Winter 2019

Who Bears the Economic Burdens of Environmental Regulations?

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Introduction

Historically, command and control approaches have dominated environmental regulation. In the United States, examples include technology standards under the 1970 Clean Air Act and state standards for electricity generation from renewable sources. These kinds of mandates account for the majority of environmental regulations not only in the United States, but also in other countries around the world. Despite the predominance of environmental mandates, most research on the distributional consequences of environmental policies has focused on environmental taxes and other market-based approaches.

Existing research on the burdens of environmental policies has also focused primarily on developed countries.[1] However, because economies in developing countries differ from those in the developed world, results of studies of the United States or Europe may not apply to developing countries. Moreover, the projected growth in developing countries means that their environmental regulations are likely to be very important.

This article is part of a symposium on the distributional effects of environmental policy.[2] Here we review the current understanding of economic "incidence"—the ultimate distribution of the burdens of taxation—and apply it not only to environmental taxes, but also to nontax environmental regulations. We also consider how the lessons and estimates from the developed world might be applied in a global context to both developed and developing countries.

The article is organized as follows. The next section draws on the theory of tax incidence to show not only how producers and consumers split the burden of an environmental tax, but also how such policies affect returns to factors like labor and capital or the prices of clean and

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We would like to thank Tatyana Deryugina, Arik Levinson, Reed Walker, and two anonymous referees for helpful comments and suggestions.

[1] A relatively small literature on developing countries is reviewed by Greenstone and Hanna (2014) and Greenstone and Jack (2015).
[2] Also in this symposium, the article by Hsiang, Oliva, and Walker (2019) discusses the distribution of benefits from environmental policy, while the article by Pizer and Sexton (2019) focuses on the distributional impacts of energy taxes within income groups.

Review of Environmental Economics and Policy, volume 13, issue 1, Winter 2019, pp. 62–82
doi: 10.1093/reep/rey023
Advance Access Published on January 31, 2019

dirty inputs. Then we discuss whether and how the theory of tax incidence can be used to understand the likely distributional effects of nontax environmental mandates or regulations and we review the emerging empirical literature in this area. The following section discusses how these burdens can be affected by various market conditions, including labor and capital mobility, the openness of the economy, evasion of regulatory enforcement, and market power. We focus in particular on the implications for developing countries, where capital and labor markets may be less well developed and regulatory enforcement may be less effective.

Finally, to show how these considerations apply to an important example of environmental policy, we consider the likely distributional burdens of a global carbon tax across countries with different levels of per capita income in both the developed and developing world. Although low-income countries tend to be net importers of fossil fuels, we find no strong relationships between carbon intensity and country income. However, we find substantial variation in both carbon intensity and trade exposure, even *within* sets of countries grouped by similar per capita income. These results suggest that assessing the distributional impacts of carbon policy across countries grouped by income may overlook important variations within income groups.

Applying the Theory of Tax Incidence to Environmental Policy

While the law might require either the seller or the buyer to pay tax on an input or output, economics textbooks are clear that this "statutory incidence" has little bearing on who actually bears the burden or "economic incidence" of the tax. Here we view pollution as an *input* to production, in order to study how a pollution tax or other environmental policy might raise the cost of that input. First we show how much of this burden is borne by producers and how much is passed to consumers, then we describe the simultaneous effects on relative factor prices and relative goods prices.

A Partial Equilibrium Model

In a simple partial equilibrium model, a pollution tax will increase the cost of production and thus raise the output price by an amount that depends on the pollution intensity of production. For energy inputs like fossil fuels, carbon intensity can be measured in carbon emissions per unit of heat generated by the fuel. Thus, for each unit of a produced good, carbon intensity equals the energy required at each stage of production times the carbon emissions per unit of the energy source used. Carbon intensity multiplied by the carbon tax rate determines the increase in production cost, and a partial equilibrium model can be used to split the burden of the tax between producers and consumers in a way that depends on market characteristics. Under perfect competition, the economic incidence of the tax depends on the relative demand and supply elasticities for the good, where the more inelastic side of the market bears a greater share of the burden of the policy.[3] Thus if the demand for fossil fuel–intensive goods

[3]Fullerton and Metcalf (2002) show that if η is the supply elasticity and ε is the absolute value of the demand elasticity, then $\varepsilon/(\varepsilon + \eta)$ is the fraction of the production cost increase borne by suppliers. This burden on suppliers rises when demand is more elastic and declines when supply is more elastic.

like gasoline or electricity is more inelastic than the supply of these goods, then consumers bear more of the burden than producers.

Two additional points clarify the usefulness of this model. First, the same kind of elasticity analysis can be applied not only to supply and demand for an output, but also to the supply and demand for an input. If a carbon-intensive fossil fuel source has inelastic supply, for example, then a carbon tax will place a larger burden on that supplier than on any purchasing firm with relatively elastic demand for the fuel input. Second, these demand elasticities depend on substitution possibilities, which themselves depend on legal restrictions and other market conditions. For example, the existence of unregulated sectors or different production technologies would allow firms to substitute away from regulated inputs and outputs, thereby avoiding the regulation (see, e.g., Gibson 2019).

A General Equilibrium Model

The usual graduate course in public economics includes discussion of the well-developed general equilibrium theory of tax incidence, which dates back at least to Harberger (1962). He models a perfectly competitive closed economy with two sectors that each produce one output using two perfectly mobile factor inputs (labor and capital). He then solves for the effects of a "partial factor tax," defined as a tax on the use of one factor input in one sector only.[4]

In this model, the incidence of the partial factor tax has two major components: the "sources side," which refers to burdens from changes in relative factor prices that affect the sources of income (e.g., placing more burden on capital or on labor income), and the "uses side," which refers to burdens from changes in relative commodity prices that affect the uses of income (e.g., placing more burden on those who buy more output from the taxed sector). This model and its results can be applied, for example, to an environmental tax on only one factor input (e.g., pollution) in only one sector (e.g., electricity). The partial factor tax raises the cost of production in that sector—and thus raises the relative price of the electricity output—but it also raises the cost of the pollution input, which causes firms to substitute away from the use of pollution and toward the use of some other input like labor or capital. Thus a tax on pollution can impose a *uses-side* burden on those for whom electricity or other pollution-intensive output accounts for more than the average share of total spending, and it can also impose a *sources-side* burden on those with more than the average share of income coming from labor (if the wage falls) or capital (if its return falls).

Hundreds of subsequent articles extended the Harberger (1962) model to consider unemployment, international trade, imperfect mobility, imperfect competition, and other market conditions. The model has also been extended to more sectors, more factors, and other tax

[4]Harberger (1962) assumes that one sector of incorporated firms produces a manufactured output and is subject to a corporation income tax on its use of capital, while the other sector of unincorporated firms produces a different good (an aggregation of agriculture, services, and housing). He then studies the incidence of the corporate income tax on factor incomes (the return to capital relative to the wage rate). To do so, production functions and other equations are differentiated to linearize the model and to solve N equations for N unknowns, including output price and factor price changes, in terms of all model parameters and an exogenous small change in the tax, t_{KX} (a tax on the use of capital, K, only in the corporate sector, X).

instruments.[5] In particular, Fullerton and Heutel (2007) extend the Harberger model to consider a clean sector and a dirty sector that have inputs of labor, capital, *and* pollution. Including three production inputs means that either labor or capital can be a better substitute for pollution. Then, depending on production technologies, firms may choose to reduce pollution by increasing demand for labor *or* by investing in abatement capital, thus raising or reducing wage income relative to capital income.

Each of these general equilibrium models is designed to consider a hypothetical policy shock (e.g., a tax) in a closed economy, all else equal, in order to identify only the effects of the tax—with no other changes in technology, other policies, or the rest of the world. For three reasons, theorems based on these Harberger-style general equilibrium models are virtually untestable. First, many other changes *do* occur simultaneously, so the effects of a tax shock are difficult to distinguish from other shocks. Second, the nature of a general equilibrium model means that everything is endogenous, because the tax change can affect all prices and all quantities in the entire economy. Third, econometric estimation of the effects of a tax would require more variation in the tax rate than is typically observed in most countries. We will return to these issues later when we discuss efforts to measure incidence empirically.

Applying the Theory of Tax Incidence to Nontax Regulations

Because most actual pollution policies are not taxes, we next examine whether tax incidence theory can be used to analyze the burdens of *non*tax environmental standards.

The use of market-based policies is increasing since the United States introduced sulfur dioxide permits under the Acid Rain Program in 1990 and the European Union (EU) launched an emission trading system for carbon in 2005. But most countries and regions, including the United States and EU, still rely on a bewildering array of emission rate standards for automobile manufacturers, renewable energy requirements for electricity-generating companies, and other mandates to control emissions or energy use.

Instead of imposing the same emission quantity limit on all firms of different sizes, many nontax regulations impose on all firms the same maximum *ratio* (e.g., emissions per mile, carbon per kilowatt-hour, or energy use per degree of heating or cooling). The first subsection below discusses the example of a maximum ratio of emissions to output of electricity and describes how this "ratio standard" can be analyzed as a combination of an implicit tax on emissions and an implicit subsidy to output. The following subsection describes research using this logic in the empirical estimation of the distributional effects of other ratio standards such as U.S. Corporate Average Fuel Economy (CAFE) standards, zoning rules that limit the use of energy per building, and state requirements on renewable energy per kilowatt-hour.

Nontax Regulations as Implicit Tax and Subsidy

When a ratio standard requires a reduction in the ratio of emissions to output, firms can comply by reducing emissions (the numerator), increasing output (the denominator), or doing some of both. Thus researchers have shown that this ratio standard is equivalent to the

[5]For example, Mieszkowski (1972) studies the residential property tax in a similar general equilibrium model that includes three factors of production (labor, capital, and land).

combination of an implicit tax on emissions and an implicit subsidy to output.[6] It does not raise any actual revenue, however, which means the implicit revenue from the implicit tax must exactly match the cost of the implicit subsidy (i.e., the mandate is "revenue neutral").

The equivalence between the ratio standard and the combination of tax on emissions and subsidy to output has two key implications. First, it means that the distributional burden of a ratio standard can be calculated, using the theory of tax incidence, as the incidence of a tax on the numerator (e.g., emissions) plus the incidence of a subsidy to the denominator (e.g., output). As described in the previous section, the distributional effects of an emissions *tax* may include effects on the sources side, if it changes the demand for labor relative to capital, but it also includes effects on the uses side from raising the price of the output produced. However, the nontax regulation includes an implicit subsidy to output, which effectively negates the increase in output price.

Second, it may help explain the preference of policymakers for nontax regulations. Because low-income families devote a higher fraction of total spending to electricity than do high-income families, a carbon tax is often found to be regressive.[7] Perhaps for this reason, actual policy proposals like the U.S. Clean Power Plan place a limit on carbon per kilowatt-hour. As shown here, such a plan can be analyzed as the combination of an implicit tax on carbon (which might be regressive) and an implicit subsidy to electricity (which offsets the regressive effect). Note, however, that this distributional objective comes at the cost of economic efficiency. A carbon *tax* reduces carbon efficiently through both a "substitution effect" among inputs to production to reduce carbon per kilowatt-hour, and an "output effect" to reduce carbon by raising the price of electricity (and thus reducing its use). In contrast, a mandate on the emission *rate* might be less efficient than the carbon tax because it does not take advantage of the carbon-reducing output effect (reducing electricity). Thus policymakers may face a trade-off between economic efficiency and distributional objectives.[8]

Concern about regressivity may also explain why policymakers have implemented other ratio standards such as CAFE standards for vehicles.[9] We next describe empirical work on the distributional effects of such standards.

Empirical Evidence on the Incidence of Nontax Regulations

An emerging empirical literature studies the incidence of nontax regulations using partial equilibrium models. To measure the distributional burdens of U.S. CAFE standards, Davis and Knittel (2019) note that CAFE standards require automakers to sell more fuel-efficient cars and fewer inefficient cars. To comply, retailers reduce prices of the former and raise prices of the latter. Since these CAFE obligations are tradable, Davis and Knittel (2019) use trading

[6] For examples, see Fischer (2001), Fullerton and Heutel (2010), and Goulder, Hafstead, and Williams (2016).

[7] Studies based on the U.S. Consumer Expenditure Survey consistently find that the fraction of total spending devoted to electricity falls with income (e.g. Cronin, Fullerton, and Sexton 2019).

[8] Presenting an alternative view, Cronin, Fullerton, and Sexton (2019) find two reasons that a U.S. carbon tax itself would be progressive. First, they rank families using annual consumption as a proxy for permanent income and find that the overall carbon intensity of all consumption is similar across consumption groups. Second, U.S. public transfers to low-income families are indexed automatically to the higher prices from a carbon tax.

[9] Electricity accounts for a relatively large share of spending for low-income U.S. families, but gasoline accounts for a small share of spending for the very poor who do not own cars. Several papers in Sterner (2012) show that a gasoline tax would be progressive in poor countries where only the rich own cars.

prices to quantify the implicit subsidy and tax rates. Then, using data on all U.S. vehicle registrations in 2012, they measure the burden of CAFE standards based on changes in each family's vehicle costs. For new vehicles, they find that CAFE standards are mildly progressive (because high-income households buy more new vehicles). When the effects on used vehicle costs are included, however, CAFE standards become mildly regressive.

Levinson (2019) broadens this analysis to consider both fuel efficiency standards for vehicles and energy efficiency standards for appliances (e.g., air conditioners). He considers not just the choice of vehicle (or appliance), but also the miles driven (or degrees of cooling). Like Davis and Knittel (2019), he finds that these standards in the United States are regressive—indeed, *more* regressive than a carbon tax. The reason is that without such standards, low-income families would tend to purchase inexpensive cars or appliances and use them less extensively, while high-income families purchase more energy efficient cars or appliances and use them more extensively. The imposition of an energy efficiency standard makes the cars or appliances more expensive, but it also reduces the cost of using them. Low-income households are then forced to pay the higher cost of purchasing these vehicles or appliances, but they generally do not want—or cannot afford—to make extended use of them. Thus low-income households bear a burden, while higher-income families were often already paying more for greater energy efficiency, because they wanted to run the equipment more extensively.

Both of these studies show that these mandates are more regressive than a carbon tax and thus undermine the case for energy efficiency standards on distributional grounds. Economists have often shown that mandates are less cost effective than pricing the pollutant. These two studies show that such mandates are also more regressive.

Another type of mandate is a "renewable portfolio standard" (RPS), which requires a certain percentage of electricity generation from renewable sources like wind and solar power. It imposes an implicit tax on fossil fuel use and an implicit subsidy to renewables. Reguant (2019) models the distributional effects of state RPS rules in the United States and compares the RPS to a tax on carbon or a subsidy to renewables.[10] She finds that although the carbon tax imposes a greater burden on consumers than the RPS, the tax actually provides gains to producers of hydro and nuclear power.

Finally, the emerging empirical literature on mandates in the United States includes analyses of state or local building codes that reduce energy use by requiring improved insulation, other building features, or overall energy efficiency. For example, Bruegge, Deryugina, and Myers (2019) empirically examine the effects of building codes in California and find that they reduce energy consumption primarily by reducing square footage—particularly in the top two income deciles. Thus these codes appear to impose costs primarily on the rich, while the bottom two deciles are essentially unaffected.

Although more research is needed, these recent studies on the distributional impacts of mandates in the United States have demonstrated the potential for using the theory of tax incidence to evaluate nontax environmental regulations.

[10]Reguant (2019) also accounts for retail market design, where renewable production subsidies are often financed by retail tariffs on consumers. Interestingly, she shows that renewable policies are substantially more efficient if their costs are reflected in retail prices, although benefits still go to renewable producers.

How Do Market Conditions Affect the Incidence of Environmental Policy?

Another body of research has examined how market conditions affect who bears the burden of environmental policy. This section describes how research has modified the basic theory just described—by relaxing assumptions such as perfect mobility, costless trade, perfect enforcement, and perfect competition. These considerations are particularly important for developing countries, where market imperfections and transaction costs may play large roles.

The Degree of Intersectoral Factor Mobility

The general equilibrium model described earlier is a long-run model that economists use to analyze the impact of a tax on output prices and factor returns after all adjustments have occurred. These adjustments include the movement of factors (labor and capital) from one sector to another. At one extreme, perfect intersectoral factor mobility would mean that displaced workers are immediately able to find new jobs in a different industry at the going market wage. At the other extreme, factor immobility would mean that labor or capital cannot move to a different industry, even though the tax change reduces the wage for labor or the asset value for capital. Either of these extremes ignores temporary adjustment costs.[11]

However, discussions of proposed environmental regulations often focus primarily on unemployment and other adjustment costs for labor and reduced asset values for capital. For example, a large carbon tax could significantly reduce the value of long-lived coal-fired power plants. These losses would be capitalized into the stock price of companies that own those plants, with large burdens on those who own shares in the companies at the time the policy is enacted (see, e.g., Bushnell, Chong, and Mansur 2013).

Analogously, coal miners have industry-specific skills that would not be valued when looking for a job in a different industry. In effect, miners can move to a different sector, but their coal-mining skills cannot. This imperfect mobility implies not just a temporary loss of wages, but a large one-time loss of human capital. Job loss can also negatively affect the physical health of displaced workers (Sullivan and von Wachter, 2009) and it can also cause severe psychological trauma.[12]

In summary, simple tax incidence models are not well suited to studying the burdens of a proposed environmental tax from temporary job loss and other adjustment costs that are of particular interest to policymakers. New research is just starting to study these issues (e.g., Hafstead and Williams 2018).

[11]Perhaps a more appropriate way to view the simple model is that it considers not the move from one equilibrium to a new equilibrium under a different tax policy (because that would require costly adjustments), but rather that it compares two different states of the world—one where the policy never existed and the other where it has always existed. This conceptual comparison isolates the impact of having the policy or not, all else being equal. It compares two worlds with the same technology, the same preferences, and the same factor endowments.

[12]For example, following the sudden bankruptcy and closure of both Eastern Airlines and Pan Am, Koeppel (1993) documented the increased rates of suicide among 42,000 highly skilled employees who lost their jobs.

The Degree of Interjurisdictional Factor Mobility

The distributional burdens of a new environmental policy also depend upon the ability of labor or capital to move from one jurisdiction to another (e.g., between provinces). A simple theory of tax incidence might assume a closed economy with a fixed amount of labor and capital, which means that changes in demand can affect the wage rate or the return to capital. Thus an environmental tax or mandate may affect not only the buyers of pollution-intensive products on the uses side, but also long-run returns to workers or investors on the sources side. Although such a model might have been appropriate for a large economy like the United States in past decades, small countries depend on *international* investment, and even the United States is subject to increasing globalization.[13] Thus the fixed factor model has become increasingly untenable.

Researchers can relax the assumption of fixed domestic labor and capital stocks (i.e., vertical supply curves). Before considering *partial* interjurisdictional factor mobility, however, we examine the opposite extreme—*perfect* international mobility of capital and a fixed worldwide rate of return that investors must earn to be willing to provide capital at all (i.e., a horizontal capital supply curve faced by firms in a small open economy). In this case, a fixed rate of return means that owners of capital cannot bear any burden from domestic policy, whether it be a tax on capital, a tax on carbon, or a mandated ceiling on pollution per unit of output. Then the burden must be on someone else (i.e., labor and consumers). Thus alternative extreme assumptions about mobility yield starkly different conclusions about the relative burdens of environmental policy on workers and investors.

For these reasons, measuring labor and capital mobility between jurisdictions is important. Moreover, the degree of mobility depends on whether the different jurisdictions are within a country or in different countries. For example, the policy might be enacted by California alone—with great factor mobility between U.S. states—or it might be enacted by an isolated nation with severe legal constraints on the inflow of labor or capital.

The bottom line is that the degree of interjurisdictional capital mobility affects the burden of environmental policy on capital. The logic is similar for labor: although workers are less mobile internationally, they can move between states or provinces within a country and thus avoid the burden of a local environmental policy.

Interjurisdictional Trade Costs

The ease with which products can be traded between jurisdictions is as relevant to the uses side of tax incidence as factor mobility is to the sources side. For example, if a substitute to a good produced and consumed locally is available in nearby jurisdictions with lower taxes, then consumers may substitute away from domestic purchases and firms may substitute away from domestic production.

Ultimately the burden of a local tax will be borne more heavily by parties with high interjurisdictional trade costs—those less able to buy from or to produce in the neighboring jurisdiction with lower tax rates. Empirical evidence focuses on the variation in firm or

[13] Furthermore, as noted by Fowlie (2009), even a large country like the United States can be affected by the presence of unregulated sectors that alter the impact of a new tax on wage rates and capital returns and that create possibilities for emissions leakage.

consumer distance from a tax border. Theory predicts that taxes on goods sold near the border of a lower-tax jurisdiction are borne more heavily by producers, as consumers can readily substitute away from local purchases. The findings of empirical research are consistent with these theoretical predictions. For example, Doyle and Samphantharak (2008) and Stolper (2018) estimate the pass-through of fuel taxes onto consumers and find that consumers who live near low-tax borders bear a lower share of the burden than consumers living further away.

Evasion and Corruption

Simple models of incidence assume that regulations are enforced and taxes are collected costlessly. In reality, evasion and corruption may hinder enforcement of regulations or collection of taxes. Just as legal tax avoidance shifts the burden of tax policies, so too do illegal tax evasion or the bribery of corrupt authorities. All of these actions involve a choice to bear some lesser cost in order to avoid the higher tax or regulatory cost.

A large literature studies the impact of evasion and corruption. A number of papers focus on drivers of the firm's evasion decision (e.g., Fisman and Wei 2004; de Paula and Scheinkman 2010; Agostini and Martinez 2014; Pomeranz 2015). Others focus on the fiscal effects of evasion and corruption—especially in relation to government size, decentralization, and tax enforcement (e.g., Kau and Rubin 1981; Sørensen 1994; Gadenne and Singhal 2014). Finally, a smaller literature examines the relationship between tax evasion and incidence (e.g., Tanzi 1992; Slemrod 2008; Kopczuk et al. 2016). Altogether, the literature highlights two mechanisms by which evasion and corruption may influence how the burden of a tax or mandate is borne by consumers and producers.

First, evasion reduces the effective rate of a tax or effective stringency of an environmental mandate. Parties engaged in evasion incur the cost of the evasive activity but obtain a benefit equal to the tax not paid. Second, and more subtly, tax evasion by some in a market may raise the burden of the tax on fully legal transactions in that market. The shift of the tax burden to legal transactions arises because tax-compliant firms face competition from tax-evading firms, preventing them from passing along a tax burden to consumers. Kopczuk et al. (2016) find empirical support for these impacts in the United States, with the pass-through of diesel taxes rising when states moved the point of taxation upstream from retailers to wholesale terminals, where evasion is more difficult.

Although indices of evasion and corruption are inherently imperfect measures, the 2015–2016 Global Competitiveness Report from the World Economic Forum finds that survey-based measures of corruption or unethical firm behavior are inversely related to country income.[14] This correlation suggests that evasion in these countries may reduce the effective tax rate and the burden on all parties. But given a particular effective tax rate, the burden of the tax may fall more heavily on producers who comply with regulations or who remit their taxes.

Market Power

The final market condition we consider is market power. As discussed earlier, the standard Harberger model of incidence assumes perfect competition. Although linear demand means

[14] http://reports.weforum.org/global-competitiveness-report-2015-2016/ .

that monopoly power reduces the pass-through of the tax burden onto consumers, Bulow and Pfleiderer (1983) show the relationship between competition and pass-through to be ambiguous and to depend on the curvature of supply and demand.[15] Weyl and Fabinger (2013) extend this result to the case of oligopoly, allowing competition between market participants to change with the imposition of tax, again illustrating that the relationship between market power and pass-through is ambiguous.

An empirical literature uses partial equilibrium models to examine the relationship between tax incidence and market power. Despite the difficulty of separately identifying the effects of market concentration and the effects of correlated supply and demand elasticities, these papers find some evidence of greater pass-through in more concentrated markets. Doyle and Samphantharak (2008) find that the pass-through of gasoline taxes in the United States is higher in more concentrated zip codes, while Kopczuk et al. (2016) find evidence of higher pass-through of diesel taxes in states with more concentrated wholesale markets.

A related literature estimates the pass-through of input cost shocks and finds that competition tends to reduce pass-through rates. For example, Miller, Osbourne, and Sheu (2017) find more than full pass-through of energy costs in the Portland cement industry, although it declines with proximity to rival firms. Ganapati, Shapiro, and Walker (2016) also find more than full pass-through in the cement industry, but they find incomplete pass-through in five other markets that are more competitive, including concrete and gasoline. In a study of the pass-through of firm-specific and marketwide shocks in the U.S. refining industry, Muehlegger and Sweeney (2017) find that pass-through increases as a greater share of firms is affected.

International Distributional Burden of Climate Policy

We next apply some of the concepts discussed in the previous sections to illustrate the possible *international* distributional effects of a climate policy such as a carbon tax, a system of tradeable permits, or even command and control regulation.

We focus here on climate policy for two reasons. First, the burdens of any climate policy likely extend beyond national borders, either as part of an international agreement or as a combination of unilateral national programs. Such policy might generate distributional impacts within each country *and* between countries. Second, although most empirical research on the incidence of environmental policy has focused on the developed world, much of the growth in future carbon emissions is likely to occur in developing countries. Thus it is important to examine how research on the incidence of environmental policy in the developed world may apply to the economic burdens created by climate policy in developing countries.

Climate policy raises the cost of fossil fuels and the goods produced using such fuels. Although a complete accounting is beyond the scope of this article, the international distributional burdens are related to three factors that we examine in turn. First, we examine trade in fossil fuels. Economies for which carbon-intensive fuels are a major export likely face

[15]Pass-through exceeds 100 percent for log-convex demand functions, such as constant elasticity demand.

greater burdens from climate policy, depending on the relative supply and demand elasticities for those fuels. Second, we examine the carbon intensity of a country's electricity industry. Countries that depend on carbon-intensive sources of electricity face higher costs from climate policy. Finally, we examine the importance of different countries' exports of energy-intensive goods. International trade allows for goods produced in two different countries to act as substitutes, so carbon policy may reduce demand for carbon-intensive products from one country and increase demand for less-carbon-intensive products from elsewhere. Thus economies that export energy-intensive goods face a greater burden from climate policy.[16] After presenting some caveats and discussing the types and sources of data used in our analysis, we compare these three factors across countries to understand whether the burden of climate policy is likely to fall on rich or poor countries.

Caveats

Because we focus on the distributional burden of economic *costs*, we do not consider the benefits from reducing climate change.[17] We also omit cobenefits from reducing local pollutants that are positively correlated with carbon emissions and the distribution of benefits from the use of any carbon tax or permit revenues.[18]

In addition, because the focus of this article is on distributional effects, we do not discuss how nations decide to impose carbon policy—whether through unilateral action, through a coalition of nations, or by imposing border tax adjustments—although such decisions are clearly relevant to distributional impacts. Rather, we discuss the relative carbon intensity of production in different countries around the world and the incidence of a generic carbon tax. For simplicity, we consider a worldwide tax. In this case, a tax on carbon used in production is equivalent to a tax on the carbon content of consumption, so border tax adjustments are irrelevant.

Finally, as discussed above, the incidence of environmental regulation depends on the ease of evasion, trade costs, and the mobility of labor and capital between sectors. Each of these characteristics is specific to the country and industry being studied; moreover, many are challenging to measure accurately. Thus we abstract away from country-level variation in these factors and focus on patterns across income groups and industries (although more research is clearly needed).

Data

To identify the possible international distributional consequences of a global carbon policy, we examine cross-sectional data on country characteristics and trade patterns for 2013–2014.

[16]Although the distribution of burdens relates to carbon intensity, shifts in trade depend on frictions such as imperfect substitutability, transportation costs, and protectionist trade policies. For this reason, production may shift toward a nation or sector that avoids the worldwide tax (e.g., due to poor enforcement capabilities).

[17]Mendelsohn, Dinar, and Williams (2006) find that poor countries face the heaviest burdens of climate change (i.e., they would benefit from climate policy). Others examine questions of environmental justice in the context of climate change (e.g., Ringius, Torvanger, and Underdal 2002; Lange, Vogt, and Ziegler 2007; Page 2008).

[18]A worldwide entity that levies a uniform carbon tax would impose burdens on countries with carbon-intensive production (as we have discussed), but a country that participates in a worldwide uniform carbon tax could also generate revenue for itself. Thus a country with a carbon-intensive economy would not necessarily bear more burden.

We use country-level data on gross domestic product (GDP) and GDP per capita, electricity generation by fuel type, and industrial activity by sector from the World Bank's annual World Development Indicators (WDI).[19] We also use the World Bank's grouping of countries into four income categories based on GDP per capita: low income, lower-middle income, upper-middle income, and high income.

We supplement the WDI data with country-level data on the value of imports and exports by industry from the United Nations Commodity Trade Statistics Database (COMTRADE).[20] We aggregate trade in all industrial sectors classified as energy-intensive by the U.S. Energy Information Administration (EIA).[21] Finally, we consider trade in four separate fossil fuel categories: coal, natural gas, crude oil, and other fuels (primarily refined petroleum products).

Fossil Fuel Production and Trade

To determine whether the burden of carbon policy is likely to fall on producing or consuming countries and whether these burdens are likely to be correlated with country income, we must first examine the production and export of fossil fuels. As shown in table 1, fossil fuel exports across all countries average 3.7 percent of GDP, of which roughly 80 percent are crude and refined petroleum products (crude oil is 1.6 percent of GDP and refined products average 1.4 percent of GDP). Exports of natural gas are only 0.6 percent of GDP, while coal exports are negligible (0.1 percent). The value of all imported fuels averages 4 percent of GDP, where again petroleum products dominate.

These worldwide averages obscure two sources of variation across countries. First, low-income countries overall are net importers of fossil fuels, with imports averaging 8.1 percent of GDP and exports averaging only 1.5 percent of GDP. Refined petroleum products (e.g., gasoline and diesel) account for the vast majority of these imports, 7.6 percent of GDP. In contrast, high-income countries are slight net importers, with fossil fuel imports averaging 4.0 percent of GDP and exports averaging 3.4 percent of GDP. Second, the standard deviations in table 1 are relatively high, which suggests substantial variation in fossil fuel exports and imports across countries *within* each income group. More specifically, most countries are net importers of fossil fuels, but fossil fuel exports are a high percentage of GDP for a few resource-rich nations in the Middle East, in central Asia (e.g., Russia, Kazakhstan, and Azerbaijan), and in a handful of other countries (e.g., Norway, Bolivia, and Nigeria).

Carbon Policy Burdens from Fossil Fuels

These trade patterns by income group beg the question of whether the burden of carbon policy is likely to fall more on consumers or producers of fossil fuels. As discussed earlier, this burden distribution (i.e., incidence) depends on the availability of substitutes for a taxed

[19] http://data.worldbank.org/data-catalog/world-development-indicators
[20] http://comtrade.un.org/db/default.aspx.
[21] Major energy-intensive industries include petroleum refining; food manufacturing; pulp and paper; primary production of iron, steel, nonferrous metals, and cement; and organic agricultural and inorganic chemicals.

Table 1 Mean (and standard deviation) of fossil fuel exports and imports as a share of GDP, by income group

	All countries	Low-income countries	Lower-middle income	Upper-middle income	High income
All fossil fuel exports	0.037	0.015	0.050	0.043	0.034
	(0.076)	(0.021)	(0.052)	(0.074)	(0.078)
Coal exports	0.001	0.000	0.004	0.001	0.001
	(0.004)	(0.000)	(0.008)	(0.003)	(0.004)
Natural gas exports	0.006	0.002	0.007	0.006	0.005
	(0.026)	(0.008)	(0.018)	(0.016)	(0.029)
Crude oil exports	0.016	0.000	0.021	0.022	0.013
	(0.054)	(0.000)	(0.046)	(0.053)	(0.054)
Refined fuel exports	0.014	0.013	0.017	0.013	0.014
	(0.023)	(0.015)	(0.014)	(0.020)	(0.025)
All fossil fuel imports	0.040	0.081	0.066	0.034	0.040
	(0.036)	(0.028)	(0.029)	(0.026)	(0.039)
Coal imports	0.001	0.001	0.004	0.001	0.001
	(0.002)	(0.001)	(0.004)	(0.001)	(0.002)
Natural gas imports	0.006	0.003	0.007	0.004	0.007
	(0.007)	(0.004)	(0.007)	(0.005)	(0.007)
Crude oil imports	0.020	0.002	0.035	0.017	0.020
	(0.018)	(0.008)	(0.031)	(0.016)	(0.016)
Refined fuel imports	0.013	0.076	0.020	0.012	0.012
	(0.021)	(0.026)	(0.017)	(0.018)	(0.022)

Notes: For each fuel type, the cell denotes fossil fuel exports or imports as a fraction of GDP in 2013 (and the standard deviation). In low-income countries, for example, total fossil fuel exports averaged 1.5 percent of GDP (for the fuel types aggregated by value), while total imports of fossil fuels averaged 8.1 percent of GDP (aggregated by value). All income group statistics are weighted by country GDP.
Sources: COMTRADE data, United Nations.

good or, more generally, on elasticities of supply and demand. We thus consider the incidence of a carbon policy on petroleum products (crude and refined) and on fossil fuels used for electricity generation (coal and natural gas), drawing upon the academic literature on consumption of fossil fuels.

Incidence of carbon policy on petroleum products

A fully combusted gallon of gasoline generates approximately 20 pounds of carbon dioxide (CO_2) and a gallon of diesel fuel generates roughly 22 pounds. That CO_2 can be valued at $42 per ton, to reflect the U.S. Environmental Protection Agency's (EPA) 2016 estimate of the social cost of carbon (SCC) in 2020.[22] Thus a tax on the carbon content of transportation fuels that reflects the SCC would increase gasoline and diesel costs by approximately 40–50 cents per gallon.

Marion and Muehlegger (2011) and Chouinard and Perloff (2004) find that the incidence of fuel taxes falls heavily on U.S. consumers, because demand for transportation fuels is inelastic in the short run (which allows producers to shift the burden of taxes or input cost changes almost fully onto consumers). If demand in developing countries is equally inelastic,

[22]https://www.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf.

then the burden of a carbon policy on transportation fuels would likely be borne by consumers (importing countries) rather than producers (exporting countries).

Long-run demand is more elastic, as consumers are able to shift toward less fuel-intensive modes of transportation, such as vehicles with higher fuel efficiency, alternative fuel vehicles, or alternative methods of commuting (e.g., public transit). If these behaviors imply a high long-run elasticity of demand for these fuels, then the burden of carbon policy might be shared more equally between consumers and producers. In practice, however, a 40–50 cent jump in the prices of transportation fuels, while significant, is of a similar magnitude to other recent jumps in input prices that did not spur substantial shifts towards alternative fuel vehicles.[23] Although Li, Linn, and Muehlegger (2014) and Rivers and Schaufele (2015) find evidence that consumers respond more to taxes than to changes in the input price of crude, even these estimates imply relatively modest tax-induced shifts in fleet fuel economy. Thus these estimates suggest that the long-run demand for transportation fuels is unlikely to be significantly more elastic than short-run demand.

More research is needed on the sensitivity of consumers in developing countries to the price of transportation fuels.[24] But if the price sensitivity of consumers in developing and developed countries is similar, the long-run burden of a carbon tax on fuels will likely be felt more by countries that are net importers of fuel. As we have discussed, low-income countries are more likely to be net importers of fossil fuels, particularly refined petroleum products, and thus a carbon tax on transportation fuels is likely to impose a heavier burden on low-income countries.

Incidence of carbon policy on coal and natural gas for electricity generation

Next we consider natural gas and coal, which compete directly as inputs to electric power (as well as to industry).[25] A carbon tax of $42 per ton is equivalent to a tax of $2.46 per million metric British thermal units (mmBTU) on natural gas and $4.43 per mmBTU on coal.[26] The greater efficiency of natural gas-fueled electricity plants magnifies the relative effects of the carbon tax,[27] increasing the cost of coal-fired electricity by roughly $26 per megawatt hour relative to natural gas. Cullen and Mansur (2017) find that this change in relative prices is sufficient to shift electricity generation in the United States towards the cheaper source of electricity—that is, from coal-fired plants to combined-cycle natural gas plants. Of course,

[23] Busse, Knittel, and Zettelmeyer (2013) estimate that the share of the new vehicle market going to the most fuel-efficient quartile of vehicles in the United States rises about 3.5 percentage points in response to a 50 cent per gallon increase in prices. Li, Timmins, and von Haefen (2009) estimate that a tax increase of comparable magnitude would increase the average fuel economy of purchased new vehicles in the United States by 1.1 percent and fleetwide fuel economy by 0.13 percent.

[24] Although Sterner (2012) reviews estimates of fuel price elasticities in developing countries, little other research has been published on this topic.

[25] Worldwide in 2015, the electricity power sector consumed approximately 60 percent of coal production and 34 percent of natural gas production (see Table F-1 on page 215 of https://www.eia.gov/outlooks/ieo/pdf/0484(2016).pdf).

[26] According to http://www.eia.gov/tools/faqs/, for U.S. generators, the carbon content is 211 pounds/mmBTU for coal and 117 pounds/mmBTU for natural gas. If electricity generation is less efficient in developing countries, these numbers likely understate the relative burden of carbon policy.

[27] The average heat rate for U.S. coal and natural gas combined-cycle generators in 2014 was 10,080 and 7,658 BTU/kWh, respectively (http://www.eia.gov/electricity/annual/html/epa_08_02.html).

this fuel switch reflects a short-run response; in the long run, new natural gas plants can be constructed, shifting the industry further away from coal.

The higher carbon intensity of coal relative to natural gas suggests that the short-run burden of carbon policy will fall more heavily on coal, as buyers substitute toward natural gas, thus imposing a greater burden on coal-producing and coal-dependent economies. As table 1 suggests, however, coal production and exports are relatively uncorrelated with income at the country level. Thus, although a carbon tax may have impacts on coal-producing nations, it appears unlikely to cause systematic redistribution between rich and poor countries.

The Carbon Intensity of Domestic Electricity Production

Next we examine whether carbon policy burdens depend on the manufacturing carbon intensity and trade patterns of rich and poor nations. We begin by estimating the carbon intensity of each country's electricity sector.[28] To do so, we make several assumptions about the nature of each country's electricity production. First, we use the EIA's estimates of CO_2 per kilowatt-hour for each fuel, which are based on data from U.S. generators. To the extent that developing countries' electricity generation is less efficient, these estimates may understate the carbon intensity of a country's electricity sector. Second, a carbon tax may shift production away from carbon-intensive sources of electricity (e.g., coal) toward less-carbon-intensive sources (e.g., natural gas, nuclear, renewables). Such substitution would reduce the impact of a carbon policy.[29]

As shown in table 2, worldwide electricity generation averages 1.093 pounds of CO_2 emissions per kilowatt-hour, but carbon intensity is highest for countries in the middle of the income distribution (1.297 for lower-middle income and 1.217 for upper-middle income countries). An examination of fuel source percentages reveals that the high carbon intensity of middle-income countries is driven by coal-fired generation, while low-income countries generate a greater share of their electricity from hydropower, emitting only 0.644 pounds of CO_2 per kilowatt-hour (see table 2). High-income countries generate a high share of electricity from nuclear and other renewable sources (emitting 1.018 pounds of CO_2 per kilowatt-hour).

Although the carbon intensity data presented in table 2 suggest an inverted U-shaped relationship between carbon emissions and income, these averages obscure the substantial variation in carbon intensity of electricity generation *within* each income group. As shown in figure 1, which plots carbon intensity against the log of GDP per capita, countries with similar levels of per capita income vary tremendously in their carbon intensity—which depends on the nature of local electricity production. In fact, we find that approximately 95 percent of the variation in CO_2 emissions per kilowatt-hour is not explained by the average for each income group.

[28]We do this by constructing the weighted average CO_2 emissions per kilowatt-hour using fuel-specific emission rates and the fraction of local electricity generated from different fuels. See http://www.eia.gov/tools/faqs/.

[29]Changes in the *relative* competitive positions of countries are less likely. Carbon-intensive countries might shift toward less-carbon-intensive fuels, but they are unlikely to leapfrog other countries that are currently less carbon intensive. Thus conclusions about relative winners and losers would likely remain unchanged.

Table 2 Mean (and standard deviation) of carbon intensity of domestic electricity production, by income group

	All countries	Low-income countries	Lower-middle income	Upper-middle income	High-income countries
CO_2 emissions per kilowatt-hour	1.093	0.644	1.297	1.217	1.018
	(0.441)	(0.695)	(0.383)	(0.474)	(0.409)
Coal generation (%)	35.189	4.531	39.379	42.856	31.565
	(24.723)	(14.213)	(30.678)	(33.587)	(17.575)
Oil generation (%)	3.808	24.654	8.444	4.359	2.950
	(8.040)	(35.740)	(11.061)	(9.629)	(5.915)
Natural gas generation (%)	24.373	9.526	27.292	20.759	25.668
	(20.282)	(18.245)	(28.663)	(24.890)	(16.331)
Nuclear generation (%)	12.541	0.000	2.683	3.657	17.531
	(16.286)	(0.000)	(7.748)	(5.105)	(17.942)
Hydro generation (%)	15.798	59.858	17.846	24.466	11.632
	(19.460)	(40.140)	(17.392)	(21.265)	(17.045)
Other renewable generation (%)	7.160	1.317	4.098	3.397	9.151
	(6.772)	(1.668)	(4.871)	(2.615)	(7.354)

Notes: The first row shows average carbon intensity (and standard deviation). For example, low-income countries average 0.644 pounds of CO_2 emissions per kilowatt-hour. Other rows show the mean and standard deviation of the percentage of electricity generation in 2013 from each different source. All income group statistics are weighted by country GDP.
Sources: Authors' calculations and World Economic Indicators, World Bank.

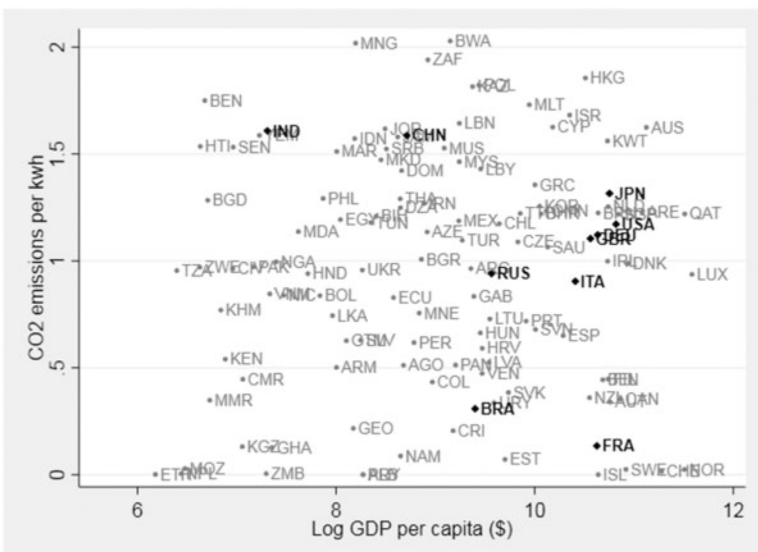

Figure 1 Country carbon intensity versus GDP per capita.
Sources: World Development Indicators and authors' calculations.

In figure 1, the world's ten largest economies are indicated in **bold.**[30] Among the five wealthiest Organization for Economic Cooperation and Development countries (United

[30]See http://wits.worldbank.org/wits/wits/witshelp/content/codes/country_codes.htm for the three-letter abbreviation for each country.

States, Japan, Germany, France, and Great Britain), four have electricity generation that is modestly more carbon intensive than average. The outlier is France, which generates a high fraction of electricity from nuclear power. Among "BRIC" countries (Brazil, Russia, India and China), electricity generation is less carbon intensive in Brazil because of its reliance on hydropower, while China and India are more carbon intensive (both generate more than 70 percent of electricity from coal).

To provide some context for the vertical axis, we convert the carbon intensity of electricity into dollar terms using the EPA's 2016 SCC estimate ($42 per ton). At this cost, a country producing electricity that emits one more pound of CO_2 per kilowatt-hour (about half the height of figure 1) would have generation costs that are 2 cents higher per kilowatt-hour, roughly 20 percent of the average retail electricity price in the United States in 2014.

The Energy Intensity of Manufactured Goods and International Trade

Finally, we consider the distributional impacts of carbon policy by examining the carbon intensity of manufactured goods and trade between countries.

The carbon intensity of a manufactured good is the product of the energy intensity at all stages of production and the carbon intensity of the local energy source. Thus identical goods produced in different countries may have different carbon intensities due to the carbon intensity of local energy. Because we do not observe each country's direct use of different fossil fuels by industry, we cannot fully characterize the carbon intensity of energy use in production. Instead, we use each country's carbon intensity of electricity as a proxy for the carbon intensity of its industrial production. However, we may overstate or understate the carbon intensity of industrial production if the mix of fuels used directly by industry differs from the mix used for electricity generation.

We then examine whether carbon-intensive countries also tend to export energy-intensive goods and face greater exposure to burdens from climate policy. We calculate exports of energy-intensive goods as a percentage of GDP from COMTRADE data, and we find little correlation with income—that is, the percentages did not vary substantially across low-income (4.8%), lower-middle-income (4.1%), upper-middle-income (3.8%), and high-income (4.7%) countries. These calculations suggest that trade in carbon-intensive goods is unlikely to lead to different burdens between rich and poor countries.

Finally, we look *within* country income groups and examine whether carbon intensity is correlated with energy-intensive exports. Figure 2, which has a separate panel for each income group, plots countries' carbon intensity of electricity generation against exports of energy-intensive goods as a fraction of GDP. Countries at the top of a panel have relatively carbon-intensive electricity, and countries to the right of a panel export higher fractions of energy-intensive goods. The horizontal dotted lines correspond to the worldwide average carbon intensity of electricity (0.99 pounds of CO_2 per kilowatt-hour) and the vertical lines correspond to the worldwide average ratio of energy-intensive exports to GDP (4.4 percent).

These two measures—carbon intensity of electricity and exports of energy-intensive goods as a share of GDP—can be used to indicate a country's export exposure to carbon policy.[31] To

[31] Differences in the carbon intensity of imports matter less than differences in the carbon intensity of exports because countries that import energy-intensive goods can substitute towards less carbon-intensive sources for the same goods. Thus more of the burden of carbon policy is pushed onto carbon-intensive exporters.

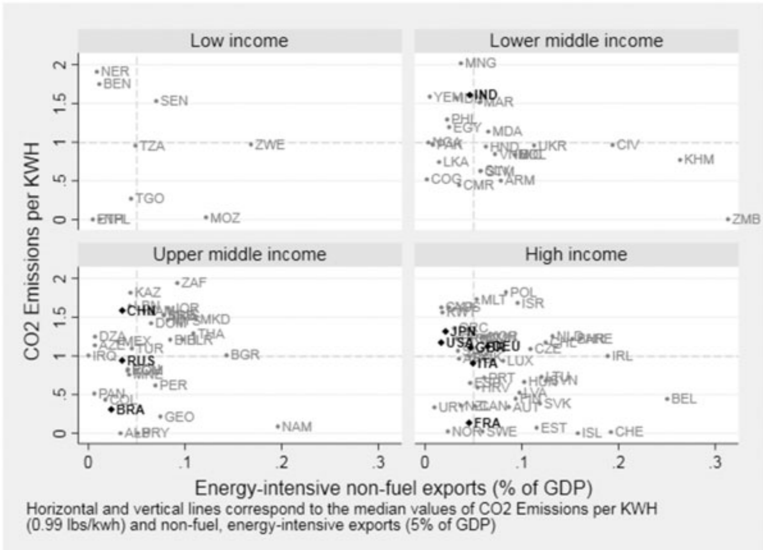

Figure 2 Carbon intensity of electricity and exports of energy-intensive goods, by income groups.
Sources: COMTRADE data, World Development Indicators, and authors' calculations.

illustrate, countries whose exports are most exposed to climate policy are those in the upper-right quadrant, such as Poland (POL), which exports a high fraction of energy-intensive goods using relatively carbon-intensive sources of production. In contrast, countries in the lower-right quadrant, such as Iceland (ISL), export a similarly high fraction of energy-intensive goods as a fraction of GDP, but do so using less-carbon-intensive energy sources. More generally, countries that are above the worldwide average carbon intensity of electricity would be at a competitive disadvantage (and face a disproportionate burden) from carbon policy. Countries that generate electricity through low-carbon sources while exporting energy-intensive goods could gain from a worldwide carbon policy.

Grouping countries by income level reveals some useful insights. Upper-middle-income countries like South Africa (ZAF) tend to produce carbon-intensive electricity and to export a high percentage of energy-intensive goods. These are the countries that are most likely to be at a competitive disadvantage in a world of unified, or at least widespread, carbon policy. In contrast, high-income countries are more likely to fall in the lower-right quadrant and are thus likely to have a competitive *advantage* in a world of widespread carbon policy. Despite variation in carbon intensity, the world's ten largest economies (in bold) tend to be located toward the left within each panel, suggesting less vulnerability to changes in the competitiveness of domestic energy-intensive manufacturing, due to their size and diversified economies.

Summary and Conclusions

In this article we examined the distributional consequences of environmental regulations—both taxes and mandates—and considered how lessons and estimates from the developed world might extend to the rest of the world. We have summarized the literature on market-based approaches and environmental mandates and discussed how market imperfections and frictions, which are more relevant in the developing world, might apply. Finally, we considered data on carbon emissions and trade for different subsets of countries grouped by income.

We conclude that low-income countries are likely to bear a disproportionate share of the burden of carbon taxes on transportation fuels. We also find that, on average, domestic electricity production tends to be slightly more carbon-intensive in middle-income countries. But we find substantial variation in carbon intensity and trade exposure. Within each income group, carbon policy benefits low-carbon economies relative to high-carbon ones, creating winners and losers within each group. These results suggest that assessing the distributional impacts of carbon policy broadly by income may overlook important variations across countries with similar incomes.

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