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I. Introduction

Treasury's Office of Tax Analysis (OTA) is responsible for estimating the revenue, economic, and distributional effects of current and alternative tax systems, including individual, business, estate, and excise tax systems. The purpose of this technical paper is to document the methodology OTA would use to estimate the revenue and distributional effects of a carbon tax. Carbon taxes have been sufficiently widely discussed that a technical assessment of the issues involved was warranted. In addition to describing the office's methodology, this technical paper lays out several of the tax policy issues that would be involved in implementing such a tax.

The majority of the tax issues involved with a carbon tax are straightforward and would be consistent with U.S. policy experience with other excise taxes in terms of how the tax could be implemented and administered and how OTA would assess its revenue and distributional effects. Other issues involve broader changes to the U.S. tax system and are not part of standard excise tax analysis. In particular, because a carbon tax would raise substantial revenue, at least in early years, and because this revenue is likely to enter general revenue (unlike other excise taxes whose revenues are typically invested in trust funds with specific spending mandates), a carbon tax would allow Congress to reduce other taxes if desired in a so-called "tax swap." Such a reduction in other taxes would raise its own set of tax policy issues in terms of timing, distributional effects, and tax administration.

The analytical and methodological issues can be more readily understood in the context of a specific example. To examine the effects of a sample carbon tax, OTA estimated the 10-year revenue effects of a carbon tax that started at $49 per metric ton of carbon dioxide equivalent (mt CO_2-e) in 2019 and increased to $70 in 2028. We estimate that such a tax would generate net revenues of $194 billion in the first year of the tax and $2,221 billion over the 10-year window from 2019 through 2028. This revenue could finance significant reductions in other taxes. In 2019, this carbon tax revenue would represent approximately 50 percent of projected corporate income tax payments or 20 percent of the OASDI portion of the payroll tax. If the revenue were rebated to individuals it would amount to $583 per person in the U.S. The last section of the paper uses Treasury's Distribution Model to provide distributional analysis of this sample tax and four possible tax swaps. Distributional analysis is particularly valuable in this context for guiding the choice of the tax swap to address possible equity considerations.

Proposals for a carbon tax are often accompanied by recommendations for changes in Federal spending (e.g., research into energy efficiency or renewable energy generation; geoengineering) or changes in environmental regulations. These items are outside the expertise of OTA and are not discussed here.

II. Revenue Estimation and Design Issues

1. The tax base – What would be taxed?

Any assessment of the revenue and distributional effects of a tax must be predicated on a choice of what the base of the tax would be and at which points the tax would be collected. Because the U.S. does not currently have a carbon tax or other excise taxes of a similar scope, some basic assumptions regarding what the base of the tax could be are necessary. This section provides a discussion of the issues in determining the tax base in terms of administrative burden, compliance, and coverage of greenhouse gas emissions.

We divide the potential tax base into three categories:[6] (i) fossil fuel emissions; (ii) non-fuel emissions, including industrial process and product use emissions, emissions of fluorinated gases, and other emissions not counted as fossil fuel emissions; and (iii) biomass fuels such as ethanol. Non-carbon-based energy sources such as nuclear, wind, solar, and geothermal do not emit greenhouse gases and would not be taxed. Although land-use-based and other non-point emissions, such as from soil management, livestock, or deforestation, might eventually be covered in some way by a carbon tax system, this paper does not address the issues that such coverage would involve.

a. Fossil Fuel emissions

Fossil fuel combustion represents roughly 76 percent of U.S. greenhouse gas emissions.[7] Essentially all of these could be covered by an excise tax levied on coal, natural gas, and petroleum at distinct points in the supply chain. A streamlined set of taxable activities and a straightforward taxable unit would give the fossil fuel component of the carbon tax a light administrative burden.

Fossil fuel emissions could be taxed using either a so-called "upstream" or "midstream" approach. The approaches differ on the point in the supply chain at which the fuel's emissions would be taxed: An upstream approach taxes raw fuels while a midstream approach taxes fuels at a designated point further down the supply chain but before they reach final consumers. A hybrid of the two approaches is also possible.

Under an upstream system, an excise tax would be levied on (i) crude oil as it reaches the refinery, (ii) natural gas as it leaves the processor to enter a pipeline system or, for gas that bypasses the processor or pipeline system, arrives at the end user, and (iii) coal as it leaves the mine. To be consistent with a carbon tax focused solely on domestic use, fuel imports would be taxed and exports would be eligible for a refundable tax credit. Aviation fuels used in foreign trade, a designation that includes international flights, would be exempt from the tax. Carbon dioxide captured from a fossil fuel plant or through industrial processes and permanently stored would be eligible for a refundable tax credit.[8]

Fuels or fuel products that are delivered to uses that do not release emissions, such as waxes, lubricants, solvents, or chemical feedstocks, would be exempted from the tax or could claim a credit. An upstream system would need to promulgate rules to govern such exemptions and credits. This issue does not arise to any great degree under a midstream tax, which aims to tax only those fuel products that are destined to be combusted.

Under a midstream system, an excise tax would be levied on (i′) petroleum-based fuels as they leave the refinery or are otherwise sold for use, an arrangement referred to as being imposed at the "terminal rack," (ii′) natural gas as it leaves local distribution centers, and (iii′) fuels used by electric generating facilities or other industrial users that have not been previously taxed. A hybrid upstream/midstream

[6] Tax categories do not necessarily conform to categories in the Greenhouse Gas Inventory (EPA, 2016a), the Greenhouse Gas Reporting Program (EPA, 2016b), or the Intergovernmental Panel on Climate Change.
[7] OTA estimate based on Environmental Protection Agency (EPA) and Energy Information Administration data.
[8] Treatment of imports, exports, aviation fuels, and captured carbon dioxide is the same under both upstream and midstream approaches.

approach that taxed natural gas and coal upstream and petroleum products midstream is also possible.

Under either upstream or midstream approach, the tax would be based on the imputed carbon dioxide emissions per unit of fuel. Table 1 shows candidate imputed emissions and per-fuel-unit taxes that would apply under the upstream and midstream approaches assuming a tax of $49 per metric ton of carbon dioxide equivalent (mt CO_2-e). A per-unit fuel tax would be cost-effective because each of these fuels' carbon dioxide emissions are essentially invariant to how the fuel is burned:[9,10] A high mileage car emits essentially the same amount of carbon dioxide per gallon of gasoline as a low mileage car, although of course, the high mileage car can go much further on that gallon of gasoline.

The carbon content of coal is more variable than the carbon content of refined fuels or natural gas. Under the imputed-emissions approach shown in Table 1 the tax would depend only on the type of coal and would not distinguish within coal of a given type. We therefore would expect consumers of each coal type to engage in some degree of "arbitrage." Coal consumers of each coal type would likely seek out coal sources that yielded higher amounts of energy per unit of tax, causing average carbon dioxide emissions for different coal types to be greater than the parameters shown in Table 1. We have not attempted to predict how large an effect this might be. To minimize distortions, the Secretary of the Treasury could be provided the authority to update periodically the carbon-content parameters used to construct the coal taxes in a way that reflects changes over time in the carbon content of coal coming to market. In the upstream tax case, similar concerns may apply to variability in the carbon content of crude oil.

Under an upstream system, crude oil would be taxed based on its total carbon content regardless of the fuels and products it is used to produce. This approach is necessary to ensure the tax falls fully on those fuel products that are later used for energy purposes. Fuels and fuel products whose emissions were substantially lower than the Table 1 coefficients would be eligible to claim a credit based on their lower emissions. This treatment may be somewhat challenging for taxation of non-fuel petroleum products that emit greenhouse gases as they breakdown over time. Secretarial discretion would be needed to define which products have emissions that are not accurately reflected in Table 1.

For electric generating facilities and other stationary combustion sources, a midstream approach could instead tax actual emissions, as measured by a continuous emissions monitoring system, rather than the fuel inputs. A measured emissions tax would not presently be possible for transport fuels or natural gas used directly by residences or commercial establishments; for these uses, some form of fuel-based tax would still be required.[11] Under a measured emissions tax, emissions from renewable fuels at electric generating facilities and other point sources would initially be taxed at the same rate as emissions from fossil fuels but they could be made eligible to claim full or partial credit based on the renewable fuel used, depending on how the system wishes to treat renewable fuels.

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[9] Fossil fuel combustion also releases small amounts of methane and N_2O and these are not invariant to the circumstances of combustion. Table 1 taxes are based solely on each fuel's CO_2 emissions. Tax legislation would determine whether the Table 1 parameters should be modified to incorporate non-CO_2 emissions or whether the non-CO_2 emissions would be covered separately as a form of industrial emission.

[10] Under an upstream system, imports of refined fuels would be taxed and exports provided a credit at the midstream rates shown in Table 1.

[11] A measured emissions tax would require writing new tax guidance for emissions measurement. Fuel-based taxes would be able to take advantage of existing guidance on fuels measurement.

Comparison of upstream and midstream approaches. Our assessment is that the upstream, midstream, or upstream-midstream hybrid approaches would tax essentially the same quantity of fossil-fuel-based emissions, with minor differences. One exception is that a midstream system would not readily cover emissions from petroleum fuels burned at the refinery. Under a midstream system, those emissions would presumably be covered instead as industrial (non-fuel) emissions, described below.

Our assessment is further that under any of these approaches the carbon tax could be collected through modest modifications to existing Form 720, the tax form on which existing federal excise taxes are reported. Furthermore, under any of the approaches, the carbon tax could, if desired, readily be imposed on top of existing fuel and energy taxes and those Federal tax revenues could continue to flow to the Highway Trust Fund, Oil Spill Liability Trust Fund, Leaking Underground Storage Tank Trust Fund, Black Lung Disability Trust Fund, and related entities.

Differences between the upstream and midstream approaches arise instead primarily from (i) the time needed to write necessary tax guidance (a function, in part of the number of taxable activities and the availability of existing tax guidance), (ii) the number and sophistication of the taxpayers and the variety of taxable activities involved, which together affect longer-term compliance and administration concerns, and (iii) the number of products or fuel uses that should be exempted from the tax or, conversely, the number of fuel uses that might be missed by the chosen tax point.[12] A midstream approach would entail fewer exemptions for non-emitting uses compared to the upstream approach but would involve a larger number of tax filers. In general, tax administration has historically been able to deal effectively with exemptions to taxable activities; this experience is particularly relevant to the upstream tax approach.

[12] In essence, tax analysis must consider errors of both Type I (fuel uses that would be taxed even though they do not release greenhouse gases) and Type II (fuel uses that would not be taxed even though they release greenhouse gases).

Table 1. CO_2 content and tax rates for fossil fuels @ $49/metric ton of carbon dioxide equivalent (mt CO2-e)		
Fuel	**CO_2 content[1]**	**Tax @ $49/mt CO_2-e**
Natural gas and coal *(Upstream or midstream approach)*[2]		
Natural gas	53.12 kg/mcf	$2.60/mcf
Anthracite	2,578.68 kg/short ton	$126.36/short ton
Bituminous	2,236.80 kg/short ton	$109.60/short ton
Sub-bituminous	1,685.51 kg/short ton	$82.59/short ton
Lignite	1,266.25 kg/short ton	$62.05/short ton
Petroleum		
Midstream approach (representative fuels):		
Gasoline	8.89 kg/gallon	$0.44/gallon
Diesel, home heating oil	10.16 kg/gallon	$0.50/gallon
Jet fuel	9.57 kg/gallon	$0.47/gallon
Upstream approach:		
Crude oil	432 kg/bbl[3]	$21.17/barrel

[1] Source: http://www.eia.gov/environment/emissions/co2_vol_mass.cfm. CO_2 content parameters represent OTA's assessment of tax-relevant emissions and should not be considered definitive for any carbon tax that may be enacted.
[2] For natural gas and coal, upstream and midstream approaches differ in the point in the supply chain at which the fuel is taxed but not the form of the fuel or the per-unit fuel tax at the point of taxation.
[3] Source: https://www.epa.gov/energy/ghg-equivalencies-calculator-calculations-and-references

Tax guidance. A variety of existing tax rules and (non-tax) regulations provide language and protocols that could be used to issue the tax guidance necessary for a carbon tax, including definitions of taxable activities.

For an upstream point of taxation for crude oil, the current tax levied for the Oil Spill Liability Trust Fund (OSLTF), described in Internal Revenue Code (IRC) Section 4611, would provide essentially all required guidance, although additional guidance would be required for an export tax credit, which is not currently provided; our assessment is that this credit would be relatively straightforward. Crude oil derived from tar sands is currently exempt from the OSLTF tax but is assumed to be subject to an upstream carbon tax.

For a midstream approach for petroleum-based emissions, which would tax refined fuels, the IRC defines the fuels currently subject to tax as well as establishes the tax rates, relevant taxable events, and exemptions, and imposes registration requirements for blenders, producers, enterers, terminal operators and others. Applicable regulations and other IRS administrative guidance provide further detail and information on taxable fuels.[13] The Leaking Underground Storage Tank (LUST) tax covers all carbon-emitting motor fuels and further includes home heating oil and other refined products not subject to the more prominent taxes that finance the Highway Trust Fund or Airport and Airways Trust Funds, which include exemptions for off-road and non-transport fuel uses, among others. In addition, LUST exempts

[13] IRS Publication 510 (https://www.irs.gov/pub/irs-pdf/p510.pdf) provides a thorough and comprehensive compilation of the rules, definitions and administrative requirements relating to the fuel excise taxes.

fuel destined for export or for use by the purchaser as supplies for vessels employed in foreign trade or trade between the United States and any of its possessions. This tax therefore covers essentially all petroleum products that lead to Table 1 emissions, and does not cover any products that do not lead to Table 1 emissions. Our assessment is that this existing tax language and guidelines could largely be adopted for a carbon tax. A tax that used the LUST tax framework would constitute a midstream point of taxation.

For an upstream point of taxation for coal, the tax could rely almost entirely on guidance issued for the existing coal excise tax, which is imposed on the first sale of coal mined in the United States. The existing tax does not apply to sales of lignite or imported coal; a cost-effective tax would cover both of these components and expanded tax rules would need to be written to cover these products. The existing coal excise tax also exempts exports but these are presumed to also be exempted under a carbon tax.

For a midstream approach, the tax on coal (and natural gas) would be levied at the electric utility or other point-source emitter rather than at the first point of sale. No current Federal excise taxes are applied at these points. Large emitters could be readily identified using protocols developed by EPA under its Greenhouse Gas Reporting Program. Although regulatory actions, including registration of emitters, undertaken for this program are not valid for IRS purposes, they provide language and procedures that could presumably be adopted by the IRS. A cost-effective tax would need to expand beyond this set of large emitters and be applied to all emitters, regardless of size.

No Federal taxes are currently levied on natural gas. New tax rules would be needed to define fuel measurement protocols and to identify and register the relevant points of taxation in the upstream case. Midstream taxation is discussed in the previous paragraph.

A cost-effective tax system would also provide a credit for carbon dioxide capture and permanent sequestration. The current Section 45Q credit for carbon sequestration provides rules needed to administer such a credit, although the current credit is not refundable. Tax treatment would be essentially the same under upstream or midstream approaches.

b. Non-fuel emissions

A number of greenhouse gas emissions would not be covered by a fuel-based emissions tax. They include: (i) emissions that arise during the production of industrial products such as cement, lime, glass, ammonia, petrochemicals, and others, (ii) emissions from the mining of coal and the extraction and refining or processing of oil and natural gas; these are mostly non-combustion emissions but some combustion emissions might be included here if they occur above the point at which the fossil fuel tax is imposed and (iii) direct emissions of fluorinated gases.

Except for fluorinated gases, these non-fuel emissions are generally not directly linked to a readily observed output or input (as is true for fossil fuel combustion) and therefore tax rules would have to be specific to each process. Because tax rules would be specific to each process, greater rule-making effort would be required, and there is the possibility that some cost-effective emissions reductions would not immediately be counted as such and might therefore not be undertaken. We expect that in most cases, tax rules could borrow from language and experience developed under the EPA's Greenhouse Gas Reporting Program. Additional tax efforts would be required to identify and register those entities that would be responsible for the tax. Such actions would benefit from previous Greenhouse Gas Reporting Program efforts but additional effort would be required.

Fluorinated gases could be taxed at the manufacturer or importer. The U.S. has experience taxing the import and manufacture of a number of ozone depleting chemicals. Although the set of fluorinated gases that are greenhouse gases is different from the set of ozone depleting chemicals, much of the tax guidance and tax administration experience for ozone depleting chemicals could be used for fluorinated gases that are greenhouse gases.

<u>Advantages and disadvantages of taxing non-fuel emissions</u>. Because non-fuel emissions require greater tax administration efforts and because some carbon tax proposals focus exclusively on fossil-fuel emissions, it is worth laying out the advantages and disadvantages of applying the tax to non-fuel emissions.

The primary advantage of extending the tax to non-fuel emissions is the potential to lower the overall costs of controlling emissions; the more sources that reduce emissions cost-effectively, the lower is the cost of any given amount of overall emissions reduction. The cost savings potential from taxing non-fuel emissions is greater the higher is the potential for sources of non-fuel emissions to develop low-cost strategies to reduce emissions.

The disadvantage of extending the tax to non-fuel emissions is that these emissions are not as easy to tax. This leads to two drawbacks: (1) Because non-fuel emissions are not directly measured and cannot generally be directly linked to a specific input or output, the basis for taxation must be described in fairly deep detail. The process would require imputing the emissions that are released by each relevant production process. The promulgation of these imputation rules is a potentially lengthy process, although some of the necessary work has again been done for the purposes of greenhouse gas reporting. (2)This imputation process runs the risk that some emissions-reducing strategies might be missed. For example, emitters may be able to find strategies to lower their emissions that would not be recognized under the potential regulations. A third, presumably minor, disadvantage is that because not all non-fuel emissions can be readily taxed and because tax rules may take a long time to develop, there is the possibility of leakage from taxed non-fuel emissions activities into other, not-yet taxed non-fuel emissions activities.

The decision to extend the tax to cover non-fuel emissions could be made on an activity-by-activity basis. OTA did not attempt to assess the tax administration requirements nor the benefits and costs for covering any specific process. A few non-fuel emissions, such as fluorinated gases, could likely be readily taxed without incurring the disadvantages described above.

c. Biomass fuels

Biomass fuels such as ethanol, wood, animal waste, and corn stover, among others, are used for transportation, power generation, and heating. OTA did not assess the rationale for taxing these fuels, if at all, nor, if they were taxed, what CO_2 content parameters would apply.

Because of the wide range of fuel sources, only a midstream-type of approach could be used. Biomass fuels used for transportation could be taxed effectively as they leave the processor or at the terminal rack, as is done for other transportation fuels. Biomass fuels used for power generation and heating may be subject to minimal processing and there may be no clear point in the supply chain until those fuels reach the electric generator or other stationary emitter.

Given these assessments, and for purposes of simplicity, the subsequent discussion of revenue estimation uses a tax base that includes fuel-and non-fuel emissions but excludes biomass fuels. However, the assessments could be modified to take account of alternative choices.

2. Revenue Estimation

To examine the revenue potential of a sample carbon tax designed as described above, OTA estimated the 10-year revenue effects of a carbon tax that started at $49 per metric ton CO_2-e on January 1, 2019 and rose at roughly a 2 percent real rate through 2040, applied to all energy-related carbon dioxide emissions and selected other major sources of greenhouse gas emissions.[14] We used 2019 as the first year of the tax because our assessment is that it would take two years to prepare to tax the three fossil fuels. Analysis assumes that in addition to full coverage of fossil fuel emissions, 33 percent of eventually-covered non-energy emissions would be covered by tax rules beginning in 2019, 67 percent in 2020, and 100 percent in 2021. Renewable fuels are assumed to not be taxed in this scenario.

The carbon tax scenario and projected net revenues and emissions are shown in Table 2.[15] OTA analysis, based on projections from the Energy Information Administration (EIA), estimates that such a tax would raise $2,221 billion in net revenue over the 10-year window from 2019 through 2028.[16] A tax applied only to energy-related carbon dioxide emissions would raise $1,846 billion in net revenue over the 2019-2028 window. In both cases, projected revenue is approximately linear in the starting tax rate.

[14] The tax (initial tax rate and real rate of growth) is presumed to be set by Congress.
[15] Emissions projections are shown to facilitate comparison with other projections of carbon tax revenue.
[16] OTA analysis does not traditionally provide an assessment of non-fiscal benefits.

Table 2. Tax, Net Revenue, and Emissions under a Carbon Tax (main scenario)										
	2019	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
Tax[a] ($/mt CO2-e, nominal)	$49	$52	$54	$56	$58	$60	$62	$65	$67	$70
Revenue and Emissions										
Net revenue[b,c] ($bn, nominal)	$194	$210	$218	$214	$214	$219	$225	$235	$240	$250
Net revenue as pct. of GDP [b,c]	0.90	0.93	0.92	0.87	0.83	0.82	0.80	0.80	0.79	0.79
Emissions (covered sources,[c] mmt CO_2-e)	6,261	5,951	5,551	5,271	5,091	5,032	5,005	4,970	4,941	4,930
Emissions (covered sources) as pct. of baseline[c]	0.95	0.91	0.86	0.82	0.79	0.79	0.79	0.79	0.79	0.79

[a] Tax levied on carbon dioxide from energy uses of fossil fuels and on selected other non-fuel emissions. Analysis assumes that 33 percent of eventually-covered non-fuel emissions will be covered by tax rules beginning in 2019, 67 percent in 2020, and 100 percent in 2021. Renewable fuels are assumed not taxed in this analysis.
[b] For purposes of making revenue estimates, a degree of non-compliance with the carbon tax is assumed to occur.
[c] OTA calculations based on EIA and EPA data. Covered source emissions are the sum of carbon dioxide from energy uses of fossil fuels and selected other taxable emissions. Baseline emissions are emissions under current law from sources that would be covered by the sample carbon tax.

OTA estimates that gross revenue under the tax scenario in Table 2 would be $2,962 billion over the ten-year window from 2019 to 2028. The difference between gross revenue raised by the tax and the net revenue available for spending or reductions in other taxes (shown in Table 2) arises because the imposition of the carbon tax reduces taxpayer income subject to other Federal taxes and thus reduces income tax revenues at least to some extent. The wedge between gross and net tax revenue due to this effect is referred to as the offset.

The magnitude of the offset depends on the full range of price changes precipitated by the carbon tax, since these affect incomes differentially, and the resulting reductions in income tax revenues depend in turn on the taxes and tax rates applied to these affected incomes. Induced price changes also affect baseline government spending; the reduction in (relative) prices that leads to reduced incomes also reduces what the government must spend on goods and services (e.g., Sheiner 1994), an effect that somewhat compensates for the loss in income tax revenues. As with the income effect, the effect on government spending depends on the full set of price changes induced by the carbon tax. The government budget effect is made more complex by the fact that many categories of spending are denominated in nominal terms or otherwise affected by price changes differently from consumer and business spending. Overall, the induced income tax effect, adjusted for government spending effects, is assumed to reduce the amount of gross carbon tax revenues available for new spending or reductions in other taxes by 25 percent.[17]

[17] The 25 percent offset for excise taxes represents long-standing practice for the Joint Committee on Taxation, the Congressional Budget Office, and OTA. Because carbon tax revenues are projected to be considerably larger than other excise taxes, more detailed analysis of the offset in the carbon tax context may be warranted.

Carbon tax revenues in Table 2 decline as a proportion of GDP over the budget window. Thus, a revenue neutral reduction in corporate, payroll, or other tax rates (the "tax swap") would have positive net revenue in the early years and negative net revenue in later years if the revised rates remained constant over the budget window. Tax rates that varied over time and were aimed at keeping the budget in balance each year would fall initially but need to rise beginning in 2021. This is roughly the experience that British Columbia had with its business tax rate, which, after the introduction of a revenue-neutral carbon tax, fell year by year from 12 percent in 2008 to 10 percent in 2011 and then rose to 11 percent in 2013 (British Columbia Ministry of Finance, 2014). Adjusting corporate, payroll, or other tax rates annually to match carbon tax revenues would be difficult to do in the U.S. and would potentially be disruptive of other tax-based decisions. A rebate could more readily be varied from year to year such that the net revenue effect of the combined carbon tax/rebate would be zero in every year.

Like other tax revenue, carbon tax revenue would be subject to uncertainty. More rapid advances in energy efficiency or renewable energy generation than initially projected would lead to unexpected reductions in carbon tax revenue. To provide preliminary analysis of the range of possible tax revenue scenarios, OTA estimated carbon tax revenues under an assumption of more rapid technological progress in which covered emissions fell to 20 percent of their baseline levels within 15 years (by 2033), with reductions accelerating over time. Results under this scenario are shown in Table 3.

Large-scale revenue uncertainty is primarily a long-run phenomenon. Nevertheless, at some point it may be necessary to revise the tax swap if future projections of carbon tax net revenues fall below initial projections. This revision would be on top of any revision due to projected decreases in tax revenue as a percent of GDP, such as in Table 2.

OTA traditionally produces revenue estimates of policy based on economic assumptions produced by the Office of Management and Budget. Revenue estimates in Tables 2 and 3 instead reflect EIA projections of macroeconomic variables.

Table 3. Tax, Net Revenue, and Emissions under a Carbon Tax (rapid technological progress scenario)										
	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Tax[a] ($/mt CO2-e, nominal)	$49	$52	$54	$56	$58	$60	$62	$65	$67	$70
Revenue and Emissions										
Net revenue[b,c] ($bn, nominal)	$189	$185	$175	$166	$160	$158	$155	$154	$149	$145
Net revenue as pct. of GDP [b,c]	0.90	0.86	0.77	0.71	0.65	0.62	0.58	0.55	0.51	0.48
Emissions (covered sources,[c] mmt CO_2-e)	6,109	5,640	5,083	4,665	4,344	4,124	3,925	3,710	3,488	3,263
Emissions (covered sources) as pct. of baseline[c]	0.93	0.86	0.78	0.73	0.68	0.65	0.62	0.59	0.56	0.53

[a] Tax levied on carbon dioxide from energy uses of fossil fuels and on selected other non-fuel emissions. Analysis assumes that 33 percent of eventually-covered non-energy emissions will be covered by tax rules beginning in 2019, 67 percent in 2020, and 100 percent in 2021. Renewable fuels are not taxed in this analysis.
[b] For purposes of making revenue estimates, a degree of non-compliance with the carbon tax is assumed to occur.
[c] OTA calculations based on EIA and EPA data. Covered source emissions are the sum of carbon dioxide from energy uses of fossil fuels and selected other taxable sources of emissions. Baseline emissions are emissions under current law from sources that would be covered by the carbon tax.

3. Other carbon tax design decisions

The analysis described above excluded effects from alternative design choices that are sometimes discussed in the context of a carbon tax. This section describes several of these design options and briefly describes how they could affect the analysis above. In each case, these options are meant to provide policymakers a fuller understanding of possible carbon tax design choices.

a. Safety Valves and Emissions Targets

The carbon tax is an alternative form of market-based environmental policy to a carbon cap-and-trade. Cap-and-trade systems in the U.S. and elsewhere have frequently included some form of safety valve (Jacoby and Ellerman, 2014), a policy provision for responding to real-world outcomes after the cap is in place.[18] This section discusses a safety valve in the context of a carbon tax.

Under a cap-and-trade policy for greenhouse gas emissions, the overall volume of emissions that the covered entities will emit is essentially certain – it is equal to the cap – but the resulting price of allowances is uncertain. Therefore a safety valve is tied to the allowance price. If, after the cap was in place, allowance prices turned out to be too high, relative to a chosen ceiling, the government would

[18] Legislation could also provide discretion to the Secretary to make future tax changes in response to economic or environmental consequences. A safety valve typically refers instead to a pre-specified legislative provision for changing the tax path that does not rely on or grant discretion to the Administration.

issue new allowances or make future allowances available sooner, thus nudging the allowance price lower. If allowance prices turned out to be too low, relative to a chosen price floor, the government would tighten the cap, either by buying up and retiring allowances or issuing fewer future allowances, thus raising the allowance price and achieving greater emissions reduction. When allowance prices fell in the middle range between the price ceiling and floor, the policy would operate as a pure cap-and-trade system. Thus the safety valve provides a check on actual allowance prices after the policy is put in place. The safety valve policy entails specifying the relevant price floor and ceiling and the mechanism by which the cap would change.

Similar principles could guide the design of a carbon tax safety valve. Under a carbon tax, the cost of controlling emissions would be certain – it would be equal to the tax rate – but the overall volume of greenhouse gas emissions that would result is uncertain. The safety valve would therefore be tied to our overall emissions. Once the tax is in place, if emissions ended up "too high" (above a chosen upper-level trigger), future taxes would be increased relative to the initial path. If emissions ended up falling more than expected – if they met a specific lower-level target – the tax would pause in its yearly rise or be dropped altogether. Thus the safety valve provides some control over the actual emissions reductions achieved after the tax policy is put in place. A safety valve policy would entail specifying the emissions reduction targets and the way in which the carbon tax would respond if these targets were met.

Qualitatively, depending on how a safety value was designed and how emissions evolved over time, this could increase or reduce the revenues associated with a carbon tax. OTA did not analyze the tax implications of a carbon tax safety valve.

b. Treatment of tax preferences

Clean energy tax preferences. The U.S. tax code currently provides tax provisions that encourage renewable energy production and improve energy efficiency. A carbon tax would provide incentives for these activities more cost-effectively, and its incentives make other tax incentives unnecessary to achieve emissions reductions goals. That is, to the extent that such tax provisions result in investments in energy efficiency or in renewable generation that would be undertaken anyway in response to the carbon tax then they entail a cost to the Treasury in terms of lower revenues without conferring any additional social benefits. To the extent that these provisions result in investments that would not otherwise be undertaken then their per-unit costs are necessarily higher than the costs of emissions reductions being undertaken elsewhere in the economy.[19] Both arguments suggest that a cost-effective tax system would not include tax preferences for clean energy.[20]

Fossil fuel tax preferences. The tax code includes a number of tax preferences for fossil fuel exploration, extraction, processing, and distribution. These provisions increase fossil fuel use and

[19] The tax provision most directly affected by these concerns is the Energy Investment Tax Credit. Several other tax provisions that have in the past provided production or investment incentives that would be more cost-effectively provided by a carbon tax either have expired or will have expired prior to the date of any carbon tax. These include the nonbusiness energy credit, the residential energy efficient property credit, the renewable electricity production tax credit, the advanced nuclear power credit, the energy efficient commercial buildings deduction, the alternative vehicle refueling property credit and the alternative motor vehicle credit.

[20] Some tax preferences may be separately warranted because they address network or learning-by-doing externalities more effectively than the carbon tax (alone) would.

greenhouse gas emissions. Thus, a cost-effective tax system would not include tax preferences for fossil fuels.

OTA did not assess the extent to which the carbon tax would affect the revenue cost of clean energy or fossil fuel tax preferences.

c. More rapid tax phase-in

A cost-effective carbon tax would fall equally on all three fossil fuels. However, the tax could potentially be phased-in more rapidly for some emissions sources. More rapid phase-in would be possible for those fuels for which a large part of the necessary tax infrastructure exists under current law. Such tax infrastructure exists for an upstream coal tax, upstream petroleum tax, or midstream transport fuels tax. That is, the tax on oil/transportation fuels could potentially be introduced before the tax on natural gas and coal. Likewise, the tax on coal could be introduced before the tax on natural gas.

The economic benefit of a more rapid phase-in comes from more rapid reduction in greenhouse gas emissions from the taxed fuels. The economic costs of differential phase-in arise from inefficiencies in how emissions are reduced, since carbon emissions would not face a uniform tax during the phase-in period. Analytically, such design choices could be readily incorporated within the methodological framework described here.

d. Border Tax Adjustments

A carbon tax could include a border tax adjustment. A standard border tax adjustment would apply the carbon tax to imports based on the greenhouse gas emissions estimated to be released during their production.[21] This standard adjustment is essentially an estimate of how much higher the imported good's price would be if an identical carbon tax had been applied in the country from which the good was being imported.[22] The standard adjustment would also provide a credit for exports, with the analogous aim of assessing how much lower the exported good's price would be if the U.S. carbon tax had not been applied. A border adjustment for the carbon tax could be applied broadly to all goods or applied only to a narrower set of goods whose production is particularly energy intensive. This narrower set of goods is typically deemed to include iron and steel, chemicals, paper, aluminum, cement, and bulk glass (Aldy and Pizer, 2011; Metcalf and Weisbach, 2009).

A border tax adjustment would effectively broaden the base of the carbon tax to include carbon-intensive products consumed in the U.S. but produced elsewhere while excluding the tax on exported products (as would be done for imported and exported fossil fuels).[23] Border tax adjustments would reduce the incentive for producers to shift the location of production of energy-intensive products abroad to avoid the tax or, analogously, for consumers to increase purchases of energy-intensive imports.

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[21] The economics of a border tax adjustment are complex and beyond the scope of this analysis. This section discusses border tax adjustment issues that we believe would be broadly relevant.
[22] A discussion of how carbon content could be imputed is provided by Perese (2010).
[23] It is not unambiguous that a border tax adjustment improves competitiveness or U.S. economic performance conditional on a greenhouse gas emissions goal. For example, possible adjustments in the exchange rate as a result of changes in patterns of trade mean that gains in more energy-intensive sectors must be weighed against losses in less energy-intensive sectors.

Border tax adjustments, however, also have substantial disadvantages in terms of complexity and administration.

OTA has not assessed the administrative burden or revenue effects of potential border adjustments for a carbon tax.[24] Such effects would depend on how broadly or narrowly was the set of goods to which the border adjustment was applied, the imputed carbon intensities by industry, product, or country of import origin and the methods by which imputations would be constructed, and the extent to which the border adjustment differentiated across the countries from which imports derive, including provisions to reduce the import tax for explicit or implicit carbon prices imposed in those countries.[25]

In lieu of a border adjustment, policymakers may choose to provide assistance to U.S. producers in energy-intensive trade-exposed industries, either through the tax code or through domestic spending. OTA did not attempt to analyze the administrative burden or revenue effects of any such policy.

Border tax adjustment for electricity. Although the volume of trade in electricity is currently small, the ease of cross-border electricity sales and electricity's high energy content suggests that a border tax adjustment for traded electricity could be desirable even if border tax adjustments for other sectors were not enacted.[26]

In the case of electricity, the standard border tax adjustment (consisting of an import tax and export credit based on the carbon intensities of the electricity sector in the country from which the electricity is imported and the U.S., respectively) would run the risk of electricity being exported and then re-imported as a means of garnering tax credits that are not associated with a reduction in greenhouse gas emissions; this pattern could occur since both Canada and Mexico have lower carbon intensities for electricity than the U.S.[27] To preclude such cycling, the export credit would need to be offered at a rate equal to or lower rate than the import tax, adjusted for transmission costs. This arrangement would remove the possibility of electricity being exported solely for the purpose of re-importation.

III. Distributional analysis

OTA provides distributional analysis of major tax proposals. In this section, we describe the Treasury Distribution Model (TDM) and use it to estimate the vertical equity impacts of a U.S. carbon tax and alternative illustrative "tax swap" provisions. We then estimate the effect of the proposed changes in tax

[24] Border tax adjustments would also have effects on greenhouse gas emissions and domestic profits, wages, and employment. Estimates of these effects are typically outside the realm of OTA.

[25] To be consistent with general tax principles, the tax on imports should be the difference between the U.S. carbon tax and the carbon tax, if any, in the country from which the imports are derived, assuming this tax is not credited on export. This is not necessarily a straightforward calculation since many countries will not have the broad-based, uniform carbon tax or equivalent emissions trading scheme discussed here.

[26] In 2014, the U.S. imported 67 million MWh and exported 13 million MWh, primarily to and from Canada, on a base of 4.1 billion MWH (EIA, 2016: http://www.eia.gov/totalenergy/data/monthly/pdf/sec7_3.pdf.)

[27] The imputed carbon intensity of imported electricity, calculated for the border tax adjustment, could, in principle, include that country's imports; if Canada imported U.S. electricity, even if on a "transitory" basis, this action should increase the carbon intensity attributed to Canadian electricity and this adjustment would provide some brake on export-import cycling. Such an adjustment would be complex however and would likely not fully eliminate cycling. Reducing the export credit would provide a more robust solution.

law on the distribution of after-tax income across families.[28] Tax law changes here include both the carbon tax and accompanying illustrative tax reductions such as a per person rebate or reduction in payroll or corporate income taxes. Estimates below show the effect of a $49 carbon tax on projected 2017 incomes.

1. The Treasury Distribution Model

The TDM uses families as the unit of analysis since families generally operate as an economic unit, making common decisions and sharing resources. The TDM estimates each family's total annual consumption using income from individual income tax and information returns and savings rates imputed from the Survey of Consumer Finances.[29] This methodology allows Treasury to preserve the accuracy of income information reported on tax returns when estimating consumption. Survey data may underreport income and using such data, without correction, can lead to implausibly high consumption to income ratios, such as those found in the U.S. Consumer Expenditure Survey (CEX). [30]

After total consumption is estimated using tax data, each tax family is matched to a similar family in the CEX. That family's expenditure shares for 33 consumption categories are then applied to Treasury's estimate of total consumption. We are careful to match families with similar characteristics, including family size. Larger families have the ability to share resources (benefit from returns to scale) so their consumption shares may be quite different from smaller families. Certain commodities like home heating are easier to share than others like clothing so a family with two members might have twice the expenditures on clothing compared to a single person but they may not have twice the expenditures on home heating. To impute the consumption shares from the CEX, we do an unconstrained statistical match with 3 years of CEX data. The statistical match is based on dividing the CEX and tax data into 900 similar cells. Each cell has a unique combination of marital status (2 possibilities), age of the oldest filer (5 age ranges), family size (5 sizes) and consumption rank (18 ranks).[31]

a. Methodology for Distributing a Carbon Tax

In general, a carbon tax would create a wedge between the prices received by producers and the prices paid by consumers. The tax might be passed forward, only increasing the prices paid by consumers, or it might be passed backward, only decreasing the prices received by producers. Or, it might be passed partly forward and partly backward, both increasing the prices paid by consumers and reducing the prices received by producers. How much of the tax is passed forward versus backward depends primarily on demand and supply price elasticities (how responsive producers and consumers are to changes in price).

[28] A summary of Treasury's methodology for distributional analysis, as well as distributions of income, current law and Administration policy, is available on the Department of Treasury's website: https://www.treasury.gov/resource-center/tax-policy/Pages/Tax-Analysis-and-Research.aspx .

[29] Savings are additional savings from cash income. Cash income already excludes some types of savings such as contributions to certain tax preferred retirement accounts (deductible 401(K) and individual retirement accounts). The savings rates for certain groups are negative, indicating that the families in this group are dissaving on average.

[30] Toder et. al. (2011) reconciles the CEX to national accounts and finds the "Personal Savings figure from the CEX is simply not credible, especially for the lower income units" (p. 61).

[31] A more complete description of the TDM, including detail on its income and consumption imputations can be found in Cronin (2017, forthcoming).

If the tax is passed forward, the prices paid by consumers are the original prices plus the tax. This would result in a general price rise which is inconsistent with revenue estimating assumptions. In contrast, if the tax is passed backward, the prices paid by consumers are unchanged and the producer receives the original price less the tax. To pay the tax, producers lower wages and capital returns. Thus, under either method the purchasing power of consumers falls (either because of higher prices or lower wages and capital income). The TDM assumes that the tax is passed back, decreasing the prices received by producers but leaving the prices paid by consumers unchanged. This assumption makes the distributional model consistent with Treasury's revenue estimation procedures, which assume that the general price level is unchanged.

Given this approach, there are three components to Treasury's carbon tax distribution estimates. First the tax is passed back to factor incomes. Second, because factor incomes fall, we assume that the taxes associated with those factor incomes (individual income, payroll and corporate income taxes) also fall. Lastly although the general price level does not change, relative prices do change. Carbon intensive goods become more expensive relative to goods that are not carbon intensive. Each component is discussed below.

Component 1: Factor income effects

Under the assumption that the carbon tax lowers the price producers receive, factors of production receive lower returns. Although the tax initially hits producers of carbon intensive goods, under the assumption of mobile labor and capital, the returns to all labor and supernormal capital would fall. As a result, labor and supernormal capital returns bear the burden of the carbon tax.[32] In the TDM, a family's share of the factor income tax is proportional to their share of total labor and supernormal capital income. Labor income, which primarily includes wages, earnings from self-employment and certain work-related fringe benefits, is estimated to be about $10.6 trillion at 2017 levels. Supernormal capital income, which includes a share of dividends, realized gains, and capital income from noncorporate businesses, is estimated to be about $1.1 trillion at 2017 levels. Families ranked in the top ten percent of the income distribution receive about 39 percent of all labor income and 83 percent of all supernormal capital income.[33] The factor income effect of the carbon tax is progressive.

Component 2: Tax offset

Because the carbon tax reduces factor incomes, it reduces the taxes that are paid by factor incomes, namely individual income, corporate income and payroll taxes. The reduction in income and payroll taxes offsets part of the revenue raised by the carbon tax. OTA uses a standard total offset of 25 percent of the excise tax revenue. In the TDM, roughly half of the offset is applied to lower individual income

[32] As discussed in Cronin et al. (2013) the normal return to capital is exempt from consumption taxes. Under a consumption tax, such as a value added tax (a VAT), new investments are expensed (allowed a full deduction). On a present value basis, this is equivalent to exempting the normal return from tax. Only returns in excess of the normal return, referred to here as the supernormal return, are taxed. In this context, the supernormal return includes all returns in excess of the normal return. Supernormal returns could be the result of successful risk taking or rents. For consistency, Treasury applies the same methodology to all forms of a consumption tax (including excises and a carbon tax).

[33] A complete distribution of family income by source both across and within decile is available on Treasury's website. https://www.treasury.gov/resource-center/tax-policy/tax-analysis/Documents/Distribution-of-Income-by-Source-2017.pdf

tax liabilities, 15 percent is for lower corporate income tax liabilities and the remaining 34 percent is for lower payroll tax liabilities. A family's share of each tax offset is in proportion to their positive tax burdens under each tax. Families ranked in the top ten percent of the income distribution bear 74 percent of the burden of the positive individual income tax, 73 percent of the corporate income tax burden and 33 percent of the payroll tax burden. On net the tax offset component is regressive.

Component 3: Relative price effects

Under the third component, consumption goods with relatively high carbon intensities are assumed to become more expensive relative to consumption goods with relatively low-carbon intensities. This occurs even though the general price level is unchanged. To achieve this relative price effect, we first estimate the increase in prices that would occur if the tax were passed forward into increases in consumer prices. We estimate how the initial increase in the price of carbon (due to the carbon tax) would flow through to the 33 consumption goods directly used by families (which, along with goods used directly by government and for export, are termed "final goods"). As discussed in Box 1, goods with high carbon content experience relatively large price increases and goods with lower carbon content experience small price increases. Next, to keep the price level unchanged, we impose a general price decrease (roughly a 2.6 percent decline) for all 33 consumption goods. We are left with higher prices for carbon intensive goods and lower prices for goods that are not carbon intensive.

Results are shown in Table 4. The table shows the price increases that would occur if the carbon tax were passed forward (column 2) without allowing consumers to switch to less expensive goods. Allowing consumers to choose less expensive alternatives would result in smaller price changes but such changes are a burden to the consumer so the distribution tables measure burden on the original market basket. The general price decrease which is the same for all goods (column 3) and the net price change (column 4) is the sum of the two price changes. By design, the net price change is zero for all goods, but as can be seen in the table, prices of carbon-intensive goods rise relative to other goods. Net prices fall between 0.6 percent and 2.6 percent for the majority of consumer purchase categories. The exceptions are energy goods, which necessarily rely heavily on the taxed commodities; price increases for electricity, natural gas, home heating oil, and gasoline are projected to rise by between 9.2 (gasoline) percent and 24.4 percent (natural gas). A few expenditure categories (water, mass transit, and air transportation) exhibit small net price increases from 1.0 to 4.9 percent.

Table 4. Relative Price Increases (percent)			
Consumer expenditure category	**Price Increase from Carbon Tax[a]**	**General Price Decrease**	**Net Change in Price**
Natural gas	27.0	-2.6	24.4
Electricity	16.9	-2.6	14.3
Home heating oil	12.4	-2.6	9.8
Gasoline	11.8	-2.6	9.2
Air transportation	7.5	-2.6	4.9
Mass transit	6.4	-2.6	3.8
Water	3.6	-2.6	1.0
Other	< 2.0	-2.6	-0.6 to -2.6
All categories	2.6	-2.6	0.0
[a] Source: OTA calculations based on BEA and EIA data.			

The relative price has little effect on vertical equity except at the very top of the distribution where the relative price effect reduces burdens slightly.

Box 1: Increase in prices for carbon-intensive goods

Although the fuel-based carbon tax would fall directly only on oil, natural gas, and coal (or in the case of a midstream approach, on their immediate products), its effects would reach throughout the economy. Firms that have to pay higher prices for energy inputs can be expected to raise prices to account for increased production costs. To the extent that these goods are in turn used in the production of still other goods, we should expect the carbon tax to potentially affect the price of any good in the economy. The approach used here assumes that business-to-business transactions would not be affected by these price effects because businesses would pass on any such price changes. Families consuming final goods are not able to offset the price effects in this manner, however, and therefore the new prices will affect family utility.

We use Input-Output (I-O) tables produced by the Bureau of Economic Analysis to convert raw energy price increases to price increases for 389 industries/commodities. The analysis uses the 2007 Benchmark tables, which are the most recent tables for which detailed information is available. We calculate implied energy price changes by applying the $49 carbon tax to projected 2019 commodity prices for oil, natural gas, and coal. We assume that there is 100 percent pass-through of the tax and then apply the calculated percentage price increases to the I-O table commodities of "Oil and Gas Extraction" (which we subdivide into separate components for oil and gas extraction) and "Coal Mining." Our results contain only the effects of the fuel-based component of the carbon tax; we do not attempt to estimate the economic effects of the non-fuel carbon tax.

Finally, the purchaser price of these goods is calculated by adding in transportation and trade margins. Using a crosswalk supplied by the Bureau of Labor Statistics, we use these purchaser prices to determine the change in price of 33 consumer price categories used in the CEX.

There are many ways in which the economy has changed since 2007, the most recent year for which the I-O tables are available. Both the energy intensity of the economy (measured in terms of BTU's per dollar of real GDP) and the carbon intensity (measured in terms of tons of greenhouse gas emissions per dollar of real GDP) have fallen substantially. To address the change in energy intensity we reduced the size of the coal, oil, and gas extraction industries by 17 percent relative to all other sectors. Value-added and import amounts were adjusted as necessary to retain the essential characteristics of the I-O table. To address changes in the carbon content of electricity and other energy market changes, we used EIA projections to assess the effect of the carbon tax on energy consumed directly by households (first four entries in Table 4.)

b. Pass-back versus Pass-forward

As discussed above, Treasury assumes all consumption taxes, including carbon taxes, are passed back to sources of income, namely labor and supernormal capital income; thus the pass-back approach is also referred to as the sources method. An alternative methodology would be to assume that carbon taxes are passed forward to the uses of income, through price increases on goods produced with carbon; this is also referred to as the uses method.[34] On a present value basis, the two methods result in the same tax lifetime burden for a family if the family consumes all of its income (leaves no bequests). Thus, when families are ranked by permanent income, the two methods typically give very similar results.

The timing of tax burdens under the two methodologies, however, is not the same. Relative to the sources method, the uses method will show a higher burden in years where a family consumes more than their income (borrows or dis-saves) and a lower burden in the years that a family consumes less than their income (saves). To the extent that low-income families are more likely to borrow against future income, the uses method will appear more regressive than the sources method when families are ranked by annual income. Likewise to the extent that elderly families are consuming out of past income (dissaving), the uses method will show a higher burden on the elderly than the sources method when families are ranked by annual income.

Bequests also affect the equivalence of the sources (income) and uses (consumption) method. If a family consumes more over its lifetime than it earns because it receives a bequest then the uses method will assign a higher lifetime burden to the family than the sources method. In contrast, if a family consumes less over its lifetime than it earns because it leaves a bequest then the uses method will assign the family a lower lifetime burden than the sources method. To the extent that high income families are more likely to leave bequests, the uses method will appear more regressive than the sources method because it will assign a lower burden to high income families who leave bequests.

Under either the sources or uses method, transfer income is left unchanged ("held harmless.") Under the sources method, transfer income does not bear the burden of the carbon tax, only factor incomes do, so the tax does not burden families that have only transfer income except to the extent that they consume a larger share of carbon intensive goods than the average family. As discussed above the carbon tax under the sources method has three components: factor income tax burden, factor income tax burden offset and the relative price change burden. The average family will not have a burden from the relative price change because it nets to zero. Families with only transfer income will not bear the factor income tax or accompanying tax offsets so they can only be affected by the burden of the relative price change. Families that consume more than the average level of the taxed good will pay more for their pre-tax level of consumption and families that consume a below average level of carbon will pay less for their pre-tax level of consumption.

Similarly, under the uses method, transfer income is indexed to the general price level so again only families who consume more than their income or who consume a relatively high share of carbon intensive goods (so the price change in their market basket is greater than the general price change) have a burden from the carbon tax. For example, if a family had only social security income and the price

[34] The Urban-Brookings Tax Policy Center (TPC) follows the sources method and the Congressional Budget Office (CBO) follows the uses method.

level rose by 3 percent, under the uses (pass-forward) method, their income would also go up by 3 percent because social security income is indexed to the general price level. If they consumed all of their income and consumed an average market basket then the price of their market basket would also rise by 3 percent. They would be held harmless. If instead, they had a carbon-intensive market basket, then cost of their market basket would rise by more than 3 percent and they would be worse off. On the other hand, families with only transfer income who consume a less carbon intensive market basket may actually win from a carbon tax as the prices of the goods that they consume fall relative to the average family (sources method) or as their indexed income increases by more than the prices of the goods that they consume (uses method).

2. Distributional analysis: Results

A carbon tax would potentially allow a reduction in other tax rates, the so-called tax swap or "revenue recycling". Distributional analysis is particularly valuable for showing how possible tax swaps could be designed to address distributional considerations (e.g., Marron and Morris, 2016). To provide information relevant to this assessment, we first show the distributional effects of the carbon tax without revenue recycling. We then show the further distributional effects of revenue recycling using four tax swap scenarios.

a. Baseline: Distribution of the carbon tax before revenue recycling

Table 5 shows the distribution of a $49 per metric ton carbon tax without revenue recycling and assuming the tax is passed back to factor income (sources method). Table 5 is a standard Treasury distribution table. The first two columns show the distribution of families and the distribution of cash income by decile. The third and fourth columns show the share of the total tax burden borne by each decile under current law and under the proposed law. In this case proposed law is current law plus the carbon tax. The fifth and six columns show the average federal tax rate by income decile under current and proposed law. Columns 7 thru 10 show the change in tax burden by decile in various forms: as a total dollar amount, as an average dollar amount, as a share of the total change in tax burden, and as a percent of the total federal tax burden under current law. Each statistic may be of interest to various users of the table.

The last column shows the change in after-tax income by decile. This is the preferred statistic to judge the regressivity (or progressivity) of a proposal. The percent change in after-tax income shows how the tax change affects each income deciles' consumption possibilities. If a proposal results in the same percentage change in after-tax income for all deciles then the proposal is considered distributionally neutral with regard to vertical equity.[35] In contrast, if a proposal results in smaller decreases in after-tax income for low-income families than for high income families then it is progressive and if a proposal results in larger decreases in after-tax income for low-income families than for high income families then it is regressive.

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[35] Treasury's standard distributional analysis only addresses questions of vertical equity. In general, vertical equity requires that families with a greater ability to pay (as measured by income) pay a higher fraction of their income in taxes. Treasury's standard tables do not address questions of horizontal equity, which is the notion that families with an equal ability to pay should have equal tax burdens.

As can be seen in Table 5, the carbon tax is progressive for much of the income distribution. The lowest income decile is estimated to have a 0.8 percent decrease in after-tax income because of the carbon tax and the magnitude of this percentage change in after-tax income rises with income through the 9th decile. In the 9th decile, after-tax income is estimated to fall by 1.8 percent because of the carbon tax.

The progressive trend reverses itself, however, at the top of the income distribution. The top 5 percent is estimated to have a smaller decrease in after-tax income than all but the bottom 3 deciles. Looking at the detail within the top ten percent, the decline in the carbon tax burden continues as income rises. The top 0.1 percent of the income distribution is estimated to have a smaller decline in after-tax income than the poorest income decile.

Table 5: Carbon Tax of $49 per Metric Ton without Revenue Recycling

Adjusted Family Cash Income Decile	Number of Families (millions)	Distribution of Cash Income (%)	Distribution of Total Federal Taxes		Average Federal Tax Rate		Tax Change				Change in After-Tax Income (%)
			Current Law (%)	Proposal (%)	Current Law (%)	Proposal (%)	Amount ($B)	Average ($)	Percent Distribution (%)	As a % of Current Law (%)	
0 to 10	16.4	1.0	-0.5	-0.4	-10.3	-9.4	1.2	72	0.6	-8.1	-0.8
10 to 20	17.2	2.1	-0.4	-0.3	-4.4	-3.2	3.9	229	2.0	-28.8	-1.2
20 to 30	17.2	2.8	0.2	0.3	1.4	2.7	5.7	332	2.9	98.1	-1.4
30 to 40	17.2	3.7	1.0	1.2	5.6	7.0	7.9	460	4.1	25.5	-1.5
40 to 50	17.2	5.0	2.2	2.4	9.2	10.7	10.8	630	5.6	15.7	-1.6
50 to 60	17.2	6.6	3.9	4.1	12.3	13.8	14.8	861	7.6	12.2	-1.7
60 to 70	17.2	8.5	6.1	6.3	15.0	16.5	19.3	1,120	9.9	10.1	-1.8
70 to 80	17.2	11.2	9.4	9.6	17.6	19.1	25.1	1,461	12.9	8.6	-1.8
80 to 90	17.2	15.5	15.5	15.6	20.9	22.4	33.8	1,964	17.4	7.0	-1.8
90 to 100	17.2	45.1	62.5	61.0	29.0	30.0	70.7	4,111	36.4	3.6	-1.5
Total	172.1	100.0	100.0	100.0	21.0	22.3	194.3	1,129	100.0	6.2	-1.6
90 to 95	8.6	11.2	12.4	12.4	23.3	24.7	23.4	2,718	12.0	6.0	-1.8
95 to 99	6.9	15.2	18.5	18.3	25.5	26.7	27.9	4,052	14.4	4.8	-1.6
99 to 99.9	1.5	9.4	14.6	14.1	32.7	33.6	13.3	8,611	6.9	2.9	-1.4
Top .1	0.2	9.4	17.0	16.2	37.7	38.2	6.1	35,640	3.2	1.2	-0.7

Compared to TPC (Marron and Toder 2013) and CBO (Dinan 2012), Treasury's distribution of a carbon tax is less regressive. Although Treasury and TPC both pass the carbon tax back to sources of income, Treasury passes the tax back only to labor and supernormal capital income whereas TPC also passes the tax back to transfer income. TPC includes transfer income in their standard analysis because Social Security benefits are indexed to the wage at retirement so new retirees will receive lower benefits. This is a very long run view. In contrast the Treasury tables represent the distributional results in the shorter run. CBO follows the uses method to distribute a carbon tax which, as discussed above, will result in a less progressive distribution to the extent that low-income households consume more than they earn and to the extent that higher income households are more likely to leave bequests.

Even if Treasury were to follow the uses method to distribute the carbon tax, Treasury would likely not find the same degree of regressivity as shown in the CBO analysis because Treasury's consumption to income ratios at the bottom of the income distribution are not as extreme as those found in the CEX (which is used by CBO).[36] The CEX is the only data set with detailed consumption information and it is the common source of data for carbon tax distributions. However, as mentioned above, the CEX has weaknesses as a source of information on total income, especially for families at the lower end of the income distribution. To better measure total consumption, the TDM uses tax data to measure income and taxes and the Survey of Consumer Finances to measure savings. The TDM uses the CEX only to partition the TDM's estimate of total consumption into commodity shares.

Treasury's imputation from the CEX also accounts for family size. The CEX, in its published tables by income decile, does not adjust for family size.[37] Its lowest income quintile has an average family size of 1.7 and its highest income decile has an average family size of 3.2. Family size affects returns to scale in consumption and it affects a family's relative well-being so it needs to be considered both when ranking families and when imputing consumption to families.[38] Without taking family size into account, it is not possible to tell if the larger share of total consumption spent by low-income families on certain carbon intensive goods is because the families are low income or because they have few members and are therefore unable to benefit from returns to scale. In the TDM, we rank families with the same income but more members lower and impute consumption based on both family size and consumption rank so we can better measure consumption shares for low and high income families.

b. Results: Distribution under four tax swaps

Table 6 shows the distributional effects of recycling all of the net revenue from the $49 per metric ton carbon tax. We considered four illustrative options for revenue recycling: (1) providing a fully refundable per person tax credit, (2) lowering the OASDI payroll tax rate, (3) lowering the corporate tax rate and (4) a combination of a per person credit, payroll tax cut and corporate tax cut. Each recycling option is static (assumes no change in family income) and revenue neutral (when combined with the carbon tax) in the first year of the tax. Lowering the payroll tax rate or corporate tax rate may result in shifting income between taxable and nontaxable compensation or shifting income between the corporate and non-corporate sector; these effects are not considered in these tables. The tax swap policies are chosen solely for illustrative purposes.

The first three columns of the table are for reference and show the distribution of families, income and average federal tax rates by income decile. Column 4 shows the carbon tax without revenue recycling, the same result as found in Table 5 and also included for reference. Columns 5 thru 8 show each recycling option. (i) Combining the per person rebate with the carbon tax results in a very progressive change in tax burdens. The TDM estimates that the poorest decile would experience almost a 9 percent increase in average after-tax income compared to a 1 percent decrease in average after-tax income for the top income decile. (ii) Combining a reduction in the OASDI payroll tax rate with the carbon tax would be distributionally neutral with only the very top of the income distribution (the top 1 percent) experiencing an average net decrease in after-tax income greater than 0.5 percent.[39] (iii) Combining a

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[36] When ranking by consumption and following the uses method, Cronin, Fullerton and Sexton (2016) find similar results.
[37] See "Table 1. Quintiles of income before taxes: Average annual expenditures and characteristics, Consumer Expenditure Survey, 2014" available on the Bureau of Labor Statistics website: http://www.bls.gov/opub/reports/consumer-expenditures/2014/home.htm#tableC
[38] See Cronin et. al. (2012) for a discussion of family size adjustments in distributional analysis.
[39] These results are for vertical equity only. As a class each decile is estimated to have only small changes in after-tax income from the combination of a payroll tax cut and carbon tax. Some families within each class, however, may be winners

reduction in the corporate tax rate with the carbon tax would be a regressive change in tax burdens. The bottom 90 percent of families in the income distribution would experience an average decrease in after-tax income but the top 10 percent would experience an average increase in after-tax income. The top 0.1 percent would be expected to increase income by about 6 percent on average under the carbon tax plus corporate rate cut. (iv) Combining the carbon tax with a revenue neutral mix of a per person rebate, payroll tax cut and corporate rate cut gives mixed results. The bottom and top of the income distribution would experience average net increases in after-tax income whereas the middle of the distribution would experience only small average changes in after-tax income.

Table 6: The Distribution of $49/mt Carbon Tax and Revenue Recycling Options

Adjusted Family Cash Income Decile	Number of Families (millions)	Distribution of Cash Income (%)	Current Law Federal Tax Burden as a % of Cash Income (%)	Change in After-Tax Income: No Revenue Recycling (%)	$583 Per Person Rebate (%)	Reduce OASDI Payroll Tax Rate (%)	Reduce Corporate Tax Rate (%)	1/3 Rebate, 1/3 Payroll 1/3, Corp Tax Cut (%)
0 to 10	16.4	1.0	-10.3	-0.8	8.9	0.0	-0.5	2.8
10 to 20	17.2	2.1	-4.4	-1.2	4.7	0.0	-1.0	1.3
20 to 30	17.2	2.8	1.4	-1.4	3.1	0.1	-1.1	0.7
30 to 40	17.2	3.7	5.6	-1.5	2.0	0.0	-1.1	0.3
40 to 50	17.2	5.0	9.2	-1.6	1.2	0.1	-1.1	0.1
50 to 60	17.2	6.6	12.3	-1.7	0.6	0.1	-1.1	-0.1
60 to 70	17.2	8.5	15.0	-1.8	0.1	0.2	-1.0	-0.3
70 to 80	17.2	11.2	17.6	-1.8	-0.3	0.3	-1.0	-0.3
80 to 90	17.2	15.5	20.9	-1.8	-0.7	0.4	-0.8	-0.4
90 to 100	17.2	45.1	29.0	-1.5	-1.0	-0.3	1.5	0.0
Total	172.1	100.0	21.0	-1.6	0.0	0.0	0.0	0.0
90 to 95	8.6	11.2	23.3	-1.8	-1.0	0.3	-0.6	-0.4
95 to 99	6.9	15.2	25.5	-1.6	-1.1	-0.2	0.1	-0.4
99 to 99.9	1.5	9.4	32.7	-1.4	-1.2	-0.9	2.1	0.0
Top .1	0.2	9.4	37.7	-0.7	-0.7	-0.6	6.3	1.7

(experience tax cuts) and others may be losers (experience tax increases).

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