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TAX REFORM, ENERGY AND THE ENVIRONMENT

WORLD RESOURCES INSTITUTE

POLICY BRIEF

# A GREEN EMPLOYMENT TAX SWAP: USING A CARBON TAX TO FINANCE PAYROLL TAX RELIEF

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## EXECUTIVE SUMMARY

As the new Congress convenes, both Democratic and Republican lawmakers are proposing limits on greenhouse gas emissions. Most of these proposals are for carbon cap and trade systems similar to the European Union Emissions Trading System.

A carbon tax is another way to limit emissions. This policy brief describes how a carbon tax could be implemented and presents an analysis of a Green Employment Tax Swap (GETS). Under this proposal, a national tax on carbon emissions is paired with a reduction in the payroll tax. In particular, the brief assesses the impact of a tax of $15 per metric ton of carbon dioxide ($CO_2$), which is used to rebate the federal payroll tax on the first $3,660 of earnings per worker. This reform is both revenue-neutral and distributionally neutral.

Congress is currently considering various legislative proposals to curb greenhouse gas emissions in the United States and a number of bills to establish carbon cap and trade schemes have been put forward.[1] A carbon tax is an additional policy instrument that can be used to control carbon emissions. To illustrate how a carbon tax could be implemented, this policy brief discusses a Green Employment Tax Swap (GETS) in which a tax of $15 per metric ton of carbon dioxide (CO2) is used to rebate the federal payroll tax on the first $3,660 of earnings per worker. [2]

### I. A GREEN EMPLOYMENT TAX SWAP AS A POLLUTION TAX

Economists have long extolled the virtues of pollution taxes to address the social damages arising from polluting activities. A central tenet of economics is that market prices do not reflect the social cost of resource use when economic activities result in pollution. The private cost of polluting activities falls short of the cost to society from the pollution. A tax on pollution is a simple way to ensure that private firms use resources that take into account the full (social) cost of their behavior.

Support for pollution taxes, also known as Pigouvian taxes, cuts across the political spectrum. N. Gregory Mankiw, professor of economics at Harvard and a former Chair of the Council of Economic Advisors under President George W. Bush, has argued in favor of higher gas taxes.[3] He has established the Pigou Club, an "elite group of pundits and policy wonks with the good sense to advocate higher Pigouvian taxes."[4] Other supporters of pollution taxes include *New York Times* columnists David Brooks and Thomas Friedman, economist and columnist Paul Krugman, economists Martin Feldstein and Joe Stiglitz, and former Vice President Al Gore.

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June 2007
Printed on recycled paper

A carbon tax is simply a pollution tax. Carbon emissions are a form of greenhouse gas emissions contributing to global warming. The societal damages from global warming have been extensively documented.[5] Concerns about global warming led the United States to sign the Framework Convention on Greenhouse Gases in 1992. Many countries have moved forward to address greenhouse gas emissions by signing the Kyoto Protocol. While the United States has not signed that protocol, it has recognized the dangers of global warming. Last year, for example, the U.S. Senate passed a non-binding resolution calling for a "national program of mandatory market-based limits and incentives on greenhouse gases."[6] In his most recent State of the Union Address, President George Bush acknowledged the need "to confront the serious challenge of global climate change."[7]

Pollution taxes have an even stronger appeal because of the opportunities for using the tax revenues to lower other distorting taxes, as we propose in the GETS reform. This reform focuses on payroll taxes, which have become increasingly burdensome for working families. In fact, for nearly three-quarters of all households, payroll taxes are their single largest tax to the federal government.[8] Because the payroll tax is a flat-rate tax up to a payroll limit of $90,000 (as of 2005), it is generally acknowledged to be a regressive tax.[9] Using the carbon tax to reduce the payroll tax burden would reduce the tax burden on working households, especially for those households earning less than the median income in the United States.

In addition to possible improvements in the progressivity of the tax code, using a carbon tax to lower the tax rate on wage income could improve the efficiency of the U.S. tax code. Economists have long noted the benefits of this second dividend from a tax on pollution. In general, taxes on labor supply discourage labor and create economic losses to workers over and above any taxes collected. Workers forego opportunities to work longer hours or engage in training that increases their productivity and wages. Moreover, workers may choose not to enter the labor force in response to taxes on wage income. Tax reductions can encourage additional labor supply either on the intensive margin (hours worked) or the extensive margin (the decision to enter the labor force). The Green Employment Tax Swap encourages additional labor supply on the extensive margin.

**Table 1** **Share of Environmental Taxes in Total Tax Revenue, 2003**

| Country | Share (percent) |
|---|---|
| Canada | 3.99 |
| Denmark | 10.27 |
| France | 4.91 |
| Germany | 7.44 |
| Japan | 6.58 |
| Netherlands | 8.93 |
| Norway | 6.86 |
| Sweden | 5.84 |
| United Kingdom | 7.57 |
| United States | 3.46 |

Source: European Environment Agency. http://www2.oecd.org/ecoinst/queries/index.htm accessed Jan. 25, 2007.

Finally, the United States is currently an outlier in its use of environmental taxes relative to other high-income countries in Europe and elsewhere. Table 1 presents the share of total tax revenues generated by environmental taxes for a sample of countries for 2003. The United States has the lowest share of taxes on environmental activities among the 27 OECD countries reporting data for 2003. As an example, the tax on gasoline in the United States is roughly one-eighth the value of the average rate across all countries in the OECD.[10]

## II. IMPLEMENTING THE GREEN EMPLOYMENT TAX SWAP

A carbon tax could best be implemented in an *upstream* system by taxing the carbon content of fuels at their source. For coal, this would be the mine mouth for domestic coal and the border for imported coal.[11] Natural gas would be taxed at the wellhead. Petroleum products would be taxed at the refinery on the various products produced from crude oil. Levying the carbon tax on refinery outputs is preferable because crude oil can have different emission factors (carbon per barrel of crude) for different shipments; for example, a single tanker could have batches of oil with different emission factors.

An upstream tax would require a few simple adjustments. First, electric power plants that sequester carbon should receive a rebate for carbon taxes previously paid on the

sequestered carbon. In addition, non-energy carbon emissions should also be brought into the system. Such emissions come from a variety of sources. For example, calcination of limestone to make clinker, an intermediate product in cement production, releases carbon. Applying the carbon tax to clinker production would address carbon emissions in the cement industry.

An upstream carbon tax would be relatively straightforward to administer with a small number of filers responsible for remitting tax revenues to the government. Ease in administration would help keep administrative and compliance costs down.

### III. ASSESSING A SWAP

This brief considers a carbon tax set at a rate of $15 per metric ton of carbon dioxide[12] ($55 per metric ton of carbon). Emissions of carbon dioxide in 2005 are estimated to be just over 6,000 million metric tons.[13] Had a carbon tax of $15 per ton of $CO_2$ been in place in 2005, the tax would have raised $89.2 billion, assuming no behavioral response. Because demand for carbon-intensive products will fall in response to a carbon tax, carbon emissions in the short run would fall by an estimated 700 million metric tons of $CO_2$ in response to the levy (12.1 percent based on price and quantity data from 2005).[14] Table 2 presents price and output impacts of the tax once it has been fully phased in.

Energy prices for the three fuel sources are average prices in 2005. A tax of $15 per metric ton of $CO_2$ would nearly double the price of coal, assuming the tax is fully passed forward. Petroleum products would increase in price by nearly 13 percent and natural gas by just under 7 percent. As a point of comparison, a carbon tax of this magnitude would raise gasoline prices by approximately 13 cents per gallon, assuming the tax is fully passed forward into consumer prices. This represents a price increase of less than 7 percent using average gas prices for 2005.

**Carbon Dioxide or Carbon?**

Carbon emissions can be reported in units of carbon or carbon dioxide. By weight, 44 units of carbon dioxide contain 12 units of carbon. To convert carbon dioxide to carbon, multiply the amount of carbon dioxide by 12/44. To convert a tax rate per unit of carbon dioxide to a rate per unit of carbon, multiply the former rate by 44/12.

The largest impact would be on the coal industry. Coal consumption would decline by nearly one-third. Successful carbon capture and sequestration (CCS) will blunt the impact on the coal industry. Pricing carbon is a necessary condition for a financially viable CCS program. The impact on petroleum and natural gas output is very small. Emissions of $CO_2$ would fall by over 700 million metric tons of $CO_2$, a decline of 12.1 percent. Most of the decline results from decreased coal use.

Allowing for these short-run demand adjustments, the carbon tax would have collected $78.5 billion if it had been in place in 2005. The GETS reform uses the revenue to reduce payroll taxes by providing a rebate of the employer and employee payroll taxes on the first $3,660 of earnings per worker. This amounts to a maximum rebate of $560 per covered worker. Given payroll tax collections of approximately $727 billion in 2005,[15] a carbon tax of $15 per MT $CO_2$ could lower payroll tax burdens on average by just under 11 percent. The benefits of the payroll tax reduction would differ by wage income. Table 3 illustrates the tax reduction for several different wage levels.

**Table 2 Short-Run Price and Output Effects of a $15 per metric ton $CO_2$ Tax**

| Energy Source | Unit | Price per Unit (2005) ($) | Tax per Unit of Energy ($) | Price Change (%) | Change in Energy Usage (%) | Emissions Reduction (million $MTCO_2$) |
|---|---|---|---|---|---|---|
| Coal | short ton | 31.22 | 28.55 | 91.4 | -32.0 | 648.8 |
| Crude Oil | bbl | 50.28 | 6.48 | 12.9 | -2.0 | 57.4 |
| Natural Gas | mcf | 12.81 | 0.82 | 6.4 | -1.0 | 11.4 |
| Total | | | | | | 717.6 |

*Source*: Author's calculations. See text for details.

**Table 3** Effect of GETS Reform on Payroll Taxes

| Wages ($) | Payroll Tax: Before Rebate ($) | Payroll Tax: After Rebate ($) | 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. Rebate of $560 per covered worker assumed.

The GETS reform benefit is greatest for low-wage workers. For a worker earning $5,000 a year, nearly three-quarters of his or her payroll taxes would be rebated. In contrast, at the maximum covered earnings, 4 percent of the tax would be rebated. Later in this brief, we analyze the impact of the GETS reform across households.[16]

## IV. RESPONDING TO CONCERNS ABOUT A CARBON TAX

The most common objection to a carbon tax is that it will hurt economic growth in the United States. However, research suggests that most industry groups would not be appreciably affected by a carbon tax swap for two reasons. First, the price impacts for most industries are small. Second, the GETS reform ensures that overall tax burdens will not rise. Offsetting the higher price of products due to the carbon tax is the higher after-tax income resulting from the reduction in the payroll tax in the GETS reform.

To illustrate the first point, Table 4 summarizes the impact on industry product prices of a carbon tax.[17] The table shows the price increases for the ten industries with the greatest price increases. With the exception of three industries—petroleum and coal products, coal mining, and utilities—the price impacts are less than 4 percent.

Coal in particular is significantly impacted by a carbon tax. But this is the natural consequence of any policy to reduce carbon emissions in the United States. We simply cannot reduce carbon emissions unless we reduce our use of coal

**Table 4** Industry-Level Price Impacts of a Carbon Tax

| Industry Product | Price Increase (%) |
|---|---|
| Petroleum and coal products | 16.1 |
| Coal mining | 15.0 |
| Utilities | 11.2 |
| Mining, except coal, oil and gas | 3.9 |
| Primary metals | 3.2 |
| Pipeline transportation | 2.4 |
| Air transportation | 1.8 |
| Waste management and remediation services | 1.7 |
| Nonmetallic mineral products | 1.6 |
| Paper products | 1.3 |

*Source*: Metcalf (2005). Industry final price increases assuming a $15 per ton $CO_2$ carbon tax is passed fully forward to consumers.

or capture and sequester its emissions. An important benefit of the carbon tax is the inducement it provides for improvements in technology that allow for coal to be burned without releasing carbon. New technologies like integrated gasification combined cycle (IGCC), which are more efficient and can be combined with carbon sequestration (the removal of carbon for storage underground), provide a future for the coal industry. Making the transition to this future will be difficult until we price coal to reflect the damages resulting from carbon emissions.[18]

Another argument commonly made against a carbon tax is that—like other energy-related taxes—it is regressive. While the carbon tax in isolation may be regressive, a carbon tax reform need not be regressive.[19] As demonstrated below, the GETS reform is specifically designed to be distributionally neutral.

A third argument against a carbon tax is that it will put U.S.-produced goods at a competitive disadvantage with other countries that do not price carbon. This is a concern for any policy that prices carbon, including cap-and-trade systems. A carbon tax would put the United States on an equal footing with members of the European Union, which have priced carbon with the EU Emissions Trading System since 2005. To date, there is no evidence that carbon trading in Europe has hurt Europe's trade competitiveness. Evidence also suggests that concerns with carbon leakage—the shift-

ing of production of carbon-intensive goods out of a country that prices carbon—may be overblown.[20]

Fourth, some have expressed concerns about revenue stability with a carbon tax. Clearly, carbon emissions will fall in response to the Green Employment Tax Swap. The initial tax rate can be set in anticipation of this emissions decline to ensure adequate revenues are collected. Revenue stability then depends on the fundamental volatility of tax collections. An analysis of historic carbon emissions and payroll tax collections indicates that the GETS reform will enhance revenue stability. One measure of revenue stability is the coefficient of variation (CV). Lower values of the CV indicate greater revenue stability.[21] The coefficient of variation for a carbon tax using historic emissions from 1959 through 2005 is 0.19, while the CV for real payroll tax collections over that period is 0.56. This suggests that carbon tax collections should be even more predictable than payroll tax collections.[22]

Finally, some may argue that if the carbon tax is effective at reducing carbon emissions, tax collections will fall over time as new technologies come into play that allow for lower carbon emissions per dollar of GDP. This is undoubtedly true. The ability of firms to adjust production to reduce their demand for fossil fuels is greater in the long run than the short run. But this should not deter policy makers from considering this policy. Taxing carbon to reflect its social marginal damage contributes to an improvement in economic efficiency, first by internalizing the carbon externality, and second by raising funds with which we can lower the payroll tax. This tax cut contributes to greater economic efficiency by raising after-tax wages and thus the benefit to working. In the long run, we may raise less revenue per dollar of GDP than in the short run. This may require a modest upward adjustment to the payroll tax over time as the United States reduces its carbon emissions.[23] But even in the long run, payroll tax burdens will be lower than if we don't implement the GETS reform.

## V. THE IMPACT ON HOUSEHOLD INCOME AND SPENDING

For a more detailed analysis of the impact on household income and spending of a Green Employment Tax Swap, we present results from an analysis using the 2003 Consumer Expenditure Survey. Table 5 provides estimates of price increases for selected commodities if a carbon tax were put in place in 2003 with a rate of $15 per ton of carbon dioxide.[24]

**Table 5 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. 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 has 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, as discussed above. The burden for consumers, however, will not be reduced as much as tax collections fall. Firms incur costs to shift away from carbon-intensive inputs. These costs will be passed forward to consumers. Consumers also will engage in welfare-reducing activities as they shift their consumption activities to avoid paying the full carbon tax. While the 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.

The GETS reform uses the revenue from the carbon tax to reduce the payroll tax by funding a rebate to workers in each household equal to their first $560 in payroll taxes, including both the employer and employee contribution.[25] This is equivalent to exempting from payroll taxation the first $3,660 of wages per covered worker.

Table 6 details the distributional impact of this carbon tax swap for households sorted on the basis of annual household income as a measure of their economic well-being.

Using an annual income measure to group households, the carbon tax in isolation is mildly regressive. The lowest half of the population faces tax increases ranging from 1.8 to 3.6

**Table 6** Distributional Impacts of the Green Employment Tax Swap

| Income Group (decile) | Change in Taxes ($) | | | Change in ATR (%) | | |
|---|---|---|---|---|---|---|
| | Carbon Tax | Payroll Tax | Net | Carbon Tax | Payroll Tax | Net |
| 1 (lowest) | 289 | -208 | 81 | 3.6 | -2.7 | 0.9 |
| 2 | 421 | -284 | 137 | 3.2 | -2.1 | 1.1 |
| 3 | 487 | -428 | 59 | 2.4 | -2.2 | 0.3 |
| 4 | 545 | -557 | -12 | 2.0 | -2.1 | 0.0 |
| 5 | 637 | -669 | -33 | 1.8 | -1.9 | -0.1 |
| 6 | 671 | -804 | -132 | 1.5 | -1.8 | -0.3 |
| 7 | 767 | -918 | -151 | 1.3 | -1.6 | -0.3 |
| 8 | 878 | -978 | -100 | 1.2 | -1.4 | -0.1 |
| 9 | 955 | -1,035 | -80 | 1.0 | -1.1 | -0.1 |
| 10 (highest) | 1,257 | -1,093 | 164 | 0.8 | -0.8 | 0.0 |

*Source*: Author's calculations. The lowest decile includes households in the 5th to 10th percentiles. Mean tax changes within each decile are reported. Positive numbers indicate a tax increase and negative numbers a tax decrease. ATR refers to average tax rate.

percent of their income, while the top half of the population faces tax increases between 0.8 and 1.5 percent of income. Rebating the first $560 of employer and employee payroll taxes offsets this regressivity quite markedly. As a fraction of income, the average payroll tax reduction falls with income. The lowest income group receives a reduction worth 2.7 percent of income, and the highest income group a reduction worth 0.8 percent of income. The final column in Table 6 shows that the lowest 20 percent of the population would face modest net tax increases of just 1 percent of income, but that otherwise the tax reform is essentially distributionally neutral.[26]

**Table 7** Varying the Green Employment Tax Swap

| Carbon Tax Rate ($/ton $CO_2$) | Rebated Taxes ($) | Income Threshold ($) |
|---|---|---|
| 5 | 180 | 1,176 |
| 15 | 560 | 3,660 |
| 25 | 960 | 6,275 |

*Source*: Author's calculations. Rebated taxes include employer and employee taxes. Income threshold are the amount of wage income for which payroll taxes are rebated.

Table 7 illustrates how the tax rebate is affected by changing the carbon tax rate. The rebate rises slightly faster than the tax rate, since rebated taxes can never exceed actual payroll taxes paid by employers and employees.

The environmental tax reform illustrated in Table 6 emphasizes an essential point: while a carbon tax may be regressive, a carbon tax reform can be designed to be distributionally neutral. The use of the carbon tax revenue to lower payroll taxes makes this distributional neutrality possible. If the revenue is not rebated or a cap-and-trade system is 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 first column of Table 6, but would not allow the offsetting reduction in the payroll tax to achieve distributional neutrality.[27]

## VI. CONCLUSION

Concerns about global warming have raised policy interest in the United States in some mechanism for discouraging carbon emissions. One such mechanism is a carbon tax. The GETS reform uses a carbon tax to rebate payroll taxes for the first $3,660 of earnings per worker. This reform is revenue and distributionally neutral and makes clear that while a carbon tax alone may be regressive, a carbon tax reform package can be designed to achieve any desired change in progressivity. While the focus here has been on distribution, carbon tax revenues provide flexibility in the policy process to help achieve any number of objectives. Fairness in taxation is one objective. But carbon tax revenues could also be used to contribute to simplification in the tax code or improved efficiency. A transparent linkage between a carbon tax and a thoughtful tax reduction could help build support for an environmental tax reform that brings the United States into closer alignment with other developed countries in their reliance on environmental taxation and in efforts to reduce global warming.

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## ACKNOWLEDGMENTS

The author thanks Wei Yao for excellent research assistance on this brief. He also thanks Craig Hanson, David Sandalow, Jonathan Pershing, Charles Iceland, and David Jhirad for helpful comments. He also thanks Hyacinth Billings, Robert Livernash, and Maggie Powell for their assistance in converting the draft version into a finished publication.

The author is grateful to The Brookings Institution and the World Resources Institute (WRI) for their support of this work. Brookings thanks the Summit Foundation and the Richard and Rhoda Goldman Fund. WRI thanks the Town Creek Foundation and several private donors for their support. The author alone is responsible for the views and perspectives expressed in this publication.

For more information about this or other *Tax Reform, Energy and The Environment* policy briefs, please contact Craig Hanson at WRI or David Sandalow at The Brookings Institution.

## NOTES

1. See discussion and analysis in Felicity Barringer and Andrew C. Revkin, 2007. "The 110th Congress; Measures on Global Warming Move to Spotlight in the New Congress." *New York Times*, January 18, 2007.
2. The payroll tax is the federal employer and employee tax that partially funds the Social Security and Medicare programs.
3. See Gregory Mankiw, "Raise the Gas Tax", *Wall Street Journal*, October 20, 2006.
4. See Mankiw's blog at http://gregmankiw.blogspot.com/2006/10/pigou-club-manifesto.html for his *Wall Street Journal* column as well as links to other discussions of Pigouvian taxes.
5. See, for example, Intergovernmental Panel on Climate Change, 2001. *Climate Change 2001: Synthesis Report: Third Assessment Report of the Intergovernmental panel on Climate Change*. Cambridge: Cambridge University Press., Intergovernmental Panel on Climate Change, 2007. "Climate Change 2007: The Physical Science Basis." IPCC: Geneva., as well as previous IPCC reports from 1990 and 1995.
6. S. Amend. 866 to HR 6.
7. A transcript of this address is available at http://www.whitehouse.gov/news/releases/2007/01/20070123-2.html.
8. Tax data reported by the Tax Policy Center indicate that 70 percent of all households that pay either payroll or income taxes faced higher payroll taxes than income taxes in the year 2000. See http://www.taxpolicycenter.org/TaxFacts/TFDB/TFTemplate.cfm?Docid=230&Topic2id=50.
9. A regressive tax is a tax whose burden falls disproportionately on lower income people. More precisely, the share of taxes in income falls as income rises for a regressive tax. In contrast, the share of taxes in income for a progressive tax rises with income.
10. See Gilbert E. Metcalf, 2006. "Federal Tax Policy Toward Energy." NBER Working Paper No. 12568. Cambridge, MA: National Bureau of Economic Research, as well as Craig Hanson and David Sandalow, 2006. Greening the Tax Code. Washington, DC: Brookings Institution and World Resources Institute.
11. The United States had 1,415 functioning mines in 2005 (see Energy Information Administration. 2006. *Annual Coal Report 2005*. Washington, DC: Energy Information Administration.) The administration of the tax could be simplified by providing an exemption for small mines. As coal mining is relatively concentrated among large firms (340 mines accounted for 90 percent of coal production in 2005), a small mine exemption would mean that relatively few mines would be required to comply with the tax.
12. The carbon rate is set to be roughly consistent with the cost of a permit for carbon dioxide under the EU ETS trading system in 2006. It is also consistent with recent estimates of the optimal initial carbon tax from Nordhaus's RICE-2001 model. See William D. Nordhaus, 2005. "Life After Kyoto: Alternative Approaches to Global Warming Policies." NBER Working Paper No 11889. Cambridge, MA: National Bureau of Economic Research.
13. See Energy Information Administration, 2006. "Emissions of Greenhouse Gases in the United States 2005." U.S. Department of Energy: Washington, DC.
14. Output responses are based on elasticities implied from Table 2.2 from A. Lans Bovenberg and Lawrence Goulder. 2000. "Neutralizing the Adverse Industry Impacts of $CO_2$ Abatement Policies: What Does It Cost?" In Carlo Carraro and Gilbert E. Metcalf, eds.

*Distributional and Behavioral Effects of Environmental Policy*. Chicago: University of Chicago Press. They phase in a carbon tax over a three-year period. The output responses are reported for the third year of the tax.

15. This is a comprehensive measure including OASDI, HI, and railroad retirement funds.
16. A reduction in the payroll tax rate could induce additional labor supply, especially among second earners in households, and an increase in payroll tax receipts. Thus payroll tax rates could potentially be lowered further than modeled in this policy brief.
17. See Gilbert E. Metcalf, "Tax Reform and Environmental Taxation." NBER Working Paper No. 11665. Cambridge, MA: National Bureau of Economic Research. 2005.
18. For new coal-fired power plant construction, a $CO_2$ tax of about $30 per metric ton would make carbon capture and sequestration (CCS) cost competitive with conventional coal power. See the recently released James Katzer *et. al,* 2007. "The Future of Coal: Options for a Carbon-Constrained World." Massachusetts Institute of Technology on this point as well as for a discussion of policy recommendations to facilitate the development and implementation of CCS technology on a large scale.
19. The distinction between environmental taxes and environmental tax reforms is elaborated in Gilbert E. Mecalf, 1999. "A Distributional Analysis of Green Tax Reforms." *National Tax Journal* 52 (4): 655–81.
20. See, for example, Matthew E. Kahn, 2003. "The Geography of U.S Pollution Intensive Trade: Evidence from 1958-1994." *Regional Science and Urban Economics 33(4): 383-400.*
21. The coefficient of variation is defined as the ratio of the standard deviation divided by the mean of a variable. The chance that a normally distributed random variable will be further than $\pm v$ times the mean of the random variable is roughly one-third, where $v$ is the CV. Thus if the CV equals 0.2, the random variable will be within 20 percent of its mean value approximately two-thirds of the time.
22. An alternative measure of revenue stability is the conditional standard deviation of the percentage change in tax revenue after controlling for trend growth. Again, lower values indicate greater revenue stability. The conditional standard deviation for the carbon tax is 0.029 while the measure for the payroll tax is 0.042. Because payroll tax rates grew between 1959 and 2005, these statistics are also reported for the period 1988–2005, a period during which little change in payroll tax rates occurred. The carbon tax continues to be less volatile than the payroll tax.
23. A revenue target in the carbon tax for payroll tax relief could be set and taxes adjusted to ensure the given funds for payroll relief will be available. Congress might, for example, adjust carbon tax rates up as carbon emissions decline to maintain revenue neutrality. Alternatively, policy makers might adjust the payroll tax exemption down as carbon tax revenues fall. Finally, Congress could make the tax reform revenue-neutral over a given time period, say five or ten years, taking into account anticipated emission reductions in response to the carbon tax. Congress would initially set the carbon tax rate and payroll tax exemption so that the carbon tax revenues exceed the payroll tax reduction, thereby building up a surplus for the latter part of the period when carbon revenues fell short of the payroll tax reduction. At the end of that period, policy makers could reset the exemption and carbon tax rates for a subsequent period of time.
24. The methodology for computing price increases is detailed in Metcalf 1999.
25. The payroll tax reduction is assumed to be fully shifted to the worker. This is a common assumption among labor economists. See Victor R. Fuchs, Alan B. Krueger, and James M. Poterba, 1998. "Economists' Views about Parameters, Values, and Policies: Survey Results in Labor and Public Economics." *Journal of Economic Literature* 36 (3):1387–1425.
26. Further refinements could reduce the net tax burden in the lowest two deciles. But the example illustrates the point that a distributionally neutral reform is possible.
27. The converse is also true. Permits in a cap-and-trade system could be auctioned and the revenue used for the payroll tax reduction described in this brief, thereby providing the same distributional outcome as under the GETS reform.



ISBN 978-1-56973-654-8