# The Distributional Impacts of Energy Taxes

William A. Pizer* and Steven Sexton†

## Introduction

Economists have long favored pollution taxes and pollution permit trading to control harmful emissions from energy production and consumption. These market-based mechanisms are generally preferred to more prescriptive instruments such as technology, emissions, and fuel economy standards because they achieve emissions reductions at the least cost. The evaluation of the efficiency characteristics of these market-based policies relative to command-and-control regulation has occupied much of the theoretical and empirical economics literature on pollution control.

By imposing opportunity costs on pollution emissions, market-based policies tend to raise the price of energy based upon the pollution attributed to the marginal fuel unit. This transmission of the pollution cost into commodity prices, which is common to both permit trading programs and taxes (and which we will refer to throughout this article simply as "taxes"), guarantees least-cost pollution control.

However, energy price increases can undermine equity objectives, posing an equity-efficiency trade-off often considered in public economics. In particular, the conventional wisdom is that the poor will be more burdened by energy price increases than the wealthy. These disparate impacts *across* the income distribution (i.e., vertical equity impacts) are believed to have diminished enthusiasm for energy taxes among policymakers (e.g., Mankiw 2009; Metcalf 2009a; Grainger and Kolstad 2010).

The distribution of energy tax burdens can also vary significantly *within* income groups. Such variation may arise from differences in transportation patterns and housing characteristics among households with similar incomes. Despite these differences within income groups, only a few studies address the horizontal (i.e., within income group) equity of energy taxes (e.g., Poterba, 1989 and Rausch, Metcalf, and Reilly, 2011).

When concerns about the equity impacts of energy taxes arise, it is commonly assumed that they can be addressed by redistributing the government revenues from pollution taxes or permit auctions. These revenues, as well as rents accruing to firms, can dwarf the net policy costs to society, suggesting significant potential for environmental policy to create both winners and losers. For example, Murray et al. (2015) estimate that if implemented, the

*Duke University, 201 Science Drive, Durham, NC 27708, Tel: 919-613-9286; e-mail: wap8@duke.edu.
†Duke University, 201 Science Drive, Durham, NC 27708. Tel: 919-613-9348; steven.sexton@duke.edu

*Review of Environmental Economics and Policy*, volume 13, issue 1, Winter 2019, pp. 104–123
doi: 10.1093/reep/rey021
Advance Access Published on January 31, 2019

Obama administration's proposed regulation of carbon emissions in the U.S. power sector would generate rents approaching $200 billion per year, whereas the costs of the regulation would be only $0.5 billion. How these rents would be allocated has significant distributional implications (Metcalf 2009b).

Amid the increased focus of researchers and policymakers on market-based pollution control policy and its distributional impacts, this article explores the distributional impacts of energy taxes and what they imply for both the design of energy taxes and the choice between taxes and other policies. We examine what lessons can be learned from the literature on distributional impacts and from a simple analysis of consumption surveys in select countries. We are particularly interested in how these impacts vary depending on the commodities subject to the tax, the characteristics of regulated jurisdictions, how distributional impacts are measured, and how the tax revenue is handled. Given the relatively scant attention in the literature, we also examine the variation in tax burdens among households with similar incomes.

We draw five general conclusions from this assessment. First, when revenue use is not considered, energy taxes may or may not have a disproportionate effect on poor households, contradicting conventional wisdom. Second, these distributional impacts—whether regressive or not—may be small enough to be far outweighed by the efficiency argument for energy taxes. Third, to the extent that we are indeed concerned about impacts *across* income groups, the available tax revenue provides a straightforward option for addressing such concerns. Fourth, we find the variation in distributional impacts *within* income groups to be significant. Finally, in contrast to impacts across income groups, these effects may be more difficult to ameliorate.

Although our discussion concerns energy taxes broadly, and is particularly relevant to carbon tax proposals. As Metcalf (2009a) and others have observed, "A carbon tax is in large measure an energy tax," and energy combustion is the predominant source of human-caused carbon emissions. Moreover, nonenergy sources are often not subject to regulation under existing and proposed climate policies (European Environment Agency 2011). Thus our conclusions directly inform the ongoing debate over the design of carbon pricing policies as well as the choice between carbon pricing and other forms of regulation.

This article is part of a symposium on the distributional effects of environmental policy.[1] We begin by reviewing the vertical equity impacts of the direct and indirect effects of energy taxes. Direct effects refer to the rise in energy prices in response to energy taxes. Indirect effects refer to changes in product prices and behavioral responses that both reduce energy use and affect the return to capital. We consider how these effects vary across countries, regulated energy commodities, and methods of measuring impacts. We next consider mechanisms to address vertical inequities before turning to a discussion of horizontal equity, including possible methods for addressing horizontal equity concerns. We conclude with a summary of our findings and implications for policymakers.

[1]The other articles are Fullerton and Muehlegger (2019), which discusses the distributional effects of environmental taxes and other nontax regulations, and Hsiang, Oliva, and Walker (2019), which examines the distribution of environmental damages.

## Impacts of Energy Taxes Across Income Groups

Energy taxes are commonly assumed to be regressive (e.g., Metcalf 2009a; Rausch, Metcalf, and Reilly 2011; Williams et al. 2015), burdening the poor more than the rich. That is, raising the cost of fuels and energy-intensive goods implies a larger percentage decline in overall consumption for poorer households because those goods often comprise relatively large shares of low-income households' budgets. Much as poor households are known to spend relatively large shares of income on food, so too are they thought to devote relatively large shares of their budgets to energy consumption, a necessity in the developed world second only to food. The poor are also likely to own older vintages of energy-consuming durable goods such as household appliances and automobiles, which are less energy efficient than the newer models adopted by rich households.

Moreover, as Fullerton (2011) observed, the direct effects of policy-induced price increases on taxed products may be compounded by indirect and general equilibrium effects (e.g., a decline in wages relative to capital returns caused by capital-intensive pollution abatement). Because poor households generate a greater share of income from wages, they are particularly harmed by relative wage declines. A tradable permit regime also confers rents to firms, which are owned predominantly by wealthy families. Fears of such regressive impacts figure centrally in the political economy of pollution control and, in particular, in climate change mitigation. Recasting a challenge posed by Baumol and Oates (1988) two decades earlier, Fullerton (2011) urged researchers "to determine whether these fears are valid, and whether anything can be done about them—other than to forego environmental improvements."

In response, a relatively recent literature has emerged that suggests emissions taxes and tradable permits are not always regressive (e.g., Cronin, Fullerton, and Sexton, forthcoming; Fullerton, Heutel, and Metcalf 2012; Parry, Morris and Williams 2015). Indeed, these studies find that the distributional impact of energy taxes depends upon the fuels and pollutants that are targeted, the characteristics of the taxed populations and their communities, how household income is measured, and, importantly, how policy-generated resource rents are distributed. We first consider the distributional consequences of the direct and indirect effects of energy taxes and then discuss how distributional impacts can vary depending upon how they are measured and how policymakers choose to distribute rents.

### Direct Effects of Energy Taxes

The vertical equity (i.e., the burden across income groups) of direct energy tax impacts is generally assessed by comparing average energy expenditures of households grouped according to annual income or annual expenditures. Energy taxes are considered to be regressive if the average shares of total expenditures (or income) allocated to energy consumption decrease as income increases across groups, which means poor households bear more of the tax burden than rich households. Data from the 2014 U.S. Consumer Expenditure Survey (Bureau of Labor Statistics 2014) confirm the conventional wisdom that general energy taxes in the United States are regressive. The average household in the lowest annual expenditure decile devotes nearly 15 percent of its budget to purchases of electricity, natural gas, gasoline, and other fuels, whereas the average household in the highest expenditure decile spends only

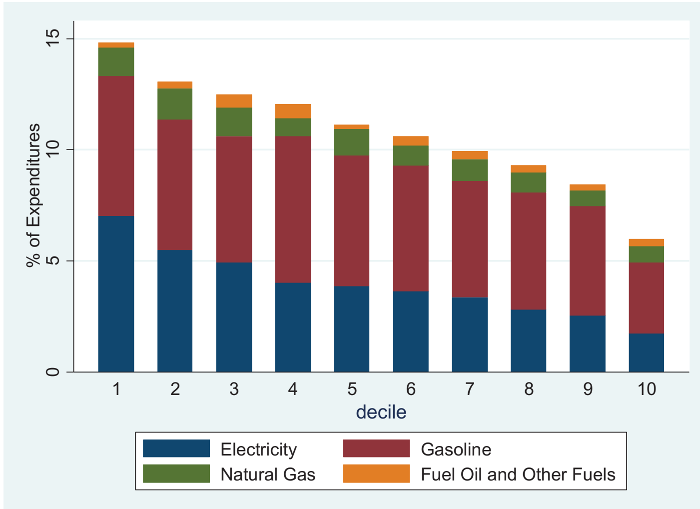


**Figure 1** Average U.S. household energy expenditure as a percentage of total expenditure by expenditure decile.
*Notes:* Decile 1 is poorest, 10 is richest.
*Source:* Bureau of Labor Statistics (2014).

5 percent on energy. As shown in figure 1, energy expenditure shares decline monotonically across expenditure deciles.

## Electricity taxes

Electricity consumption drives much of this regressivity. U.S. households in the poorest decile devote nearly 7 percent of total spending to electricity, more than triple the electricity spending for the wealthiest decile. The share of average household spending on electricity consistently declines across expenditure deciles, as shown in panel A of figure 2.

This phenomenon is not unique to the United States. Virtually every country-level consumption survey exhibits a similar pattern. For example, data from the UK Living Costs and Food Survey (Office of National Statistics 2014) reveals that the variation in average budget shares across the poorest and richest households is even greater than in the United States. Panel B of figure 2 shows that the electricity budget share of total expenditures declines from approximately 8.8 percent among the poorest households to barely 1 percent among the wealthiest.

An analysis of consumption data from Mexico's 2012 National Survey of Income and Expenditure (Instituto Nacional de Estadística y Geografía 2012) shows a more modest decline, from nearly 2 percent among the poorest households to just over 1 percent for the wealthiest (see panel C of figure 2). Electricity expenditure shares in Mexico are smaller than in the United States and the UK, particularly for poor households, which likely reflects differences in the countries' electricity prices and incomes.

More generally, Flues and Thomas (2015) find that electricity taxes are almost universally regressive across 21 Organization for Economic Cooperation and Development (OECD) countries. This regressivity has become more pronounced in recent years as electricity prices have increased around the world. In the UK, for instance, household spending on electricity


**Figure 2** Average household electricity and motor fuels expenditures as percentage of total spending for the United States, the UK and Mexico, by expenditure decile.
*Notes:* Decile 1 is poorest, 10 is richest.
*Sources:* Instituto Nacional de Estadística y Geografía (2012), Office of National Statistics (2013), and Bureau of Labor Statistics (2014).

increased 43 percent from 2002 to 2012, with the average household's electricity budget share growing more than 50 percent (Office of National Statistics 2014). The poorest quintile of households spent 11 percent of their income on household energy in 2012, up from 8 percent in 2002, while the richest quintile spent just 3 percent in 2012, up from 2 percent in 2002. There are similar patterns in other European countries (Eurostat 2013; BDEW 2016). In the United States, however, electricity prices have remained unchanged and have even begun to fall in real terms due to the expansion of domestic natural gas production (Energy Information Administration 2016).

This pattern can vary in lower-income countries. Despite Mexico's warm climate, electricity budget shares in Mexico are relatively low and decline only modestly with income, likely due to lower household income and the resulting low air conditioner penetration rates (Davis, Fuchs, and Gertler 2014). In other, poorer countries where rates of residential electrification are low, electricity budget shares are likely to be higher for wealthier households, which implies that electricity taxes are progressive.

**Transportation fuel taxes**

In contrast to electricity consumption patterns, transportation fuel consumption across income levels suggests that taxes on gasoline and diesel fuels are less regressive than electricity taxes. In the United States, for example, average budget shares vary by only 1.5 percentage points across deciles (with the exception of the highest expenditure decile). The poorest households spend on average 6.5 percent of their budgets on gasoline while the richest spend only 3 percent (Bureau of Labor Statistics 2014). In contrast to electricity expenditure shares in the United States, gasoline expenditure shares do not decline monotonically across expenditure deciles (see panel D of figure 2).

In some countries, the direct impacts of fuel taxes appear to be progressive. For example, in Mexico, gasoline expenditure shares *increase* with income up to the last income decile, suggesting that the direct effects of gasoline taxes in Mexico are generally progressive (Instituto Nacional de Estadística y Geografía 2012). The poorest households spend less than 1 percent of their annual budgets on gasoline consumption, while households in the second-to-highest decile spend more than 4 percent of their budgets on gasoline purchases (see panel F of figure 2). Gasoline consumption in the UK, however, exhibits a different pattern, with the greatest expenditure share (4 percent) incurred by households in the middle of the income distribution (the sixth expenditure decile). The richest and poorest households spend 2.2 percent and 1.5 percent of their respective budgets on gasoline (see panel E of figure 2).

More generally, the variation in gasoline expenditure patterns indicates that the distributional impacts of the direct effects of transportation fuel taxes are determined by individual country characteristics, including vehicle ownership rates and worker commuting patterns. The direct impacts of such taxes are regressive in Austria, Switzerland, Spain, and France, among others (Flues and Thomas 2015). However, Flues and Thomas (2015) find that the taxes are progressive in Turkey, where an estimated one in four of the poorest households operates a motor vehicle, compared with three in four of the wealthiest households. The direct effects of transportation fuel taxes are also estimated to be progressive in Chile and Hungary, as well as China, Costa Rica, and Brazil. In Ethiopia, where modern transportation in any form is beyond the reach of the poorest households, a transportation fuels tax is strongly progressive, as it is in Ghana and Kenya (Sterner and Carlsson 2012; Flues and Thomas 2015).

While the direct effects of transportation fuel taxes tend to be increasingly progressive in poorer countries, there is heterogeneity among wealthy countries, likely due to commuting patterns. That is, such taxes are regressive in the United States; fairly neutral in the UK, Germany, and France; and progressive in Sweden (Sterner and Carlsson 2012; Office of National Statistics 2013; Flues and Thomas 2015). In the United States, for example, low-income individuals are likely to own automobiles that they drive relatively long distances for work commutes, while in much of Europe, long commutes are less common (Stutzer and Frey 2008). Moreover, robust public and mass transit systems in Europe lower the share of private vehicle use (Haghshenas and Vaziri 2012). This suggests that poor households in the United States may be particularly disadvantaged by gasoline taxes.

### Heating fuel taxes

Flues and Thomas (2015) generally find that heating fuel taxes are slightly regressive across 21 OECD countries, although in some countries (e.g., Germany), the taxes are estimated to be progressive. The regressivity of heating fuel taxes is diminished when poor households live in smaller and multifamily homes with less area to heat and less heat loss (Hernández 2014). On the other hand, the regressivity of heating fuel taxes may be exacerbated if poor households live in older, less efficient housing stock and own older, less efficient household appliances (Hernández 2014). For example, in India and Tanzania, taxes on biomass and kerosene are highly regressive (Datta 2012; Mkenda, Mduma, and Ngasamiaku 2012).

Differences in home heating demand and technologies may explain the disparate patterns of natural gas expenditures between the UK and Mexico. Natural gas budget shares consistently decrease across expenditure deciles in the UK, where households are relatively dependent upon natural gas for home heating and where home heating demand is relatively high (Palmer and Cooper 2013; King Abdullah Petroleum Studies and Research Center 2015; Parliamentary Office of Science and Technology 2015). In contrast, Mexico has lower natural gas demand for home heating due to its relatively warm climate and the relatively low heating capital adoption (and natural gas access) among Mexico's poor (King Abdullah Petroleum Studies and Research Center 2015; International Energy Agency 2017). Thus our analysis shows that natural gas budget shares consistently increase across Mexico's expenditure deciles.

## Indirect Effects of Energy Taxes

Assessments of the direct distributional effect of energy taxes are straightforward because they rely only on survey data about household consumption by income group. But by ignoring the *indirect* effects of these taxes, including both the rising price of energy-intensive goods and potential behavioral responses, such assessments can present an incomplete and distorted view of distributional effects. In Mexico, for instance, the direct effect of transportation fuel taxes is progressive. However, because such taxes are likely to increase the cost of public transportation and taxi services that comprise larger expenditure shares for the poor than the rich, the effect of transportation fuel taxes net of these indirect effects is slightly regressive (Sterner and Lozada 2012).

The indirect effects of energy taxes may not be obvious ex ante. For instance, the indirect effects of transportation fuel taxes may not differ from the direct effects, as in Europe, or they may compound the direct effects, as in poor countries like Ethiopia and China. In some countries, like Costa Rica, the net effects can depend upon which transportation fuels are taxed; a gasoline tax is progressive whereas a diesel tax disproportionately harms the poor by raising the costs of the public transportation upon which they rely (Mekonnen, Deribe, and Gebremedhin 2013; Sterner and Cao 2012; Sterner and Carlsson 2012).

There are two main approaches for assessing indirect effects: a simple, relatively transparent approach based on input–output tables and a more complex but realistic approach based on modeling the behavior of energy users and other actors in the economy.

**Input–output methods**

The first approach follows Fullerton (1996) and Metcalf (1999), using input–output (I-O) matrices that relate industry outputs to the inputs of other industries. These studies specifically model how higher energy costs ripple through the economy and thus affect the costs of producing myriad goods and services for which primary energy is an input. However, these analyses also include the simplifying assumption that the amount of energy used to produce each good and service remains the same despite higher energy prices. Fullerton (1996) and Metcalf (1999) show that whereas low-income households are disproportionately impacted by the direct impacts of some energy taxes (because of the relatively large budget shares they devote to some direct energy expenditures), they are likely to be less affected by indirect impacts than high-income households (precisely because of the correspondingly lower budget shares low-income households devote to nonenergy expenditures, which are where indirect impacts occur).

This means that including an accounting of these indirect effects is likely to increase the perceived progressivity of energy taxes (Hannon et al., 1978; Herendeen, Ford, and Hannon 1981). The burden imposed by the indirect effects can be substantial. For example, Bull, Hassett, and Metcalf (1994) evaluate the direct and indirect effects on U.S. households of a \$0.27 per British thermal unit (Btu) tax on select energy commodities, including coal, gasoline, natural gas, and electricity. They find that the tax directly increases the cost of the energy commodities by 3–16 percent and induces indirect cost increases on other goods ranging from 1 to 2.5 percent. They estimate that more than half of the average household burden of the Btu tax is attributable to indirect tax impacts. Thus, while the direct effect of the tax is regressive, the progressive indirect effects result in a tax whose net (indirect + direct) burden is approximately proportional across income groups, or neutral with respect to distribution.

Mathur and Morris (2014) also use I-O matrices to estimate the distributional impact of a \$15 per ton tax on carbon dioxide ($CO_2$) emissions. They find that indirect effects constitute less than one-third of the tax burden for households in low-consumption deciles and more than half of the total burden for households in high-consumption deciles. Nevertheless, when indirect effects are included in their distributional analysis, the energy (i.e., carbon) tax appears to be modestly regressive, with poor household expenditures increasing more than 2 percent while rich household expenditures rise by 1.3 percent. Indirect tax impacts are greatest among the air transport, other transport, automotive parts, food at work, and recreation expenditure categories of the U.S. Consumer Expenditure Survey, reflecting impacts on discretionary spending (Mathur and Morris 2014).

Because I-O analyses ignore behavioral changes, namely substitution away from inputs and consumption goods and services that become costlier due to an energy tax, they should be considered only first approximations of tax impacts. As Hassett, Mathur, and Metcalf (2011) note, higher prices for industrial inputs and consumer products will induce substitution away from carbon-intensive items. This substitution erodes the carbon tax base, but it lowers the burden of the tax by less than tax collections fall because of the costs of tax avoidance behavior. Because I-O analyses do not consider behavioral changes, they are better for examining tax impacts in the short run, when options for avoiding higher prices are fewer and costlier, than in the long run.

**Addressing behavioral changes**

The second approach to assessing indirect effects tackles these behavioral changes head on, providing more realistic estimates, but at the expense of additional assumptions, larger data requirements, and greater complexity. In the longer run, behavioral changes to avoid energy taxes, such as substitutions away from energy-intensive goods and services, make energy demand more elastic, lowering the impact of the tax on consumer welfare relative to the short run. Elastic demand also implies that tax-induced price increases may not be fully passed onto consumers; rather they may be passed backward onto the owners of capital and energy resources (e.g., Fullerton, Heutel, and Metcalf 2012; Rausch, Metcalf, and Reilly 2011). In fact, studies using computable general equilibrium (CGE) models that account for behavioral changes suggest that regressivity is overstated in short-run analyses to the extent that owners of capital and natural resources have higher incomes. This is because the decline in returns to capital and natural resource ownership disproportionately impacts the rich (Bovenberg and Goulder 2001; Metcalf et al. 2008).

## Measurement Issues: Consumption versus Income Measures

Determining the distributional effects of energy taxes depends upon how income is measured. Ranking households by annual expenditures—or consumption—is generally preferred to rankings based on annual income, because expenditures correspond more closely to lifetime income (Poterba 1991). Annual income is subject to shocks due to spells of unemployment and exit from the workforce due to health problems and changes in family conditions. These shocks shift into the ranks of low-income households those individuals that experience idiosyncratic low income but are otherwise not poor. Moreover, annual income exhibits well-known life cycle patterns in earnings and asset accumulation, which cause annual income to poorly reflect the lifetime income of some subsets of the population (e.g., young workers, the elderly). Annual expenditure is a better measure of lifetime income than annual income because of the Permanent Income Hypothesis (Friedman 1957), which asserts that households smooth their consumption across lifetimes and across idiosyncratic shocks to income by accessing credit or drawing down savings during periods of low income.

Calculations of the incidence (i.e., distributional impact) of energy taxes that rely on annual income rather than annual consumption tend to exhibit greater regressivity of electricity, gasoline, and broad-based energy taxes (e.g., Poterba 1989; Bull, Hassett, and Metcalf 1994; Sterner and Carlsson 2012). For example, Sterner and Carlsson (2012) finds that regressivity is increased when income-based measures are used for incidence analysis of taxes in France, Germany, Spain, Sweden, and the UK. Fuel taxes in Germany and Sweden are regressive when income strata are used, but they are progressive when households are ranked by expenditures. In China, however, the use of expenditure strata causes progressive taxes to appear more neutral than suggested by income strata (Sterner and Carlsson 2012).

## Addressing Equity Concerns Across Income Groups

What can be done when energy taxes lead to undesirable distributional impacts across income groups? There are three possible options: accept (i.e., ignore) the distributional impacts, choose other tax rates or policies, or make use of tax revenues to adjust outcomes. The first option arises because, although energy taxes may introduce undesirable disparities, these disparities may be so small that overriding efficiency considerations is not justified. In some countries, including Finland, France, Ireland, Mexico, and Spain, energy expenditure shares are 5 percent or less for the poorest 20 percent of households, implying an annual direct burden of only several hundred dollars even from energy taxes that increase energy costs by 50 percent (Sterner and Carlsson 2012). This is also generally true of regressive electricity taxes, with, for example, U.S. and Mexican households spending on average only 4 percent and 2 percent of their annual budgets, respectively, on electricity. These small expenditure shares limit the magnitude of any undesirable impacts from the direct effect of energy taxes, regardless of differences in expenditure shares across poor and rich households.

If it is determined that distributional issues must be addressed, one could instead advance fuel-specific, sector-specific, or source-specific policy—for example, by setting lower tax rates on fuels, sectors, and sources that have larger effects on poor households. However, one of the basic tenets of microeconomics dictates that efficient pollution control policy not preferentially target particular sources of emissions because least-cost pollution abatement requires that all polluters face a common price per unit of pollution. Fowlie, Knittel, and Wolfram (2012) illustrate this principle, showing that stricter regulation of pollution from smokestacks relative to emissions from automobile tailpipes raises the cost of pollution abatement in the United States by $1.6 billion annually.

A third option arises because energy taxes generate revenues that the government can use to achieve its objectives, including neutralizing the distributional impacts of the taxes themselves (e.g., through new government transfer programs or adjustments to existing taxes and transfers). Several studies have examined how the distributional impact of energy taxes changes depending upon how energy tax revenues are used (Metcalf 2009b). Mathur and Morris (2014) estimate for the United States that if 11 percent of the revenues from a $15 tax per ton of $CO_2$ were returned to the poorest 20 percent of households, then the tax would make these households, on average, no worse off. Similar results can be achieved under a tradable permit program if the government auctions the permits to generate revenues.

The way in which energy tax revenues are used can have important efficiency implications, too. Much as the initial choice of tax instruments over other policies can create efficiency and equity trade-offs, so too can secondary decisions about the expenditure of tax revenues. Uniform payments across households tend to yield tax and rebate packages that are progressive. However, that same revenue could be used instead to cut other, distortionary taxes, thus raising overall welfare relative to uniform payments. For instance, several studies in the United States have found that using carbon tax revenue to finance a reduction in marginal income tax rates would reduce distortions in the labor market and the associated disincentive to work. Although this creates a welfare gain in that market and dramatically lowers the cost of the energy taxes, it does so at the cost of burdening the poorest households three times more than the richest households (Goulder 1995; Parry and Bento 2000; Rausch, Metcalf, and Reilly

2011; Dinan 2012; Rausch and Reilly 2012). This suggests that the most efficient use of pollution tax revenues is unlikely to also be the most equitable.

Dinan (2012) examines alternative revenue and expenditure mechanisms to address distributional concerns and highlights the challenges of ensuring that low-income households in the United States are made no worse off by the tax and that economy-wide costs are minimized. For example, she finds that a revenue-neutral payroll tax rebate on the first $3,660 of earnings would return $560 per worker, which is sufficient to compensate the average low-income household for the cost of a $28 per ton tax on $CO_2$. Thus such a tax reform would be progressive across households *with earnings*, providing benefits that constitute a greater share of income to poor households. However, households with *no earnings*—just less than half of all households in the lowest fifth of the income distribution—would receive no compensation. The recycling of revenues from pollution taxes through increased generosity of existing government transfer programs (e.g., the Earned Income Tax Credit and Temporary Aid to Needy Families in the United States) could also reduce the regressivity of an energy tax, but transfer program participation varies considerably even within low-income deciles (Dinan 2012).

Metcalf (1999) proposes a potential revenue-neutral, nonregressive pollution tax swap in the United States whereby $126 billion in revenues is raised from pollution taxes on carbon, sulfur dioxide, nitrogen oxide, and particulate matter emissions and from gasoline and diesel purchases. These revenues are then used to fund a 4 percent across-the-board income tax cut, a $150 income tax credit per person, and an exemption from payroll taxes for the first $5,000 in earnings. The *net* effect of the tax swap is to reduce the progressivity of the tax system. Still, the tax burden for all households changes by less than 0.5 percent of annual lifetime income, which suggests the tax swap has only a small distributional impact.[2]

## Impacts of Energy Taxes on Horizontal Equity

The emphasis in the literature on impacts across income groups (i.e., vertical equity) ignores the distribution of welfare changes for households *within* income groups (i.e., horizontal equity). For example, a payroll tax reduction financed by an energy tax may raise the income of some households in the lowest income decile but lower the incomes of others in the same decile (e.g., those who are unemployed). Heterogeneity of impacts within income groups does not affect evaluations of the regressivity of energy taxes. Nevertheless, such unequal policy treatment of households with similar incomes may have implications for social welfare or the policymaker's objective. There is interest in heterogeneous policy impacts across regions, for instance, Bull, Hassett, and Metcalf (1994), Blonz, Burtraw, and Walls (2010), and Mathur and Morris (2014).

Within broad income categories such as quintiles or deciles, household incomes will vary nontrivially. But even for households with identical incomes, energy tax impacts may vary due to household characteristics. For example, a household located in a temperate, coastal region whose earners walk to work consumes less energy for home heating and transportation than a household located in an area with a harsher climate and earners who rely upon lengthy

[2]The progressivity could be enhanced by scaling payroll tax exemptions to family size and increasing the refundable tax credit to $300 per exemption (Metcalf 1999).

work commutes via personal vehicles. An energy tax on transportation or home heating energy will impact the two households differently. Generally the impacts of energy taxes and any revenue recycling will vary across households with similar incomes due to differences in climate, characteristics of the electricity-generating fleet and housing stock, and the energy efficiency of household durables, as well as commuting distance, transportation infrastructure, income sources, and participation in transfer benefit programs, among other characteristics. While capital investments such as purchases of energy-efficient durables, as well as other household adjustments such as relocation to a milder climate, can mitigate the burden of the energy tax over time, such behaviors themselves constitute burdens.

This potential for significant variation in impacts within income groups is not mitigated by common proposals for addressing vertical equity. In the remainder of this section we will examine the extent of tax treatment disparities among households with similar incomes and identify mechanisms for minimizing horizontal inequities. First, however, we consider the relevance of such disparities for social welfare and policymakers' objectives.

## Horizontal Equity, Social Welfare, and Policymaker Objectives

The utilitarian social welfare framework, which dates back at least to Bentham (1789), asserts the diminishing marginal utility of income that motivates policy interest in the vertical equity of tax changes. Less established is the theoretical foundation for horizontal equity. Musgrave (1959, 1990) asserts the seemingly appealing notion that policy should treat equals equally, which suggests that tax impacts should be uniform for households similarly situated along the income distribution. But as Kaplow (1989, 1992) argues, tax impacts vary across households with similar incomes not because of government arbitrariness, but rather because of household differences in other dimensions, such as sources of income, family size, home characteristics, and behaviors. An emphasis on horizontal equity also violates the Pareto principle by implicitly favoring homogeneous income changes over those that may yield higher but heterogeneous income changes. Finally, horizontal equity concerns implicitly prioritize or value status quo ante income distributions, which can be arbitrary. Such criticisms not withstanding, horizontal equity does enter into the social welfare functions of Slesnick (1989), Auerbach and Hassett (2002), and Bourguignon (2011).

Regardless of the philosophical debate concerning the ethical basis for horizontal equity, it may be of concern to policymakers for political economy reasons. That is, a progressive tax reform is likely to be viewed less favorably if progressivity is achieved through gains to a small fraction of poor households but losses to the majority of the poor. Cronin, Fullerton, and Sexton (forthcoming), for instance, show that several potential carbon tax and rebate reforms achieve progressivity in precisely this way—imposing small losses on most families in low consumption deciles. The share of winners versus losers and the magnitudes of their gains and losses may also have political implications. Political support for a policy may require a broad set of winners within income classes. Alternatively, the minority that has much to gain or lose from policy reform may be more likely to attempt to influence political outcomes. For example, strong opposition to energy taxes from small fossil energy–producing regions may discourage implementation of such a policy even if that policy is favored by a much larger group of non-fossil energy–producing regions.

## Variation in Energy Tax Effects Within Income Groups

Although the literature investigating the heterogeneity of energy tax effects within income groups is limited, the evidence suggests that the variation in tax treatment could be large. In one early contribution to this literature, Poterba (1991) finds considerable within-decile variation in gasoline expenditure shares in the United States even though gasoline expenditure shares do not vary considerably across income groups. Poterba (1991) also shows that variability in expenditure shares is greatest among low-income groups. One-third of households in the lowest income decile incurred no gasoline expenditures, but they accounted for more than 10 percent of total expenditures for about one-sixth of households in the lowest decile. In contrast, in the highest income decile, all households incur some gasoline expenses but none spend more than 10 percent of their annual budgets on gasoline. Thus it is not surprising that in a simulation of the effects of a carbon tax in the United States, Rausch, Metcalf, and Reilly (2011) find significant variation in burdens within income groups, particularly among low-income groups. Indeed, they find that the variation in impacts among the poorest households in the lowest income decile exceeds the variation in average impacts across income groups.

An examination of consumption survey data in the United States, the UK, and Mexico reveals the same kind of variation in electricity and gasoline expenditures. Using microdata from national consumption surveys in these countries (Instituto Nacional de Estadística y Geografía 2012; Office for National Statistics 2013; Bureau of Labor Statistics 2014), we find that energy expenditures vary considerably within income groups. For each expenditure decile and each country, figure 3 shows the interquartile range of electricity and gasoline expenditure shares (from the 25th to the 75th percentile, “the box”) along with the range of values that are within 1.5 times the interquartile range (“the whiskers”).

For electricity, we find a consistent pattern of considerable within-decile variation. Variation in expenditure shares decreases across consumption deciles. For the United States and the UK, the variation in average electricity expenditure shares across deciles is comparable to the within-decile variation, indicating that horizontal equity impacts vary as much as vertical equity impacts. Electricity expenditures are as high as 20 percent of budgets for some households in the lowest consumption decile, while others have no direct expenditures. In the UK, some of the households with the least consumption have negative expenditures, reflecting their eligibility for various rebate programs. In Mexico, electricity taxes would have greater effects on horizontal than vertical equity, as the across-decile variation is small while the within-decile variation remains comparable to the United States and the UK.

Gasoline expenditure data also suggest that a fuel tax would have greater impact on horizontal than vertical equity. In the UK and Mexico, a very large number of consumers incur no direct expenditures on gasoline, including at least 75 percent of households in the lowest consumption decile. In the United States, relatively few households have no gasoline expenditures. The range of expenditures incurred by the middle 50 percent of households in the lowest consumption decile nearly covers the middle 50 percent range for every other consumption decile.

To put these figures into perspective, the level of and variation in energy expenditures within consumption groups identified in these three countries is greater than the level of and

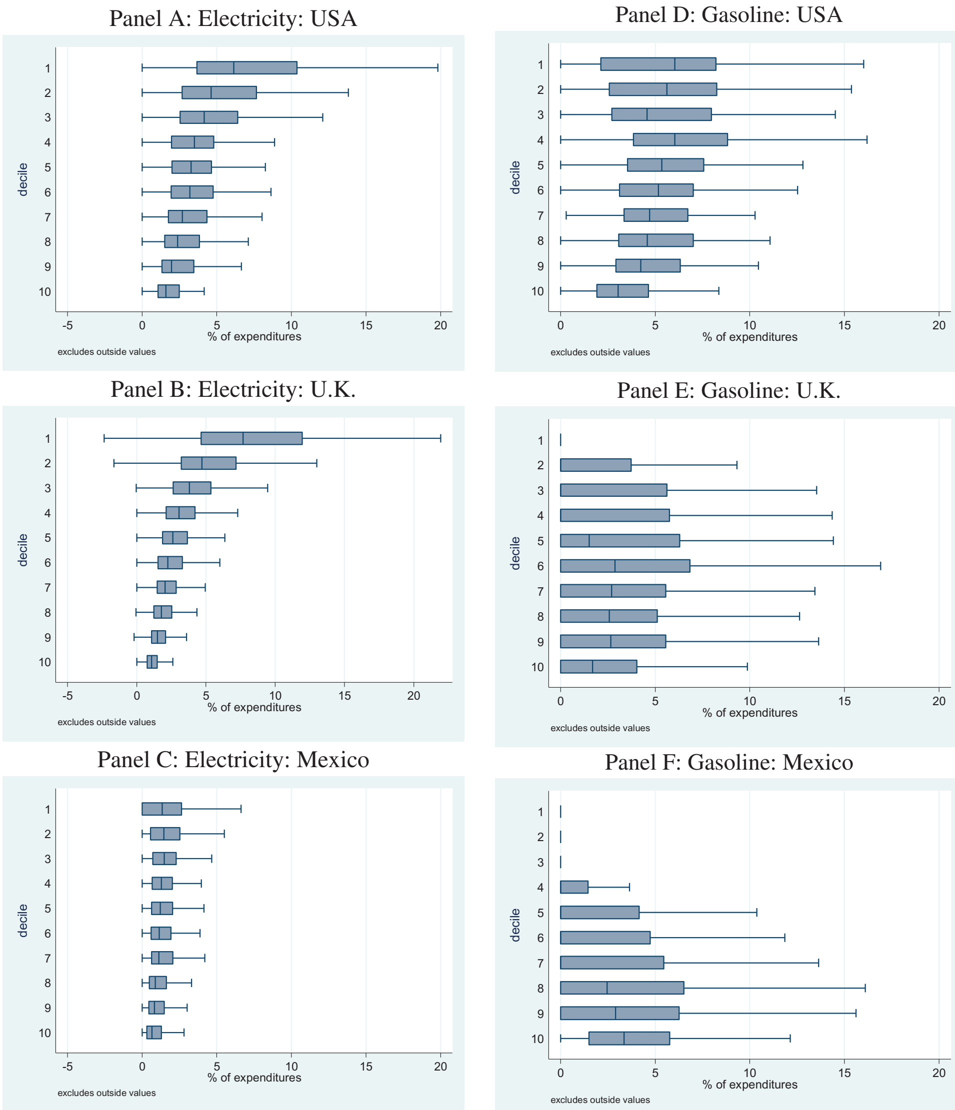


**Figure 3** Within-decile variation in electricity and gasoline expenditures, by total expenditure decile.
*Notes:* For each decile (1 = poorest, 10 = richest), the shaded box shows the interquartile range (IQR) with the median indicated by a line; the whiskers show the range of values within 1.5 times the IQR on either side of the box.
*Sources:* Instituto Nacional de Estadística y Geografía (2012), Office of National Statistics (2013), and Bureau of Labor Statistics (2014).

variation in tobacco or alcohol expenditures in the United States. However, the magnitude of the tax burdens depends not only on this direct calculation, but also on the cost of tax avoidance behaviors. That is, if households can substitute away from energy consumption at low cost, then the burdens will be small and the different tax impacts across households within income groups will not introduce much variation in welfare impacts. If, however, the costs of tax avoidance are high, then heterogeneous energy expenditures imply relatively large disparities in welfare impacts.

Some variation in energy expenditures is attributable to regional variations in climate and geography (Aldy et al. 2010; Rausch, Metcalf, and Reilly 2011), although it is not clear how much variation is due to these characteristics (Pizer, Sanchirico, and Batz 2009). Such physical characteristics are presumed to be costly to change; doing so would require households to move and change places of employment. Changes to appliance settings and utilization of home energy services may be relatively costless, particularly in the short run, but the limited research that is available suggests that such adjustments are responsible for only a small fraction of variation in energy expenditures (Pizer, Sanchirico, and Batz 2009).

### Mechanisms for Achieving Horizontal Equity

If policymakers value horizontal equity in principle, they may nevertheless have limited capacity to achieve it. Unlike efforts to address the vertical equity effects of energy taxes, whereby compensation targets households by income, addressing horizontal equity effects requires compensation that targets energy use itself (or reasonable proxies for energy use). Directly targeting compensation to high-energy-using consumers implies a lower energy tax rate for at least some households, but this undermines efficiency. One could instead base compensation on historical energy use rather than current energy use. This could avoid efficiency losses if such transfers are not expected by households and it is clear that they will be made only once. Nevertheless, such one-time transfers would undercompensate forward-looking households who made investments to lower their exposure to future energy taxes, while myopic households would be rewarded for not anticipating the policy.

Another option for addressing horizontal equity concerns would be to focus on the variation in the impacts of energy taxes that is due to geographic location or other proxies. For example, the federal government could rebate some portion of the energy tax revenue to households through states, counties, or perhaps utility service areas in well-defined geographic areas. Based on aggregate energy demand information for the region, such an approach could reduce inequality across regions. But it, too, would reduce energy tax efficiency by decreasing incentives to migrate to low-energy-consuming regions. It is possible, however, that such a decrease in incentives would not be significantly distortionary because it would not affect the migration decisions of many households. More importantly, such a region-specific policy would not address other, larger sources of inequity within income groups (Pizer, Sanchirico, and Batz 2009).

Finally, policymakers could choose a lower energy tax rate and/or other policies. That is, if the concern over unequal effects within income groups is significant and otherwise difficult to address, policymakers could choose not to create the unequal effects in the first place. Regulations that do not raise the price of energy may be more costly to society, but they have considerably smaller distributional effects (Fischer and Pizer, forthcoming).

## Conclusions and Policy Implications

Energy taxes and tradable permit programs, like those to limit $CO_2$ emissions, have unequal effects both across and within income groups. These redistributions are a central concern in policy debates, particularly given the common belief that such policies are regressive. We have reviewed the robust literature on distributional impacts across the income distribution and used survey data to present our own analysis of the effects of energy taxes on vertical equity and on horizontal equity. This exercise suggests several lessons and implications for policymakers.

1. **The direct effects of energy taxes are not always regressive. This is particularly true for gasoline taxes in poorer countries.** Although energy taxes are often assumed to put a greater burden on poor households than rich households, this belief is not always correct. We have shown that the distributional impact of energy taxes depends upon several factors. First, the regressivity of any energy tax depends upon the commodity that is taxed. Electricity taxes tend to be highly regressive, whereas gasoline taxes are less regressive, and in fact may be progressive in some settings and over some ranges of income. Second, the overall level of economic development of the country implementing the tax is important. Energy taxes in general, and gasoline taxes in particular, tend to be progressive in less-developed countries because the poor may not have electrified homes or access to automobiles or affordable public transportation. Third, the incidence of energy taxes varies according to the climate and cultural characteristics of jurisdictions, along with features of the housing stock and transportation and electricity generation infrastructure. This is why the regressivity of gasoline taxes varies across high-income countries like the United States and the UK.

   Regressivity is diminished when evaluated using proxies for lifetime earnings (e.g., annual expenditures), which is widely considered by economists to better measure the well-being of households. Regressivity is also generally reduced when both direct and indirect tax effects are considered.
2. **Even if energy taxes have regressive impacts, this does not necessarily mean that there should be cause for policy concern.** To the contrary, in some settings, direct expenditures on particular energy commodities account for only a small share of household budgets. This limits the magnitude of distributional effects that are caused by energy taxes and thus the losses to those poor households that are negatively impacted by regressive energy taxes.
3. **Unlike other forms of regulation, energy taxes generate revenues that can be used to achieve distributional goals across income groups.** This means that even in settings where energy taxes would impose a greater burden on the poor, policymakers could design a series of transfers or changes to other taxes in order to cause no harm to low-income populations, at least on average, or make tax reform proportional or neutral to distributions, or increase the progressivity of government tax and transfer programs. However, policymakers often face a trade-off between accomplishing progressivity and achieving maximum efficiency as they recycle revenue. Using energy tax revenue to cut existing taxes that have the highest potential to raise welfare typically leads to less progressive outcomes.
4. **Variation in energy expenditure shares is typically greater within than across income groups.** This intraclass variation tends to be greatest for the poorest households. Moreover, this variation among households with similar incomes stems from differences in climates, geography, built environment, and households' characteristics and behaviors. Some behaviors can be easily changed to avoid higher tax burdens, but many important characteristics cannot. On the one hand, this points to a potential for groups

that are negatively impacted by energy taxes to mobilize political opposition to such taxes. On the other hand, there is a long-standing ethical debate about the extent to which horizontal equity should matter for social welfare or other policy objectives.

5. **Policymakers that are concerned about significant variation in the effect of energy taxes within income groups may find such effects difficult to address.** Compensation could be tied to historic energy use or proxies such as location. However, such approaches may be imperfect or impractical. In these cases, more costly (i.e., less efficient) regulation may be needed in order to replace or scale back energy taxes in the first place. Policymakers may also want to consider introducing energy taxes more gradually to afford those households most harmed by the taxes cheaper options to reduce their energy tax exposure.

In summary, traditional distributional concerns about energy taxes—that they disproportionately impact the poor—need not be a reason to avoid such taxes and/or to choose other forms of regulation. The design of the tax policy can address real or perceived concerns about impacts across income groups. However, energy taxes do lead to significantly different outcomes among households within income groups that cannot be so easily addressed, which may argue in favor of implementing lower energy taxes or other, nontax policies.

## References

Akpalu, W. and E. Robinson. 2012. Political petrol pricing: the distributional impact of Ghana's fuel subsidies. In *Fuel taxes and the poor: the distributional effects of gasoline taxation and their implications for climate policy*, ed. T. Sterner. New York: Routledge.

Aldy, J.E., A.J. Krupnick, R.G. Newell, I.W. Parry and W.A. Pizer, 2010. Designing climate mitigation policy. *Journal of Economic Literature*, 48(4): 903–34.

Auerbach, A. J., and K. A. Hassett. 2002. A new measure of horizontal equity. *American Economic Review* 92:1116–25.

Baumol, W. J., and W. E. Oates. 1988. *The theory of environmental policy*. Cambridge: Cambridge University Press.

BDEW. 2016. *BDEW electricity price analysis: households and industry*. Berlin: BDEW. https://www.bdew.de/internet.nsf/res/17C4483BB515C7F4C125807A0035E077/$file/161124_BDEW_Strompreisanalyse_November2016.pdf.

Bentham, Jeremy (1789). *An introduction to the principles of morals and legislation*. London: T. Payne and Son.

Blonz, J., D. Burtraw, and M. Walls. 2010. Climate policy's uncertain outcomes for households: the role of complex allocation schemes in cap-and-trade. *BE Journal of Economic Analysis and Policy* 10(2):1–35.

Bourguignon, F. 2011. Status quo in the welfare analysis of tax reforms. *Review of Income and Wealth* 57:603–21.

Bovenberg, A. L., and L. Goulder. 2001. Neutralizing the adverse industry impacts of $CO_2$ abatement policies: what does it cost? In *Distributional and behavioral effects of environmental policy*, ed. C. Carraro and G. E. Metcalf, 45–85. Chicago: University of Chicago Press.

Bull, N., K. A. Hassett, and G. E. Metcalf. 1994. Who pays broad-based energy taxes? Computing lifetime and regional incidence. *Energy Journal* 15:145–64.

Bureau of Labor Statistics. 2014. Consumer expenditure survey. https://www.bls.gov/cex/.

Cronin, J. A., D. Fullerton, and S. Sexton. Forthcoming. Vertical and horizontal redistributions from a carbon tax and rebate. *Journal of the Association of Environmental and Resource Economists*.

Datta, A. 2012. Are fuel taxes in India regressive? In *Fuel taxes and the poor: the distributional effects of gasoline taxation and their implications for climate policy*, ed. T. Sterner. New York: Routledge.

Davis, L. W., A. Fuchs, and P. Gertler. 2014. Cash for coolers: evaluating a large-scale appliance replacement program in Mexico. *American Economic Journal: Economic Policy* 6:207–38.

Dinan, T. 2012. Offsetting a carbon tax's costs on low-income households. Working Paper 2012-16, Congressional Budget Office.

Energy Information Administration. 2016. *U.S. residential electricity prices decline for the first time in many years*. Washington, DC: Energy Information Administration. https://www.eia.gov/todayinenergy/detail.php?id=28252.

European Environment Agency. 2011. *Energy and non-energy related greenhouse gas emissions*. Brussels: European Environment Agency. http://www.eea.europa.eu/data-and-maps/indicators/specification.2010-08-09.2026605593/assessment-1.

Eurostat. 2013. *Analysis of EU-27 household final consumption expenditure*. Brussels: Eurostat. http://ec.europa.eu/eurostat/statistics-explained/index.php/Archive:Household_consumption_expenditure_-_national_accounts.

Fischer, C., and W. A. Pizer. Forthcoming. Horizontal equity effects in energy regulation. *Journal of the Association of Environmental and Resource Economists*.

Flues, F., and A. Thomas. 2015. *The distributional effects of energy taxes*. Paris: Organization for Economic Cooperation and Development.

Fowlie, M., C. R. Knittel, and C. Wolfram. 2012. Sacred cars? Cost-effective regulation of stationary and nonstationary pollution sources. *American Economic Journal: Economic Policy* 4:98–126.

Friedman, M. 1957. The permanent income hypothesis. In: *A theory of the consumption function*, 20–37. Princeton, NJ: Princeton University Press.

Fullerton, D. 1996. Why have separate environmental taxes? *Tax Policy and the Economy* 10:33–70.

———. 2011. Six distributional effects of environmental policy: six distributional effects of environmental policy. *Risk Analysis* 31:923–29.

Fullerton, D., G. Heutel, and G. E. Metcalf. 2012. Does the indexing of government transfers make carbon pricing progressive? *American Journal of Agricultural Economics* 94:347–53.

Fullerton, D., and E. Muehlegger. 2019. Who bears the Economic Burdens of environmental regulations? *Review of Environmental Economics and Policy*. 13:62–82.

Goulder, L. H. 1995. Effects of carbon taxes in an economy with prior tax distortions: an intertemporal general equilibrium analysis. *Journal of Environmental Economics and Management* 29:271–97.

Goulder, L. H., I. W. H. Parry, R. C. Williams III, and D. Burtraw. 1999. The cost-effectiveness of alternative instruments for environmental protection in a second-best setting. *Journal of Public Economics*, 72:329–60.

Grainger, C. A., and C. D. Kolstad. 2010. Who pays a price on carbon? *Environmental and Resource Economics* 46:359–76.

Haghshenas, H., and M. Vaziri. 2012. Urban sustainable transportation indicators for global comparison. *Ecological Indicators* 15:115–21.

Hannon, B., R. G. Stein, B. Z. Segal, and D. Serber. 1978. Energy and labor in the construction sector. *Science* 202:837–47.

Hassett, K. A., A. Mathur, and G. E. Metcalf. 2011. The consumer burden of a carbon tax on gasoline. In *Fuel taxes and the poor: the distributional effects of gasoline taxation and their implications for climate policy*, ed. T. Sterner. New York: Routledge.

Herendeen, R. A., C. Ford, and B. Hannon. 1981. Energy cost of living, 1972–1973. *Energy* 6: 1433–50.

Hernández, D. 2014. Affording housing at the expense of health exploring the housing and neighborhood strategies of poor families. *Journal of Family Issues* 37:921–46.

Hsiang, S., P. Oliva, and R. Walker. 2019. The distribution of environmental damages. *Review of Environmental Economics and Policy*. 13:83–103.

International Energy Agency. 2017. Energy policies beyond EIA countries: Mexico. Paris: International Energy Agency.

Instituto Nacional de Estadística y Geografía. 2012. *Encuesta Nacional de Ingresos y Gastos de los Hogares*. Mexico City: Instituto Nacional de Estadística y Geografía.

Kaplow, L. 1989. Horizontal Equity: Measures in Search of a Principle. *National Tax Journal* 42(2): 139–54.

——— 1992. A note on horizontal equity. *Florida Tax Review* 1:191.

King Abdullah Petroleum Studies and Research Center. 2015. Global degree days database. https://www.kapsarc.org/research/projects/global-degree-days-database/.

Mankiw, N. G. 2009. Smart taxes: an open invitation to join the Pigou club. *Eastern Economic Journal* 35:14–23.

Mathur, A., and A. C. Morris. 2014. Distributional effects of a carbon tax in broader U.S. fiscal reform. *Energy Policy* 66:326–34.

Mekonnen, A., R. Deribe, and L. Gebremedhin. 2013. Fossil fuel and food tax incidence in Ethiopia. *Eastern Africa Social Science Research Review* 29(2):1–23.

Metcalf, G. E. 1999. A distributional analysis of green tax reforms. *National Tax Journal* 52:655–81.

———. 2009a. Designing a carbon tax to reduce U.S. greenhouse gas emissions. *Review of Environmental Economics and Policy* 3:63–83.

———. 2009b. Market-based policy options to control US greenhouse gas emissions. *Journal of Economic Perspectives* 23(2):5–27.

Metcalf, G. E., S. Paltsev, J. M. Reilly, H. D. Jacoby, and J. Holak. 2008. Analysis of U.S. greenhouse gas tax proposals. Report 160, MIT Joint Program on the Science and Policy of Global Change.

Mkenda, A.F., J.K. Mduma, and W.M. Ngasamiaku. 2012. Fuel taxation and income distribution in Tanzania. In *Fuel taxes and the poor: the distributional effects of gasoline taxation and their implications for climate policy*, ed. T. Sterner. New York: Routledge.

Murray, B., W.A. Pizer, and M. Ross. 2015. Regulating Existing Power Plants under the Clean Air Act: Present and Future Consequences of Key Design Choices. *Energy Policy* 83:87–98.

Musgrave, R.A. 1959. *The Theory of Public Finance.* New York: McGraw Hill.

Musgrave, R. 1990. Horizontal equity, once more. *National Tax Journal* 43:113–22.

Mutua, J., M. Borjesson, and T. Sterner. 2012. Distributional Effects of Transport Fuel Taxes in Kenya: Case of Nairobi. In *Fuel taxes and the poor: the distributional effects of gasoline taxation and their implications for climate policy*, ed. T. Sterner. New York: Routledge.

Office of National Statistics. 2013. *Living costs and food survey, 2013.* London: Office of National Statistics.

———. 2014. *Household energy spending in the UK, 2002–2012.* London: Office of National Statistics.

Palmer, J., and I. Cooper. 2013. *United Kingdom housing energy fact file.* London: Department of Energy and Climate Change.

Parry, I. W. H. 1995. Pollution taxes and revenue recycling. *Journal of Environmental Economics and Management* 29(3):S64–77.

Parry, I. W. H., and A. M. Bento. 2000. Tax deductions, environmental policy, and the "double dividend" hypothesis. *Journal of Environmental Economics and Management* 39:67–96.

Parry, I. W. H., A. Morris, and R.C. Williams III, eds. 2015. *Implementing a U.S. carbon tax: challenges and debates.* New York: Routledge.

Pizer, W., J. N. Sanchirico, and M. Batz. 2009. Regional patterns of U.S. household carbon emissions. *Climatic Change* 99(1–2):47–63.

Parliamentary Office of Science and Technology. 2015. Future of natural gas in the UK. *POST Note* 513:1–6.

Poterba, J. M. 1989. Lifetime incidence and the distributional burden of excise taxes. *American Economic Review* 79:325–30.

———. 1991. Is the gasoline tax regressive? *Tax Policy and the Economy* 5:145–64.

Rausch, S., G. E. Metcalf, and J. M. Reilly. 2011. Distributional impacts of carbon pricing: a general equilibrium approach with micro-data for households. *Energy Economics* 33(Suppl 1):S20–33.

Rausch, S., and J. Reilly. 2012. Carbon tax revenue and the budget deficit: a win-win-win solution? Report 228, MIT Joint Program on the Science and Policy of Global Change.

Slesnick, D. T. 1989. The measurement of horizontal inequality. *Review of Economics and Statistics* 71:481–90.

Sterner, T., and J. Cao. 2012. Is fuel taxation progressive or regressive in China? In *Fuel taxes and the poor: the distributional effects of gasoline* *taxation and their implications for climate policy*, ed. T. Sterner, New York: Routledge.

Sterner, T., and E. Carlsson. 2012. Distributional effects in Europe. In *Fuel taxes and the poor: the distributional effects of gasoline taxation and their implications for climate policy*, ed. T. Sterner. New York: Routledge.

Sterner, T., and A. Lozada. 2012. The income distribution effects of fuel taxes in Mexico. In *Fuel taxes and the poor: the distributional effects of gasoline taxation and their implications for climate policy*, ed. T. Sterner. New York: Routledge.

Stutzer, A., and B. S. Frey. 2008. Stress that doesn't pay: the commuting paradox. *Scandinavian Journal of Economics* 110:339–66.

Williams, R. C. III, H. Gordon, D. Burtraw, J. C. Carbone, and R. D. Morgenstern. 2015. The initial incidence of a carbon tax across income groups. *National Tax Journal* 68:195–214.