Who Bears the Economic Costs of Environmental Regulations?

Don Fullerton, University of Illinois and NBER

Erich Muehlegger, U.C. Davis and NBER

July 27, 2017

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. Recent papers find that mandates can be more regressive than carbon taxes. We also 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, we review data on carbon-intensity of production and exports around the world in order to describe implications for effects of possible carbon taxation on countries with different levels of income per capita.

Our email addresses are dfullert@illinois.edu and emuehlegger@ucdavis.edu. For helpful comments and suggestions, we would like to thank Tatyana Deryugina, Arik Levinson, and Reed Walker.

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 focused on environmental taxes or other market-based approaches, the burdens from effects on output prices rather than on factor prices, and the effects in developed countries.

This paper has four main objectives. First, we summarize existing understanding of tax 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 environmental policy, 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.

A third objective of the paper is to 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 particularly relevant to developing countries: (a) the degree of labor and capital mobility between sectors, (b) the mobility of those factors between jurisdictions, (c) the openness of an economy to trade, (d) the degree of regulatory evasion, and (e) market concentration in the regulated market.

Labor and capital mobility help determine the ways in which domestic wages and rental rates depend on worldwide wage rates and rental prices, rather than just on domestic markets. Openness to trade helps determine the extent to which goods' prices depend on world prices rather than domestic markets. Regulatory evasion affects the distribution of the burden of environmental policy, and it poses greater challenges in developing countries where monitoring and enforcement tend to be imperfect. Finally, market power can also affect the distribution of burdens from taxes – and presumably from non-tax regulations.

Finally, we discuss how existing research ought to be able to inform the incidence of environmental regulation in developing countries. With the exception of a small literature, as reviewed by Greenstone and Hanna (2014) and Greenstone and Jack (2015), the vast majority of 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 on 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, it is in these locations where future environmental regulation may be most important.

We cannot apply all of the concepts just described to all environmental taxes around the world, but we find it somewhat more manageable to take the specific example of a widespread carbon tax and to describe its likely distributional effects on countries at different levels of per capita income. To do so, 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 types of variation.

2. The Theory of Tax Incidence Applied to Environmental Policy

When a tax is applied to each unit of an input to production or to an 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. Actual distributional effects are known as "economic incidence." Here, we consider pollution as an input to production, in order to study a pollution tax or other pollution 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, for example, 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 its 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.[1] 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 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

[1] If η is the supply elasticity, and ε 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 $\eta/(\varepsilon+\eta)$ is the fraction borne by consumers (which rises when supply is more elastic).

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.[2] 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).

For at least two reasons, theorems from these Harberger-style general equilibrium models are virtually untestable. First, 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. Second, each 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 exogenous shocks to technology, no new conflicts, nor changes in other nations' policies. Consequently, empirical studies get to observe precious little random variation in the key tax rate across many jurisdictions or time periods, and they are bedeviled by other simultaneous changes in the economy. We return below to discussion of valiant attempts at empirical measurement.

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

[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).

We next turn to the observation above that most actual pollution policies are not taxes at all. How can tax incidence theory be used to analyze the burdens of *non*-tax environmental technology 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 for electricity generating companies, and other mandates to control emissions or energy use.

An answer to that question is in the nature of those regulations. Instead of imposing the same emission limit on all firms of different sizes, these rules tend to impose on all firms the same maximum *ratio*, such as emissions per mile, carbon per kilowatt hour, or energy use per degree of cooling. As it turns out, 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 by some of 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. This insight is important for incidence analysis, because the emissions tax alone would raise the cost of production and thus raise the break-even product 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" on 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, the carbon tax is often found to have a regressive burden.[3] In contrast, a mandate on emission *rate* might be less efficient than the carbon tax alone, 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

[3] But see Cronin *et al.* (2017) for an alternative view. Because public transfers increase automatically by a consumption price index, low-income families are protected against the costs of climate policy. When families are ranked by annual consumption as a proxy for lifetime income, a carbon tax is progressive.

a tradeoff between economic efficiency and distributional objectives.

Because a carbon tax would raise the price of electricity and gasoline, and place disproportionate burdens on low-income households who spend a high fraction of their budget on those necessities, policymakers may be concerned about regressivity.[4] They might therefore prefer mandates such as CAFE standards for vehicles or energy efficiency standards for appliances (e.g. refrigerator, furnace, or air conditioner). But, what are the distributional effects of those mandates? [5]

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 permit prices can be used to quantify the implicit subsidy and tax rates. They have comprehensive data on all U.S. vehicle registrations in 2012, including rich data on characteristics of those cars, and 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 also compare alternative policies. They find that a carbon tax alone is more regressive than CAFE standards, but progressivity can more easily be achieved by a carbon tax with a revenue rebate such as 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 even more regressive than a carbon tax. His logic is that 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).

Thus, the imposition of an energy efficiency standard requires the manufacturer to sell only the more expensive appliances with greater energy efficiency, which reduces the cost per unit of services from the appliance (e.g. heating in the winter, cooling in the

[4] 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.

[5] A new literature is emerging on distributional effects of mandates via invitations to a special issue of the *Journal of the Association of Environmental and Resource Economists* (*JAERE*) including working papers by Davis and Knittel (2016), Levinson (2016), Reguant (2017), and Bruegge, *et al*. (2016).

summer, or miles driven in the vehicle). 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 vehicles or appliances, so they effectively are just hit with the raised cost of purchasing such equipment. In contrast, higher-income families may have wanted to purchase the greater energy efficiency anyway, 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.

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.

Other kinds of mandates may impose constraints on electricity providers. For example, a renewable portfolio standard (RPS) may require a certain percentage of generation from sources like wind and solar power. In order to compare efficiency and distributional effects of such mandates to other policies like a tax on carbon or a subsidy to renewables, Reguant (2017) constructs a partial-equilibrium simulation model with multiple generation technologies and demand sectors.

Previous simulation studies have assumed that final consumers face wholesale prices, which tend to rise with an RPS or carbon tax but fall with renewable subsidies. However, Reguant explicitly accounts for retail market design, where renewable production subsidies are often financed by retail tariffs on consumers. She finds that the carbon tax has two efficiency advantages: first, it can induce substitution not only to the relatively expensive renewables but also to inexpensive natural gas. Second, it incorporates demand responses. Results indicate that the carbon tax imposes burdens on consumers but provides gains to producers of hydro and nuclear power. Interestingly, renewable policies are made substantially more efficient if their costs are reflected in retail prices, though of course benefits still go to producers of renewables. Overall, these results point to the importance of details in policy design, electricity pricing, and potential tradeoffs between economic efficiency and distributional impacts.

Lastly, the burgeoning new literature on distributional effects of mandates includes analysis of state or local building codes that may achieve reduced energy use by requiring better insulation, particular building features, or overall energy efficiency. To identify the effects of actual building energy codes, Bruegge *et al*. (2016) use spatial variation in the strictness of California's building requirements created by the state's 16 distinct sets of climate zone requirements. They use data on over 350,000 homes located within five kilometers on both sides of each climate zone border, and household electricity and natural gas billing data for the years 2009-2015 from four California utilities, to estimate the effect of these building codes on characteristics of houses built, on energy use, and on sales prices. They find that building codes reduce total energy consumption by about 6.2% for the average household, 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. But, on a per square-foot basis, no income group experiences a significant change in house prices.

4. Other Considerations that can Alter the Incidence of Environmental Policy

In several ways, existing research has modified the basic theory described above to relax restrictive 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 discussed 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. An even 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 this environmental policy always existed. It is not a move from one to the other, but a conceptual comparison to isolate the impact of having the policy versus not having the policy, all else equal. It compares two worlds with the same technology, the same preferences, and the same factor endowments.

However, many discussions of proposed environmental regulations are often *mostly* about short run adjustment costs and the imperfect mobility of workers. Coal miners live in a town dominated by the coal industry, a town where they have lived all their life and do not want to leave. Moreover, they have industry-specific skills that would be not be valued when looking for a job in a different industry. The cost of displacement is not just lost wages, as job loss can negatively affect the displaced worker's health (see e.g., Sullivan and Von Wachter (2009)). It can also cause severe psychological trauma.[6]

The lost value of this imperfectly mobile human capital is analogous to the lost value of imperfectly mobile physical capital. If a large carbon tax were to apply to all coal used by existing power plants, then the market value of the stock in companies that own coal-fired power plants would fall significantly. Losses are capitalized into the stock price of those companies, with potentially huge burdens on those who happen to own shares in that company at the time of the policy change (see e.g., Bushnell *et al.* 2013). Analogously, losses are capitalized into the market value of human capital for those who work in coal mines and those with specific training to work in coal-fired power plants.

b. Inter-jurisdictional Factor Mobility

The 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, part of the burden of any environmental tax or mandate might not just affect buyers of pollution-intensive products on the uses side, but can affect long-run relative returns to workers or investors on the sources side. That assumption might have been appropriate for a large economy like the U.S., at least in past decades, but small countries depend on international capital markets, and even the U.S. is subject to increasing globalization. Furthermore, as Fowlie (2009) highlights for a large country like the U.S., the presence of unregulated sectors create analogous effects.

Before looking at the degree of factor mobility, first consider the opposite extreme. Instead of a fixed stock of capital or vertical supply curve as in the Harberger model, consider the case of perfect international mobility of capital and a fixed worldwide rate of

[6] To emphasize the very real nature of psychological trauma as part of the distributional effect of a major policy shock to the economy, consider a 1993 article in the *Washington Post*. "In January 1991, after a bitter strike, Eastern Airlines grounded its planes forever. In a stroke, the 30,000 highly skilled and well-paid Eastern employees -- most of whom had 20 or 30 years with the company – joined the ranks of the jobless. Just 11 months later, Pan Am, the one-time aviation giant, went under. When its remaining 12,000 employees arrived at work on Dec. 4, 1991, security staff gave them one hour to clear out. 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, as did the wife of an Eastern pilot. In one case, a mechanic also shot his children." (Barbara Koeppel, "For Airline Workers the Crash Can Be Fatal," *Washington Post*, Sunday, September 5, 1993).

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

This discussion points to the importance of empirical measurement of 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 factor flows between countries with different policies about the inflow of labor or capital. Or, the jurisdiction imposing the tax or other policy under consideration might be a European country within the European Union, where labor and capital mobility is greater, or the policy might be enacted by California only – with much greater factor mobility between U.S. states.[7]

Further analysis in Gravelle and Smetters (2006) suggests two further points. First, they show that 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 burden on capital owners also depends on savings behavior, since even a closed economy does not have a fixed vertical capital supply curve if savers respond to lower rates of return by saving less. The bottom line, for now, is that the possible burdens on capital from environmental policy remains an open question. And while labor is less mobile internationally, workers also can change their labor supply in response to changes in the real net wage, and so the extent of burden on labor also depends on relative supply and demand elasticities in the labor market.

c. Inter-jurisdictional Trade Costs

Once we move beyond the model of a simple closed economy, the ease with which products can be traded between jurisdictions is equally as relevant to the uses-side of incidence as is factor mobility to the sources-side. If a substitute to a good produced and

[7] Our focus here is on how openness affects factor returns and thus the distribution of burdens, but see Fowlie (2009) and others about how openness affects leakage – the increase in emissions in other jurisdictions.

consumed locally is available in a nearby jurisdiction with more lax regulations (or lower tax rates), 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 the more carbon-intensive location. On balance, the burden of a local tax will shift away from the party less able to move their consumption or production to the neighboring jurisdiction. For example, theory predicts that taxes levied 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 in response to a tax increase.

Empirical research finds results broadly consistent with these predictions by using inter-jurisdictional variation in tax rates. In energy, Doyle and Samphantharak (2008) and Stolper (2016) estimate the pass-through of fuel taxes near borders at which tax rates change discontinuously. In both studies, consumers near borders bear a lower fraction of fuel tax burdens than do those far from the border, because these customers have more elastic demand for the more-heavily-taxed item than do customers further from borders.[8]

d. Evasion and corruption

Classic models of incidence assume that regulations are enforced fully and that taxes are collected costlessly. Yet, in many jurisdictions, evasion and corruption may prevent jurisdictions from complete implementation of taxes or non-tax regulations. Here, we do not draw sharp distinctions between tax avoidance, evasion, or bribing corrupt authorities to relax enforcement, as all three cases may involve a choice to bear some lesser cost in order to reduce the higher tax or regulatory cost. [9]

Most existing literature on corruption and evasion focuses either on drivers of the firm's evasion decision[10] or on fiscal effects of evasion and corruption – especially on

[8] Outside of energy, a companion literature on cigarette tax pass-through finds similar patterns (Hanson and Sullivan (2009), Harding *et al*. (2012), DeCicca *et al*. (2013), and Chiou and Muehlegger (2014)).

[9] In the normal parlance of public economics, tax avoidance is legal and tax evasion is not. However, either kind of activity may reduce taxes paid while incurring some additional cost. The taxpayer may incur extra fees paid to lawyers and accountants to reduce the legal tax burden. The consumer near a border may incur some extra cost of driving to the low-tax jurisdiction. Also, a bribe reflects a transfer of surplus between two parties, while avoidance or evasion may entail a real resource cost incurred to face less stringent regulation.

[10] See Pomeranz (2015), Fisman and Wei (2004), de Paula and Scheinkman (2010), or Agostini and Martinez (2014).

government size, decentralization, and tax enforcement.[11] A more modest literature examines the relationship between evasion and the incidence of taxes (see e.g., Tanzi (1992), Slemrod (2008), and Kopczuk *et al*. (2016)). Collectively, these papers highlight how evasion and enforcement may influence the uses-side incidence of a tax or mandate.

Evasion reduces the effective rate of a tax or the effective stringency of an environmental mandate. Parties engaged in evasion face the tax wedge as the benefit of evasion, while incurring costs of the evasive activity. Evasion reduces tax revenues or the efficacy of an environmental mandate. More subtly, tax evasion in *part* of a market can impact tax incidence for fully-legal transactions in the market that do not involve evasion. Tax evasion reduces the aggregate tax elasticity for the side of the market engaged in evasion. As a result, the fully-legal party on the evasion-prone side of the market bears a higher burden of the tax than in a world in which no evasion exists. Thus, if only a subset of firms evade a tax, the burden of the tax on legal transactions falls more heavily on tax-compliant firms. Intuitively, a tax increase makes tax-compliant firms less able to pass-through the extra tax to consumers if they face competition from tax-evading firms.

Few papers map empirical evidence of evasion onto incidence. Kopczuk *et al*. (2016) test the relationship between evasion and incidence by exploiting changes in the identity of the party statutorily responsible to remit state fuel taxes. Consistent with predictions, they find that the pass-through of diesel taxes to retail prices increased after states moved the point of remittance from a point of the supply chain where monitoring was difficult (retailers) to a point where enforcement was easier (wholesalers).

Although comprehensive indices of evasion and corruption are inherently imperfect measures, the Global Competitiveness Report by the World Economic Forum generally documents that survey-based measure of corruption or unethical firm behavior are inversely related to country income.[12] These statistics suggest that the impacts of evasion and corruption might be especially relevant for developing countries.

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

---

[11] See, as examples, Sørensen (1994), Kau and Rubin (1981), Balke and Gardner (1991), or Gadenne and Singhal (2014).

[12] Global Competitiveness Report, World Economic Forum, 2015-2016.

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. Weyl and Fabinger (2013) extend this result to the case of oligopoly, where the conduct of market participants can change with the imposition of a tax. This research has renewed interest in the relationship between competition and incidence, but even these new studies are in developed countries. Yet we still lack a clear prediction about the effect of market concentration on incidence in developing countries.

Using partial equilibrium models, an empirical literature examines the relationship between 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. Several papers examine market concentration and the pass-through of diesel taxes. Doyle and Samphantharak (2008) find that gasoline tax pass-through to retail customers is several percentage points higher in zip codes with more concentrated market power and in zip codes with a smaller fraction of independent retail stations. Kopczuk *et al*. (2016) also find weak 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, in contrast, finds that competition tends to reduce pass-through rates. Miller *et al.* (2017) find evidence of 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 products 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. And moreover, all of these market conditions depend on the country being studied.

5. International Incidence of Carbon Policy

In order to look at incidence around the world, and to apply some of the concepts just discussed, we now look at possible distributional effects of a climate policy such as a carbon tax, a system of tradeable permits, or even command-and-control regulation. Any such policy will raise the cost of fossil fuels and of goods produced using such fuels, so it will impose burdens that depend on the relative carbon-intensity of each nation's electric power generation and of its 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 the benefits from reducing climate change, other potential co-benefits from reducing local polluting emissions that are positively correlated with carbon emissions, and distribution of benefits from the use of any carbon tax or permit revenues.[13]

Even with this focus on costs, however, the analysis could depend on many details of the climate policy – and on who imposes it. A worldwide agreement to adopt a uniform carbon tax seems unrealistic, of course, but one nation with a unilateral carbon tax places itself at a competitive disadvantage abroad unless it also adopts border tax adjustments. It could rebate the carbon tax already collected on production of goods that get exported; it could impose a tax on the carbon embodied in goods imported from a country that does not have a carbon tax; or it could do both.[14] Incidence is complicated with only one such adjustment, but both together effectively convert it from a tax on carbon used in production to a tax on the carbon content of consumption. And since the tax would then apply to a different activity, that policy choice affects the economic burden of a tax. For example, the burden of a tax on carbon used in production could fall more on the owners of fossil fuel resources and less on producers who can substitute towards renewable fuels, whereas the burden of a tax on the carbon content of consumption goods can be passed from producers in one country to consumers in other countries.

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. Therefore, although we note the importance

---

[13] 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 agreement for all nations to impose a 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. Any actual worldwide agreement would likely be a mix of those outcomes, where rich countries pledge some of their carbon tax revenue to help poorer countries – in order to achieve their acquiescence to the agreement.

[14] Here, we set aside the details of how one might calculate the increase in the final price of the imported good attributable to a carbon tax at each stage of production in the other country, or indeed whether the World Trade Organization would allow a tax upon import and a rebate upon export. For a more complete discussion of border tax adjustments, see Fischer and Fox (2012).

of such considerations, 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).

These considerations suggest that a carbon policy is likely to have different incidence for three categories of goods: (a) primary energy inputs such as coal, natural gas, and crude oil; (b) energy-intensive produced commodities; and (c) non-energy-intensive goods. For each group of commodities, one could examine both the incidence between producers and consumers within a country (and effects on rich and poor who live there). One could also examine the incidence between countries. Some data can shed light on how these inter- and intra-jurisdictional effects are related to country income.[15]

a. Data

To address these questions, we collect 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).[16] Most relevant for our analysis are GDP and GDP

---

[15] Analogously, Mendelsohn *et al*. (2006) examine distributional impacts of climate change and find that its burdens 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)).

[16] http://data.worldbank.org/data-catalog/world-development-indicators

per capita, electricity generation by fuel type, and industrial activity by sector. The World Bank classifies countries into one of four income groups based on GDP per capita: low income, lower-middle income, upper-middle income, and high income. We adopt their classification as one method of grouping countries by income. Most of the nations classified as "low income" are located in Sub-Saharan Africa. "Lower-middle income" nations include South Asian and Southeast Asian nations (e.g., India, Indonesia, and Vietnam). "Upper-middle income" nations includes China, Russia, Brazil, Turkey and South Africa. "High income" nations are predominately from the OECD. To summarize these categories, Appendix Table A1 presents country counts by income group and region of the world.

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), a comprehensive panel of country-to-country product flows.[17] We aggregate export values into energy-intensive goods and non-energy intensive goods, using industrial classifications by the EIA as part of the International Energy Outlook.[18] We separately aggregate the value of fossil fuel exports, distinguishing four groups of 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, using data from the COMTRADE database to track exports and imports of fossil fuels.

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 two through five present statistics by WDI income group. The bold value in the first row is the total value of the 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 particular fossil fuels as a fraction of GDP.

---

[17] http://comtrade.un.org/db/default.aspx

[18] See 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.

Across all nations, fossil fuel exports average 3.7% of GDP, of which roughly eighty percent are crude and refined petroleum products (the crude oil average 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% of GDP). Imports of all fuels constitute 4% of GDP, where again petroleum products are greater than imports of coal and gas.

Worldwide averages in the first column of Table 1 obscure two sources of variation across countries. First, on average, less wealthy countries are net importers of fossil fuels. These imports in low-income countries average 8.1% of GDP. Exports for these countries are modest, only 1.5% of GDP. Refined petroleum products (e.g., gasoline and diesel) make up the vast majority of the imports for low-income countries, 7.6% of their GDP. In contrast, wealthy countries both import and export fossil fuels; high income countries are slight net importers, importing fossil fuels worth 4.0% of GDP and exporting fuel worth 3.4% of GDP.

Second, even within each income group, Table 1 shows substantial variation in fossil fuel exports and imports.[19] Fossil fuel exports are a high fraction of GDP for resource-rich nation 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). In seven countries, exports of natural gas exceed 5% of GDP: Qatar (42% of GDP), Brunei (33%), Bolivia (19%), Algeria (11%), Norway (7.5%), Oman (6.8%) and Malaysia (6.5%). Coal exports tend to be a smaller fraction of GDP; the five countries for which coal exports are greatest relative to GDP are Mongolia (6.7%), Australia (2.2%), Indonesia (2.0%), Columbia (1.6%) and South Africa (1.4%).

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 products) and fossil fuels used for electricity generation (coal or natural gas).

For refined petroleum products such as gasoline and diesel fuel, carbon content is unrelated to where the fuel was produced. Fully-combusted, a gallon of gasoline generates

[19] A hint of this variation can been seen in the column for "All Countries" by comparing the standard deviations of fossil fuel exports (0.076) and fossil fuel imports (0.036).

roughly 20 pounds of CO_2, and a gallon of diesel fuel generates roughly 22 pounds of CO_2. Using as a benchmark the EPA's 2015 estimate of the social cost of carbon in 2020 of $42 per ton CO_2, a Pigouvian tax at that rate levied on the carbon in gasoline and diesel fuel would increase prices by approximately 40-50 cents per gallon. A number of papers on developed countries (e.g., Marion and Muehlegger (2011), or Chouinard and Perloff (2004)) find that consumers bear the vast majority of gasoline taxes and input cost changes 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).[20]

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 shifts significantly increase the 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. 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. Busse *et al*. (2013) estimate that the *new* vehicle market share of the most fuel-efficient quartile of vehicles rises about 3.5 percentage points in response to a 50-cent per gallon increase in prices. Also for the U.S., 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%. Gallagher and Muehlegger (2011) estimate that an increase from $3.00 per gallon to $3.50 per gallon leads to an 11 percentage point increase in sales of hybrid vehicles.

More research is needed on price sensitivity of consumers in developing

[20] Though we discuss only a "generic" carbon tax, this statement about relative burdens holds generally, regardless of details such as how many countries have adopted policies that raise carbon prices.

countries.[21] But if those consumers are similar to those in developed countries, the implication is that 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.

Petroleum products have few easy substitutes in transportation, but natural gas and coal compete more directly as inputs in the electric power sector and as thermal inputs for industry.[22] Cullen and Mansur (2014) infer the empirical effect of a carbon tax on the substitution of coal-fired for gas-fired electricity generation by examining how electricity generation changes in response to fluctuations in the commodity spot prices of the two fuels. They find that a tax of $42 / ton CO_2 has the potential to make coal-fired electricity more expensive than electricity generated by 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.

A carbon tax of $42 / ton CO_2 is equivalent to a tax of $2.46 / mmBTU on natural gas and of $4.43 / mmBTU on coal.[23] Taking into account the greater efficiency of combined cycle natural gas generators magnifies this advantage:[24] a carbon tax of $42/ton CO_2 would increase the cost of burning coal by $5/mmBTU relative to natural gas.

The carbon intensity of coal relative to natural gas suggests that the short-run burden of carbon policy falls more heavily on coal, as consumers can substitute towards natural gas. With increases in the number and economic power of fossil-fuel-consuming countries that adopt carbon policy, substitution away from coal and towards natural gas will affect the worldwide market prices for coal and natural gas, thus imposing relative burdens on coal producing and coal-dependent economies.

c. Carbon-intensity of Domestic Electricity Production

We now consider the impacts of carbon policy on electricity and manufactured goods. The carbon-intensity of a manufactured good is the product of the energy-intensity at all stages

[21] Sterner (2012) reviews some initial estimations of fuel price elasticities in developing countries.

[22] 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

[23] 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.

[24] 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).

of production and carbon-intensity of the 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 production.

We construct a proxy for the weighted-average carbon-intensity of each country's local electricity generation by using its fractions of electricity generated from different fuel sources (from the WDI) as weights for the estimated CO_2 emissions per kWh for each fuel source (from the EIA).[25] In doing so, we make several implicit assumptions about the nature of country-level energy production. First, the EIA's estimates of CO_2-per-kWh for each fuel are based on data from U.S. generators. To the extent that electricity generation is less efficient in developing countries, these numbers might understate carbon-intensity in developing countries. It also abstracts away from an obvious shortcoming of analyzing average costs in the electricity market: a carbon tax of sufficient magnitude 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 of this form would likely attenuate the absolute competitive impact of carbon policy.[26] Finally, the proxy only reflects the carbon-intensity of electricity production; we do not observe direct industrial consumption of different fossil fuels, so a full characterization of the carbon-intensity of all energy consumption is beyond our capability here. If the mix of fossil fuels used directly by industry differs from the mix used for electricity generation, we may overstate or understate the carbon-intensity of industrial production.[27]

Table 2 summarizes the relative carbon intensity of domestic electricity production across all countries in the World Bank data along with the sources of electricity. The first row of Table 2 presents the 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 CO_2 emissions

---

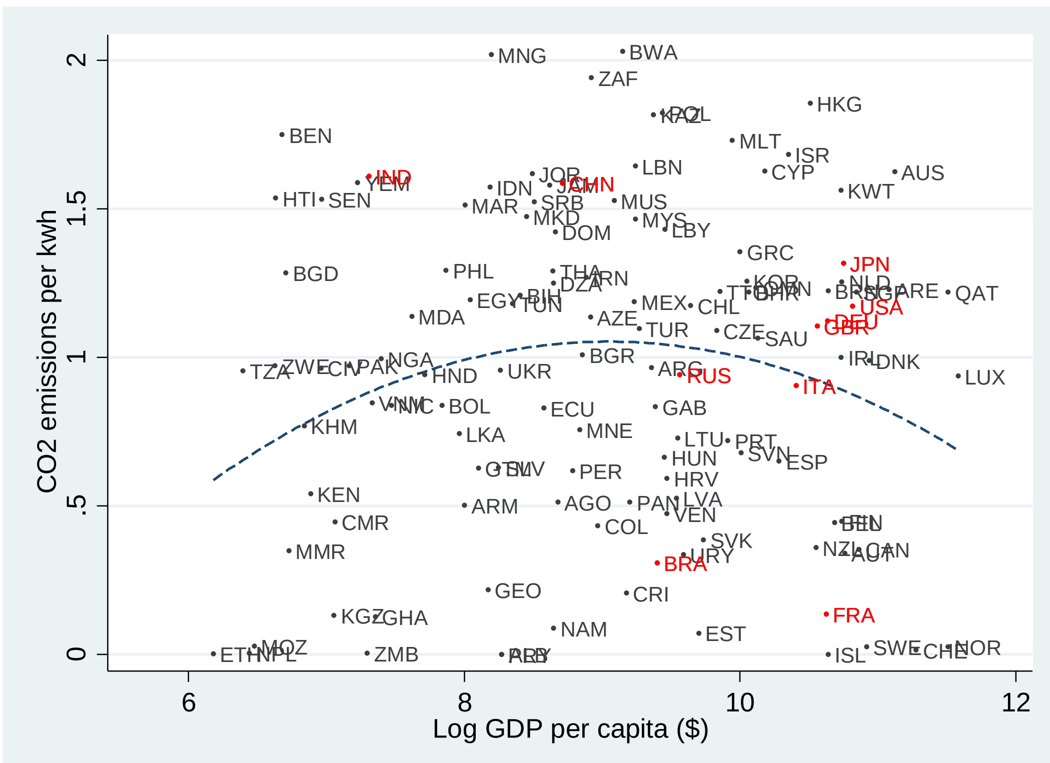
[25] http://www.eia.gov/tools/faqs/.

[26] Less likely are changes in *relative* positions of different countries because of substitution to different fossil sources for electricity generation. Carbon-intensive countries might shift production towards less-carbon-intensive fuels, but they are unlikely to leapfrog other countries that currently generate electricity in less carbon-intensive ways. Thus, conclusions about relative winners and losers would likely remain unchanged.

[27] Although we cannot observe industrial consumption of fossil fuels directly, we can compare the use of fossil fuels for electricity generation and the export of those same fuels. The correlation between the fraction of generation and exports as a fraction of GDP for coal is 0.38, for oil is 0.43, and for natural gas is 0.30.

per kwh, but this 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 fractions of electricity generated from coal, oil, natural gas, nuclear, hydroelectricity, and other renewable sources. The high carbon intensity in middle-income countries is attributable to their relatively high generation of coal-fired electricity. In contrast, low-income countries generate a greater fraction of electricity from hydropower and emit only 0.644 pounds of CO_2 per kwh of electricity. High-income countries generate a higher fraction of electricity from nuclear and other renewable sources and produce 1.018 pounds of CO_2 per kwh.

Figure 1: GDP per Capita and Average CO_2 Emissions per KWH



To better convey the substantial variation in carbon-intensity of electricity generation *within* each income group, Figure 1 plots each country's carbon intensity (in pounds of CO_2 per kwh) against the log of GDP per capita. We highlight the world's ten largest economies in red. In addition, we plot the quadratic line that best fits the data.[28]

The inverted U-shaped shape of the quadratic line matches the pattern of average

[28] Three letter abbreviations for each country can be found at: http://wits.worldbank.org/wits/wits/witshelp/content/codes/country_codes.htm

carbon-intensity in Table 2. To be clear, however, this curve should not be interpreted as an "Environmental Kuznets Curve". It is intended only to show a cross-sectional snapshot of carbon intensity and not a causal relationship between income and emissions. Indeed, the point of Figure 1 is the weakness of the relationship between income and emissions. Roughly 95% of the variation in CO_2 emissions per kwh is unexplained by GDP per capita. In other words, countries at very similar levels of per-capita income vary tremendously with respect to their carbon-intensity, which depends instead on the nature of local electricity production.

In four of the five wealthiest OECD countries (U.S., Japan, Germany, France, and Great Britain), electricity generation is modestly more carbon intensive than their average. The outlier is France, which generates a high fraction of electricity from nuclear power and is less carbon-intensive than average. 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.

To put the vertical scale of Figure 1 in perspective, we can translate electricity carbon intensity into dollar terms using the EPA's 2015 estimate of the social cost of carbon, $42 per ton of CO_2. At this "price," a country producing electricity that creates one more pound of CO_2 per kilowatt-hour (about half the height of Figure 1) would have generation costs that are 2 cent per kilowatt-hour higher. As a point of reference, the average retail electricity price in the U.S. in 2014 was roughly 10 cents per kilowatt-hour.

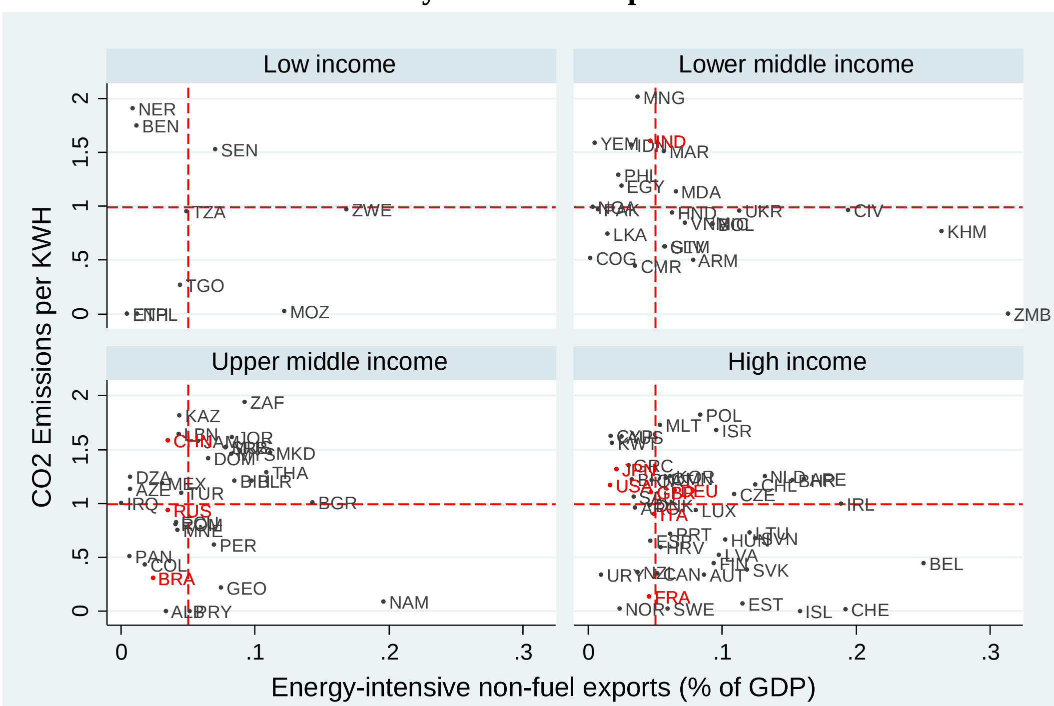
d. Trade in Energy-Intensive Goods

We now examine whether the carbon intensity of domestic energy production is correlated with the goods traded by a country. Specifically, 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 make it hard to suggest that trade in carbon-intensive goods introduces much difference in burdens between rich and poor countries.

We further explore the relationship between carbon intensity of electricity and the energy intensity of exports within each income group. For each of the four income groups, Figure 2 plots the carbon-intensity of a country's electricity generation against its 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 CO_2 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).

Figure 2: CO_2 Emissions per kwh and Energy-intensive exports by Income Groups



Horizontal and vertical lines correspond to the median values of CO2 Emissions per KWH (0.99 lbs/kwh) and non-fuel, energy-intensive exports (5% of GDP)

Some combination of these two measures can indicate the degree to which a country's exports might determine burden from carbon policy.[29] Thus, countries whose

[29] 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).

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.

Thus, if enough countries institute carbon policies that lead to reduced demands for carbon-intensive goods, then countries above the horizontal dotted line (at 0.99 lbs / kwh) would be placed at a competitive disadvantage (and thus face more 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.

When grouped by income in Figure 2, an interesting pattern emerges. The relationship between exports and carbon intensity varies substantially by income group. 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, which means they are less exposed to changes in competitiveness of domestic energy-intensive manufacturing, by virtue of their size and diversification of their economies.

Within a country, carbon policy may also affect the distribution of economic activity across energy-intensive and non-energy intensive goods. Carbon policy raises the price of energy-intensive goods relative to non-energy-intensive goods, so it likely leads to a shift away from production of energy-intensive goods toward production of non-energy-intensive goods. It therefore implies short-run burdens on sector-specific factors, as the tax is capitalized into their market value. In the long run, the mix of industries in countries with carbon-intensive energy will shift towards less trade-exposed industries, with the exit of local companies in trade-exposed, energy-intensive industries.

6. Conclusion

In this paper, we consider the 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 environmental regulations internationally, the literature focuses heavily on environmental taxes, and largely only in the context of developed countries. With a few exceptions, work on the incidence of environmental policy has focused on the developed world. Yet, 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 taxes and other market-based approaches, arguing that analogous logic can apply to the case of environmental mandates. We then summarize how deviations from the initial simple model affect incidence on the sources-side and uses-side. 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.

References

Agostini, Claudio A., and Claudia Martinez. 2014. Tax credits response to tax enforcement: Evidence from a quasi-experiment in Chile. *Fiscal Studies* 35 (1): 41-65.

Balke, Nathan S., and Grant W. Gardner. 1991. Tax collection costs and the size of government. Working paper, Mimeo, Southern Methodist University.

Bruegge, Chris, Tatyana Deryugina, and Erica Myers. 2016. The distributional effect of building codes. Working paper, University of Illinois at Champaign-Urbana.

Bulow, Jeremy I. and Paul Pfleiderer. 1983. A note on the effect of cost changes on prices. *Journal of Political Economy*, 91 (1), pp.182-185.

Bushnell, James B., Howard Chong, and Erin T. Mansur. 2013. Profiting from regulation: Evidence from the European carbon market. *American Economic Journal: Economic Policy* 5 (4): 78–106.

Busse, Meghan R., Christopher R. Knittel, and Florian Zettelmeyer. 2013. Are consumers myopic? Evidence from new and used car purchases. *The American Economic Review* 103 (1): 220-256.

Chiou, Lesley, and Erich Muehlegger. 2014. Consumer response to cigarette excise tax changes. *National Tax Journal* 67 (3): 621-650.

Chouinard, Hayley, and Jeffrey M. Perloff. 2004. Incidence of federal and state gasoline taxes. *Economics Letters* 83 (1): 55-60.

Cronin, Julie Anne, Don Fullerton, and Steven Sexton. 2017. Vertical and horizontal redistribution from a carbon tax and rebate. NBER Working Paper No. 23250.

Cullen, Joseph A., and Erin T. Mansur. 2014. Inferring carbon abatement costs in electricity markets: A revealed preference approach using the shale revolution. NBER Working Paper No. 20795, NBER, Cambridge, MA.

Davis, Lucas, and Christopher R. Knittel. 2016. Are fuel economy standards regressive? NBER Working Paper No. 22925, NBER, Cambridge, MA.

de Paula, Áureo, and Jose A. Scheinkman. 2010. Value-added taxes, chain effects and informality. *American Economic Journal: Macroeconomics* 2 (4): 195-221.

DeCicca, Philip, Donald Kenkel, and Feng Liu. 2013. Who pays cigarette taxes? The impact of consumer price search. *Review of Economics and Statistics* 95 (2): 516-529.

Doyle, Joseph J., and Krislert Samphantharak. 2008. $2.00 Gas! Studying the effects of a gas tax moratorium. *Journal of Public Economics* 92 (3): 869-884.

Fischer, Carolyn, and Alan K. Fox. 2012. Comparing policies to combat emissions leakage: Border tax adjustments versus rebates. *Journal of Environmental Economics and Management* 64 (2):199-216.

Fisman, Raymond, and Shang-Jin Wei. 2004. Tax rates and tax evasion: Evidence from missing imports in China. *Journal of Political Economy* 112 (2): 471-496.

Fowlie, Meredith L. 2009. Incomplete environmental regulation, imperfect competition, and emissions leakage. *American Economic Journal: Economic Policy* 1 (2): 72-112.

Fullerton, Don, and Garth Heutel. 2007. The general equilibrium incidence of environmental taxes. *Journal of Public Economics* 91 (3-4): 571-591.

Fullerton, Don, and Garth Heutel. 2010. The general equilibrium incidence of environmental mandates. *American Economic Journal: Economic Policy* 2 (3): 64-89.

Fullerton, Don, and Gilbert Metcalf. 2002. Tax incidence. In *Handbook of public economics*, eds. A. Auerbach, and M. Feldstein. Amsterdam: Elsevier.

Gadenne, Lucie, and Monica Singhal. 2014. Decentralization in developing economies. *Annual Review of Economics* 6 (1): 581-604.

Gallagher, Kelly Sims, and Erich Muehlegger. 2011. Giving green to get green? Incentives and consumer adoption of hybrid vehicle technology. *Journal of Environmental Economics and Management* 61 (1): 1-15.

Ganapati, S., Joseph S. Shapiro, and Reed Walker. 2016. Energy prices, pass-through, and incidence in US manufacturing. NBER working paper No. 22281, Cambridge MA.

Gibson, Matthew. 2015. Regulation-induced pollution substitution. Working paper, Department of Economics, William College.

Goulder, Lawrence H., Marc A. C. Hafstead, and Roberton C. William III. 2016. General equilibrium impacts of a federal clean energy standard. *American Economics Journal: Economics Policy* 8 (2): 186-218.

Gravelle, Jane G., and Kent A. Smetters. 2006. Does the open economy assumption really mean that labor bears the burden of a capital income tax? *B.E. Journal of Economic Analysis & Policy: Topics in Economic Analysis & Policy* 6 (1): 1-42.

Greenstone, Michael, and Rema Hanna. 2014. Environmental regulations, air and water pollution and infant mortality in India. *American Economic Review* 104 (10): 3038-3072.

Greenstone, Michael, and B. Kelsey Jack. 2015. Envirodevonomics: A research agenda for an emerging field. *Journal of Economic Literature* 53 (1): 5-42.

Hanson, Andrew, and Ryan Sullivan. 2009. The incidence of tobacco taxation: Evidence from geo-graphic micro-level data. *National Tax Journal* 62 (4): 677-698.

Harberger, Arnold C. 1962. The incidence of the corporation income tax. *Journal of Political Economy* 70 (3): 215-240.

Harding, Matthew, Ephraim Leibtag, and Michael F. Lovenheim. 2012. The heterogeneous geo-graphic and socioeconomic incidence of cigarette taxes: Evidence from Nielsen Homescan data. *American Economic Journal: Economic Policy* 4 (4): 169-198.

Kau, James B., and Paul H. Rubin. 1981. The size of government. *Public Choice* 37 (2): 261-274.

Kopczuk, Wojciech, Justin Marion, Erich Muehlegger, and Joel Slemrod. 2016. Does tax-collection invariance hold? Evasion and the pass-through of state diesel taxes. *American Economic Journal: Economic Policy* 8 (2): 251-286.

Lange, Andreas, Carsten Vogt, and Andreas Ziegler. 2007. On the importance of equity in international climate policy: An empirical analysis. *Energy Economics* 29 (3): 545-562.

Levinson, Arik. 2016. Energy efficiency standards are more regressive than energy taxes: Theory and evidence. NBER Working Paper No. 22956, NBER, Cambridge, MA.

Li, Shanjun, Joshua Linn, and Erich Muehlegger. 2014. Gasoline taxes and consumer behavior. *American Economic Journal: Economic Policy* 6 (4): 302-342.

Li, Shanjun, Christopher Timmins, and Roger H. von Haefen. 2009. How do gasoline prices affect fleet fuel economy? *American Economic Journal: Economic Policy* 1 (2): 113-137.

Marion, Justin, and Erich Muehlegger. 2011. Fuel tax incidence and supply conditions. *Journal of Public Economics* 95 (9): 1202-1212.

Mendelsohn, Robert, Ariel Dinar, and Larry Williams. 2006. The distributional impact of climate change on rich and poor countries. *Environment and Development Economics* 11 (2): 159-178.

Mieszkowski, Peter. 1972. The property tax: An excise tax or a profits tax? *Journal of Public Economics* 1 (1): 73-96.

Miller, Nathan H., Matthew Osborne, and Gloria Sheu. 2017. Pass-through in a concentrated industry: empirical evidence and regulatory implications. *The RAND Journal of Economics*, 48: 69–93.

Muehlegger, Erich and Richard Sweeney. 2017. Competition and pass-through of input cost shocks: Evidence from the oil shale boom. Working paper, U.C. Davis, CA.

Page, Edward A. 2008. Distributing the burdens of climate change. *Environmental Politics* 17 (4): 556-575.

Pomeranz, Dina. 2015. No taxation without information: Deterrence and self-enforcement in the value added tax. *American Economic Review* 105 (8): 2539-2569.

Reguant, Mar. 2017. The efficiency and distributional impacts of large-scale renewable policies. Working paper, Northwestern University.

Ringius, Lasse, Asbjørn Torvanger, and Arild Underdal. 2002. Burden sharing and fairness principles in international climate policy. *International Environmental Agreements* 2 (1): 1-22.

Rivers, Nicholas, and Brandon Schaufele. 2015. Salience of carbon taxes in the gasoline market. J*ournal of Environmental Economics and Management* 74: 23-36

Slemrod, Joel. 2008. Does it matter who writes the check to the government? The economics of tax remittance. *National Tax Journal* 61 (2): 251-275.

Sørensen, Peter Birch. 1994. From the global income tax to the dual income tax: Recent tax reforms in the Nordic countries. *International Tax and Public Finance* 1 (1): 57-79.

Sterner, Thomas (Editor). 2012. *Fuel Taxes and the poor: The distributional effects of gasoline taxation and their implications for climate policy*. Washington DC: RFF Press.

Stolper, Samuel. 2017. Competition and incidence: Automotive fuel tax pass-through at state borders. MIT working paper, Cambridge MA.

Tanzi, Vito. 1992. Theory and policy: A comment on Dixit and on current theory. *Staff Papers- International Monetary Fund* 39 (4): 957-966.

Sullivan, Daniel, and Till Von Wachter. 2009. Job displacement and mortality: An analysis using administrative data. *The Quarterly Journal of Economics* 124 (3): 1265-1306.

Weyl, E. Glen, and Michal Fabinger. 2013. Pass-through as an economic tool: Principles of incidence under imperfect competition." *Journal of Political Economy* 121 (3): 528-583.

Table 1: Imports and Exports of Fossil Fuels as Fractions 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)

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

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

Source: 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 CO_2 emissions per kwh. Other rows show the mean and standard deviation of the fraction of electricity generation in 2013 from each different source. All group statistics are weighted by country GDP.

Appendix

Appendix Table A1: Countries by Region and Income Group, 2013

	Low income	Lower middle income	Upper middle income	High income	Total
East Asia & Pacific	1	**15**	8	13	37
Europe & Central Asia	0	7	14	**37**	58
Latin America & Caribbean	1	5	**19**	16	41
Middle East & North Africa	0	7	6	**8**	21
North America	0	0	0	**3**	3
South Asia	2	**5**	1	0	8
Sub-Saharan Africa	**27**	13	7	1	48
Total	31	52	55	78	216