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DESIGNING A CARBON TAX TO REDUCE U.S. GREENHOUSE GAS EMISSIONS

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ABSTRACT

This article describes a revenue and distributionally neutral approach to reducing U.S. greenhouse gas emissions that uses a carbon tax. The revenue from the carbon tax is used to finance an environmental earned income tax credit designed to be distributionally neutral. The credit is linked to earned income and helps offset the regressivity of the carbon tax. The carbon tax reform proposal is also revenue neutral and avoids conflating carbon policy with debates over the appropriate size of the federal budget. The article provides a distributional analysis of the proposal and also makes a number of political, economic and administrative arguments in favor of a carbon tax and responds to the arguments that have commonly been made against using a tax-based approach to reducing U.S. emissions.

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1. Introduction

Public sentiment and political opinion have recently shifted dramatically in favor of the United States taking action on climate change. As illustration, the Democratic and Republican nominees for president last year supported imposing limits on U.S. carbon emissions. This would complement European actions on carbon emissions through the European Union's (EU) Emission Trading Scheme (ETS), which recently finished the first year of its second phase of emission limits. With the United States poised to take the major policy step of initiating limits on carbon emissions, this article reviews the economic and political arguments for using a carbon tax as the policy instrument for curtailing domestic greenhouse gas (GHG) emissions.

Conventional wisdom holds that a carbon tax is not a politically viable option for controlling carbon emissions because the tax makes overly explicit the costs associated with controlling GHG emissions. While this has perhaps been true historically, it is also true that *any* form of carbon pricing has not been politically viable in the United States up until now. However, as the political discussion and consideration of carbon pricing schemes has progressed over the last year and a half, it has become clear that a thoughtfully designed carbon tax would address many of the concerns of those who oppose carbon pricing in general while overcoming many of the shortcomings of a cap and trade system. Indeed, the most serious cap and trade proposals include features that make them "feel" like a tax while looking like a cap and trade system.

A carbon tax is in large measure an energy tax. Because any policy to raise the price of energy will disproportionately impact poor households, one of the major concerns that always arises when energy taxes are discussed is equity. This article describes how a carbon tax swap can be designed for the United States that specifically addresses this distributional concern. Such a tax swap would be distributionally neutral by using the proceeds in a way that offsets the regressivity of the carbon tax.

The remainder of this article is organized as follows. Section 2 describes a revenue and distributionally neutral carbon tax proposal in detail. A detailed distributional analysis of this proposal is presented in section 3. In Section 4 I argue that a carbon tax is preferable to a cap and trade system in a number of ways. In section 5 I respond to the main arguments that have been made against a carbon tax. Some concluding comments are presented in the final section.

2. A Revenue and Distributionally Neutral Carbon Tax Proposal

This section describes the key elements of a carbon tax reform that is both revenue and distributionally neutral. The carbon tax rate would be set, ideally, to maximize social welfare, taking into account the dynamic nature of the problem as well as the interaction between the carbon tax and the various distortionary taxes currently in place. A starting point for thinking about the optimal tax rate is an estimate of the social marginal damages of GHG emissions denominated in dollars per metric ton of CO_2 equivalent (CO_2e). Unfortunately, precise estimates of these social marginal damages do not exist. The IPCC's Working Group II estimates a mean cost for 2005 of $12 per metric ton of CO_2, but notes that social cost estimates range from $3 to $95 per ton in a survey of 100 estimates (IPCC 2007b, p. 16). The report goes on to note that these costs are likely to underestimate the social costs of carbon because of the difficulty in quantifying many impacts. This report attributes its higher estimate to its explicit treatment of risk and the newer evidence on which it relies. Despite the uncertainties, the report suggests that the "net damage costs of climate change are likely to be significant and to increase over time" (p. 16). Stern (2007) estimates the social cost of CO_2 at $85 per ton. In contrast, Nordhaus (forthcoming), using his Dynamic Integrated Model of Climate and the Economy (DICE) model, estimates an optimal tax rate of just over $11 per ton CO_2e in 2015 (in year 2005 dollars). Simply put, the literature does not provide a consensus view on the marginal damages of GHG emissions and the optimal tax rate.

Another way to set the initial tax rate is to focus on a given stabilization target. A recent analysis by researchers at MIT suggests that an initial carbon price of $18 per ton CO_2e that rises over time at 4 percent per year (real) is consistent with the U.S. policy modeled in the recent U.S. Climate Change Science Program (CCSP) exercise to achieve a CO_2 target by 2100 of 550 parts per million (Paltsev et al., 2007). Whether this is a sufficiently stringent target is open to debate.

The proposal presented here takes a more modest approach. It suggests setting an unambiguous price signal through a tax at a modest level initially with a commitment to increase it over time. The revenue would be used to fund a reduction in the income tax. A clear price signal would provide the incentive for firms to begin the process of adjusting their behavior and investment to offset and avoid emissions. Specifically, the tax proposal contains the following elements:

- A tax on GHG emissions at an initial rate of $15 per metric ton of CO_2e that gradually increases over time.
- A refundable tax credit for sequestered emissions and other approved sequestration activities.

- A refundable credit for the embedded CO_2 in exported fuels and taxation imposed on the embedded CO_2 in imported fossil fuels.
- An environmental earned income tax credit on personal income taxes equal to the employer and employee payroll taxes on initial earnings, up to a limit.

Carbon stays in the atmosphere for hundreds of years. Enacting a carbon tax now and gradually increasing it is more cost effective than having to cut emissions drastically in the future. As new information emerges on the appropriate time path for carbon prices, Congress can revisit the issue and adjust the tax rate's time path as needed.

2.1. The Carbon Tax

The first component of the carbon tax reform proposal is the carbon tax itself.[1] I begin with some discussion of the tax's short-run impact as well as important design considerations. Emissions of CO_2 were slightly more than 6,000 million metric tons in 2005 (Energy Information Administration, 2006). At these emission levels, a charge of \$15 per metric ton of CO_2e would raise \$90.1 billion in tax revenues, assuming no behavioral response.[2] In response to the tax, we would expect substantial emissions reductions in the long run and smaller emission declines in the short run. Table 1 shows the short-run impact of a carbon tax imposed on all GHGs in the United States in 2015 based on modeling using the Massachusetts Institute of Technology's (MIT's) Emissions Prediction and Policy Analysis (EPPA) model.

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[1] A carbon tax can be levied in units of carbon (C) or carbon dioxide (CO_2). One can convert a tax rate denominated in units of carbon dioxide to a rate in units of carbon by multiplying by 44/12. Thus a \$15 per ton CO_2 tax is equivalent to a tax rate of \$55 per ton C.

[2] This distributional analysis focuses only on CO_2 emissions. If a carbon tax includes other greenhouse gases, revenues before any behavioral response would be \$100.8 billion.

Table 1. Short-Run Emissions Reductions With a Carbon Tax			
Source	Reference	Reductions with Tax	Percentage Reduction
Emissions (mmt CO_2e)			
GHGs	8,201.5	1,151.7	14.0
CO_2 emissions	6,995.2	586.4	8.4
Other GHGs*	1,206.3	565.3	46.9
Primary Energy Use (EJ)			
Coal	25.8	3.8	14.7
Petroleum products	49.6	2.8	5.6
Natural gas	26.8	0.9	3.4

Source: Metcalf et al. (2008).
* - Methane, nitrous oxide, and fluorinated gases.
mmt = million metric tons
Note: Results are for a \$15 per ton CO_2e carbon tax in 2015. The tax is in 2005 dollars

The EPPA model shows a 14 percent reduction in GHG emissions. CO_2 emissions fall by 8.4 percent, and other GHGs (methane, nitrous oxide, and fluorinated gases) fall by nearly 50 percent. CO_2 emissions account for just over one half of the CO2-equivalent emissions reductions, while other GHGs account for the remaining half. Although CO_2 emissions make up the largest volume of anthropogenic emissions, they are less potent than other GHGs and relatively more costly to reduce. This speaks to the importance of including as many of the non-CO_2 emissions as possible in any GHG pricing plan. Early emission reductions are less costly among non-CO_2 gases, and their inclusion provides flexibility that reduces the overall costs of any given reduction in emissions.

The lower part of Table 1 shows the reduction that would occur in fossil fuels used for energy. Based on the carbon content of these fuels (as found in Table 6-1 of Energy Information Administration, 2006), reductions in coal consumption would be responsible for 59 percent, petroleum for 34 percent, and natural gas for 8 percent of energy-related CO_2 emissions reductions.

Next I analyze this carbon tax reform using consumption data from 2003. I assume that a carbon tax levied in 2003 would achieve the same percentage reduction in carbon emissions as is modeled in the short-run EPPA analysis described above. With this behavioral response, the tax would collect $82.5 billion in revenues. This may be a conservative estimate of the initial revenue from the tax. An analysis by the EIA, for example, suggests that a $15 tax on CO_2 would reduce emissions by only about 5 percent in the short run (see Energy Information Administration, 2006). With a smaller reduction in emissions, the initial carbon tax revenues would be higher.

2.2 Administrative Issues

Administrative costs are reduced if a carbon tax is levied upstream on fuel producers rather than downstream on fuel users. The tax could be applied at the mine mouth for domestic coal, and at the border for imported coal. The United States had 1,415 functioning mines in 2005. The tax would be based on the amount of coal extracted (i.e., the tax is applied to coal used at the mine). Natural gas could be taxed at the processor or on import. Most natural gas is treated at one of 530 processors, imported through one of forty-nine import pipelines, or one of seven LNG ports. Petroleum products could be taxed on the crude as it enters the refinery or on the various products produced from crude oil along with refinery process emissions. Again, the administrative burden is not particularly cumbersome because there are roughly 150 refineries in the United States. In all cases above, the taxed firms are already reporting data to the IRS and paying taxes. A carbon tax would likely create less of an administrative burden than creating an entirely new accounting scheme for carbon allowances.

One might argue that it would be better to levy the tax downstream because the carbon price would be more visible to end users and thus more likely to figure into energy consumption and planning decisions. Such an argument ignores a basic principle of tax incidence analysis: the ultimate burden and behavioral response to a tax does not depend on where in the production process the tax is levied. This principle could fail if consumers respond to the visibility of a tax—the sort of behavioral response that has recently been studied by economists. It is doubtful that this effect could be very large in the case of a carbon tax for two reasons. First, firms are likely to advertise the embedded tax in, say, gasoline so that drivers would be aware that part of the cost of the gasoline is the tax they are paying. Second, key energy consumers—electric utilities and industrial energy users—are unlikely to be affected by this behavioral phenomenon. They are more influenced by the final price of energy, whether that price is affected by taxes or other factors. Offsetting any apparent advantage of downstream visibility is the greater administrative burden of levying the tax on many more firms and individuals. A report by Cambridge Energy Research Associates (2006) estimates that millions of point sources would fall under an inclusive downstream carbon pricing system.

Non-energy carbon emissions come from a variety of sources, predominantly iron, steel, and cement production. These CO_2 emissions, along with many other GHGs, could be taxed either at the point of production or at the point of consumption. Metcalf and Weisbach (2008) estimate that roughly 90 percent of U.S. GHGs could be brought into the tax base at relatively low cost.

With the carbon tax applied at upstream points, it is important to provide tax credits for carbon capture and storage (CCS) at downstream levels and for fossil fuels used as feedstocks in manufacturing activities where the carbon is permanently stored. CCS refers to technologies that remove carbon from the exhaust streams of fossil fuel burning plants and store it underground – either locally or after transportation to a storage site – for many centuries. Electric utilities that burn coal in an advanced boiler with CCS, for example, would be allowed a tax credit equal to the tax paid on the carbon that is sequestered. Since firms that engage in sequestration activities (e.g. coal-fired electric power plants) may not be the firms subject to the carbon tax (e.g. coal mines), allowing the permits to be traded would ensure that the credits for sequestration would have full value. Thus coal companies with carbon tax liability could purchase carbon tax credits from downstream firms that earn the credits for sequestering CO_2.[3] Credits for certain land-use activities, including forestry sequestration, could also be considered for credit eligibility. This would be a way of allowing sectors not covered by the carbon tax to opt in to the system and receive payments for approved carbon reducing activities.

2.3. An Offsetting Income Tax Cut

The carbon tax will raise the price of carbon-intensive products. In order to address any regressivity in the carbon tax, the reform proposed here uses the tax revenue to provide an offsetting cut in the income tax tied to payroll taxes. Specifically, an environmental earned income tax credit is allowed that is equal to the employer and employee portion of the payroll taxes paid by the worker in the current year, up to a cap. The cap serves two purposes. First, it contributes to the progressivity of the rebate by putting a limit on the rebate for higher income workers. Second, it ensures revenue

[3] Alternatively, firms with carbon tax credits could receive a refund from the IRS directly, thereby obviating the need for tradability. This would be similar to the treatment of zero-rated firms who receive a credit for a Value Added Tax (VAT) paid at earlier stages of production but pay no gross VAT on their value added.

neutrality by putting a limit on the aggregate rebate to workers. The credit would be designed to ensure that households with very low income tax liability would still be able to receive the credit. In this regard, the environmental earned income tax credit would operate like the current earned income tax credit.

An alternative mechanism for providing the offsetting income tax credit would be to directly rebate payroll taxes and credit the Social Security Trust Fund with the carbon tax revenue. While this approach would have an equivalent impact, two problems make the environmental earned income tax credit approach preferable. First, public sensitivity with "tampering" with Social Security may make this approach politically difficult. Second, the IRS has considerable experience in providing tax credits through the income tax, something the Social Security Administration is not well equipped to deal with in the payroll tax.

Setting the cap depends on the amount of carbon tax revenue collected and the number of workers and hours worked. A higher cap will be more costly and could lead to the rebate exceeding the carbon tax revenue. Using data from the Consumer Expenditure Survey for 2003 and applying the carbon tax to energy related CO_2, I calculate that the revenue-neutral cap on rebated taxes for that year would be \$560 per worker. Broadening the coverage of the carbon tax to include other GHGs would increase revenue by roughly 13 percent and raise the cap to approximately \$630. Capping the rebate contributes to the progressivity of the tax cut. The payroll tax cut is greatest for low-wage workers. Nearly three-quarters of the payroll taxes for a worker earning \$5,000 a year would be offset by the credit (see Table 2). In contrast, at maximum covered earnings ($90,000 in 2005), workers would receive a tax credit equal to 4 percent of the payroll tax.

This distributionally neutral reform has some modest offsetting efficiency benefits since the rebate is tied to labor supply. While the rebate is unlikely to appreciably affect labor supply of current workers, it may contribute to greater labor force participation among lower-income workers.[4] To be clear, however, the reform has been designed to emphasize distributional neutrality rather than to maximize efficiency gains.

Table 2 Relation of the Environmental Tax Credit to Payroll Taxes

	Payroll tax		
Wages ($)	Before credit ($)	After credit ($)	Reduction (%)
5,000	765	205	73
10,000	1,530	970	37
15,000	2,295	1,735	24
20,000	3,060	2,500	18
30,000	4,590	4,030	12
50,000	7,650	7,090	7
90,000	13,770	13,210	4

Source: Author's calculation.
Note: Credit of $560 per covered worker assumed. This assumes payroll tax rules as of 2005.

2.4 Additional Components of a Comprehensive Carbon Policy

While I note arguments for a carbon tax that is revenue and distributionally neutral, a comprehensive carbon policy would include three other policies that are modest in cost (or reduce federal spending) and would not jeopardize the overall framework of revenue and distributional neutrality. These policies would complement the carbon tax and contribute to reductions in carbon emissions while potentially improving energy security in the United States. First, increased spending on energy-related research and

[4] For example, Meyer and Rosenbaum (2001) find that changes to the earned income tax credit had substantial effects on the labor force participation of single mothers.

development (R&D) would be valuable both in the area of renewable fuels as well as in CCS. To the extent that R&D is a pure public good, a role for government exists to increase the amount of R&D carried out. While the technologies for CCS are basically well understood, it is not clear how the United States will develop CCS on the scale required given projected coal consumption over the next 30 years.[5]

Second, the United States provides substantial energy production subsidies that contribute to a continuing reliance on fossil fuels. These subsidies are often justified on the basis of encouraging energy independence in the United States since they replace imported fuels with domestic fuels. However, as argued in Metcalf (2007), energy security is enhanced by reducing our consumption of petroleum products overall rather than by simply reducing the share of imports. Many of these subsidies work against achieving that goal.

Third, enhanced support for energy efficiency investments contributes to a reduction in energy consumption and carbon emissions. Increasing energy prices through a carbon tax will surely contribute to increased efficiency investments, but two factors suggest additional benefits from more generous tax credits for efficiency investments. First, certain sectors of the economy may not respond to energy price increases arising from a carbon policy. Commercial real estate and rental housing are sectors where the economic agent who makes efficiency investments (developer or homeowner) is not necessarily the person who benefits from the energy savings (tenant). Second, the hidden nature of many efficiency improvements makes it difficult to recapture the energy savings through their capitalization into building prices or rents. In addition, empirical

[5] EIA's Annual Energy Outlook projects a 47 percent increase in coal consumption between 2005 and 2030 in its reference scenario (see Energy Information Administration, 2007).

work suggests that efficiency investment tax credits have a substantial impact on efficiency investments (see Hassett and Metcalf, 1995).

3. Distributional Analysis of the Carbon Tax Proposal

This section describes the distributional impacts of the proposed carbon tax swap. I present results from an analysis using the 2003 Consumer Expenditure Survey (CES). The CES provides very detailed expenditure data at the household level that allows me to track spending on energy and other commodities whose prices may be increased by a carbon tax. I begin with an analysis of the price impacts of the tax.

3.1 Price Impacts

Assuming that the tax is fully passed forward into higher consumer prices, the direct impact of a \$15 per ton CO_2 tax would be to raise the price of gasoline by 13¢ a gallon and the price of natural gas by 54¢ per thousand cubic feet. This would raise the price of gasoline by just under 7 percent, based on the price of gasoline in 2003, and the price of natural gas for industrial users by 9 percent.[6] Based on data from EPA's Emissions & Generation Resource Integrated Database, the carbon tax would raise the price of coal fired electricity by 1.78¢ per kilowatt hour, an increase of 24 percent, based on the average retail price of electricity in 2003.

These price increases are the direct impacts of the carbon tax on fuels. However, because fossil fuels are used as intermediate inputs in the production of other goods (including energy products such as gasoline and electricity), the consumer impacts will differ from the carbon tax based on the embedded carbon in gasoline and other energy

[6] Prices of gasoline and natural gas from Energy Information Administration website (www.eia.gov) accessed April 2, 2008.

sources. Table 3 provides estimates of price increases for selected commodities if a carbon tax of $15 per ton of CO_2were implemented in 2003 based on the methodology of Metcalf (1999). This methodology uses U.S. input-output tables to trace through the use of fossil fuels in the production of other goods and services in the U.S. economy. The overall price impact of a carbon tax is to raise the price of gasoline by nearly 9 percent once it is taken into account that fossil fuels are used, among other things, to process petroleum into gasoline and transport it to service stations.

Table 3. Consumer Price Impacts of a Carbon Tax

Commodity	Price increase (%)
Electricity and natural gas	14.1
Home heating	10.9
Gasoline	8.8
Air travel	2.2
Other commodities	0.3 to 1.0

Source: Author's calculations using the input/output accounts and the Consumer Expenditure Survey.
Note: A 2003 tax of $15 per metric ton of CO_2 (year 2005 dollars) is assumed to be passed fully forward to consumers.

Except for energy products, the carbon tax appears to have only modest impacts on consumer prices. These budget impacts for the carbon tax assume no consumer behavioral response. Consumer substitution away from more carbon-intensive products will contribute to an erosion of the carbon tax base. The burden for consumers, however, will not be reduced as much as tax collections will fall. Firms incur costs to shift away from carbon-intensive inputs, costs that will be passed forward to consumers. Consumers will also engage in welfare-reducing activities as they shift their consumption activities to avoid paying the full carbon tax. Although the burden impacts reported here do not take account of the range of economic responses to the tax, the impacts provide a reasonable first approximation of the welfare impacts of a carbon tax.

In addition to any consumer substitution effects, a worldwide carbon pricing policy will reduce the demand for energy and shift some of the burden of the U.S. carbon tax onto owners of fossil fuel resources. My assumption of complete forward shifting likely biases my results toward less progressivity than would occur with some backward shifting. In the short run, the price reductions received by producers of oil, natural gas, and coal would be less than 4 percent based on the analysis in Metcalf et al. (2008).

3.2 Impacts on Household Income

As described above, the proposed carbon tax uses the revenue from the carbon tax to reduce the payroll tax by providing a rebate to workers in each household that is equal to their first $560 in payroll taxes (including the employer portion of the tax). This is equivalent to exempting from payroll taxation the first $3,660 of wages per covered worker in 2003.

Table 4 details the distributional impact of this carbon tax swap on households based on annual household income.

Table 4. Distributional Impacts of the Carbon Tax Swap

	Change in disposable income ($)			Change as a percentage of income		
Income group (decile)	Carbon tax	Tax credit	Net	Carbon tax	Tax credit	Net
1 (lowest)	−276	208	−68	−3.4	2.7	−0.7
2	−404	284	−120	−3.1	2.1	−1.0
3	−485	428	−57	−2.4	2.2	−0.2
4	−551	557	6	−2.0	2.1	0.1
5	−642	668	26	−1.8	1.9	0.1
6	−691	805	115	−1.5	1.8	0.3
7	−781	915	135	−1.4	1.6	0.2

8	−883	982	99	−1.2	1.4	0.2
9	−965	1,035	70	−1.1	1.1	0.0
10 (highest)	−1,224	1,093	−130	−0.8	0.8	-0.0

Source: Author's calculations.
Note: The lowest decile includes households in the 5th to 10th percentiles. Mean tax changes within each decile are reported. The columns titled "Carbon tax" report the change in income ($ or %) following price changes arising from carbon tax. The columns titled "Tax credit" report changes in disposable income arising from the new tax credit.

Using an annual income measure to group households, the carbon tax in isolation is regressive. The bottom half of the population faces losses in after-tax income ranging from 1.8 to 3.4 percent of its income, whereas the top half of the population faces losses between 0.8 and 1.5 percent of its income. Providing a credit of up to the first $560 of employer and employee payroll taxes largely offsets this regressivity. The average credit as a fraction of income falls with income, with the lowest income group receiving a credit worth 2.7 percent of income and the highest income group receiving a credit worth 0.8 percent of income. The final column in Table 4 shows that the lowest 20 percent of the population faces modest net reductions in after-tax income of between 0.7 and 1 percent of its income. Otherwise, the tax reform is essentially distributionally neutral.[7]

In Table 5, I modify the rebate component of the carbon tax to show how the distribution of carbon taxes net of the tax credit can be altered through policy design. The first two columns repeat net distributional information from Table 4. The next two columns extend the rebate to include recipients of Social Security. Social Security recipients receive a lump sum rebate equal to the maximum credit for workers. This could be done by increasing monthly Social Security checks by the amount of the rebate

[7] Note that ranking households using an annual income measure biases energy-related taxes to appear more regressive than they would be if households were ranked using a measure of lifetime income. See Hassett, Mathur, and Metcalf (2007) for more discussion of this point.

divided by twelve. Unlike the income tax-based approach, this would require an explicit bookkeeping adjustment to reflect a transfer of funds from the general fund to the Social Security Trust Fund to prevent the rebate affecting balances in this latter fund.

Broadening the recipient pool lowers the maximum credit or rebate to $420. The effect is to increase the progressivity of the reform. A carbon tax combined with an earned income tax credit is essentially distributionally neutral. In the last two columns, I replace the environmental tax credit with a per capita lump sum rebate of $274. This increases the progressivity of the reform even further. Note though that the costs of administering a carbon tax with a lump sum rebate will be higher given the need to track people in households not currently in the federal tax system.

Table 5. Modifying the Rebate in the Carbon Tax Swap

	Earned income		Earned income and Social Security		Lump sum	
Income group (decile)	Net ($)	Net (%)	Net ($)	Net (%)	Net ($)	Net (%)
1 (lowest)	−68	−0.7	112	1.4	166	2.1
2	−120	−1.0	125	1.0	128	1.0
3	−57	−0.2	114	0.6	120	0.6
4	6	0.1	70	0.3	103	0.4
5	26	0.1	54	0.1	108	0.3
6	115	0.3	66	0.1	26	0.1
7	135	0.2	35	0.1	−32	−0.1
8	99	0.2	−61	−0.1	−52	−0.1
9	70	0.0	−95	−0.1	−171	−0.2
10 (highest)	−130	-0.0	−332	−0.2	−355	−0.2

Source: Author's calculations.
Note: This table reports the change in disposable income resulting from different proposals for rebating the carbon tax. See text for descriptions of rebate proposals. The lowest decile includes households in the 5th to 10th percentiles. Mean net tax changes within each decile are reported. Positive numbers indicate an increase in disposable income and negative numbers indicate a decrease. Net (%) indicates the change as a share of income.

Table 5 illustrates the trade-off between distributional and efficiency concerns. As noted above, the rebate was tied to earned income to provide a modest incentive to labor supply. Providing a lump-sum rebate of the tax revenue to households would increase the progressivity of the reform but at the cost of losing the labor supply incentive.

The environmental tax reform illustrated in Table 5 emphasizes an essential point: while a carbon tax itself may be regressive, a carbon tax policy can be designed to be distributionally neutral. The use of the carbon tax revenue to offset payroll taxes makes this distributional neutrality possible. If the revenue were not rebated or if a cap-and-trade system were implemented with freely allocated permits such that the market permit price equaled \$15 per ton of CO_2, the reform would raise prices (as illustrated in the second column of Table 5) but would not provide the offsetting reduction in the payroll tax to achieve distributional neutrality.

3.3 Geographic Impacts

Finally, in Table 6, I show the distribution of the net tax across geographic regions under the three policy scenarios. The largest average difference across regions in household net disposable income is \$100 when the carbon tax is rebated on the basis of earned income. Similar findings hold for the other policy scenarios. A carbon tax does not appear to disproportionately burden one region of the country.

Table 6. Regional Distribution						
	Earned income		Earned income and Social Security		Lump sum	
Region	Net ($)	Net (%)	Net ($)	Net (%)	Net ($)	Net (%)
New England	17	0.0	−36	0.2	−65	-0.1
Middle Atlantic	−9	−0.2	−13	0.2	−18	-0.2
East North Central	30	−0.2	−14	0.1	−37	-0.1
West North Central	30	0.1	52	0.5	−26	-0.2
South Atlantic	24	−0.1	17	0.3	2	0.3
East South Central	−75	−0.5	−6	0.3	−75	-0.2
West South Central	−12	0.0	−42	0.2	9	0.4
Mountain	17	0.1	46	0.5	34	0.4
Pacific	5	0.0	−4	0.2	59	0.6

Source: Author's calculations. Mean net changes in disposable income within each age group are reported. Positive (negative) numbers indicate an increase (decrease) in disposable income. Net (%) indicates the change as a share of income. The regions are defined as follows:
New England: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
Middle Atlantic: New Jersey, New York, Pennsylvania
East North Central: Illinois, Indiana, Michigan, Ohio, Wisconsin
West North Central: Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota
South Atlantic: Florida, Georgia, North Carolina, South Carolina, Virginia, West Virginia
East South Central: Alabama, Kentucky, Mississippi, Tennessee
West South Central: Arkansas, Louisiana, Oklahoma, Texas
Mountain: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming
Pacific: Alaska, California, Hawaii, Oregon, Washington

3.4 Applications to a Cap and Trade System

The distributional results shown in Tables 4 through 6 apply equally to a cap and trade system in which the permits are fully auctioned and the revenue used to finance the environmental earned income tax credit. However, the distributional implications of a cap and trade system in which permits are given to the energy sector through grandfathering are strikingly different.[8] Theory and experience with freely allocated permits in the first phase of the EU-ETS suggest that the value of permits given to the energy sector is capitalized into the equity prices of these firms. To model the distribution of a cap and trade system with freely allocated permits requires knowing the distribution of shareholdings of energy stocks in the U.S. The CES contains a limited set of information on wealth holdings that can be used to distribute the value of permits across households. I allocate the value of permits on the basis of these wealth holdings. This approach is accurate to the degree that energy shares and wealth are distributed similarly. The results, shown in Table 7, indicate that this approach is decidedly regressive, with disposable income falling most (in percentage terms) for the lowest income groups and rising only for the top two income deciles.

Table 7. Distributional Impacts of a Cap and Trade System with Grandfathered Permits

	Change in disposable income ($)			Change in disposable income as a percentage of income		
Income group (decile)	Carbon tax	Value of grandfathered permits	Net	Carbon tax	Value of grandfathered permits	Net
1 (lowest)	−276	130	−145	−3.4	1.6	−1.8
2	−404	321	−83	−3.1	2.4	−0.6
3	−485	371	−115	−2.4	1.8	−0.6
4	−551	435	−116	−2.0	1.6	−0.4
5	−642	454	−191	−1.8	1.3	−0.5
6	−691	473	−215	−1.5	1.1	−0.5
7	−781	647	−134	−1.4	1.1	−0.2
8	−883	752	−131	−1.2	1.0	−0.2
9	−965	1,087	121	−1.1	1.2	0.1
10 (highest)	−1,224	2,191	967	−0.8	1.3	0.5

Source: Author's calculations. The lowest decile includes households in the 5th to 10th percentiles. Mean changes in disposable income within each decile are reported.

[8] Grandfathering means that permits are freely allocated to large energy users on the basis of historic emissions.

3.5 Efficiency Implications

While this section focuses on the distributional implications of a revenue-neutral carbon tax reform, a few comments on efficiency are in order. First, there is no question that carbon pricing—whether through a carbon tax or a cap-and-trade system—has efficiency costs. Carbon pricing is a tax on inputs used in the production process and hence gives rise to distortions.[9] Carbon pricing, however, is likely to be less costly from an efficiency point of view than an increase in gasoline taxes because the tax is more broadly focused and does not single out particular fossil fuels.[10] More to the point, the appropriate tax depends on what you want to achieve. A carbon tax more directly addresses a carbon emissions externality than taxing a proxy for carbon (e.g. gasoline). Second, the efficiency costs of carbon pricing are not that large. Metcalf et al. (2008) find welfare losses for a carbon tax similar in size to the one considered in this analysis to be less than 0.5 percent per year. Third, one can reduce the efficiency losses by using carbon revenue to lower other distortionary taxes.[11] Estimates of the marginal excess burden of taxes on income range from 0.2 to 0.4, depending on a number of factors, including whether capital or labor income taxes are changed (Ballard, Shoven, and Whalley, 1985). At the upper end of this range, a carbon tax raising $82 billion could achieve an efficiency gain of more than $30 billion when used to lower income tax rates, relative to a lump-sum distribution.

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[9] The trade-off in benefits and costs of environmental taxes in the presence of other tax distortions has been extensively discussed in the double-dividend literature. See Goulder (1995) and Fullerton and Metcalf (1998) for a review of this literature.

[10] On the other hand, taxing gasoline reduces congestion, accidents, and local pollution. Parry and Small (2005) note that the optimal tax on gasoline is well above current levels of taxation in the United States.

[11] Metcalf (2007), for example, examines the impact of a carbon tax used to finance corporate tax integration.

4. Advantages of a Carbon Tax

In the past several years, momentum has developed for a national cap and trade program in the United States and several proposals have been put forward (see Paltsev et al., 2007). While cap and trade has considerable support in the policy community, a carbon tax remains as a viable policy option. The recent discussion in the Senate of the Lieberman-Warner cap and trade bill illustrates policymakers' concerns about the trading prices for emissions permits.[12]

The carbon tax proposal here has several important advantages over cap and trade. First, the tax by its very nature makes explicit the price that Congress will impose on carbon emissions. As noted above, the large uncertainties about the optimal amount of emissions make any policy at this point simply the first step in a U.S. policy contribution to international reductions in GHG emissions. However, setting a clear price on emissions provides the impetus for emitters to begin to reduce emissions through process changes and investment. Second, a commitment to a revenue and distributionally neutral carbon tax could create political discipline that limits the scope of discussion and focuses the policy debate. President Ronald Reagan placed similar constraints on the tax reform debate that contributed to the successful enactment of the Tax Reform Act of 1986. Finally, administrative concerns suggest a carbon tax can be put in place more rapidly than a cap and trade system. I discuss in greater detail below these and other advantages of a carbon tax over a cap and trade system.

[12] The Lieberman-Warner Climate Security Act (S. 2191) implements a cap and trade system on fossil fuel related gases primarily at the upstream level (with the major exception of coal where it is implemented on large coal using facilities). Hydrofluorocarbons are covered under a separate cap. Initially a little over one-fifth of the permits would be auctioned with this share rising to just over seventy percent by 2031. See Appendix D to Paltsev et al. (2007) for a detailed analysis of this bill.

4.1. Revenue

A cap and trade system is built around the instrument of tradable permits. Permits are valuable assets. They can be auctioned by the government, thus raising revenue. But historically they have been given away to industry as part of a process of obtaining support for the system. To be fair, prior domestic cap and trade programs were an order of magnitude smaller than any potential carbon cap and trade program. Thus, given the revenues involved, auctioning permits in those programs was simply not that important.

The stakes are higher with a carbon cap and trade bill and the need for fiscal discipline that much greater. The debate last year over the Boxer Amendment to the Lieberman-Warner Bill is instructive. The bill set very specific uses for the freely allocated permits as well as for spending from auctioning. In effect the bill implemented a large-scale set of revenue and spending programs that circumvented the normal committee process.

The Congressional Budget Office recognized these indirect revenue implications of cap and trade bills with its decision in late 2007 to begin counting freely allocated permits as revenue and offsetting spending (see the CBO cost estimate of S. 2191 released on April 10, 2008). One could push this point further and argue that any new major revenue source – such as arises from a tradable permit system whether the permits are auctioned or freely allocated – should go through the usual Congressional budget process. This ensures that Congress weighs the best use of funds from the initiative against all the pressing budget needs. This is precisely the process that would occur with a carbon tax.

This is not to suggest that proponents of carbon pricing couldn't propose fiscal constraints on the use of carbon revenue. On the contrary, the constraint to be revenue and distributionally neutral could be imposed and might provide appropriate fiscal discipline that would contribute to support for the passage of a cap and trade bill. Note though that the incentives for this sort of discipline may be stronger for a tax than a cap and trade bill. Any tax bill, including a carbon tax, would emerge from the House Committee on Ways and Means, which initiates all tax legislation in the House, and the Senate Finance Committee, which controls tax legislation in the upper chamber. Members of these committees can more easily impose the revenue and distributional neutrality constraint than can members of the House Committee on Energy and Commerce or the Senate Committee on Environment and Public Works, which are responsible for cap and trade legislation. These committees have a narrower fiscal focus and the natural incentive for committee members is to spend revenues on programs under their purview.

4.2. Administration

We have a time-tested administrative structure for collecting taxes that can ramp up a carbon tax in relatively short order. Firms that would be subject to a carbon tax are already registered with the IRS and have whole departments within their firms that carry out the record keeping and reporting for tax payments. Coal producers already pay an excise tax to fund the Black Lung Trust Fund and oil producers pay a tax to fund the Oil Spill Trust Fund (see Metcalf (2007) for a description of these funds). We also have precedents for refundable credits for sequestration activities in federal fuels tax credits. In contrast, we have no administrative structure for running an upstream carbon cap-and-trade program. A report by the Congressional Budget Office (2008) details the lead-time required to establish allocations. All this suggests that we can implement carbon pricing through a tax more quickly than through a cap and trade system.

4.3. Efficiency in the Face of Uncertainty

GHG emissions are an example of what economists call a negative externality: an activity taken by an individual or firm with social costs that exceed the private cost. In general, competitive markets will not lead to the socially optimal level of emissions in the absence of government intervention. In the absence of any controls on emissions, firms will release GHGs to the point where the marginal cost of emissions equals marginal abatement costs.

With full information about the costs and benefits of GHG emissions, the carbon tax and the cap-and-trade system are both efficient and lead to the same outcome. However, with uncertainty over the marginal abatement costs of emissions, the two policy instruments are no longer equivalent. In a pioneering paper, Weitzman (1974) describes conditions under which a tax provides higher or lower expected social benefits than a cap-and-trade system in a world with uncertainty. His analysis demonstrates the importance of the relative slopes of marginal damages and abatement costs in choosing the optimal instrument.

Marginal abatement costs are a function of the flow of emissions, whereas marginal damages are a function of the stock of gases in the atmosphere. Several economists have modified Weitzman's model to allow for the stock nature of GHGs (see, for example, Hoel and Karp, 2002), Newell and Pizer, 2003), and Karp and Zhang, 2005). While this makes the analysis more complicated and involves more than simply the relative slopes of the marginal abatement and damage curves, the analyses consistently find that taxes outperform cap-and-trade systems on efficiency grounds for a broad range of parameter values consistent with scientific understanding of the global warming problem. A tax is especially efficient relative to a cap that provides no protections against unexpectedly high permit prices. Adding safety valves and price floors or banking and borrowing reduces the tax advantage. But this simply reflects the fact that such modifications make the cap and trade system act increasingly like a tax.

These analyses of price versus quantity instruments assume no other market distortions. In reality, the decision to choose a carbon pricing instrument takes place in an economic environment with pre-existing tax and regulatory distortions. Quirion (2004) adds distortions to the Weitzman analysis and finds that the presence of pre-existing distortionary taxes enlarges the set of parameters under which a tax dominates a permit system in expected value. Quirion also adds a political economy dimension by allowing for industry opposition that must be overcome for carbon pricing to be enacted. He finds that the expected transfer required to overcome industry opposition is smaller with a tax-based approach than with a permit-based approach.

4.4. Price Volatility

The previous discussion suggests a further point. Carbon taxes ensure a given price for carbon emissions while permit prices in a cap-and-trade system are uncertain. The price volatility of cap-and-trade systems has been well documented. The EU ETS illustrated this dramatically in April 2006 when futures prices for CO_2 permits fell sharply following the release of information indicating that the ETS Phase I permit allocations were overly generous. The December 2008 futures price fell from a peak of

€32.25 on April 19 to €22.15 on April 26, and to €17.80 on May 12. Prices rebounded briefly but drifted downward for much of the rest of the year.

Volatility in the Phase I permit prices themselves (December 2007 contracts) was even higher. These permit prices fell from €31.50 on April 19 to €11.95 on May 3, before rebounding briefly. In late September 2006, the December 2007 contract prices again fell sharply and proceeded to fall to their recent price of €0.07 on September 17, 2007. Permit prices fell and remained at low levels because of the over-allocation of permits in Phase I along with the inability to bank permits across the two control periods.

Price volatility has been an issue for other cap and trade systems. Permit prices for the California Regional Clean Air Incentives Market (RECLAIM) rose abruptly from under \$5,000 per ton of NO_x to nearly \$45,000 per ton in the summer of 2000. Ellerman, Joskow, and Harrison (2003) explain that the price spike arose because of sudden demands for electricity combined with an inability to import power from out of state. Permit prices in EPA's Acid Rain Program spiked to nearly \$1,600 per ton SO_2 in late 2005 from a price of roughly \$900 at the beginning of the year. And NO_x prices in the Northeast states' Ozone Transport Commission spiked to nearly \$8,000 per ton in early 1999 before falling back to more typical levels between \$1,000 and \$2,000 per ton.

Concern over permit price volatility led the drafters of the Lieberman-Warner Climate Security Act of 2008 to propose a Carbon Market Efficiency Board to be modeled on the Federal Reserve System. This board would be able to relax firms' borrowing limits against future permits, extend the repayment period for borrowed permits, and lower the interest rate on borrowed permits in periods of high permit prices. However, such a system has the potential to increase political uncertainty and undermine the credibility of our commitment to a given level of GHG emissions. Moreover, the board may not be able to alleviate price volatility. Efforts to reduce price volatility by allowing short-term borrowing could be hampered by private banking of permits to offset longer-term anticipated increases in permit prices.[13] The ability of borrowing to dampen short-run price volatility depends importantly on expectations about long-run permit prices. If a cap is truly binding over a control period (say from 2012 to 2050), borrowing is unlikely to be effective at reducing price volatility. Any provision for borrowing, it must be emphasized, is entirely unnecessary under a carbon tax.

Another approach to limiting price volatility is to include a "safety-valve" provision. This allows firms to purchase an unlimited number of permits at a set price and thus sets a ceiling on the price of permits. If the market price for permits is below the safety valve price, then firms will simply purchase permits in the open market. Once permit prices reach the value of the safety valve, firms will purchase any needed permits directly from the government. A cap and trade system with a binding safety valve in effect becomes a carbon tax while maintaining the complexity and other disadvantages of the cap and trade system.

Burtraw and Palmer (2006) note that a safety valve lowers the expected permit price and can discourage investment in new technologies to reduce emissions. They recommend combining a safety valve with a price floor to maintain the same expected permit price as would occur in the absence of a safety valve. Low permit prices are a significant problem for induced innovation because predictability about the returns to investments in innovative technologies to reduce carbon emissions is an essential

[13] This is a larger issue that exists with any borrowing scheme.

condition for stimulating that investment. If permit prices fall – as they have done in the EU and as it appears they will in the Regional Greenhouse Gas Initiative (RGGI) program (see Daley, 2008) – we will not see the investment that is needed to move away from a carbon-based economy. Other flexible cap systems (banking and borrowing or modifications of the cap based on current price) are critiqued in Congressional Budget Office (2008). This report finds that an emissions tax "would be the most efficient incentive-based option for reducing emissions and could be relatively easy to implement" (p. viii).

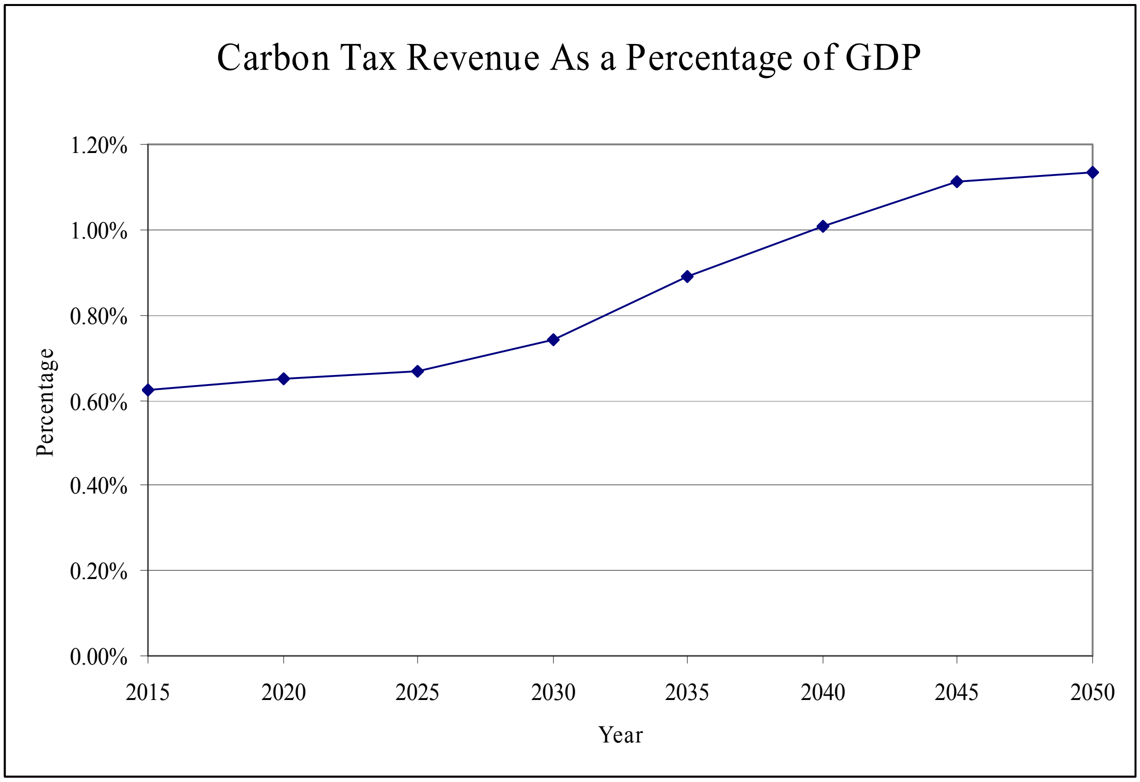
5. A Response to Criticisms of a Carbon Tax

This section responds to a number of arguments that have been made against using carbon taxes as an instrument for carbon pricing in the United States. I do not consider objections that have been raised to carbon pricing in general. For a discussion of those issues, see Metcalf (2007).

5.1. Tax Base Stability

One concern with a carbon tax is that it may not provide a consistent and steady stream of revenue. This is of particular concern if the revenues are earmarked for tax reductions. If the carbon tax is effective, so the argument goes, carbon emissions will fall, as will carbon tax revenues. This is a legitimate concern, but it may not be a significant issue if the tax rate is increased over time to achieve meaningful reductions in GHGs and stabilize carbon emissions. An analysis of carbon taxes in the U.S. by Metcalf et al. (2008) is instructive. One of the scenarios it considers is a tax that begins at $15 per ton CO_2e rising at an annual rate of 4 percent after inflation until 2050, at which point the tax rate will have risen to just under $60 per ton (in 2005 dollars). Figure 1 shows how carbon tax revenues as a share of GDP evolve under this scenario using the EPPA model, with revenue rising over time from about 0.66 percent of GDP in 2015 to 1.1 percent by 2050.

FIGURE 1 Expected Carbon Tax Revenue as a Percentage of GDP, 2015–2050



Source: Metcalf et al. (2008).

These results are dependent on the assumptions built into the EPPA model and must be viewed with the same caution as any economic model providing scenarios about the future. The results, however, suggest that a steadily rising tax rate can offset the reduction in carbon emissions to provide a stable revenue source for the next several decades.

5.2. No Binding Cap on Emissions

A common criticism of carbon taxes is that they do not provide any binding cap on emissions. The problem with this argument is that no policy is immutable. Even if Congress were to enact a cap and trade bill with hard caps, nothing prevents a future Congress from altering the law. If abatement costs turn out to be unexpectedly high, the resulting high permit prices will create political pressure for Congress to relax the quantity constraint. In effect Congress serves as the ultimate safety valve and it is not clear that this body would allow permit prices in a rigid system to rise to very high levels. In short, a hard cap and trade system only provides the illusion of certainty over emissions.

5.3 Tipping Points

Tipping points provide an important qualification to the efficiency argument for taxes that was discussed above. Tipping points are discontinuities in marginal damages that may arise if critical concentrations of GHGs lead to temperature increases that are sufficiently high to cause large-scale and abrupt climate change. The existence of a tipping point, it is argued, favors cap and trade type programs to ensure that we avoid crossing such a threshold.

The problem with this argument is that we do not know where the tipping point is or whether we are close to it. Setting a fixed cap at an inappropriately low level could lead to unnecessarily large welfare losses. Until our knowledge about climate processes and threshold effects improves we are likely better off setting a gradually increasing price on GHG emissions and providing clear market signals to firms to reduce emissions.

5.4. Efficiency and Political Expediency

A political realist might argue that it is inevitable that concessions will have to be made to the energy industry as part of a grand deal on U.S. carbon policy. Proponents of a cap-and-trade system argue that concessions in a cap and trade system will not bring about an efficiency loss whereas concessions in a carbon tax regime would be distortionary. Concessions in a cap and trade system would be given in the form of a free distribution of permits, which is a lump-sum transfer. The argument goes that with a carbon tax, the only way to make concessions is to exempt entire sectors or segments of sectors. This clearly would be distortionary. But nothing precludes a carbon tax from providing lump-sum transfers similar in impact to lump-sum distributions of free permits. A carbon tax, for example, could levy the tax on emissions above some threshold. The similarity between lump-sum distributions made under cap and trade systems and those made under tax systems has been pointed out by Pezzey (1992) among others.

5.5 Interactions with International Systems

A final argument against a U.S. carbon tax is that it is incompatible with efforts to bring the developing world into an international agreement. The argument is that we will need to use monetary transfers and technology transfer programs such as the Clean Development Mechanism (CDM) to engage the large developing countries in setting limits on GHG emissions, and that such mechanisms are only compatible with cap and trade programs, where they can be used as offsets to domestic caps.[14] However, nothing about a carbon tax precludes the use of CDM-type projects as offsets. If the United States so desires it could allow certain offsets like CDM projects to be taken as credits

[14] The Clean Development Mechanism was developed under the Kyoto Protocol as a way to allow GHG reducing projects in developing countries that are not subject to emissions limits to count towards the targets for countries that are subject to such limits. See Lecocq and Ambrosi (2007) for a history and analysis of CDMs.

against the carbon tax. To reduce the administrative burden for firms, the offsets could be made tradable, in which case brokers would likely emerge to serve as a clearing house for firms with carbon tax liability to purchase offsets.

On a related matter, nothing precludes the United States from employing a carbon tax while other countries rely on cap and trade systems. In the end what matters is that the international community coordinate on harmonizing carbon prices. Some countries may choose to do this through a carbon tax while others through cap and trade systems. So long as the prices are broadly in line across countries, concerns about leakage (i.e. movements of economic activity from high carbon price to low or no carbon price countries) should be minimized.[15]

6. Conclusion

Global warming is one of the greatest challenges facing our world today. The challenge arises in part from the international dimension of the problem and the inability of individual countries to solve the problem unilaterally. In addition, the costs and benefits of addressing global warming accrue to different groups. The *Stern Review*'s Executive Summary notes this clearly: "Climate change presents a unique challenge for economics: it is the greatest and widest-ranging market failure ever seen. The economic analysis must therefore be global, deal with long time horizons, have the economics of risk and uncertainty at centre stage, and examine the possibility of major, non-marginal change" (Stern (2007), Executive Summary, p. i.)

Carbon pricing is a necessary policy step toward addressing this challenge in the United States. The carbon tax reform presented here would begin with a modest price on

[15] Nordhaus (2007) discusses the advantages of a tax-based approach in the context of global systems. I take a more modest position here, arguing that a domestic tax-based approach can be made compatible with whatever international system evolves elsewhere.

CO_2 emissions that would gradually rise over time and be subject to Congressional review as more information becomes available on the costs and benefits of GHG reductions. The revenue from the tax would be predominantly used to fund an environmental earned income tax credit tied to payroll tax collections. The combination of revenue and distributional neutrality could provide the political discipline needed to overcome obstacles to the proposal's passage. Allowing a credit for approved sequestration and offset activities would also provide incentives to stimulate low and zero emission R&D activities that will be necessary if the United States is to make meaningful reductions in its GHG emissions.

This article has argued that strong economic, administrative, and efficiency arguments can be made for a carbon tax. Constructing a distributional and revenue neutral reform addresses many of the concerns raised by opponents to carbon pricing. It addresses the negative impact of carbon pricing on low income households and avoids conflating carbon policy with debates over the appropriate size of the federal budget. In this changing political climate, we may find that the conventional wisdom that cap and trade is the only way to control GHG emissions no longer holds and that a carbon tax is a viable policy option in the ongoing U.S. policy discussion over how best to address global warming.

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