rebate to households

II. Regulatory and rule-based CO_2 controls

Each regulatory or rule-based policy in place in the United States for CO_2 abatement and analyzed by this report generally targets one of the major sources of CO_2 emissions in the US economy. Broadly, CAFE standards and RFS reduce transportation emissions (encompassing 36% of emissions), while AEES and the CPP reduce emissions related to the generation of electric power (encompassing 34% of emissions). An overview of US energy-related emissions by major type of economic activity is presented in Figure 1.

Figure 1. US energy-related CO_2 emissions, by major type of economic activity (2018)



Note: The transportation sector includes personal and commercial vehicles. Figures are rounded.
Source: US Energy Information Administration Annual Energy Outlook 2018.

To fully reflect a comprehensive regulatory-focused CO_2 abatement approach, the stylized representation includes policies that may or may not go into effect (e.g., the Clean Power Plan). Additionally, the stylized representation of recent regulatory policies assumes that any future increases in the stringency of these recent regulatory policies are immediately in effect in order to highlight the difference in approach instead of policy timing.

Corporate Average Fuel Economy standards

The two classes of CAFE standards focus on increasing fuel efficiency for: (1) light-duty and (2) medium- and heavy-duty vehicles. The light-duty CAFE standards apply to new passenger cars, pick-up trucks up to 8,500 lbs gross vehicle weight rating (GVWR), and sport-utility vehicles and minivans up to 10,000 lbs GVWR. CAFE standards for medium- and heavy-duty vehicles apply to new heavy-duty engines and trucks of 8,500 lbs GVWR and higher, including combination tractors, school and transit buses, and motor vehicles of 8,500 lbs GVWR or greater (except for those already covered by the light-duty vehicles regulations). Transportation emissions not affected by CAFE standards include the emissions of aircraft, boats and ships, pipelines, and rail.[1]

Clean Power Plan

The CPP aims to reduce CO_2 emissions in the power sector. The CPP requires that states choose one of three approaches: (1) a nation-wide maximum emissions rate for each electricity-generating unit (EGU) (in CO_2/MWh), (2) a state-specific emissions rate for the state's overall electricity portfolio (in CO_2/MWh), or (3) state-specific mass-based limits (in CO_2/year).

The national emissions rate option requires specific rates of CO_2 emissions per MWh of electricity generation – effectively a separate rate for coal and gas EGUs – to be met by each individual EGU. In contrast, the state-specific emissions rate is a blend of the national emissions rates for coal and gas weighted to reflect each state's individual mix of electricity generated from each EGU type. For this approach, rather than each individual EGU meeting the national coal or gas emissions rate, the entire electricity portfolio of a state must meet the state-specific blended rate. The state-specific mass-based limits – estimated from the state-specific emissions rate option – sets the maximum annual amount of CO_2 that a state can emit.

The CPP allows states considerable flexibility in how CO_2 emission targets are reached, including multi-state emissions rate trading or mass-based trading systems. Such trading mechanisms, which allow the trading of emissions credits (for state-specific emissions rates) and emissions allowances (for state-specific mass-based limits), are market-based tools that enable CO_2-intensive industries to eliminate their CO_2 footprints in a cost-effective way. Businesses that face comparatively higher costs of reducing their CO_2-producing processes can trade emissions credits or allowances with firms that face comparatively lower costs of reducing their CO_2-producing processes, simultaneously reducing total CO_2 emissions while also allowing firms to account for their own unique costs of production.

The implementation of these rules would still leave considerable uncertainty about how states would choose to comply. As such, the modeling of the CPP in this report includes a 50-50 split of a relatively efficient implementation and relatively inefficient implementation. In particular, the modeling assumes 50% of the CPP is implemented by states cooperating in creating a single, multi-state cap-and-trade program (relatively efficient) and 50% of the CPP is implemented by states choosing to adopt the national emissions rate option without inter-industry trading (relatively inefficient).[2]

Renewable Fuel Standards

RFS, enacted in the 2005 Energy Policy Act (RFS1) and later expanded upon in the 2007 Energy Independence and Security Act (RFS2), reduce CO_2 emissions by requiring of fuel distributors that a specific percentage of total sales be renewable fuels or "biofuels" (including advanced biofuels, biodiesel, renewable diesel, biogas, and sugarcane ethanol). RFS2 is slated to increase the number of gallons of renewable fuel in domestic transportation fuels to 36 billion gallons by 2022. It requires that at least 16 billion gallons are from cellulosic biofuels and, at most, 15 billion gallons are from corn-starch ethanol.

Businesses obligated to comply with the RFS are refiners or importers of gasoline or diesel fuel. These businesses meet their compliance requirement, also known as a Renewable Volume

Obligation (RVO), by either blending renewable fuels into transportation fuels or obtaining credits. The Environmental Protection Agency calculates annual RVOs based on the Clean Air Act's volume requirements and projected diesel and gasoline production for the year.[3]

Appliance and equipment efficiency standards

The AEES program regulates the manufacture or import for sales of more than 60 categories of appliances and equipment used in both the residential and commercial sectors. To reduce energy consumption, the program sets efficiency standards for appliances and equipment. There are four broad areas of affected appliances and equipment: (1) consumer products, (2) commercial and industrial products, (3) lighting products, and (4) plumbing products. Consumer products include dishwashers, refrigerators and freezers, and water heaters. Commercial and industrial products include computers, room air conditioners, electric motors, and walk-in coolers and freezers.

III. Comparing the economic impact of a regulatory carbon abatement approach to a revenue-neutral, emissions-equivalent carbon tax

Key takeaways

- *When compared to the regulatory CO_2 abatement approach, the revenue-neutral carbon tax with the same emissions reduction would result in significantly greater US GDP for each revenue use considered. This analysis estimates:*
  - *Using carbon tax revenues to fund permanent extension of expiring individual income tax provisions in the TCJA and permanent 100% bonus depreciation would, in the long-run, increase GDP per household by $5,090 annually and the size of the US economy would increase by 3.2% relative to the regulatory CO_2 abatement approach.*
  - *Using carbon tax revenues to fund increased investment in sufficiently productive public infrastructure would, in the long-run, increase GDP per household by $3,290 annually and the size of the US economy would increase by 2.1% relative to the regulatory CO_2 abatement approach.*
  - *Using carbon tax revenues to fund a household rebate would, in the long-run, increase GDP per household by $1,170 annually and the size of the US economy would increase by 0.7% relative to the regulatory CO_2 abatement approach.*

This report compares the economic impact of a regulatory CO_2 abatement approach to a market-based alternative in the form of a revenue-neutral, emissions-equivalent carbon tax with all reported economic impacts scaled to the size of the 2018 US economy.

The economic impacts are estimated using the EY GE Model. This model is designed to capture the major features of the US economy and the key economic decisions of businesses and households affected by energy and tax policy. It is an overlapping generations model similar to models used by the Congressional Budget Office, Environmental Protection Agency, Joint Committee on Taxation, and US Department of the Treasury to analyze changes in energy and tax policy.[4]

The EY GE Model includes a detailed modeling of industries, as well as their inter-industry linkages. Each industry differs in its relative use of capital, labor, and energy inputs, as well as in the CO_2 content of its outputs. Each industry is responsive to the price of capital, labor, and energy, as firms choose the optimal mix based on relative prices and industry-specific characteristics. Businesses and households incorporate the after-tax return from work and savings into their decisions of how much to produce, save, and work. A description of the EY GE Model is provided in Appendix A.

Another important element of a revenue-neutral carbon tax is that it generates revenue, which creates opportunities inherent with the use of these revenues. The revenue could be used, for example, to reduce preexisting taxes, fund additional government spending or transfers, or reduce the federal deficit. To contrast the potential benefits associated with the use of revenue from the revenue-neutral, emissions-equivalent carbon tax analyzed by this report, three alternative uses for the revenue are considered:

1. *Permanent extension of expiring individual income tax provisions in the TCJA and permanent 100% bonus depreciation*, which would (1) increase the after-tax reward to work, resulting in higher real wages and/or increases in the US workforce, and (2) increase the after-tax return for savings and investment, which would encourage more capital investment and contribute to higher labor productivity.

2. *Investment in public infrastructure*, which would boost private sector productivity and, consequently, private sector output.

3. *Rebate to households*, which would offset some of the impact of the carbon tax on household incomes.

Economic impact of a regulatory CO_2 abatement approach

This report models each of the policies in the stylized regulatory CO_2 abatement approach in their entirety. That is, while some of these policies are either at least partially implemented or may never go into effect, to fully reflect a comprehensive regulatory-focused CO_2 abatement approach the entirety of each policy and any recently planned expansion is modeled. As displayed in Table 1, this report estimates that regulatory CO_2 controls reduce CO_2 emissions by approximately 22%, but also reduce GDP in the long-run by 1.1%, or approximately $1,770 per household annually.[5] These economic impacts are primarily driven by CAFE standards and the CPP.

Table 1. Estimated economic impact of regulatory-focused CO_2 abatement approach
Percent change from baseline with no major federal CO_2 abatement policy

	2018-22	2023-27	2028-32	2033-37	Long-run
CO_2 emissions reduction	-16.3%	-20.9%	-21.7%	-22.0%	-22.0%
GDP					
Gross domestic product	-0.4%	-0.9%	-1.1%	-1.1%	-1.1%
Consumption	-0.1%	-0.2%	-0.8%	-0.8%	-0.8%
Private investment	-1.2%	-3.3%	-1.8%	-1.9%	-1.8%
Labor					
After-tax wage rate	-0.1%	-0.5%	-0.6%	-0.6%	-0.5%
Labor quantity	0.4%	0.4%	0.4%	0.4%	0.4%
Economic impact measures (2018$)					
GDP change per household ($)	-630	-1,500	-1,740	-1,790	-1,770
GDP change per ton of CO_2 reduction ($)	-90	-170	-190	-190	-190

Note: Equivalent dollar measures are scaled to the 2018 US economy. The regulatory-focused CO_2 abatement approach is a stylized representation of the regulatory abatement approach in the United States. This includes: (1) Corporate Average Fuel Economy standards, (2) the Clean Power Plan, (3) Renewable Fuel Standards, and (4) energy efficiency standards. To fully reflect a comprehensive regulatory-focused CO_2 abatement approach, the stylized representation includes policies that may or may not go into effect (e.g., the Clean Power Plan). Additionally, the stylized representation of recent regulatory policies assumes that any future increases in the stringency of these recent regulatory policies are immediately in effect to highlight the difference in approach instead of policy timing. Economic impacts are presented as the 5-year average over the indicated time period. The results presented assume the Clean Power Plan is implemented as 50% national emissions rate and 50% mass-based. Figures are rounded.

Source: EY analysis.

Market-based alternative of a revenue-neutral, emissions-equivalent carbon tax

A key benefit of a revenue-neutral, emissions-equivalent carbon tax is that it leverages the knowledge and behavior of consumers and producers to find the least costly ways to reduce CO_2 emissions. In particular, rather than mandating that CO_2 emissions be reduced in a particular sector or via a particular restriction on the choices of consumers and producers, the carbon tax incentivizes consumers and producers to reduce emissions where it is least costly through their efforts to reduce their own tax burden. To the extent that the regulatory-focused approach mandates reductions that are not the lowest-cost abatement opportunities, it will be less cost effective.

There are even more significant economic benefits from the revenue-neutral, emissions-equivalent carbon tax when the revenue is used for efficiency-improving tax reduction or public infrastructure investment. In particular, when used to fund the permanent extension of expiring individual income tax provisions in the TCJA and permanent 100% bonus depreciation, the EY GE Model finds that the economy would be larger by 3.2% in the long-run relative to the regulatory CO_2 abatement approach (Table 2).[6] Similarly, when revenues are used to fund stylized public infrastructure investment, the US economy would be larger by 2.1% in the long-run relative to the regulatory CO_2 abatement approach (Table 3).[7] In the long-run, this outcome implies an additional $5,090 in annual GDP per household for the permanent extension of selected TCJA provisions and $3,290 in GDP per household for the stylized public infrastructure investment.

Notably, while the long-run results from these two uses of the carbon tax revenue are similar, the paths to the long-run results differ. In particular, where more than 90% of the long-run result of the permanent extension of expiring individual income tax provisions in the TCJA and permanent 100% bonus depreciation is achieved by 2033-37 (3.0%/3.2%), less than 50% of the long-run result of using the carbon tax revenue for public infrastructure investment is achieved by 2033-37 (1.0%/2.1%). The reason is that significant and sustained increases in public infrastructure investment are necessary to increase the approximately $14 trillion stock of public capital in the United States.[8]

Table 2. Estimated economic impact of revenue-neutral, emissions-equivalent carbon tax relative to regulatory-focused CO_2 abatement approach (Carbon tax revenue used to fund permanent extension of expiring individual income tax provisions in the TCJA and permanent 100% bonus depreciation)

Percent change; carbon tax relative to regulatory-focused CO_2 abatement approach

	2018-22	2023-27	2028-32	2033-37	Long-run
GDP					
Gross domestic product	0.4%	1.8%	2.9%	3.0%	3.2%
Consumption	-1.2%	-3.7%	2.2%	2.4%	3.0%
Private investment	7.2%	24.1%	7.4%	7.1%	5.9%
Labor					
After-tax wage rate	0.3%	2.6%	5.4%	5.7%	6.4%
Labor quantity	-0.2%	0.3%	1.0%	0.9%	0.7%
Economic impact measures (2018$)					
GDP change per household ($)	670	2,830	4,630	4,790	5,090
GDP change per ton of CO_2 reduction ($)	100	320	500	500	540
Carbon price ($/ton)	32	46	51	53	55

Note 1: Equivalent dollar measures are scaled to the 2018 US economy. Analysis compares the macroeconomic impacts of two alternative paths for CO_2 abatement in the United States: (1) a regulatory-focused CO_2 abatement approach, and (2) an economy-wide, emissions-equivalent carbon tax. Specifically, the analysis separately models the alternative paths relative to a baseline that includes no major federal CO_2 abatement policies and reports the difference between the two alternative paths for CO_2 abatement. The regulatory-focused CO_2 abatement approach is a stylized representation of the regulatory abatement approach in the United States. This includes: (1) Corporate Average Fuel Economy standards, (2) the Clean Power Plan, (3) Renewable Fuel Standards, and (4) energy efficiency standards. To fully reflect a comprehensive regulatory-focused CO_2 abatement approach, the stylized representation includes policies that may or may not go into effect (e.g., the Clean Power Plan). Additionally, the stylized representation of recent regulatory policies assumes that any future increases in the stringency of these recent regulatory policies are immediately in effect to highlight the difference in approach instead of policy timing. The carbon price for the economy-wide, emissions-equivalent carbon tax is set in each year such that it achieves the same CO_2 reductions as the regulatory-focused CO_2 abatement approach.

Note 2: The estimates include the permanent extension of the following provisions: 10%, 12%, 22%, 24%, 32%, 35%, and 37% income tax rate brackets, modify standard deduction ($12,000 for singles, $24,000 for married filing jointly, $18,000 for HoH), repeal of deduction for personal exemptions, allow 20% deduction of qualified business income and certain dividends for individuals and for gross income of agricultural or horticultural cooperatives, disallow active pass-through losses in excess of $500,000 for joint filers, $250,000 for all others, modification of child tax credit: $2,000 not indexed; refundable up to $1,400 indexed down to nearest $100 base year 2018; $2,500 refundability threshold not indexed; $500 other dependents not indexed; phase outs $200K/$400K not indexed, require valid Social Security number of each child to claim refundable and non-refundable portions of child credit, non-child dependents, and any child without a valid Social Security number still receives $500 non-refundable credit, repeal of itemized deductions for taxes not paid or accrued in a trade or business (except for up to $10,000 in state and local taxes), interest on mortgage debt in excess of $750K, interest on home equity debt, non-disaster casualty losses, and certain miscellaneous expenses, increase percentage limit for charitable contributions of cash to public charities, repeal of overall limitation on itemized deductions, repeal exclusion for employer-provided bicycle commuter fringe benefit, repeal exclusion for employer-provided qualified moving expense reimbursements (other than members of the Armed Forces), repeal of deduction for moving expenses (other than members of the Armed Forces), limitation on wagering losses, double estate, gift, and GST tax exemption amount, increase the individual AMT exemption amounts and phase-out thresholds, restore a medical expense deduction for expenses in excess of 7.5% of adjusted gross income, allow for increased contributions to ABLE accounts; allow saver's credit for ABLE contributions, allow rollovers from 529 accounts to ABLE accounts, treatment of certain individuals performing services in the Sinai Peninsula of Egypt, treatment of student loans discharged on account of death or disability, and 100% bonus depreciation. Economic impacts are presented as the 5-year average over the indicated time period. The results presented assume the Clean Power Plan is implemented as 50% national emissions rate and 50% mass-based. Figures are rounded.

Source: EY analysis.

Table 3. Estimated economic impact of revenue-neutral, emissions-equivalent carbon tax relative to regulatory-focused CO_2 abatement approach (Carbon tax revenue used to fund public infrastructure investment)

Percent change; carbon tax relative to regulatory-focused CO_2 abatement approach

	2018-22	2023-27	2028-32	2033-37	Long-run
GDP					
Gross domestic product	0.1%	0.6%	0.9%	1.0%	2.1%
Consumption	0.2%	-0.1%	0.4%	0.6%	2.0%
Private investment	-0.8%	2.9%	2.3%	2.7%	3.2%
Labor					
After-tax wage rate	0.2%	0.3%	0.3%	0.3%	0.8%
Labor quantity	-0.6%	-0.4%	-0.2%	*	0.7%
Economic impact measures (2018$)					
GDP change per household ($)	120	950	1,380	1,660	3,290
GDP change per ton of CO_2 reduction ($)	20	110	150	170	340
Carbon price ($/ton)	32	44	47	48	52
Annual investment in infrastructure ($b)	140	180	190	200	260

*Magnitude less than 0.05%

Note: Equivalent dollar measures are scaled to the 2018 US economy. This analysis models a stylized increase in public infrastructure investment. Depending on the specifics of a policy proposal to increase public infrastructure investment, the effects could be significantly different than those reported in this analysis. Analysis compares the macroeconomic impacts of two alternative paths for CO_2 abatement in the United States: (1) a regulatory-focused CO_2 abatement approach, and (2) an economy-wide, emissions-equivalent carbon tax. Specifically, the analysis separately models the alternative paths relative to a baseline that includes no major federal CO_2 abatement policies and reports the difference between the two alternative paths for CO_2 abatement. The regulatory-focused CO_2 abatement approach is a stylized representation of the regulatory abatement approach in the United States. This includes: (1) Corporate Average Fuel Economy standards, (2) the Clean Power Plan, (3) Renewable Fuel Standards, and (4) energy efficiency standards. To fully reflect a comprehensive regulatory-focused CO_2 abatement approach, the stylized representation includes policies that may or may not go into effect (e.g., the Clean Power Plan). Additionally, the stylized representation of recent regulatory policies assumes that any future increases in the stringency of these recent regulatory policies are immediately in effect to highlight the difference in approach instead of policy timing. The carbon price for the economy-wide, emissions-equivalent carbon tax is set in each year such that it achieves the same CO_2 reductions as the regulatory-focused CO_2 abatement approach. Economic impacts are presented as the 5-year average over the indicated time period. The results presented assume the Clean Power Plan is implemented as 50% national emissions rate and 50% mass-based. Figures are rounded.
Source: EY analysis.

As seen in Table 4, this report finds significant gains to the US economy from a revenue-neutral, emissions-equivalent carbon tax relative to regulatory CO_2 controls, even without the improvement in economic efficiency from the use of revenue to extend tax cuts or to spend on public infrastructure. As a quantification of these gains, this analysis finds that the use of carbon tax revenues for rebates to households would increase GDP in the long-run by 0.7%, or $1,170 per household annually relative to the regulatory-focused approach. Because this use of proceeds does not improve economic efficiency, it effectively isolates the benefit of leveraging the knowledge and behavior of consumers and producers in choosing where CO_2 emissions could be reduced at least cost.

Table 4. Estimated economic impact of revenue-neutral, emissions-equivalent carbon tax relative to regulatory-focused CO_2 abatement approach (Carbon tax revenue used to fund household rebate)

Percent change; carbon tax relative to regulatory-focused CO_2 abatement approach

	2018-22	2023-27	2028-32	2033-37	Long-run
GDP					
Gross domestic product	0.1%	0.5%	0.6%	0.7%	0.7%
Consumption	*	-0.1%	0.2%	0.2%	0.4%
Private investment	*	2.4%	1.7%	1.8%	1.6%
Labor					
After-tax wage rate	0.1%	0.5%	0.6%	0.7%	0.9%
Labor quantity	-0.5%	-0.6%	-0.6%	-0.6%	-0.6%
Economic impact measures (2018$)					
GDP change per household ($)	200	840	1,030	1,080	1,170
GDP change per ton of CO_2 reduction ($)	30	100	110	120	130
Carbon price ($/ton)	32	44	46	47	48
Rebate ($b)	140	180	180	190	190
Rebate per household ($)	1,080	1,390	1,440	1,470	1,510

*Magnitude less than 0.05%

Note: Equivalent dollar measures are scaled to the 2018 US economy. Analysis compares the macroeconomic impacts of two alternative paths for CO_2 abatement in the United States: (1) a regulatory-focused CO_2 abatement approach, and (2) an economy-wide, emissions-equivalent carbon tax. Specifically, the analysis separately models the alternative paths relative to a baseline that includes no major federal CO_2 abatement policies and reports the difference between the two alternative paths for CO_2 abatement. The regulatory-focused CO_2 abatement approach is a stylized representation of the regulatory abatement approach in the United States. This includes: (1) Corporate Average Fuel Economy standards, (2) the Clean Power Plan, (3) Renewable Fuel Standards, and (4) energy efficiency standards. To fully reflect a comprehensive regulatory-focused CO_2 abatement approach, the stylized representation includes policies that may or may not go into effect (e.g., the Clean Power Plan). Additionally, the stylized representation of recent regulatory policies assumes that any future increases in the stringency of these recent regulatory policies are immediately in effect to highlight the difference in approach instead of policy timing. The carbon price for the economy-wide, emissions-equivalent carbon tax is set in each year such that it achieves the same CO_2 reductions as the regulatory-focused CO_2 abatement approach. Economic impacts are presented as the 5-year average over the indicated time period. The results presented assume the Clean Power Plan is implemented as 50% national emissions rate and 50% mass-based. Figures are rounded.

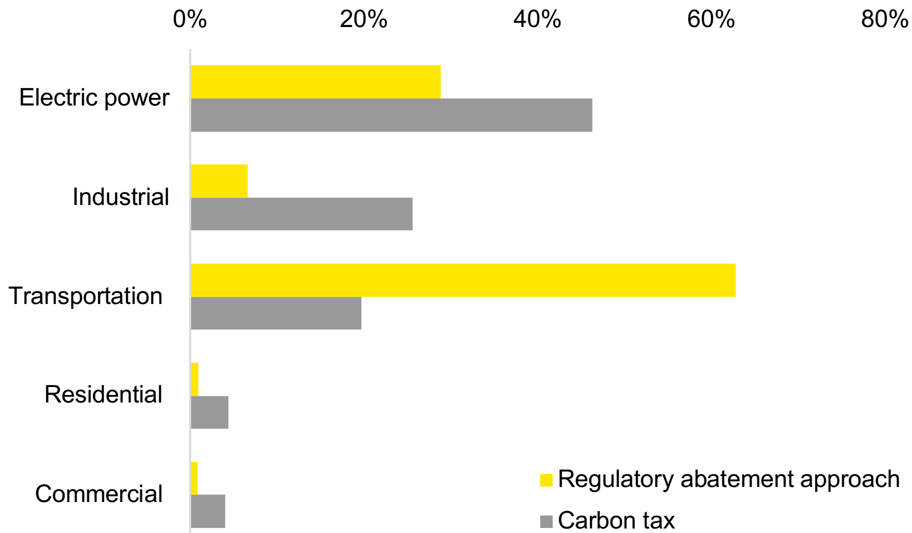
Source: EY analysis.

Benefits of re-investing carbon tax revenue

Comparative evaluation

This analysis suggests that regulatory CO_2 controls mandate costlier emissions abatement than are available elsewhere. This extra cost is in large part attributable to the costliest of the rule-based policies, CAFE standards. Whereas the regulatory CO_2 abatement approach achieves more than one-half of its emissions reduction in transportation, Figure 2 shows that this fraction declines to less than one-fifth when consumers and producers are allowed to reduce emissions where it is least costly to do so. In contrast, the CPP – the second costliest of the regulatory CO_2 controls – mandates emissions reductions in the electric power sector, which this analysis suggests has relatively low-cost emissions abatement opportunities. In particular, under the revenue-neutral, emissions-equivalent carbon tax, nearly half of all emissions reductions occur in the electric power sector. Notably, the appliance and energy efficiency standards also contribute to the electric power sector's emissions reductions.

Figure 2. Share of CO_2 emissions reduction in revenue-neutral, emissions-equivalent carbon tax relative to the regulatory CO_2 controls, by sector



Note: Carbon tax scenario in which revenues are rebated to households is displayed. The transportation sector includes personal and commercial vehicles. Each set of bars sum to 100%.
Source: EY analysis.

IV. Caveats and limitations

Any modeling effort is only an approximate depiction of the economic forces it seeks to represent, and the economic model developed for this analysis is no exception. Although various limitations and caveats might be listed, several are particularly noteworthy:

- **Estimates are based on a stylized depiction of the US economy.** The general equilibrium model used for this analysis is, by its very nature, a stylized depiction of the US economy. The model was developed to capture the key details important to analyzing the impacts of the regulatory CO_2 controls relative to a revenue-neutral, emissions-equivalent carbon tax, but simplifies assumptions around many details of the economy.
- **The United States is assumed to be on a fiscally sustainable path.** The model used for this analysis assumes that the United States is on a fiscally sustainable path under current law and remains on a fiscally sustainable path after the policy change, when neither may necessarily be the case.
- **Estimates are limited by calibration to the 2018 US economy.** This model is calibrated to represent the US economy in 2018 and then forecast forward, but, because any particular year may reflect unique events and also may not represent the economy in the future, no particular baseline year is completely general.
- **Estimates are limited by available public information.** The analysis relies on information reported by government agencies (primarily the Bureau of Economic Analysis, US Energy Information Administration, Environmental Protection Agency, and Internal Revenue Service). The analysis did not attempt to verify or validate this information using sources other than those described in the report.
- **Full employment is assumed.** The EY GE Model, like many general equilibrium models, focuses on the long-run growth effects of policy changes and thus relies on a full employment assumption (i.e., no involuntary unemployment). Any increase in labor supply is a voluntary response to a change in income or the return to labor that makes households wish to substitute consumption for leisure.
- **Estimates are based on a stylized depiction of own-use vehicle transportation.** In this model, households consume fossil or renewable fuel, vehicles, and fuel efficiency improvements. That is, in the model's stylized depiction of own-use vehicle transportation, households choose the optimal amount of each of these consumer goods rather than make the choice between discrete vehicle types. Notably, this stylized depiction also abstracts from household decisions about whether to purchase vehicles with internal combustion engines versus electric vehicles.
- **State policies are not modeled.** The simulations do not account for interactions with or potential changes in state policies. This includes, for example, state renewable portfolio standards that require a certain percentage of electricity generation in the state to be met by renewable sources (e.g., wind and solar power).

Appendix A. EY General Equilibrium Model of the US Economy

The EY GE Model was used to compare the macroeconomic impacts of regulatory CO_2 controls with those of a revenue-neutral, emissions-equivalent carbon tax. This model, which is an overlapping generations computable general equilibrium model, is similar to economic models used by the Congressional Budget Office, Environmental Protection Agency, Joint Committee on Taxation, and US Department of the Treasury for estimating the potential economic impacts of various environmental and tax policies.[9]

Behavioral responses are modeled in a general equilibrium framework whereby representative firms and individuals incorporate changes in current and future prices when deciding how much to produce, save, and consume in each period. In this framework, individuals are assumed to be responsive to changes in the prices of consumer goods. Thus, as the price of CO_2-intensive consumer goods increase, consumers substitute their consumption toward other goods and services. Similarly, firms alter their mix of capital, labor, and energy used in production in response to regulatory and tax policies.

An overview of the model follows:

Production

Firm production is modeled with the constant elasticity of substitution (CES) functional form in which firms choose the optimal level of capital and labor subject to the gross-of-tax cost of capital and gross-of-tax wage. The model includes industry-specific detail through use of differing costs of capital, factor intensities, and production function scale parameters. Such a specification accounts for differential use of capital and labor across industries, as well as distortions in factor prices introduced by the tax system. The cost of capital measure models the extent to which the tax code discriminates by asset type, organizational form, and source of finance. Estimates of the cost of capital generally follow the formulation from Hall and Jorgenson (1967), expanded by Fullerton and Mackie (1987), and described in detail by Gravelle (1994) and Mackie (2002).

Each industry differs in its relative use of capital, labor, and energy inputs, as well as in the CO_2 content of its outputs. Each industry is responsive to the price of capital, labor, and energy, and chooses the optimal mix based on relative prices and industry-specific characteristics. The inclusion of inter-industry linkages is important for this type of analysis because CO_2 abatement policies have both direct and indirect effects that increase the costs of production. The direct effects are reflected in the increased costs created by the imposition of the policy on the use of CO_2-emitting industries. Indirect costs are incurred through the use of inputs or processes in production that have previously been subject to the policy. This means that even industries that are not directly impacted by a policy are subject to potentially significant cost increases through increased prices of intermediate inputs from other industries used in their production processes.

Consumers

The overlapping generations framework is modeled with 55 generational cohorts. That is, in any one year, the model includes a representative household optimizing lifetime consumption and savings decisions for each age 21 through 75 (i.e., 55 representative cohorts). For each generational cohort, the endowment of human capital exogenously changes with age – growing early in life and declining later in life. This overlapping generations framework is especially well-suited for estimating both the short-run transitional and long-run effects of a policy change.

The utility of representative individuals is modeled as a CES function allocating a composite good consisting of consumer goods and leisure over their lifetimes. Representative individuals optimize their lifetime utility through their decisions of how much to consume, save, and work in each period subject to their preference parameters and the after-tax returns from work and savings in each period. In determining their labor supply, representative individuals respond to the after-tax return to labor, as well as their overall income levels, in determining whether to work and thereby earn income that is used to purchase consumer goods or to consume leisure by not working.

Other features

The model includes a simple characterization of the government. The model includes a sector representing state and local governments, as well as a sector representing the US federal government. Government spending is assumed to be used for either (1) transfer payments to representative individuals, or (2) the provision of public goods. Public goods are assumed to be provided by the government in fixed quantities through the purchase of industry outputs as specified in a Leontief function. This spending is financed in the model by collecting taxes. All tax policy changes are assumed to be offset by a contemporaneous and offsetting change in government spending or taxes.

Table A-1. Key model parameters

	Central	Low	High
Intertemporal substitution elasticity	0.4	0.3	0.5
Intratemporal substitution elasticity	0.6	0.5	0.7
Leisure share of time endowment	0.4	0.3	0.5
International capital flow elasticity	3.0	1.0	5.0
Capital-labor substitution elasticity	0.8	0.5	1.0
Elasticity of private output with respect to public capital	0.04	0.02	0.06
Clean Power Plan implementation	50-50	Mass	Rate

Source: Central key model parameters are generally from Joint Committee on Taxation, Macroeconomic Analysis Of The Conference Agreement For H.R. 1, The "Tax Cuts And Jobs Act," December 22, 2017 (JCX-69-17), Congressional Budget Office, The Macroeconomic and Budgetary Effects of Federal Investment, June 2016, and Jane Gravelle and Kent Smetters, "Does the Open Economy Assumption Really Mean That Labor Bears the Burden of a Capital Income Tax?," Advances in Economic Analysis and Policy 6(1) (2006): Article 3.

Appendix B. Sensitivity analysis

Table B-1. Estimated economic impact of regulatory-focused CO_2 abatement approach: Low values for key parameters

Percent change from baseline with no major federal CO_2 abatement policy

	2018-22	2023-27	2028-32	2033-37	Long-run
CO_2 emissions reduction	-15.7%	-20.1%	-20.9%	-21.2%	-21.1%
Gross domestic product	-0.2%	-0.6%	-0.8%	-0.8%	-0.7%
Labor quantity	0.4%	0.4%	0.4%	0.4%	0.4%
GDP change per household ($)	-320	-1,030	-1,280	-1,310	-1,140
GDP change per ton of CO2 reduction ($)	-50	-120	-140	-140	-120

Note: See "Low" column of Table A-1 for list of changes in key parameters. Economic impacts are scaled to the size of the 2018 US economy. Figures are rounded.
Source: EY analysis.

Table B-2. Estimated economic impact of revenue-neutral, emissions-equivalent carbon tax relative to regulatory-focused CO_2 abatement approach, by carbon tax revenue use: Low values for key parameters

Percent change; carbon tax relative to regulatory-focused CO_2 abatement approach

	2018-22	2023-27	2028-32	2033-37	Long-run
Permanently extend selected TCJA provisions					
CO_2 emissions reduction	-15.7%	-20.1%	-20.9%	-21.2%	-21.1%
Gross domestic product	0.2%	1.1%	1.7%	1.8%	1.8%
Labor quantity	-0.2%	*	0.4%	0.4%	0.4%
GDP change per household ($)	380	1,680	2,660	2,800	2,920
GDP change per ton of CO_2 reduction ($)	60	190	290	300	310
Carbon price ($/ton)	31	44	47	49	50
Invest in public infrastructure					
CO_2 emissions reduction	-15.7%	-20.1%	-20.9%	-21.2%	-21.1%
Gross domestic product	*	0.4%	0.6%	0.7%	1.2%
Labor quantity	-0.4%	-0.4%	-0.3%	-0.2%	0.1%
GDP change per household ($)	*	630	960	1,120	2,000
GDP change per ton of CO_2 reduction ($)	*	70	100	120	210
Carbon price ($/ton)	31	42	45	46	49
Annual investment in infrastructure ($b)	140	180	190	200	230
Household rebate					
CO_2 emissions reduction	-15.7%	-20.1%	-20.9%	-21.2%	-21.1%
Gross domestic product	*	0.3%	0.5%	0.5%	0.6%
Labor quantity	-0.4%	-0.5%	-0.5%	-0.5%	-0.5%
GDP change per household ($)	10	560	780	850	990
GDP change per ton of CO_2 reduction ($)	*	70	80	90	100
Carbon price ($/ton)	31	42	45	46	47
Annual rebate ($b)	140	180	180	190	200
Annual rebate per household ($)	1,070	1,380	1,440	1,480	1,570

* Magnitude less than 0.05% or $5
Note: See "Low" column of Table A-1 for list of changes in key parameters. Economic impacts are scaled to the size of the 2018 US economy. Figures are rounded.
Source: EY analysis.

Table B-3. Estimated economic impact of regulatory-focused CO_2 abatement approach: High values for key parameters

Percent change from baseline with no major federal CO_2 abatement policy

	2018-22	2023-27	2028-32	2033-37	Long-run
CO_2 emissions reduction	-17.3%	-21.9%	-22.9%	-23.2%	-23.2%
Gross domestic product	-0.3%	-0.9%	-1.1%	-1.2%	-1.2%
Labor quantity	0.3%	0.4%	0.3%	0.3%	0.4%
GDP change per household ($)	-560	-1,480	-1,810	-1,860	-1,850
GDP change per ton of CO2 reduction ($)	-70	-160	-180	-180	-180

Note: See "High" column of Table A-1 for list of changes in key parameters. Economic impacts are scaled to the size of the 2018 US economy. Figures are rounded.
Source: EY analysis.

Table B-4. Estimated economic impact of revenue-neutral, emissions-equivalent carbon tax relative to regulatory-focused CO_2 abatement approach, by carbon tax revenue use: High values for key parameters

Percent change; carbon tax relative to regulatory-focused CO_2 abatement approach

	2018-22	2023-27	2028-32	2033-37	Long-run
Permanently extend selected TCJA provisions					
CO_2 emissions reduction	-17.3%	-21.9%	-22.9%	-23.2%	-23.2%
Gross domestic product	0.3%	2.1%	3.7%	3.8%	3.9%
Labor quantity	-0.2%	0.6%	1.7%	1.6%	1.1%
GDP change per household ($)	490	3,310	5,960	6,050	6,200
GDP change per ton of CO_2 reduction ($)	60	350	600	600	610
Carbon price ($/ton)	35	51	57	59	62
Invest in public infrastructure					
CO_2 emissions reduction	-17.3%	-21.9%	-22.9%	-23.2%	-23.2%
Gross domestic product	-0.1%	0.4%	0.8%	1.1%	2.7%
Labor quantity	-0.7%	-0.4%	-0.1%	0.2%	1.5%
GDP change per household ($)	-220	690	1,350	1,770	4,380
GDP change per ton of CO_2 reduction ($)	-30	80	130	170	430
Carbon price ($/ton)	34	47	50	52	58
Annual investment in infrastructure ($b)	140	190	200	220	300
Household rebate					
CO_2 emissions reduction	-17.3%	-21.9%	-22.9%	-23.2%	-23.2%
Gross domestic product	*	0.4%	0.5%	0.5%	0.5%
Labor quantity	-0.5%	-0.6%	-0.6%	-0.7%	-0.8%
GDP change per household ($)	-40	560	780	810	830
GDP change per ton of CO_2 reduction ($)	-10	60	80	80	80
Carbon price ($/ton)	34	47	49	50	51
Annual rebate ($b)	140	180	190	190	190
Annual rebate per household ($)	1,130	1,420	1,470	1,500	1,520

* Magnitude less than 0.05%
Note: See "Low" column of Table A-1 for list of changes in key parameters. Economic impacts are scaled to the size of the 2018 US economy. Figures are rounded.
Source: EY analysis.

Endnotes

[1] CAFE requirements for passenger cars and light-duty trucks (i.e., light-duty vehicles) were largely unchanged from the early 1990s through model year (MY) 2004. CAFE standards were increased for light-duty trucks starting with MY2005 and for passenger cars starting with MY2011. By MY2004, CAFE standards do not appear to have been significantly binding. For example, National Highway Traffic Safety Administration (NHTSA) CAFE performance data reports that, for passenger vehicles, between MY1990 and MY2004, miles per gallon (MPG) increased from 28.0 to 29.5 (relative to a CAFE requirement of 27.5). Likewise, between MY1990 and MY2004, MPG for light-duty trucks increased from 20.8 to 21.5 relative to a CAFE requirement of 20.7. Notably, for total light-duty vehicles, the NHTSA CAFE performance data reports that MPG declined from 25.2 in MY1990 to 24.0 in MY2004, which reflects the growing share of light-duty trucks in total light-duty vehicles over this period.

Consistent with these facts, this analysis models the baseline forecast that does not include any binding CAFE standards (as for the MY2004 light-duty vehicle fleet). See US Environmental Protection Agency, "Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2017," January 2018. Relative to this baseline forecast, this analysis models the impact of CAFE standards through the most recent increase in CAFE standards to 55.3 MPG for passenger cars and 39.3 for light-duty trucks in MY2025. For the most recent increase in CAFE standards see US Environmental Protection Agency and National Highway Traffic Safety Administration, "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule," Federal Register, Vol. 77, No. 199 (Washington, DC: October 15, 2012).

CAFE standards for medium- and heavy-duty vehicles were enacted in two phases first applicable for MY2012 vehicles. The regulatory impact analysis for Phase 1 estimated that it would reduce fuel usage in medium- and heavy-duty vehicles approximately 10% relative to constant MY2010 performance. The regulatory impact analysis for Phase 2 estimated the additional fuel usage in medium- and heavy-duty vehicles relative to alternative baseline forecasts, but it estimated a reduction in the range of 18.5% to 20.0%. Accordingly, this analysis models a baseline forecast that does not include CAFE standards as MY2010 performance of the Phase 1 regulatory impact analysis modified to include the fuel efficiency improvements consistent with the midpoint of the range in the Phase 2 regulatory impact analysis. See US Environmental Protection Agency and National Highway Traffic Safety Administration, "Final Rulemaking to Establish Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles; Regulatory Impact Analysis," August 2011 and US Environmental Protection Agency and National Highway Traffic Safety Administration, "Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles - Phase 2; Regulatory Impact Analysis; Final Rule," August 2016. Relative to this no-policy baseline forecast, this analysis models the impact of CAFE standards through the most recent increase in CAFE standards as required by the US Environmental Protection Agency and National Highway Traffic Safety Administration, "Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles—Phase 2," Federal Register, Vol. 81, No. 206 (Washington, DC: October 25, 2016).

Note that, even though the stylized representation assumes that planned future increases in the stringency of these recent regulatory policies are immediately in effect, modeled impact of CAFE standards are still effectively "phased in" because even an immediate change in CAFE standards only applies to new vehicles. Older vehicles remain, but they depreciate away over time.

[2] For more information see Environmental Protection Agency, "Regulatory Impact Analysis for the Clean Power Plan Final Rule," August 2015.

[3] RFS, which requires a specified quantity of renewable fuels be included in the US fuel supply, include targets for each year through 2022. These targets increase, for example, from 11.1 billion gallons in 2009 to 26.0 billion gallons in 2018 and 36.0 billion gallons in 2022. This analysis starts with a baseline forecast that does not include RFS and then models this policy change. In particular, the forecast of the most recent RFS regulatory impact analysis is updated and used here, in order to be consistent with more recent estimates of the volume of renewable fuels that would be in the US fuel supply if RFS were not in effect. The regulatory impact analysis uses a modified version of the US Energy Information Administration's Annual Energy Outlook 2007. As noted in the regulatory impact analysis (from 2010), while this is an older forecast it has the benefit of not including the impact of in the Energy Independence and Security Act on

the forecast of renewable fuel volume. This forecast is then updated to be consistent with a more recent Congressional Budget Office estimate that if RFS were not in effect the volume of renewable fuels in the US fuel supply would have been 14 to 15 billion gallons in 2017. The forecast of the regulatory impact analysis was 12.44 billion gallons in 2017. See US Environmental Protection Agency, "Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis," February 2010 and Congressional Budget Office, "Issues for the Renewable Fuel Standard," June 2017.

[4] See, for example, Shinichi Nishiyama, "Fiscal Policy Effects in a Heterogeneous-Agent Overlapping-Generations Economy With an Aging Population," Congressional Budget Office, Working Paper 2013-07, December 2013; Joint Committee on Taxation*, Macroeconomic Analysis of the "Tax Reform Act of 2014,"* February 2014 (JCX-22-14); Joint Committee on Taxation, *Macroeconomic Analysis of Various Proposals to Provide $500 Billion in Tax Relief*, March 2005 (JCX-4-05); Robert Carroll, John Diamond, Craig Johnson and James Mackie III, "A Summary of the Dynamic Analysis of the Tax Reform Options Prepared for the President's Advisory Panel on Federal Tax Reform," Office of Tax Analysis, US Department of the Treasury, May 25, 2006; Martin Ross, "Documentation of the Applied Dynamic Analysis of the Global Economy (ADAGE) Model," Research Triangle Institute, 2009; Richard Goettle, Mun Ho, Dale Jorgenson, and Peter Wilcoxen, "Energy, The Environment, and U.S. Economic Growth," in *Handbook of Computable General Equilibrium Modeling*, edited by Peter Dixon and Dale Jorgenson, 2013.

[5] Following the convention of recent environmental CGE models, rule-based policies (i.e., the addition of constraints in the constrained optimization choices of households and businesses) are modeled as (formally equivalent) revenue-neutral tax-subsidy combinations. They are shown to be formally equivalent in Carolyn Fischer and Richard Newell, (2008), "Environmental and Technology Policies for Climate Mitigation," *Journal of Environmental Economics and Management* 55(2): 142-62. For example, the national emissions rate CPP scenario is modeled as revenue-neutral tax-subsidy combinations on the relevant power generation industries that reduce the emissions per unit of output (e.g., the coal national emissions rate standard was modeled via a revenue-neutral combination of a tax on the coal input to the coal power generation industry paired with a subsidy on coal power generation output). For modeling the carbon tax, because the emissions of CO_2 are explicitly traced through the economy in the EY GE Model, a uniform carbon price is imposed at the point of emission.

[6] The JCT estimated that the TCJA will increase the level of US GDP, on average, by 0.7% over 10 years. The JCT analysis does not present long-run impacts. EY, using a variant of the model used in this analysis, estimated that the TCJA will increase the level of US GDP, on average, by 1.0% over 10 years. This analysis models a different policy: the permanent extension of expiring individual income tax provisions in the TCJA and permanent 100% bonus depreciation. See Joint Committee on Taxation, Macroeconomic Analysis Of The Conference Agreement For H.R. 1, The "Tax Cuts And Jobs Act," December 22, 2017 (JCX-69-17), and Brandon Pizzola, Robert Carroll, and James Mackie, "Analyzing the macroeconomic impacts of the Tax Cuts and Jobs Act on the US economy and key industries," 2018.

Barro and Furman (2018) estimated that permanent extension of the TCJA would increase long-run GDP by 3.1%. See Robert Barro and Jason Furman, "The macroeconomic effects of the 2017 tax reform," Brookings Papers on Economic Activity, BPEA Conference Drafts, March 8-9, 2018, p.41.

It is estimated that, on a conventional basis, the permanent extension of expiring individual income tax provisions in the TCJA and permanent 100% bonus depreciation will reduce revenue approximately $750 billion over the budget window. This revenue estimate is based on the budgetary effects of extending certain expiring revenue provisions reported in the supplemental data accompanying the Congressional Budget Office's April 2018 report, The Budget and Economic Outlook: 2018 to 2028. Notably, the revenue cost of making selected provisions of the TCJA permanent increases over time as the economy grows, whereas projections of CO_2 emissions over time are relatively flat (i.e., CO_2 emissions per unit of GDP are forecast to decline over time). Consequently, both with and without discounting, the carbon tax eventually would no longer fully fund making selected provisions of the TCJA permanent. It is estimated that, in present value, the carbon tax would fund making the selected provisions of the TCJA permanent for approximately 50 years. Because the carbon tax is estimated to fund this policy change for such a lengthy period of time it is assumed in the modeling to be able to permanently fund the policy change.

Note the central key model parameters for the EY GE Model are generally from Joint Committee on Taxation, Macroeconomic Analysis Of The Conference Agreement For H.R. 1, The "Tax Cuts And Jobs Act," December 22, 2017 (JCX-69-17) and Jane Gravelle and Kent Smetters, "Does the Open Economy Assumption Really Mean That Labor Bears the Burden of a Capital Income Tax?," Advances in Economic Analysis and Policy 6(1) (2006): Article 3.

[7] There is no consensus in the academic literature on the responsiveness of private output with respect to changes in the stock of public capital. This report is consistent with the Congressional Budget Office's review of the academic literature and related analysis that estimated a 1% increase in public capital would be associated with an increase in private output of between 0.04% and 0.09% in the long-run. In particular, the central estimate of the EY GE Model is calibrated such that a 1% increase in public capital is associated with a 0.04% increase in private output. The lower bound of the Congressional Budget Office's range is used because there are likely to be significant diminishing returns to investment in public capital as well as potentially high adjustment costs associated with the sizable increase in public capital modeled in this analysis. See Congressional Budget Office, The Macroeconomic and Budgetary Effects of Federal Investment, June 2016.

It is important to note that this analysis models a stylized increase in public infrastructure investment. Depending on the specifics of a policy proposal, the effects could be significantly different than those reported in this analysis. That is, specific policy proposals could result in differences in the overall magnitude of the impact, the adjustment costs associated with the investment, and the sector-specific impact resulting from the investment. Additionally, there could be important interactions between the specifics of a public infrastructure policy proposal and a carbon tax. For example, to the extent increased public infrastructure facilitates driving (e.g., via new or improved roads and bridges), this could result in increased CO_2 emissions from the transportation sector. Overall, the results of this analysis should be viewed as illustrative of the potential impact of a stylized increase in public infrastructure investment. Any specific policy proposal should be explicitly modeled to examine its economic impact.

An additional area of uncertainty is the time horizon in which funding for public infrastructure investment is spent and when this public infrastructure investment, in turn, impacts productivity in the private sector. Specifically, while public infrastructure can generally be used and impact the productivity of the private sector once it is built, large increases in federal infrastructure can be subject to significant delays. For example, in the aftermath of the American Recovery and Reinvestment Act of 2009, less than 10% of infrastructure funds had been spent by the end of fiscal year 2009. This analysis assumes that investment in public infrastructure is spent ratably over four years. See Congressional Budget Office, Policies for Increasing Economic Growth and Employment in 2012 and 2013, November 2011.

[8] Public capital is defined as the current-cost net stock of government fixed assets.

[9] See, for example, Shinichi Nishiyama, "Fiscal Policy Effects in a Heterogeneous-Agent Overlapping-Generations Economy With an Aging Population," Congressional Budget Office, Working Paper 2013-07, December 2013; Joint Committee on Taxation, *Macroeconomic Analysis of the "Tax Reform Act of 2014,"* February 2014 (JCX-22-14); Joint Committee on Taxation, *Macroeconomic Analysis of Various Proposals to Provide $500 Billion in Tax Relief*, March 2005 (JCX-4-05); Robert Carroll, John Diamond, Craig Johnson and James Mackie III, "A Summary of the Dynamic Analysis of the Tax Reform Options Prepared for the President's Advisory Panel on Federal Tax Reform," Office of Tax Analysis, US Department of the Treasury, May 25, 2006; Martin Ross, "Documentation of the Applied Dynamic Analysis of the Global Economy (ADAGE) Model," Research Triangle Institute, 2009; Richard Goettle, Mun Ho, Dale Jorgenson, and Peter Wilcoxen, "Energy, The Environment, and U.S. Economic Growth," in *Handbook of Computable General Equilibrium Modeling*, edited by Peter Dixon and Dale Jorgenson, 2013.