Who Bears the Economic Costs of Environmental Regulations?

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Abstract:

Public economics has a well-developed literature on tax incidence – the ultimate burdens from tax policy. This literature is used here to describe not only the distributional effects of environmental taxes or subsidies but also the likely incidence of non-tax regulations, energy efficiency standards, or other environmental mandates. We describe how the distributional effects of such policies can be altered by various market conditions such as limited factor mobility, trade exposure, evasion, corruption, or imperfect competition. Finally, using carbon policy as an example, we apply these lessons to data on carbon-intensity of production and exports around the world in order to describe implications for effects of possible carbon policy on countries with different levels of income per capita.

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1. Introduction

Historically, command and control approaches have dominated environmental regulation. Examples in the U.S. include technology standards embedded in non-attainment state implementation plans in response to the 1970 Clean Air Act; state renewable portfolio standards; and the recent water restrictions in California. These kinds of mandates account for a majority of environmental regulations not only in the U.S. but also in other countries around the world. Despite the ubiquity of environmental mandates, most research examining the distributional consequences of environmental policies has limited focus to environmental taxes or other market-based approaches, to burdens from effects on output prices rather than factor prices, and to effects in developed countries.

This paper has four main objectives. First, we summarize existing understanding of “incidence” – defined as the distributional consequences – of environmental taxes or pollution pricing. Starting with some theoretical literature, we describe how producers and consumers split the burden of an environmental tax, and how such policies affect returns to factors like capital and labor, or prices of clean and dirty inputs. For market-based approaches, we can draw on the large existing literature summarizing these effects, including the well-developed empirical literature on the incidence of environmental taxes.

Second, we extend these existing concepts to an initial understanding of the likely distributional effects of mandates, as discussed for example in Fullerton and Heutel (2010) and Goulder et al. (2016). We then review a new and emerging empirical literature on distributional effects of non-tax environmental mandates and regulations.

Third, we describe how alternative market conditions can affect these distributional results. Initial models of tax incidence are based on assumptions of perfect competition, perfect factor mobility, and perfect enforcement – either in a closed economy or in a small open economy with free trade at fixed world prices. We therefore discuss how the burden of environmental taxes and mandates might vary along five dimensions: (a) the degree of labor and capital mobility between sectors, (b) mobility of those factors between jurisdictions, (c) openness of an economy to trade, (d) the degree of regulatory evasion, and (e) market concentration in the regulated market. We examine these five dimensions with a particular eye towards informing incidence in developing countries, where capital and labor markets may be less well-developed, and regulatory enforcement less effective. With the exception of a small literature reviewed by Greenstone and Hanna (2014) and
Greenstone and Jack (2015), work on the distribution of the burdens of environmental policy has focused on the developed world. Yet, the market imperfections faced in the developed world may differ from those faced by developing countries. Consequently, empirical estimates of environmental incidence in the U.S. or Europe may not be a good guide to the international experience. Furthermore, given the projected growth of the developing world, these locations are where future environmental regulation may be most important.

Finally, we apply these concepts to consider the specific example of a widespread carbon tax and the likely distributional effects on countries at different levels of per capita income. We group countries into four income categories and calculate summary statistics for each group such as their carbon-intensity of electricity generation, the importance of their direct fossil fuel exports, and their relative dependence on exports of carbon-intensive manufactured goods. Although low-income countries tend to be net importers of fossil fuels (particularly refined petroleum products), we do not find strong relationships between carbon-intensity and country income. Rather, we find substantial variation in both carbon intensity and trade exposure, even after conditioning on income. These results suggest that assessing the distributional impacts of carbon policy broadly by country income may overlook important variation within income groups.

2. The Theory of Tax Incidence Applied to Environmental Policy

For a tax on an input or output, the law might state that the seller or that the buyer must pay the tax. But economics textbooks are clear that this “statutory incidence” has little bearing on who really bears the burden – “economic incidence.” Here, we consider pollution as an input to production, in order to study a pollution tax or other policy that similarly raises the cost of that input. How much of this burden is passed to consumers?

In a simple partial equilibrium model, a pollution policy will increase the cost of production and thus raise the output price by an amount that depends on the pollution-intensity of production. For primary energy goods like fuels, carbon intensity can be measured in carbon emissions per unit of heat generated by the fuel. For each unit of a produced good, carbon-intensity equals the energy required at each stage of production or consumption times the carbon per unit of the energy source employed. Then the burden of the extra tax cost is generally split between producers and consumers in a way that depends on market characteristics. Under perfect competition, economic incidence depends on the
relative demand and supply elasticities of the good, where the more inelastic side of the
market bears a greater fraction of the costs of the policy.\footnote{If $\eta$ is the supply elasticity, and $\varepsilon$ is the absolute value of the demand elasticity, then Fullerton and Metcalf (2002) show that $\varepsilon / (\varepsilon + \eta)$ is the fraction of the price increase borne by suppliers (which rises when demand is more elastic and declines when supply is more elastic).} In other words, if demand for
fossil-fuel-intensive goods like gasoline or electricity is more inelastic than supply, then
consumers bear more of the burden than producers.

Here we make two additional points. First, the same kind of elasticity analysis can
be applied to a market for an input to production, including supply by the natural resource
owner and demand by a firm. The burden of a tax on that carbon-intensive resource can be
higher for the owner/supplier if supply is inelastic, or it can be higher for the purchasing
firm if demand is more inelastic. 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
allows firms to substitute away from regulated inputs and outputs, thereby avoiding
regulation, similar to the substitution in Gibson (2015).

The usual graduate course in public economics includes a well-developed general
equilibrium theory of tax incidence dating at least back to Harberger’s (1962) analytical
two-sector model. He studies the incidence of the corporate income tax in a model with
two sectors and two inputs – labor and capital – owned by a single aggregate household.
One sector produces a corporate manufactured output, $X$, and the other produces a non-
corporate output, $Y$ (an aggregation of agriculture, services, and housing). Harberger
models the corporate income tax as a “partial factor tax” on capital used in the corporate
sector, $K_X$. Equations are then differentiated to linearize the model and solve $N$
equations for $N$ unknowns, including the key price changes, in terms of all model parameters and an
exogenous small change in the tax, $t_{KX}$.

The incidence of the tax in this context has two major components: the “sources
side” refers to burdens from changes in the rental/wage ratio that affect sources of income,
and the “uses side” refers to burdens from changes in relative commodity prices that affect
uses of income. This partial factor tax raises the cost of production in the corporate sector,
so it raises the relative price of $X$, but it also raises the cost of capital and induces firms to
substitute from capital to labor. Mobile capital can bid down the return in the noncorporate
sector, but if the shrinking corporate sector is labor intensive then labor also moves and can bid down the wage in the noncorporate sector; the overall incidence via the rental/wage ratio depends on parameters that affect the relative strength of these two effects.

Hundreds of subsequent articles extended this model to consider unemployment, international trade, imperfect mobility, imperfect competition, and other market conditions. The model was extended to more sectors, or more factors, or other tax instruments. In particular, Fullerton and Heutel (2007) extend Harberger’s 1962 model to consider a clean sector and a dirty sector with inputs of labor, capital, and pollution. Three inputs to production mean that either labor or capital can be a relative substitute or complement for pollution, so a tax on pollution can increase relative demand for labor or for capital – with consequent effects on the rental/wage ratio (and thus burdens on the sources side).

Each such model is designed to consider a one-time hypothetical policy shock in a closed economy, all else equal, in order to identify the effects of this tax alone with no other changes in technology, other policies, or the rest of the world. For three reasons, theorems from these Harberger-style general equilibrium models are virtually untestable. First, many other changes do occur simultaneously, so effects of a tax change are difficult to distinguish. Second, the nature of a general equilibrium model means that everything is endogenous, as the tax change can affect all prices and all quantities in the entire economy. Third, infrequent changes in one nation’s corporate tax (or carbon tax) rate provide insufficient variation to allow econometric estimation of effects. We return below to discuss attempts at empirical testing or measurement.

3. Can We Use the Theory of Tax Incidence for Non-Tax Regulations?

We next turn to the observation that most actual pollution policies are not taxes. How can tax incidence theory be used to analyze the burdens of non-tax environmental standards? The U.S. has employed some pollution-pricing instruments since the Acid Rain Program introduced sulfur dioxide permits in 1990, but like most other nations, the U.S. still employs a bewildering array of emission rate standards for automobile manufacturers, renewable portfolio standards (RPS) for electricity generating companies, and other mandates to control emissions or energy use.

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2 For example, Mieszkowski (1972) studies the residential property tax in a similar analytical general equilibrium model with three factors of production (labor, capital, and land).
An answer to our question is in the nature of those regulations. Instead of imposing the same emission quantity limit on all firms of different sizes, these rules often impose on all firms the same maximum ratio, such as emissions per mile, carbon per kilowatt hour (kwh), or energy use per degree of cooling. As it turns out, yes, such ratio standards can adequately be represented in general-equilibrium models. Fullerton and Heutel (2010) note that a newly binding ceiling on emissions per unit output can be satisfied by reducing emissions in the numerator, or by increasing output in the denominator, or both. Thus, as shown by them and by Goulder et al. (2016), that ratio standard is equivalent to the revenue-neutral combination of an implicit tax on emissions and subsidy to output. So, incidence of the mandate can be calculated as the incidence of an emissions tax plus output subsidy.

This insight is important for incidence analysis, because the emissions tax alone would raise the cost of production and output price. Thus, the addition of the implicit output subsidy tends to offset some of the likely increase in the relative price of that output. For example, the limit on carbon-per-kwh in the U.S. Clean Power Plan is effectively an implicit tax on carbon and subsidy to electricity. That subsidy helps prevent increases in the price of electricity (and burdens on the uses side).

A carbon tax, however, has both a “substitution effect” among inputs to production that could reduce carbon per kwh and an “output effect” that further reduces carbon by raising the price of output and reducing the purchase of kilowatt hours. Because low-income families devote a higher fraction of total spending to electricity than high-income families, a carbon tax is often found to have a regressive burden (before recycling the revenues, as we discuss below). In contrast, a mandate on the emission rate might be less efficient than the carbon tax, by failing to take advantage of the carbon-reducing output effect just mentioned. On the other hand, it might also be less regressive, if it does not raise the price of electricity as much. Thus arises the possibility of a tradeoff between economic efficiency and distributional objectives.

Because a carbon tax could place disproportionate burdens on low-income

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3 But see Cronin et al. (2017) for an alternative view. Because U.S. public transfers increase automatically by a consumption price index, low-income families are protected against the costs of climate policy. When they rank families by annual consumption as a proxy for lifetime income, a carbon tax is progressive.
households, policymakers may be concerned about regressivity. They might therefore prefer mandates such as corporate average fuel economy (CAFE) standards for vehicles or energy efficiency standards for household appliances. But, what are the distributional effects of those mandates?

Most empirical work is partial equilibrium in nature. To measure incidence of CAFE standards, Davis and Knittel (2016) note that automakers are required to sell more fuel-efficient cars and fewer inefficient cars, so retailers reduce prices of the former and raise prices of the latter. These CAFE obligations are tradable, so trade prices can be used to quantify implicit subsidy and tax rates (and calculate incidence). Using comprehensive data on all U.S. vehicle registrations in 2012, including characteristics of those cars, they measure CAFE burdens by changes in a family’s vehicle costs. For new vehicles, they find that CAFE is mildly progressive (because high-income households buy more new vehicles). Including effects on used vehicle costs makes CAFE mildly regressive. They find that a carbon tax alone is more regressive than CAFE standards, but progressivity can be achieved by a carbon tax with a revenue rebate through uniform transfers.

Levinson (2016) tackles a similar question but uses other data that include both vehicle information and miles driven. He finds that energy efficiency standards are more regressive than a carbon tax. Without such policies, low-income families would tend to purchase inexpensive cars (or appliances), and use them less extensively than do high-income families. In contrast, “richer households will purchase more energy efficiency and more energy” (p.10). The imposition of a standard requires the manufacturer to sell only the more expensive cars or appliances with greater energy efficiency, which reduces the cost per unit of services from the appliance (e.g. heating, cooling, or miles driven). Low-income households do not get to take much advantage of those lower-cost services, since they do not want – or cannot afford – to make extended use of those durables, so they effectively just pay the raised cost of purchasing such equipment. In contrast, higher-income families may have wanted to purchase the greater energy efficiency, because they can afford its higher price and want to run the equipment more extensively. The mandate then puts less burden on high-income families.

Electricity is a relatively high fraction of spending for low-income U.S. families, but gasoline is a low fraction of spending for the very poor who do not own cars. Various papers in the book edited by Thomas Sterner (2012) show that a gasoline tax would be progressive in poor countries where only rich own cars.
Both of these papers show that mandates are more regressive than a carbon tax when compared in a revenue-neutral way, and so both undercut the case for energy efficiency standards on distributional grounds. Economists have often shown that mandates are less cost-effective than pricing the pollutant, and now they have shown that such mandates are also more regressive.

Among other kinds of mandates, an RPS requires a certain percentage of electricity generation from renewable sources like wind and solar power, which Reguant (2017) compares to a tax on carbon or a subsidy to renewables. She also accounts for retail market design, where renewable production subsidies are often financed by retail tariffs on consumers. She finds that the carbon tax imposes burdens on consumers but provides gains to producers of hydro and nuclear power. Interestingly, renewable policies are substantially more efficient if their costs are reflected in retail prices, though benefits still go to renewable producers.

The burgeoning new literature on mandates includes analysis of state or local building codes that reduce energy use by requiring better insulation, building features, or overall energy efficiency. To identify the effects of actual building codes, Bruegge et al. (2016) use spatial variation in the strictness of California’s rules created by the state’s 16 distinct sets of climate zone requirements. They find that building codes reduce energy consumption primarily by reducing square footage – particularly in the top two income deciles. Codes thus impose costs primarily on the rich, while the bottom two deciles are essentially unaffected.

Thus, this emerging literature shows much potential for using the theory of tax incidence to evaluate non-tax environmental regulations, though much remains to be done.

4. Other Considerations Can Alter the Incidence of Environmental Policy

Existing research has modified the basic theory described above to relax assumptions such as perfect mobility, costless trade, perfect enforcement, and perfect competition. These considerations are particularly important for developing countries where market imperfections or other frictions may play large roles. Moreover, these market conditions can change the answer about who bears the burden of regulation.

a. The Degree of Inter-sectoral Factor Mobility

The basic model above is a long-run general equilibrium model used to think about output
prices and factor returns after all adjustments. Workers might be displaced in the short run, but are expected be able to find a new job in an expanding industry at the going market wage. A better view of the model, however, is not that it considers the move from one equilibrium to a new equilibrium with a different tax policy, because that would require costly adjustments. Instead, it compares two different states of the world: one where this policy never existed and the other where it always existed. It is a conceptual comparison to isolate the impact of having the policy or not, all else equal. It compares two worlds with the same technology, the same preferences, and the same factor endowments.

However, discussions of proposed regulations are often mostly about short run adjustment costs and capitalized asset values. A large carbon tax would significantly reduce the value of long-lived coal-fired power plants. Those losses are capitalized into the stock price of companies that own those plants, with large burdens on those who own shares in that company at the time of the policy enactment (see e.g., Bushnell et al. 2013).

Analogously, coal miners have industry-specific skills that would not be valued when looking for a job in a different industry, so this loss is capitalized into the market value of their human capital. Thus, the cost of displacement is not just temporary loss of wages, but a large one-time loss of human capital. In addition, job loss can negatively affect the displaced worker’s physical health (Sullivan and Von Wachter, 2009).

Unlike the imperfect mobility of physical capital, affecting stock prices held in diversified portfolios, the imperfect mobility of labor can cause large personal difficulties. Coal miners live in a town dominated by the coal industry, where they have lived all their life and do not want to leave. Job loss can also cause severe psychological trauma.5

b. Inter-jurisdictional Factor Mobility

Discussion of the theory of tax incidence above pertains to a simple static model of a closed economy, with a fixed amount of labor and capital, so changes in the demand for either factor can affect its return. In that way, an environmental tax or mandate might affect not just buyers of pollution-intensive products on the uses side, but long-run returns

5 Consider a 1993 article about the sudden bankruptcy and closure of both Eastern Airlines and Pan Am, causing job loss for 42,000 highly skilled employees. “A year and a half later, suicide among these laid off workers has reached epidemic proportions. Since Pan Am’s demise, eight former employees have killed themselves – double the normal rate for men in their forties and fifties. Since the Eastern strike began in 1989, at least 14 former employees have killed themselves, … .” (Barbara Koeppel, “For Airline Workers the Crash Can Be Fatal,” Washington Post, Sunday, September 5, 1993).
to workers or investors on the sources side. That assumption might have been appropriate for a large economy like the U.S. in past decades, but small countries depend on international capital markets, and even the U.S. is subject to increasing globalization.⁶

Before looking at degrees of mobility, consider the opposite extreme. Instead of a fixed stock of capital or vertical supply curve as in Harberger, consider perfect international mobility of capital and a fixed worldwide rate of return that investors must earn to be willing to provide capital at all – in other words, a horizontal capital supply curve faced by firms in a small open economy. In that case, owners of capital cannot bear any burden whatever from domestic policy, whether it be a tax on capital, a tax on carbon, or a mandated ceiling on pollution per unit output. And, if workers are less mobile between countries, then only they can bear burdens on the sources side. Thus, alternative extreme assumptions about mobility yield starkly different conclusions about relative burdens of environmental policy on workers or investors (through a lower wage or rate of return).

This discussion points to the importance of measuring capital mobility between jurisdictions. Moreover, that degree of mobility must also depend on whether the jurisdictions are different provinces within a country, or different countries. Severe legal constraints might hinder a country’s inflow of labor or capital. Or, the jurisdiction imposing the tax or other policy might be a European country within the European Union, where factor mobility is greater, or the policy might be enacted by California only – with much greater factor mobility between U.S. states.

Gravelle and Smetters (2006) suggest two further points. First, imperfect substitution between imports and exports of the industry’s outputs in an open-economy model can allow much of the burden to remain on capital owners. Second, the capital burden also depends on savings behavior, since even a closed economy does not have a fixed vertical capital supply curve if savers respond to rates of return. The bottom line, for now, is that possible burdens on capital from environmental policy remain unresolved. And while labor is less mobile internationally, workers also can change their labor supply in response to changes in the real net wage, so the extent of burden on labor also depends on relative supply and demand elasticities in the labor market.

⁶ Furthermore, as Fowlie (2009) highlights, even a large country like the U.S. can be affected by the presence of unregulated sectors that change local demands for labor and capital, affect wage/rental ratios, and create possibilities for emissions leakage.
c. Inter-jurisdictional Trade Costs

Beyond the model of a simple closed economy, the ease with which products can be traded between jurisdictions is as relevant to the uses-side of incidence as factor mobility is to the sources-side. If a substitute to a good produced and consumed locally is available in nearby jurisdictions with less regulation (or lower taxes), then consumers may substitute away from domestic purchases, and firms may substitute away from domestic production. Analogously, if locations producing the same goods vary in carbon intensity, a uniform tax on carbon production will place more burden on producers in carbon-intensive locations. On balance, the burden of a local tax will shift towards the party less able to move their consumption or production to the neighboring jurisdiction. For example, theory predicts that taxes on retail 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.

Empirical research finds results broadly consistent with these predictions by using tax rates differences across jurisdictional borders. Doyle and Samphantharak (2008) and Stolper (2016) estimate the pass-through of fuel taxes on consumers in the high-tax jurisdiction and find that those near the border bear a lower fraction of burdens than others, a result consistent with less tax-elastic demand further from borders.

d. Evasion and corruption

Simple models assume regulations are enforced fully and taxes are collected costlessly. In many jurisdictions, however, evasion and corruption may impair implementation of taxes or regulations. Just as legal tax avoidance behavior shifts burdens, so do illegal tax evasion or the bribery of corrupt authorities. All involve a choice to bear some lesser cost in order to avoid the higher tax or regulatory cost.

Existing papers focus on drivers of the firm’s evasion decision.7 Others focus on fiscal effects of evasion and corruption – especially in relation to government size, decentralization, and tax enforcement.8 A modest literature examines the relationship between evasion and incidence (e.g., Tanzi (1992), Slemrod (2008), and Kopczuk et al. (2016)). Collectively, these papers highlight two mechanisms by which evasion and

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enforcement may influence the uses-side incidence of a tax or mandate.

First, and most obviously, evasion reduces the effective rate of a tax or effective stringency of an environmental mandate. Parties engaged in evasion incur the cost of evasive activity but obtain a benefit equal to the tax not paid. Second, and more subtly, tax evasion by some in a market can raise the burden of a tax on fully-legal transactions in that market. Intuitively, tax-compliant firms are less able to pass-through an extra tax burden to consumers if they face competition from tax-evading firms. Kopczuk et al. (2016) find empirical support for these predictions – pass-through of diesel taxes rose when states moved the point of taxation upstream from retailers to wholesale terminals where monitoring is easier.

Although comprehensive indices of evasion and corruption are inherently imperfect measures, the 2015-2016 Global Competitiveness Report by the World Economic Forum documents that survey-based measure of corruption or unethical firm behavior are inversely related to country income. These statistics suggest that the impacts of evasion and corruption might be especially relevant for developing countries. In these countries, evasion lowers the effective tax rate, reducing the burden on all parties. But, conditional on a lower effective tax rate, the burden of the tax falls more heavily on producers, and in particular, producers who comply with regulations or who remit their taxes.

e. Market Power

Finally, the standard model of incidence assumes perfect competition. For linear demand, monopoly power reduces the pass-through of a tax onto consumers (because more of the burden appears as a reduction in profits). In general, however, Bulow and Pfleiderer (1983) show that the relationship between competition and pass-through is ambiguous, depending on the curvature of supply and demand. Pass-through exceeds 100% for log-convex demand functions, such as constant elasticity demand. Weyl and Fabinger (2013) further extend this result to the case of oligopoly, where the conduct of market participants can change with imposition of a tax. The literature provides clearer predictions about the scope or breadth of tax or regulation. If a policy affects a subset of firms in direct competition within a market, those firms have less ability to pass the tax onto consumers. In contrast, the costs of economy-wide regulation is more likely to be borne by consumers.

Using partial equilibrium models, an empirical literature examines the relationship between fuel tax incidence and market power. Results are ambiguous, as causal
identification is complicated by unobservable factors correlated with the supply elasticity, demand elasticity, and market concentration. Doyle and Samphantharak (2008) find that gasoline tax pass-through is higher in zip codes with more market power and in those with fewer independent stations. Kopczuk et al. (2016) find evidence of higher pass-through of diesel taxes in states with more concentrated wholesale markets.

A related literature estimates pass-through of input cost shocks and finds that competition tends to reduce pass-through rates. Miller et al. (2017) find more than full pass-through of energy costs in the Portland cement industry, although pass-through declines with proximity to rival firms. Ganapati et al. (2016) also find more than full pass-through in the cement industry, but incomplete pass-through in five other markets including concrete and gasoline. Muehlegger and Sweeney (2017) study pass-through of firm-specific and market-wide shocks in the refining industry and find that pass-through declines when firms face local competition.

The bottom line is that the analyst’s job is not easy. The incidence of environmental regulation depends on market concentration, the ease of evasion, trade costs, and mobility of labor and capital between sectors or jurisdictions. All of these market conditions depend on the country or policy being studied.

5. **International Incidence of Carbon Policy**

We now apply some of the concepts just discussed to consider 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 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 a country and between countries. Second, much of the empirical work on the incidence of environmental policy has focused on the developed world. Yet, much of the growth in carbon emissions is likely to occur in developing countries. Thus, it is natural to consider how the lessons from the developed world inform incidence in countries that are likely to account for much of the growth in CO₂ emissions over the coming decades.

Any effective climate policy raises the cost of fossil fuels, and of goods produced using such fuels, and impose burdens on nations that depend on the carbon-intensity of their electric power generation and exports. We therefore collect and discuss some relevant
data that can help determine whether more of this burden would likely be on rich or poor countries. In order to focus on the distributional incidence of climate policy costs, we ignore: benefits from reducing climate change; co-benefits 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.

Because this paper is about distributional effects, we wish to avoid discussion of how nations decide whether to impose unilateral carbon policy, or to join a coalition of nations, or to impose border tax adjustments. Although such considerations are important, we now set aside further discussion of them. Instead, we discuss the relative carbon-intensity of production in different nations around the world and the incidence of a generic carbon tax that would raise the price of carbon-intensive products and thus impose burdens on producers that depend on their supply elasticities and burdens on consumers that depend on their demand elasticities. We interpret it as a worldwide tax, simply so that a tax on carbon used in production is equivalent to a tax on the carbon content of consumption: for a worldwide tax, border tax adjustments are irrelevant.

International trade allows for goods produced in two different countries to act as substitutes, so any type of carbon policy can reduce demand for carbon-intensive products from one country and increase demand for less-carbon-intensive products from elsewhere. Thus, the distribution of burdens between countries is affected by carbon-intensity, although the extent of these shifts in demand must depend on frictions such as imperfect substitutability, transportation costs, and various protective national policies. In any case, local factors of production used by firms in countries that rely on relatively carbon-intensive sources of energy will bear more burden than those employed by firms with less use of carbon. And, for this reason, production may shift toward a nation or sector that avoids the worldwide tax (such as by poor enforcement capabilities).

Thus, the incidence of carbon policy is likely to vary across nations according to

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9 Mendelsohn et al. (2006) examine distributional impacts of climate change and find that the costs of climate change fall heavily on poor countries. Others examine questions of environmental justice in the context of climate change (e.g., Ringius et al. (2002), Page (2008), and Lange et al. (2007)).

10 A worldwide entity that levied a uniform carbon tax would impose burdens on countries with carbon-intensive production, as discussed here (ignoring benefits from the use of the revenue). But a country that participates in a worldwide uniform carbon tax would generate revenue for itself. In this latter case, the carbon-intensive economy would not necessarily bear more burden as a nation, because it would generate more revenue from the tax that it could use for itself.
their production and use of primary energy inputs such as coal, natural gas, and crude oil. For the raised price of each such commodity, one could examine both the relative burdens between rich and poor countries and also between producers and consumers within a country – and effects on the rich and poor families who live there.

a. Data

To shed light on these possible distributional consequences, we collect cross-sectional data on country characteristics and trade patterns for 2013-2014. Data on country characteristics are published annually by the World Bank in “World Development Indicators” (WDI). Most relevant for our analysis are GDP and GDP per capita, electricity generation by fuel type, and industrial activity by sector. In addition, we adopt 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 U.N. Commodity Trade Statistics Database (COMTRADE). We aggregate energy-intensive goods based on industrial classifications by the EIA. We separately distinguish trade in four fossil fuels: coal, natural gas, crude oil, and other fuels (primarily refined petroleum products).

b. Fossil Fuel Production and Trade

We first examine primary production of fossil fuels to consider whether the burden of carbon policy is likely to fall on producing or consuming states and whether these relative burdens are likely to be correlated with country income.

Table 1 presents the mean and standard deviation of fossil fuel exports and imports as a share of GDP. The first column presents statistics for all countries; columns 2-5 present statistics by income group. The bold value in the first row is the total value of all four fossil fuel exports as a fraction of GDP (and its standard deviation). The bold value in row six is the total value of the four fossil fuel imports as a fraction of GDP for those countries (and its standard deviation). The remaining rows present exports or imports of

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13 See [https://www.eia.gov/forecasts/ieo/pdf/industrial.pdf](https://www.eia.gov/forecasts/ieo/pdf/industrial.pdf). Major energy-intensive industries include petroleum refining; food manufacturing; pulp and paper; primary production of iron, steel, non-ferrous metals, and cement; and organic, agricultural and inorganic chemicals.
particular fossil fuels as a fraction of GDP.

Across all nations, fossil fuel exports average 3.7% of GDP, of which roughly eighty percent are crude and refined petroleum products (crude oil is 1.6% of GDP, and refined products average 1.4% of GDP). Exports of natural gas are only 0.6% of GDP, while coal exports are negligible (0.1%). Imports of all fuels constitute 4% of GDP, where again petroleum products are greater than coal and gas.

Worldwide averages in the first column of Table 1 obscure two sources of variation across countries. First, low-income countries overall are net importers of fossil fuels. Their imports average 8.1% of GDP, while their exports are only 1.5%. Refined petroleum products (e.g., gasoline and diesel) make up the vast majority of these imports, 7.6% of GDP. In contrast, high-income countries both import and export fossil fuels; they are slight net importers, importing fossil fuels worth 4.0% of GDP and exporting fuel worth 3.4% of GDP. Second, relatively high standard deviations in Table 1 suggests substantial variation in fossil fuel exports and imports across countries within each income group. Most nations are net importers of fossil fuels, but fossil fuel exports are a high fraction of GDP for a few resource-rich nations in the Middle East, central Asia (e.g., Russia, Kazakhstan and Azerbaijan) and a handful of other locations (e.g., Norway, Bolivia, Brunei and Nigeria).

Trade patterns by income group beg the question of whether the burden of carbon policy is likely to fall on consumers or producers of fossil fuels. As noted above, incidence depends on the availability of substitutes for a taxed good, or more generally, on elasticities of supply and demand. Thus, we separately consider the incidence of a carbon policy on petroleum products (crude and refined) and fossil fuels used for electricity generation (coal and natural gas).

Fully-combusted, a gallon of gasoline generates roughly 20 pounds of CO2, and a gallon of diesel fuel generates roughly 22 pounds. That CO2 can be valued at $42 per ton, to reflect the EPA’s 2016 estimate of the social cost of carbon in 2020.14 Then a Pigouvian tax would increase gasoline and diesel prices by approximately 40-50 cents per gallon.

Marion and Muehlegger (2011) and Chouinard and Perloff (2004) find that U.S. consumers bear the vast majority of fuel taxes in the short-run. Demand for transportation fuels is inelastic in the short-run, allowing producers to shift the burden of taxes or input

cost changes almost fully onto consumers. If demand in developing countries is equally inelastic, then the burden of a carbon policy on transportation fuels is likely borne by consumers (importing countries) rather than producers (exporting countries).

Long-run demand is more elastic, as consumers shift towards modes of transportation that are less fuel intensive, such as vehicles with higher fuel-efficiency, alternative fuel vehicles, or alternative methods of commuting (e.g., public transit). If these behaviors imply large elasticity of demand for these fuels, the burden of carbon policy might be shared more equally between consumers and producers. In practice, though, a 40-50 cent jump in prices of transportation fuels, while significant, is of a magnitude similar to other recent jumps in input prices that did not spur substantial shifts towards alternative fuel vehicles. Busse et al. (2013) estimate that, as a share of the new vehicle market, the most fuel-efficient quartile of vehicles rises about 3.5 percentage points in response to a 50-cent per gallon increase in prices. Li et al. (2009) estimate that a tax increase of comparable magnitude would increase average fuel economy of purchased new vehicles by 1.1% and fleet-wide fuel economy by 0.13%. Although Li et al. (2014) for the U.S. and Rivers and Schaufele (2015) for Canada 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.

More research is needed on the price sensitivity of consumers in developing countries. But if those consumers are similar to those in developed countries, even the long run burden of a carbon tax on fuels is likely to be felt more by countries that are net importers of fuel. As table 1 shows, low-income countries are more likely to be net importers of fossil fuels, and particularly of refined petroleum products. As a result, a carbon tax on fuels is likely to impose relatively heavy burdens on low-income countries.

Next, consider natural gas and coal, which compete directly as inputs to electric power and other industry. A carbon tax of $42 / tonCO2 is equivalent to a tax of $2.46 / mmBTU on natural gas and of $4.43 / mmBTU on coal. Taking into account the greater

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15 Sterner (2012) reviews estimates of fuel price elasticities in developing countries.

16 Worldwide in 2015, the electricity power sector consumed approximately 60% of coal production and 34% of natural gas production. Source: EIA International Energy Outlook 2016, Table F-1

17 According to [http://www.eia.gov/tools/faqs/], the carbon content of coal is 211 lbs/mmBTU, and of natural gas is 117 lbs/mmBTU for U.S. generators. If electricity generation is less efficient in developing countries, these numbers might understate the relative burden.
efficiency of combined cycle natural gas generators magnifies this difference: a carbon
tax of $42/ton CO₂ would increase the cost of burning coal by $5/mmBTU relative to
natural gas. Cullen and Mansur (2017) find this change in relative price sufficient to
switch the cheaper source of electricity from coal-fired plants to combined cycle natural
gas plants. Of course, the dispatch order is a short-run response, while the construction of
new plants can shift from coal to natural gas in the long run.

The carbon intensity of coal relative to natural gas suggests that the short-run
burden of carbon policy falls more heavily on coal, as buyers can substitute towards
natural gas. With increases in the number and size of countries that adopt carbon policy,
substitution away from coal and towards natural gas will affect the worldwide market
prices and impose relative burdens on coal producing and coal-dependent economies. Yet,
coal production is relatively uncorrelated with income at the country-level. Although a
carbon tax may have important implications for a subset of coal-producing nations, it is
unlikely that it would cause systematic redistributions between rich and poor nations.

c. Carbon-intensity of Domestic Electricity Production

Here, we examine the impact of carbon policy on local electricity prices (while the next
section looks at manufacturing, trade, and burdens between countries). We estimate
carbon-intensity of each country’s electricity by constructing its weighted average CO₂
emissions per kwh from fuel-specific emission rates and the fraction of local electricity
generated from different fuels. In doing so, we make several implicit assumptions about
the nature of country-level electricity production. First, the EIA’s estimates of CO₂-per-
kwh for each fuel are based on data from U.S. generators. To the extent that developing
countries’ electricity generation is less efficient, these numbers might understate their
carbon-intensity. Second, a carbon tax may shift the merit order of electricity plants,
causing suppliers to substitute away from carbon-intensive sources of electricity (such as
coal) towards less carbon-intensive sources (like natural gas, nuclear, or renewables).
Substitution would attenuate the impact of carbon policy.

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18 The average heat rate for U.S. coal and natural gas combined cycle generators were 10,080 and 7,658
mmBTU/kwh, respectively (http://www.eia.gov/electricity/annual/html/epa_08_02.html).

19 http://www.eia.gov/tools/faqs/.

20 Less likely are changes in relative positions of different countries because of substitution among sources
for electricity. Carbon-intensive countries might shift towards less-carbon-intensive fuels, but they are
For countries in the World Bank data, Table 2 summarizes our calculated relative carbon-intensity of domestic electricity production. The first row presents mean carbon-intensity (and standard deviation) of electricity generation – for all countries in the first column and by income group in columns two through five. Worldwide, electricity generation averages 1.093 pounds of CO₂ emissions per kwh, but carbon intensity is greatest for countries in the middle of the income distribution (1.297 for lower-middle income countries and 1.217 for upper-middle income countries). To explain these differences, other rows of Table 2 show fuel source percentages. The high carbon-intensity of middle-income countries is driven by coal-fired generation. In contrast, low-income countries generate a greater fraction of electricity from hydropower and emit only 0.644 pounds of CO₂ per kwh. High-income countries generate a higher fraction of electricity from nuclear and other renewable sources and produce 1.018 pounds of CO₂ per kwh.

To convey the substantial variation in carbon-intensity of electricity generation within each income group, Figure 1 plots each country’s carbon intensity against the log of GDP per capita. Although the averages in the first row of table 2 suggest an inverted-U shaped relationship between carbon emission and income, these averages obscure substantial heterogeneity within every income group. Roughly 95% of the variation in CO₂ emissions per kwh is unexplained by income group means. Countries with similar levels of per-capita income vary tremendously with respect to their carbon-intensity, which depends instead on the nature of local electricity production.

We highlight the world’s ten largest economies in red. Among the five wealthiest OECD countries (U.S., Japan, Germany, France, and Great Britain), four have electricity generation modestly more carbon intensive than average. The outlier is France, which generates a high fraction of electricity from nuclear power. Amongst “BRIC” countries (Brazil, Russia, India and China), electricity generation in Brazil is less carbon-intensive because of its reliance on hydropower. In contrast, China and India are more carbon-intensive, both generating over seventy percent of their electricity from coal.

21 See http://wits.worldbank.org/wits/wits/witshelp/content/codes/country_codes.htm for the three-letter abbreviation of each country.
To put the vertical scale of Figure 1 in perspective, we can translate electricity carbon-intensity into dollar terms using the EPA’s 2016 estimate of the social cost of carbon, $42 / tonCO2. At this “price,” a country producing electricity that creates one more pound of CO2 per kwh (about half the height of Figure 1) would have generation costs that are 2 cents higher per kwh. As a point of reference, the average retail electricity price in the U.S. in 2014 was roughly 10 cents per kwh.

d. The Energy Intensity of Manufactured Goods and International Trade

Finally, we consider effects of carbon policy on incidence through prices 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 carbon-intensity of the local energy source. As a result, identical goods produced in different countries may have differential carbon-intensity that depends on the carbon-intensity of local energy. We do not observe each nation’s direct use of different fossil fuels by industry, so a full characterization of the carbon-intensity of energy use in production is beyond us. Instead, we use each nation’s carbon-intensity of electricity calculated above as a proxy for its
carbon-intensity of industrial production. If the mix of fuels used directly by industry differs from the mix used for electricity generation, we may overstate or understate the carbon-intensity of industrial production.

Then, we examine whether carbon-intensive nations also tend to export energy-intensive goods (such that they would face greater exposure to climate policy). As a first step, we calculate COMTRADE exports of energy-intensive goods as a percentage of GDP, and we find little correlation with income: the percentage does not vary substantially between low-income countries (4.8%), lower-middle-income (4.1%), upper-middle-income (3.8%), and high-income countries (4.7%). Those calculations suggest that trade in carbon-intensive goods is unlikely to lead to a differential burden between rich and poor countries.

How carbon-intensive is energy for countries with more energy-intensive exports? In a separate panel for each income group, Figure 2 plots countries’ carbon-intensity of electricity generation against exports of energy-intensive goods as a fraction of GDP. Each panel includes a horizontal dotted line corresponding to worldwide average carbon-intensity of electricity (0.99 lbs of CO₂ per kwh), and a vertical line corresponding to worldwide average ratio of energy-intensive exports to GDP (4.4%). Thus, any country at the top of a panel has relatively carbon-intensive electricity, and any to the right exports a higher fraction of energy-intensive goods (has more trade vulnerability).

These two measures can indicate the degree to which a country’s exports might determine burden from carbon policy. Countries whose exports are most exposed to climate policy are those in the upper-right-hand 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-hand 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.

If enough countries institute carbon policies that reduce demands for carbon-intensive goods, then countries above the worldwide average (0.99 lbs/kwh) would be

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22 Differential carbon-intensity of imports matters less: countries that import energy-intensive goods can substitute towards less carbon-intensive sources for the same goods. Easier substitution pushes more burden onto carbon-intensive exporters (which is why we are looking at carbon-intensity of exporters).
placed at a competitive disadvantage (and face disproportionate burden). Countries like Iceland that generate electricity through low-carbon means while exporting energy-intensive goods could face a negative burden – a gain from worldwide carbon policy.

**Figure 2: CO₂ Emissions per kwh and Energy-intensive exports by Income Groups**

When grouped by income in Figure 2, notable variation in export carbon intensity emerges. In particular, upper-middle-income countries like South Africa (ZAF) tend both to produce carbon-intensive electricity and to export a high fraction of energy-intensive goods. These are countries most likely to be placed 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-hand quadrant and are thus likely to receive a competitive advantage in a world of widespread carbon policy. Despite variation in carbon-intensity, the ten largest countries in the world (in red) are located to the left in the figure, suggesting less exposure to changes in competitiveness of domestic energy-intensive manufacturing, by virtue of their size and diversification of their economies.

6. Conclusion
In this paper, we consider distributional consequences of environmental regulations, either taxes or mandates, focusing specifically on how lessons and estimates from the developed world might map to the international context. Although mandates account for the majority of actual environmental regulations internationally, the research literature focuses heavily on environmental taxes, and largely only in developed countries. Results from the U.S. and Europe are not directly applicable to the developing world, where future environmental regulations may be most relevant, yet where market frictions and imperfections may be more pronounced.

We summarize the literature related to market-based approaches, arguing that analogous logic can apply to the study of environmental mandates. We then summarize how deviations from the initial simple model affect incidence. Finally, we gather country-level data on carbon emissions, trade, and per capita income, and we consider how policies to address carbon emissions might impose distributional burdens across countries and within countries, in both the developed and developing world.

Examining patterns of production, consumption and trade, we find evidence suggesting that low-income countries are likely to bear a disproportionate burden of carbon taxes on imports of transportation fuels. Likewise, on average, we find that domestic electricity production tends to be slightly more carbon-intensive in middle-income countries. But, we also find substantial variation in carbon-intensity and trade exposure, even after conditioning on income. Each income group has winners and losers (e.g., countries that currently export energy-intensive goods using carbon-intensive production). Therefore, results suggest that assessing the distributional impacts of carbon policy broadly by country income group may overlook important variation within each group.

References


Table 1: Imports and Exports of Fossil Fuels as Fractions of GDP, by income group

<table>
<thead>
<tr>
<th></th>
<th>All countries</th>
<th>Low income countries</th>
<th>Lower middle income</th>
<th>Upper middle income</th>
<th>High income</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Fossil Fuel Exports</td>
<td>0.037 (0.076)</td>
<td>0.015 (0.021)</td>
<td>0.050 (0.052)</td>
<td>0.043 (0.074)</td>
<td>0.034 (0.078)</td>
</tr>
<tr>
<td>Coal Exports</td>
<td>0.001 (0.004)</td>
<td>0.000 (0.000)</td>
<td>0.004 (0.008)</td>
<td>0.001 (0.003)</td>
<td>0.001 (0.004)</td>
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<tr>
<td>Natural Gas Exports</td>
<td>0.006 (0.026)</td>
<td>0.002 (0.008)</td>
<td>0.007 (0.018)</td>
<td>0.006 (0.016)</td>
<td>0.005 (0.029)</td>
</tr>
<tr>
<td>Crude Oil Exports</td>
<td>0.016 (0.054)</td>
<td>0.000 (0.000)</td>
<td>0.021 (0.046)</td>
<td>0.022 (0.053)</td>
<td>0.013 (0.054)</td>
</tr>
<tr>
<td>Refined Fuel Exports</td>
<td>0.014 (0.023)</td>
<td>0.013 (0.015)</td>
<td>0.017 (0.014)</td>
<td>0.013 (0.020)</td>
<td>0.014 (0.025)</td>
</tr>
<tr>
<td>All Fossil Fuel imports</td>
<td>0.040 (0.036)</td>
<td>0.081 (0.028)</td>
<td>0.066 (0.029)</td>
<td>0.034 (0.026)</td>
<td>0.040 (0.039)</td>
</tr>
<tr>
<td>Coal Imports</td>
<td>0.001 (0.002)</td>
<td>0.001 (0.001)</td>
<td>0.004 (0.004)</td>
<td>0.001 (0.001)</td>
<td>0.001 (0.002)</td>
</tr>
<tr>
<td>Natural Gas Imports</td>
<td>0.006 (0.007)</td>
<td>0.003 (0.004)</td>
<td>0.007 (0.007)</td>
<td>0.004 (0.005)</td>
<td>0.007 (0.007)</td>
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<tr>
<td>Crude Oil Imports</td>
<td>0.020 (0.018)</td>
<td>0.002 (0.008)</td>
<td>0.035 (0.031)</td>
<td>0.017 (0.016)</td>
<td>0.020 (0.016)</td>
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<tr>
<td>Refined Fuel Imports</td>
<td>0.013 (0.021)</td>
<td>0.076 (0.026)</td>
<td>0.020 (0.017)</td>
<td>0.012 (0.018)</td>
<td>0.012 (0.022)</td>
</tr>
</tbody>
</table>

Source: COMTRADE data, United Nations. Note: For each fuel type, the cell denotes fossil fuel exports as a fraction of GDP in 2013 (and standard deviation). In low-income countries, for example, total fossil fuel exports averaged 1.5% of GDP (for the fuel types aggregated by value), while total imports of fossil fuels averaged 8.1% of GDP (aggregated by value). All group statistics are weighted by country GDP.
### Table 2: Carbon intensity of domestic electricity production, by income group

<table>
<thead>
<tr>
<th></th>
<th>All countries</th>
<th>Low income countries</th>
<th>Lower middle income</th>
<th>Upper middle income</th>
<th>High income countries</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CO₂ emissions per kwh</strong></td>
<td>1.093</td>
<td>0.644</td>
<td>1.297</td>
<td>1.217</td>
<td>1.018</td>
</tr>
<tr>
<td></td>
<td>(0.441)</td>
<td>(0.695)</td>
<td>(0.383)</td>
<td>(0.474)</td>
<td>(0.409)</td>
</tr>
<tr>
<td><strong>Coal Generation (%)</strong></td>
<td>35.189</td>
<td>4.531</td>
<td>39.379</td>
<td>42.856</td>
<td>31.565</td>
</tr>
<tr>
<td></td>
<td>(24.723)</td>
<td>(14.213)</td>
<td>(30.678)</td>
<td>(33.587)</td>
<td>(17.575)</td>
</tr>
<tr>
<td><strong>Oil Generation (%)</strong></td>
<td>3.808</td>
<td>24.654</td>
<td>8.444</td>
<td>4.359</td>
<td>2.950</td>
</tr>
<tr>
<td></td>
<td>(8.040)</td>
<td>(35.740)</td>
<td>(11.061)</td>
<td>(9.629)</td>
<td>(5.915)</td>
</tr>
<tr>
<td><strong>NG Generation (%)</strong></td>
<td>24.373</td>
<td>9.526</td>
<td>27.292</td>
<td>20.759</td>
<td>25.668</td>
</tr>
<tr>
<td><strong>Nuke Generation (%)</strong></td>
<td>12.541</td>
<td>0.000</td>
<td>2.683</td>
<td>3.657</td>
<td>17.531</td>
</tr>
<tr>
<td></td>
<td>(16.286)</td>
<td>(0.000)</td>
<td>(7.748)</td>
<td>(5.105)</td>
<td>(17.942)</td>
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<tr>
<td><strong>Hydro Generation (%)</strong></td>
<td>15.798</td>
<td>59.858</td>
<td>17.846</td>
<td>24.466</td>
<td>11.632</td>
</tr>
<tr>
<td></td>
<td>(19.460)</td>
<td>(40.140)</td>
<td>(17.392)</td>
<td>(21.265)</td>
<td>(17.045)</td>
</tr>
<tr>
<td><strong>Other Renew Gen (%)</strong></td>
<td>7.160</td>
<td>1.317</td>
<td>4.098</td>
<td>3.397</td>
<td>9.151</td>
</tr>
<tr>
<td></td>
<td>(6.772)</td>
<td>(1.668)</td>
<td>(4.871)</td>
<td>(2.615)</td>
<td>(7.354)</td>
</tr>
</tbody>
</table>

Source: Authors’ calculations, and World Economic Indicators, World Bank. Note: The first row shows average carbon intensity (and standard deviation). For example, low-income countries average 0.644 pounds of CO₂ emissions per kwh. Other rows show the mean and standard deviation of the percentage of electricity generation in 2013 from each different source. All group statistics are weighted by country GDP.