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Carbon Tax Competitiveness Concerns: Assessing a Best Practices Carbon Credit

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This analysis was conducted as part of *Considering a US Carbon Tax: Economic Analysis and Dialogue on Carbon Pricing Options*, an RFF initiative. www.rff.org/carbontax

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RESOURCES FOR THE FUTURE

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Abstract

This paper considers how industry-focused revenue rebating could be used to address competitiveness and leakage concerns arising from a unilaterally imposed carbon tax. Building on previous work, it investigates how firms in specific energy-intensive, trade-exposed (EITE) sectors would fare under various carbon crediting approaches. Specifically, it focuses on the use of output-based carbon credits tied to best practices in the sector and considers its efficiency and administrative characteristics. It also investigates whether firms have sufficient tax appetite to use such a credit. Our analysis shows that there is considerable variation across sectors in average emissions intensity as well as variation in the shape of sector-specific intensity distributions. Establishments that are older, larger, and less productive tend to have higher emission intensities. A "best practices" carbon credit for firms in EITE sectors could provide compensation for firms and mitigate competitiveness issues to some extent. Some firms, however, would not be able to utilize all of their carbon credits due to insufficient tax appetite. The share of unused credits falls with the stringency of the rebate plan. We also compare crediting with deductibility and find the latter has weaker incentive effects for reducing emissions.

Key Words: carbon tax, competitiveness, EITE sectors, output-based carbon credits

Contents

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I. Introduction

The election of Donald Trump as the 45th president of the United States has raised significant questions about the future of US climate policy. During the campaign, Trump promised to remove the United States from the Paris Agreement on day one of his presidency. Since the election he has been more equivocal, stating in an interview with the *New York Times* two weeks after the election that he has an "open mind" on the agreement. While Trump's overall position on climate change is not entirely clear, there is little doubt that the regulatory approach under the Clean Power Plan will not go forward in its current form (if it goes forward at all).

Even as the future of a regulatory approach for addressing greenhouse gas emissions looks dim, there continues to be considerable interest among both Democrats and Republicans in Washington in a carbon tax both for environmental as well as for revenue reasons. A key concern with any carbon pricing instrument is competitiveness and these concerns are often addressed in proposed carbon tax bills by protecting firms in energy-intensive, trade-exposed (EITE) sectors through border adjustments in the form of tariffs on goods imported from countries that do not price carbon and border rebates on exports.

Border adjustments are one approach to addressing competitiveness concerns. An alternative approach is to provide some form of support to domestic firms in EITE sectors. Such was the approach in the Waxman–Markey Bill (H.R. 2454) which provided allowances over a 15-year period for firms in EITE sectors with allowance allocation based on historic emissions and output. A US government interagency report assessed those sectors most likely to be vulnerable to trade and leakage issues (US Environmental Protection Agency 2009).

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Metcalf (2014) showed how the Waxman–Markey allowance allocation approach could be replicated with the use of tax credits on the corporate income tax. This paper builds on that analysis by analyzing a best practices output-based tax credit on the corporate income tax. Using establishment- and firm-level data, we make the following points:

- There is considerable variation across sectors in both their average emissions intensities and the shape of the within-sector distribution of those intensities.
- Controlling for variation across industries and regions, establishments that are older, larger, and less productive tend to have higher emissions intensities.
- A properly allocated system of carbon credits could provide some compensation for firms in EITE sectors, with considerable variability across sectors in the share of carbon taxes returned to the sector, depending on the within-sector distribution of emissions intensities.
- Output-based tax credits are likely to create better incentives for firms than allowing a deduction on the corporate income tax for carbon tax payments. The latter approach reduces the marginal incentive of the carbon tax by the corporate income tax rate—by over one-third.
- These carbon credits are large enough in some sectors (relative to sector-average corporate income taxes owed) that firms in many sectors would not be able to utilize all of their carbon credits, even under less generous rebate plans.
- Within sectors, there is considerable variability across firms in the ability to use their carbon credits, but much of this variability derives from firms that have zero or negative tax liability, who wouldn't be able to use any carbon credits anyway.

In the next section, we provide some background on the issue of competitiveness concerns with carbon pricing. Section III describes the data we use for the analysis. Results are presented in Section IV. We conclude with final thoughts on paths forward given the results of this analysis.

II. Background

How industry is impacted by carbon pricing has been a long-standing subject of research. A number of papers have focused on the required compensation to offset windfall losses to owners of equity. Bovenberg and Goulder (2001), for example, track equity impacts of carbon policy on 12 industries using a computable general equilibrium (CGE) model of the US economy. They simulate a number of policies to return revenue from a $25-per-ton carbon tax, including ways to achieve equity-value neutrality such as industry-specific reductions in the corporate income tax rate, lump-sum transfers, grandfathered emissions permits, and inframarginal tax exemptions. An important finding in their analysis is that full rebating of carbon pricing revenue to industry sectors in general will lead to overcompensation due to the ability of firms to pass a considerable amount of the tax (or value of allowances) forward to consumers in the form of higher product prices. Sijm, Neuhoff, and Chen (2006) provide evidence for overcompensation to the electric power sector in Germany and the Netherlands in the EU Emissions Trading System (EU-ETS).

A second strand of analysis focuses on leakage resulting from unilateral carbon pricing policies. Leakage can be defined in a number of ways (see Baylis, Fullerton, and Karney [2013] for one treatment) but, at its simplest level, it equals one minus the change in global emissions divided by emissions in a particular jurisdiction after controlling for other emissions drivers. Ho, Morgenstern, and Shih (2008), analyze manufacturing at the two- and three-digit Standard Industrial Classification level and find that the petroleum refining, chemicals and plastics, primary metals, and nonmetallic minerals industries suffer significant reductions in domestic output in response to US carbon pricing. They find an aggregate leakage rate of 26 percent, with some sectors suffering leakage rates as high as 40 percent. Ho et al. do not consider compensation approaches to address leakage. Fischer and Fox (2009) analyze various approaches for addressing emissions leakage and competitiveness issues; they note the importance of focusing compensation on those firms that are strong substitutes for carbon-intensive, unregulated goods and goods that are complements of employment. This suggests the importance of focusing compensation on EITE sectors. They also find that optimal rebates may exceed a sector's emissions tax payments by a factor of two or more for certain industries.[1]

A third strain of research focuses on responses to leakage and competitiveness concerns. Fischer and Fox (2007) investigated various ways to allocate allowances under a national cap-and-trade system, including consideration of an output-based allowance allocation. An output-based allocation can work in a number of ways. Fischer and Fox considered an allocation approach where a fixed number (or share) of allowances is allocated to sectors. Then firms within each sector are allocated a share of the sector-specific number of allowances based on the

[1] Ederington, Levinson, and Minier (2005), who consider the puzzle of why environmental regulatory stringency does not appear to affect trade flows in the aggregate, argue that aggregate-level analysis masks competitiveness impacts on geographically mobile industry sectors. They also find that polluting industries tend to be relatively immobile, thereby mitigating the impact of regulatory stringency.

firms' share of industry output. Output-based allocations serve as an indirect subsidy to production and, as such, help offset leakage. The subsidy, however, drives up the required permit price to achieve a given emissions cap and leads to excess production (relative to a first-best policy). The lower product price benefits consumers but shuts off one channel of emissions reduction through consumer demand responses to higher prices. A similar analysis focused on the European Union is undertaken by Monjon and Quirion (2011), who find that output-based allocations are less effective than border adjustments to combat leakage but are more effective at addressing production losses in domestic firms in EITE sectors.

Fischer and Fox (2012) undertake a similar analysis in the context of a carbon tax. Output-based rebating can lead to increases in emissions in certain sectors and the authors note the difficulty of measuring output in what appear to be at first glance homogeneous sectors. Differences in degree in vertical integration, for example, can lead to different emission intensities for firms.[2] The analysis by Fischer and Fox focuses on policies that rebate emission rents in all industries. An important question is the breadth of adjustments required to address competitiveness concerns. There would appear to be little need, for example, to provide adjustments for non-traded goods.

The Fischer and Fox paper is part of an Energy Modeling Forum study published in *Energy Economics*. Bohringer, Balistreri, and Rutherford (2012) provide an overview of the study and conclude that border adjustments can reduce leakage and alleviate adverse impacts on EITE sectors in countries with unilateral carbon pricing. This benefit is largely offset by costs borne by countries not implementing carbon policies. Global cost savings through border adjustments are minimal.

Metcalf (2014) considers a variety of adjustments to the tax code to address competiveness concerns including EITE sector-directed and general cuts to payroll, and corporate income taxes and corporate income tax credits tied to carbon tax payments. Metcalf found that determination of eligibility for relief analogous to the free allowance allocation in H.R. 2454 is sensitive to changes in energy intensity over time. He also found that providing compensation to EITE sectors through the corporate income tax—analogous to the output-based allowance allocation in Waxman–Markey—is certainly feasible, but tax appetite within the EITE sectors is insufficient to fully use any credits that attempted to offset more than about one-quarter

[2] They provide an example in the cement industry where some producers may also produce emissions-intensive clinker while other firms may purchase the input.

of their carbon tax liability. In lieu of specific tax credits, he found that certain reforms to the tax system do better than others at providing disproportionate relief to EITE sectors. Finally, he argued that economic theory predicts a substantial cost to diverting carbon tax revenue toward compensation of specific sectors. Theory also suggests that firms should treat policy risk no differently from the way they treat the other risks they face as they do business.

In the US context, the US Environmental Protection Agency (EPA; 2009) led an interagency effort to study which industrial sectors would be most impacted by the enactment of the Waxman–Markey cap-and-trade legislation (H.R. 2454). The report identifies 44 manufacturing sectors and 2 additional mining sectors at the six-digit North American Industry Classification System (NAICS) level that would fall in the category of EITE sectors presumptively eligible for compensation under the proposed legislation. The study also highlights the highly skewed nature of emissions intensity for US manufacturing firms. The report documents that the average energy intensity of manufacturing is 2 percent, with roughly 90 percent of manufacturing produced by sectors with an energy intensity no greater than 10 percent. Presumptively eligible sectors are responsible for roughly half of manufacturing emissions and account for about 5 percent of manufacturing employment (0.5 percent of total nonfarm employment). A $20-per-ton carbon price would lead to a greenhouse gas (GHG) intensity measure (carbon tax payments per dollar of shipment) that is less than 5 percent for all but eight industry sectors. The impact is even lower if process emissions are excluded from the carbon tax.[3]

Aldy and Pizer (2011) take a different approach to measuring the competitiveness effect by measuring the difference between the change in domestic supply when all countries implement carbon pricing and the change when only the United States implements carbon pricing. This makes international harmonized carbon pricing the benchmark counterfactual. They find that domestic supply falls by 3 to 4 percent for the most energy-intensive sectors, with the competitiveness effect responsible for roughly one-third of this fall. The remainder comes from declines in domestic demand as consumers of energy-intensive goods substitute into less energy-intensive goods. The most significantly impacted industries (in terms of reduced domestic supply) are aluminum, cement, chemicals, paper, bulk glass, and iron and steel.

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[3] Process emissions are nonenergy combustion-related emissions arising from production. The production of clinker, an essential component of cement, involves heating limestone and other ingredients; this leads to the direct release of carbon dioxide (CO_2) separate from the emissions associated with energy use in production. The United Nations Environment Programme (2010) reports that process emissions account for half of total emissions from the production of clinker.

Adkins et al. (2012) consider a carbon tax ($15 per ton) over four time horizons. They use an input–output model for the very short and short run, and CGE models for the medium and long run. The very short-run time horizon has no price adjustment. The short-run horizon uses price elasticities to allow for demand to adjust. The medium run has input substitution, and the long run has capital mobility. In the short run, highly affected industries include some industries within the manufacturing sector—petroleum and coal products, chemicals, ferrous and nonferrous primary metals, and textiles—as well as electric utilities, natural gas, and petroleum. The paper also shows that allowance allocations in H.R. 2454 significantly dampen the reductions in output for industries receiving subsidies.

Finally, there are practical questions about the merits of undertaking any sort of border adjustment. Aldy (2016) argues that the production, employment, and emissions competitiveness concerns for firms in EITE sectors are relatively small and that any policy to address competitiveness concerns creates its own risks in the areas of efficiency and equity as well as in the area of trade diplomacy. Kortum and Weisbach (2016) focus specifically on the design of border tax adjustments and consider which goods should be subject to a border adjustment if adjustments are to be made, which emissions should be covered, and which countries should be subject to border adjustments. A major theme in their paper is the high complexity and administrative costs of border adjustments. Moreover, the authors argue, the recent Paris Agreement under which nearly all emitting countries have pledged to undertake some degree of emission reduction (either absolute, relative to gross domestic product, or relative to some counterfactual baseline) may weaken the need for border adjustments entirely.

In addition to practical and administrative issues with border adjustments, there are legal issues as well. Trachtman (2016) goes through the issues raised by World Trade Organization (WTO) rules and assesses various design criteria with respect to their likelihood of conforming to WTO law. It is clear that a great deal of complexity and uncertainty arises when WTO considerations come into play. While much has been written on the topic, the applicable case law is thin and does not provide clear guidance on how border adjustments would fare under the WTO.[4]

[4] Nordhaus (2015) proposes a "club" approach in which countries that do not join the club and establish a minimum carbon price as determined by the club would be subject to tariffs on all imports to club countries (as opposed to tariffs designed to internalize a carbon price on embodied carbon in imports). Such an approach would pose real risks for the current international trading regime supported by WTO rules. Nordhaus recognizes these risks and emphasizes the need to assess the benefits of the club approach against the possible risks to the international trading system.

Our analysis focuses on the use of output-based tax credits in the corporate income tax to provide compensation to firms in EITE sectors. It uses a "best practices" design based on Metcalf (2014), which is similar to the benchmark allocation approach in the Phase III EU-ETS allowance allocation as well as the tax threshold idea of Pezzey and Jotzo (2013). The next section describes the data we use for the analysis.

III. Data Description

We construct a dataset that measures emissions at the establishment level in EITE sectors and combine that with corporate income tax data for firms in those sectors. We assess both the variability of emissions within six-digit NAICS sectors and the ability of firms to utilize those carbon credits to offset their income tax liabilities (their “tax appetite” for the credits). Our analysis of emissions variability is done at the establishment level, while the analysis of tax appetite is done at the firm level, combining data from all establishments owned by a given firm within a six digit NAICS code. Emissions data are constructed from the 2012 Census of Manufactures (CMF) supplemented by data from the 2010 Manufacturing Energy Consumption Survey (MECS). Emissions are derived from the establishment’s fossil fuel consumption, its electricity consumption generated from fossil fuels, and its process emissions. We discuss each of these in turn, then discuss the sources of firm-level income tax data.

The 2012 CMF has data on establishment-level energy expenditures. These are divided into electricity expenditures and non-electricity energy expenditures (fuels), but the CMF does not identify which fuels are being consumed. The 2010 MECS does report establishment-level fuel consumption quantities for different types of fuels. We compute the average fuel expenditure shares for coal, natural gas, and petroleum within each sector-census division cell of the 2010 MECS data. We use these cell-average fuel cost shares from the 2010 MECS to allocate each establishment’s total fuel expenditures from the 2012 CMF to the various fossil fuels. We then convert these expenditures on each fuel into quantities, dividing by the state-level prices for each fuel as purchased by industrial customers in 2012, taken from the US Energy Information Administration's (EIA’s) State Energy Data System (SEDS).[5] Finally, we convert fuel consumption to emissions using EIA's national fuel-specific emission factors.[6]

[5] The SEDS data are available at http://www.eia.gov/state/seds/seds-data-complete.cfm?sid=US.

[6] Emissions factors are available at http://www.eia.gov/environment/emissions/co2_vol_mass.cfm. There is some variation in emissions for specific fuels, mainly for coal. Since coal is predominantly used for electricity production in electric utilities and we use a different data source to capture those emissions, little is lost in using a weighted average factor for coal.

Emissions per MWh of electricity generation are available from EPA's eGRID dataset. The Power Profiler spreadsheet[7] computes emissions per MWh of electricity at the zip code level. We compute emissions at the establishment level by multiplying each establishment's electricity consumption in the CMF with the Power Profiler emissions factor for the establishment's zip code. Note that emissions from self-generated electricity are already captured in the establishment's fuel consumption data.

Process emissions are important for a few sectors. We followed the approach used by EPA (2015) in its GHG inventory, which applied an emissions factor to production levels in order to estimate process emissions for those sectors. We allocate the aggregate process emissions for each sector as reported in EPA's GHG inventory to establishments in each sector according to each establishment's share of the value of shipments in the aggregate value of shipments for that sector.

We use two different approaches to calculate the available "tax appetite" for comparison with the carbon credits. The first approach provides tax data for all sectors, but only at the sector level, using the IRS Integrated Business Data described in Metcalf (2009)[8]. We divide sector-level taxes by sector-level shipments to get taxes per unit of shipments, then apply that ratio to the shipments for each establishment in that sector to generate estimated corporate income taxes owed for those shipments. However, since the tax ratio is calculated at the sector level, this does not provide any within-sector variation in tax appetite.

The second approach uses firm-level data on corporate income taxes owed, taken from the Census' 2012 Quarterly Financial Reports (QFR) survey. The problem is that the QFR covers only a relatively small fraction of our CMF establishments, so that only a few sectors have a sufficiently large sample size to report the resulting tax numbers at the sector level.[9] We discuss this further below.

Our analysis in the next section applies a best practices tax credit to firms in certain EITE sectors. We follow the methodology of the interagency report (EPA 2009) as updated with more recent data by Metcalf (2014). Sectors are presumptively eligible to be included in our analysis if any of the following hold:

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[7] Available at http://www2.epa.gov/sites/production/files/2015-10/power_profiler_zipcode_tool_2012_v6-0.xlsx. We downloaded the spreadsheet on August 18, 2015.

[8] Data available at https://www.irs.gov/uac/SOI-Tax-Stats-Integrated-Business-Data.

[9] We have QFR data for about 850 establishments in about 250 firms, out of a CMF sample of about 7500 establishments in about 5000 firms (sample size counts rounded per Census rules).

- energy intensity is 5 percent or greater, and trade intensity is 15 percent or greater;
- greenhouse gas intensity is 5 percent or greater, and trade intensity is 15 percent or greater;
- energy intensity is 20 percent or greater;
- greenhouse gas intensity is 20 percent or greater.

Most sectors that gain eligibility do so on the basis of the first criterion. Table 1 shows the sectors included in the analysis. A few sectors are excluded, either because they are not manufacturing sectors (iron ore and copper/nickel mining) or because they have too few establishments for us to report their results. The five sectors excluded from our analysis account for 3.3 percent of overall emissions from the presumptively eligible sectors, based on data from Metcalf (2014). Table 1 also reports the number of establishments for each sector, taken from published 2012 CMF data. Figure 1 ranks each sector by its share of overall emissions among the manufacturing firms in our sample and also shows the number of establishments in each sector. For most of the sectors that account for the bulk of emissions from manufacturing, we have a large number of establishments from many firms. This will allow us to carry out a within-sector analysis below as well as construct a tax credit that is tied to the emissions intensity (emissions per $1000 of the value of shipments) of low-emitting establishments.

Table 2 reports statistics on the emissions intensity of the top 20 emitting sectors, which are responsible for over 90 percent of total CO_2 emissions from our sample. The top emitting sector, iron and steel, is responsible for nearly one-sixth of the total, and the top five sectors account for nearly one-half of total emissions from our sample. Emissions intensity varies widely among the top 20 sectors, from 394 pounds per $1000 of shipments (plastics) to a high of 16,844 pounds per $1000 of shipments (lime manufacturing)—perhaps not surprising given the price differentials among high- and low-value (per unit of production) manufactured products. We also see considerable variation across sectors in the sources of their CO_2 emissions. Those sectors with substantial process emissions, such as cement and alumina refining, tend to have the highest overall emissions intensities. Other sectors show considerable variation in their relative proportions of electricity-based and fuels-based emissions.

The emissions intensity distributions differ substantially in terms of their variation, reported both in the form of the standard deviation of intensity within sector as well as the skewness and the coefficient of variation (the standard deviation divided by the mean). Lime manufacturing and cement are tightly distributed around their means with a standard deviation that is one-fifth of their means. Nitrogen fertilizers, aluminum refining, and newsprint mills are also tightly bunched around their means. In contrast, the standard deviations for plastics and nonferrous metal smelting are more than double their means. Focusing on the top five sectors, we see that four of the five have considerable variability in emissions intensity relative to their means. This variation is important if we are to tie a tax credit to the emissions intensity level of a low-intensity establishment. Variation suggests both a greater incentive for moving toward the threshold level of intensity as well as the capability for doing so—as evidenced by the fact that some establishments are operating at or below that intensity level in their sector. We turn next to an analysis of the data.

IV. Analysis

As demonstrated in Table 2, sectors differ in their variability of emissions intensity. We begin our analysis with some simple regression diagnostics to understand better what drives differences in emissions intensity. Table 3 reports regressions of the log of emissions intensity at the establishment level against various covariates. Model 1 focuses on the age of the establishment.[10] We also include sectoral and regional fixed effects in the regression. We expect older establishments to have higher emissions intensity and that is borne out in model 1. Establishments constructed before 1976—around the time of the first oil shock—have an emissions intensity 24.7 percent higher than newer establishments. The coefficient is statistically significant at the 1 percent level. Adding one year to an establishment's age raises the emissions intensity by 0.1 percent but is not statistically significant. Models 2 and 3 focus on establishment size and productivity. Establishments with 10 percent more employees have a 1 percent higher emissions intensity, while establishments with 10 percent higher productivity (output per production worker hour) have 1 percent lower emissions intensity. To see whether these variables are acting independently, models 4 and 5 include all the variables in the regression. Model 4 includes sectoral and regional fixed effects while model 5 has fully interacted sectoral by regional fixed effects. The annual age effect is now stronger and statistically significant in model 4—but it has shifted sign (becoming surprisingly negative), while the pre-1976 dummy continues to have a large positive impact.[11] The impacts of employment size and productivity are

[10] Age is constructed based on the first year that the plant is found in the Longitudinal Business Database (LBD): age= 2013 minus entry year. Since the first year in the LBD is 1976, we also include a dummy variable for all plants that have been in the dataset the entire time (age=37).

[11] When we expressed the age coefficient with dummies for each decade of age, establishments 20–29 years old (born 1984–1993) had the lowest emissions, but those 30+ years old had the highest emissions.

similar across all the models.[12] In sum: older, larger, and less-productive establishments tend to have higher emissions intensities after controlling for sectoral and regional differences.

We next turn to our carbon tax calculations. Our analysis models a $20-per-ton carbon tax on energy- and process-related emissions in 2012. Thus for establishments in our dataset, we compute the tax as the product of establishment-related emissions times the tax rate.[13] Ignoring any behavioral response, the tax would collect roughly $100 billion in the first year, of which $11 billion is attributed to establishments in our EITE sectors.[14] For firms in those EITE sectors, we provide an output-based carbon credit on the corporate income tax tied to best practices in each sector.

Let E_{ij} and Y_{ij} represent the emissions and value of shipments respectively of establishment *i* in sector *j*. Let θ_j represent a sector-specific intensity credit floor. This credit floor will be defined based on some policy-predetermined emissions intensity level for the sector. We return to how θ_j is set in a moment. If the carbon tax rate equals τ then the carbon credit (C_{ij}) that may be taken by firm *i* in sector *j* (applied to their firm's corporate income tax) will be

(1) $$C_{ij} = \tau\theta_j Y_{ij}.$$

Figure 2 illustrates how the carbon credit works. The figure graphs a hypothetical distribution of carbon emissions intensity for a manufacturing sector defined at the six digit NAICS level. In the example, emissions are clustered at the lower end but there is a rightward skew of high emissions intensity among a few establishments in the sector. This is the pattern demonstrated in Table 2 for most EITE sectors. The emissions intensity labeled θ_j represents the intensity for the establishment at the 90th percentile (i.e., 90 percent of establishments weighted by output have an emissions intensity higher than θ_j). The tax credit in equation (1) provides a credit on the corporate taxes for each firm with establishments in sector *j* equal to the carbon taxes those establishments would have paid if their emissions intensity were at the 90th percentile within that sector.

[12] We tested whether the reason that larger plants had higher emissions was due to their being more likely to generate their own electricity by including a dummy for self-generation in the regression. The dummy was significantly positive, but the establishment size effect was essentially unchanged from that reported here.

[13] Note that our definition of establishment-related emissions includes the carbon emissions associated with the generation of electricity purchased by the establishment.

[14] The interagency report (EPA 2009) found that EITE sectors accounted for approximately 15 percent of total emissions covered by the Waxman–Markey Bill.

This tax credit has a number of important characteristics. First, the credit is inframarginal on emissions and so does not undermine the carbon price's incentive to reduce emissions. Second, the credit is tied to firm output and so provides an implicit subsidy to production by firms in this sector with a price decrease equal to $\tau\theta_j$. While potentially offsetting some of the higher production costs arising from the carbon tax—and so addressing competitiveness concerns with competing firms from countries that do not price carbon—the output subsidy dampens one of the channels by which carbon emissions are reduced: demand responsiveness in the face of higher product prices. Third, the tax credit can be structured in different ways regarding firms with emissions intensity below the threshold level θ_j. Without any adjustment to the credit rule, these firms would have a tax credit in excess of their carbon tax liability. It then becomes a policy decision whether to limit their credit to their actual carbon tax liability or to allow them to take the credit without adjustment. In the former case, these best-performing firms would not receive the output subsidy at the margin, but would also not receive the incentive for further reductions in their carbon emissions. Fourth, the threshold level defining "best practices" is a policy choice. In Figure 2 we set it at the 90th percentile. A higher threshold percentile lowers the cost of the tax credit.

Table 4 reports cost estimates for the tax credit for different thresholds and rules on credits in excess of actual carbon tax payments. As noted above, firms in our EITE sectors would have paid $11 billion in taxes based on their estimated carbon emissions for 2012. The first row allows firms with emissions intensity below the credit cutoff to take the full carbon credit while the second row caps their credit at their actual carbon tax liability. We report tax expenditure estimates for four cutoff levels ranging from 50 to 95 percent. The cost of the tax credit ranges from just under $4 billion (95th percentile cutoff) to over $9 billion (50th percentile cutoff and firms allowed to take carbon credit in excess of carbon tax liability). As the threshold percentile is lowered, the number of firms above the threshold increases as does the cost of allowing a tax credit in excess of actual carbon tax payments. At the 95th percentile, the cost of the credit is increased by only 0.7 percent when firms may take a credit in excess of carbon tax liability. For a threshold set at the median intensity level, the cost of the tax credit increases by nearly 19 percent when excess credits are allowed, but the increase ($1.5 billion) is still small relative to total carbon tax liability for our EITE sectors.[15]

[15] In the following tables we report only the results for the uncapped carbon credit, but the results are similar when the carbon credit is capped; results available from authors.

We have assumed that firms receive a carbon credit against corporate income tax liability in this analysis. This credit would be in place of the standard practice of allowing a deduction for carbon tax payments in the calculation of taxable income. A crude estimate of the value of that deduction is simply the corporate income tax rate times carbon tax payments which, for our sample, equals (.35)(11.01) = $3.85 billion. This is an upper-bound estimate since not all firms will have sufficient taxable income to deduct their carbon tax payments in full.[16] At the aggregate level, we observe that the carbon credit approach is more generous to firms than deductibility with the increased generosity rising with less stringent cutoffs. The output-based credit approach has the advantage over tax deductibility of ensuring that the marginal impact of the carbon tax is felt by the firm, thereby driving incentives for emission reductions. At a 35 percent corporate income tax rate, deductibility reduces the marginal impact of a $20-per-ton carbon tax to $13 a ton.

Table 5 reports carbon tax payments and carbon credits at the sector level for the top 20 emitting sectors. Firms in the iron and steel sector have the largest carbon tax obligation, totaling $1.7 billion. The cement sector follows with carbon tax payments of $1.1 billion. These two sectors account for over one-quarter of emissions in our sample. They would fare very differently under the tax credit plan. Under a 95 percent cutoff, iron and steel firms would receive credits equal to 16.1 percent of their overall taxes, while cement firms would receive credits for 58.7 percent. This relates back to differences in the distribution of emissions intensity in the two sectors, with much higher skewness in the iron and steel sector. Moving to less-stringent cutoffs yields larger carbon credits, with a few sectors getting overall carbon credits that are larger than their original carbon tax owed. Capping the tax credits at the level of carbon tax liability makes little difference to the overall size of the tax credit for the 95 percent cutoffs, with larger impacts for the less stringent cutoffs, with the exact relationship depending on the distribution of emissions intensities below the cutoff level in the sector.[17]

The table also shows the value of carbon tax deductibility to each sector, assuming that firms face the 35 percent corporate income tax rate. Carbon tax deductibility is more generous to some sectors than the carbon credit, in particular iron and steel, paper, and plastics. One design question for a carbon credit would be whether to allow firms the choice to deduct carbon taxes rather than take the output-based credit. One factor mitigating against allowing this option is the reduced marginal incentive to reduce emissions that comes about with deductibility.

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[16] Any unused deductions could be carried back two years or forward up to twenty years.

[17] Results available from authors.

We now turn to an examination of the tax appetite of firms in these EITE sectors, assuming that the income tax credits received by a firm could be used only to offset against that firm's corporate income taxes, so that a firm that owed no corporate income tax after all other tax credits would get no benefit from the carbon credits in the current year, while those with little tax liability would get only a partial benefit. As noted earlier, we have two sources of corporate income tax data, one at the sectoral level using published IRS data and one at the firm level using Census Bureau data from the QFR survey. The former data covers all sectors but provides only an average tax rate (with no within-sector variation), while the latter provides firm-level data but covers only a small fraction of the firms in our dataset and provides releasable numbers for only three sectors.

Table 6 shows the results using the sector-level data. For each of the top 20 emitting sectors we compare the overall income taxes owed by firms in the sector to the carbon credits they would receive. The calculations of both income taxes owed and the carbon credit are proportional to the firm's value of shipments with the same factor for every firm in the sector, so there is no within-sector variability—either all firms within the sector can use all their credits, or none of them can. We see that there are relatively few sectors in which firms have sufficient tax appetite to use all of their credits for the most generous plan with 50 percent cutoffs. A few sectors could use only a small fraction of their carbon credits, even under the 95 percent cutoff plan. Note that the credits may still be taken in future years if carried forward, although they would be diminished in value to some extent given the time value of money if the tax savings are deferred to the future.

Table 7 shows the results using the QFR firm-level data. One key point we observed in the QFR data is that a sizable fraction (35.2 percent) of firms in our QFR sample report owing no income taxes for the year or even receiving a net income tax credit.[18] These firms account for 26.9 percent of total emissions from our QFR sample. These no-tax firms help drive the result in the overall QFR data that about 40 percent of the carbon credits would go unused in the current year—the majority of that is due to firms that owe no federal corporate income taxes. This also contributes to the relatively small differences in unused credits across the different plans, as compared to the results in Table 6 where there were considerable differences in unused credits across plans. As noted earlier, the availability of QFR data for only a small fraction of our firms greatly limits our ability to report sector-specific results. We report sector-level results for

[18] We also examined Compustat data and found that a sizable fraction of firms operating in these EITE sectors reported zero or negative federal taxes owed.

plastics, organic chemicals, and iron and steel. Of these, plastics firms could use only about one-third of their carbon credits in the current year, while iron and steel firms could use more than half, and organic chemicals firms could use nearly 90 percent of their carbon credits. Given the small number of firms in our QFR sample, it is not clear whether the results from Table 7 generalize. But it is certainly the case that those firms that cannot benefit from a carbon credit due to a lack of tax liability would also not be able to benefit from the ability to deduct carbon taxes as an expense. So our general finding that the carbon credit would be more generous to firms than carbon tax deductibility still holds.

V. Conclusion

We use establishment-level data from the Census of Manufacturing database to estimate emissions aggregated to the firm level at the six digit NAICS level. This provides the first detailed analysis of within-sector emissions variation relative to firm production. We also estimate the ability of firms to use the carbon credits generated from different plans, based on sector-level and firm-level data on corporate income tax payments, although the firm-level data are available for only a small fraction of our sample. Using emissions and tax data, we consider the impact and cost of a best practices carbon credit on the corporate income tax for firms in designated EITE sectors.

We find the following:

- There is considerable variation across sectors in both their average emissions intensities and the shape of the within-sector distribution of those intensities.
- Controlling for variation across industries and regions, establishments that are older, larger, and less productive tend to have higher emissions intensities.
- A properly allocated system of carbon credits could provide some compensation for firms in EITE sectors, with considerable variability across sectors in the share of carbon taxes returned to the sector, depending on the within-sector distribution of emissions intensities.
- Output-based tax credits are likely to create better incentives for firms than allowing a deduction on the corporate income tax for carbon tax payments. The latter approach reduces the marginal incentive of the carbon tax by the corporate income tax rate—by over one-third.

- These carbon credits are large enough in some sectors, relative to sector-average corporate income taxes owed, that firms in many sectors would not be able to utilize all of their carbon credits, even under the less generous rebate plans.
- Within sectors, there is considerable variability across firms in the ability to use their carbon credits, but much of this variability derives from firms that have zero or negative tax liability, who wouldn’t be able to use any carbon credits anyway.

Whether and how any border adjustments would be needed with a carbon tax is a matter still unresolved and may hinge more on political than economic considerations. We have shown in this paper how one could use a "best practices" output-based credit on the corporate income tax for carbon tax payments that could potentially address competitiveness concerns while also providing incentives for investments in capital that lower the emissions intensity of firms within sectors.

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Tables and Figures

Table 1. Energy Intensive Trade Exposed Sectors

Included in Analysis			Excluded from Analysis	
NAICS	**Sector**	**CMF**	**NAICS**	**Sector**
311213	Malt manufacturing	31	212210	Iron Ore Mining
311221	Wet Corn Milling	64	212234	Copper/Nickel Mining
311613	Meat Processing	213	314992	Tire Cord/Fabric
313111	Yarn Spinning Mills	188	331411	Copper Smelting/Refining
321219	Wood Product	218	335991	Carbon/Graphite Products
322110	Pulp Mills	32		
322121	Paper	166		
322122	Newsprint Mills	17		
322130	Paperboard	156		
325110	Petrochem	55		
325131	Inorganic Dyes	80		
325181	Alkalies/Chlorine	53		
325182	Carbon Black	28		
325188	Inorganic Chem	564		
325192	Cyclic Crude	28		
325193	Ethyl Alcohol	222		
325199	Organic Chem	865		
325211	Plastics	1144		
325212	Synthetic Rubber	147		
325221	Cellulosic Fiber	11		
325222	Noncellulosic Fiber	113		
325311	Nitrogen Fertilizer	189		
327111	China Plumbing Fixtures	23		
327112	China Pottery	547		
327113	Porcelain Electric Supply	99		
327122	Ceramic Tile	126		
327123	Other Clay Products	34		
327125	Nonclay Refractory	98		
327211	Flat Glass	62		
327212	Other Glass	440		
327213	Glass Containers	61		
327310	Cement	241		
327410	Lime Manufacturing	94		
327992	Ground Mineral Mfg	252		
327993	Mineral Wool	271		
331111	Iron+Steel	380		
331112	Ferroalloy Product	26		
331210	Steel Pipe/Tube	206		
331311	Alumina Refining	19		
331312	Primary Aluminum	26		
331419	Non-Fe Smelting	195		
331511	Iron Foundries	401		

Notes: This table includes all sectors deemed presumptively eligible for carbon credit based on Metcalf (2014). Our analysis included all sectors in the left column. Census confidentiality rules precluded release of data for sectors in the right column. The CMF column reports the number of establishments in each sector as reported in the published 2012 Census of Manufactures.

Table 2. Sector-Level Emissions Intensity Distribution

				Emissions Intensity				Emissions Sources		
NAICS	Sector	Emissions Share	2012 Value of Shipments ($ millions)	Mean	Standard Deviation	Skewness	Coefficient of Variation	Electricity	Fuels	Process
331111	Iron+Steel	15.66%	109,991	943.3	1,546.7	6.4	1.6	481.1	462.2	0.0
327310	Cement	9.78%	5,895	16,685.3	5,515.3	2.1	0.3	1,665.4	4,464.6	10,555.3
325311	Nitrogen Fertilizer	7.57%	9,493	8,267.6	2,007.3	9.5	0.2	296.3	434.3	7,536.9
325199	Organic Chem	7.07%	90,347	807.5	1,036.7	6.0	1.3	247.7	393.1	166.7
322121	Paper	5.80%	44,027	1,753.9	2,894.5	9.8	1.7	595.7	1,158.2	0.0
322130	Paperboard	5.78%	28,441	2,084.7	1,205.3	1.1	0.6	897.6	1,187.1	0.0
325211	Plastics	5.23%	91,522	394.1	918.4	13.1	2.3	271.8	122.4	0.0
325193	Ethyl Alcohol	4.92%	42,649	1,435.3	1,239.3	7.0	0.9	444.1	991.2	0.0
331312	Primary Aluminum	4.77%	5,066	6,579.4	4,216.7	0.9	0.6	3,417.5	138.5	3,023.4
325188	Inorganic Chem	4.21%	24,210	1,199.8	1,345.4	6.2	1.1	377.3	401.3	421.2
325181	Alkalies/Chlorine	4.18%	8,087	4,180.4	2,454.0	0.7	0.6	1,507.1	1,728.0	945.3
327410	Lime Manufacturing	3.95%	2,355	16,844.1	4,475.9	0.0	0.3	691.3	6,309.4	9,843.4
325110	Petrochem	3.34%	82,370	617.5	862.9	4.6	1.4	179.5	420.0	17.9
311221	Wet Corn Milling	2.31%	12,984	1,433.2	926.2	0.7	0.6	507.2	926.0	0.0
331311	Alumina Refining	1.80%	1,429	12,792.0	3,228.7	2.7	0.3	508.5	1,523.1	10,760.4
331419	Non-Fe Smelting	1.41%	9,168	755.2	1,628.8	4.7	2.2	439.4	99.1	216.7
331511	Iron Foundries	1.35%	10,938	1,078.5	1,000.9	5.2	0.9	634.3	444.1	0.0
322122	Newsprint Mills	1.06%	2,720	4,093.2	1,752.4	0.0	0.4	3,197.1	896.1	0.0
331112	Ferroalloy Product	0.88%	2,603	3,580.7	2,337.0	1.0	0.7	1,763.3	492.2	1,325.2
327213	Glass Containers	0.85%	4,995	1,782.2	909.5	0.9	0.5	789.5	953.0	39.7

Notes: Emissions share calculated as share of each sector in total emissions from all 42 EITE sectors in our CMF database. Emissions intensity (pounds of CO_2 emissions per $1,000 of shipments) based on establishment-level Census data. Value of shipments taken from published 2012 Census of Manufactures. Top 20 emitting sectors.

Table 3. Determinants of Emissions Intensity

MODEL	1	2	3	4	5
Age	0.001 (0.001)			-0.004** (0.001)	-0.002 (0.002)
Pre-1976 dummy	0.247*** (0.036)			0.238*** (0.036)	0.211*** (0.035)
log(employees)		0.110*** (0.007)		0.105*** (0.008)	0.085*** (0.007)
log(productivity)			-0.081*** (0.013)	-0.098*** (0.013)	-0.116*** (0.013)
Sector Fixed Effects	x	x	x	x	
Region Fixed Effects	x	x	x	x	
Sector*Region Fixed Effects					x
N (rounded)	7500	7500	7500	7500	7500
R^2	0.561	0.569	0.558	0.575	0.618

Notes: This table reports regressions of the log of emissions intensity on various covariates. Regressions are at the establishment level, using data for all 42 sectors listed in Table 1.
* - statistically significant at the 10 percent level
** - statistically significant at the 5 percent level
*** - statistically significant at the 1 percent level

Table 4. Cost of Carbon Credit

Cap Carbon Credits at Carbon Taxes Paid?	Carbon Tax Payments	Carbon Credit Cutoff:			
		95%	90%	75%	50%
No	11,010	3,968	4,675	6,588	9,500
Yes	11,010	3,939	4,594	6,197	8,004
Millions of dollars. See text for details.					

Table 5. Carbon Taxes and Credits

NAICS	Sector	Emissions Share	Carbon Tax Owed	Value of Carbon Tax Deduction	Carbon Credit 95% Cutoff	Carbon Credit 90% Cutoff	Carbon Credit 75% Cutoff	Carbon Credit 50% Cutoff
331111	Iron+Steel	15.66%	1,724	603	278	407	772	1,437
327310	Cement	9.78%	1,076	377	632	700	917	1,042
325311	Nitrogen Fertilizer	7.57%	834	292	732	751	763	819
325199	Organic Chem	7.07%	779	273	213	258	389	506
322121	Paper	5.80%	638	223	96	96	266	601
322130	Paperboard	5.78%	636	223	269	307	415	608
325211	Plastics	5.23%	576	202	80	147	224	371
325193	Ethyl Alcohol	4.92%	541	189	223	274	412	513
331312	Primary Aluminum	4.77%	525	184	169	185	283	636
325188	Inorganic Chem	4.21%	464	162	118	119	154	228
325181	Alkalies/Chlorine	4.18%	460	161	103	139	235	425
327410	Lime Manufacturing	3.95%	434	152	244	305	403	439
325110	Petrochem	3.34%	368	129	160	160	178	226
311221	Wet Corn Milling	2.31%	254	89	67	137	188	210
331311	Alumina Refining	1.80%	198	69	156	156	171	204
331419	Non-Fe Smelting	1.41%	156	55	20	20	22	40
331511	Iron Foundries	1.35%	148	52	41	57	77	114
322122	Newsprint Mills	1.06%	117	41	77	86	95	106
331112	Ferroalloy Product	0.88%	97	34	39	43	75	75
327213	Glass Containers	0.85%	94	33	52	58	63	90

Notes: Carbon tax liability, value of carbon tax deduction and carbon credit in millions of dollars. Calculated from establishment-level Census data. See text for details. Top 20 emitting sectors shown.

Table 6. Unusable Carbon Credits

NAICS	Sector	Emissions Share	Unusable Credits 95% Cutoff	Unusable Credits 90% Cutoff	Unusable Credits 75% Cutoff	Unusable Credits 50% Cutoff
331111	Iron+Steel	15.66%	0.0%	0.0%	26.4%	60.5%
327310	Cement	9.78%	97.1%	97.4%	98.0%	98.2%
325311	Nitrogen Fertilizer	7.57%	87.3%	87.6%	87.8%	88.7%
325199	Organic Chem	7.07%	0.0%	0.0%	0.0%	0.0%
322121	Paper	5.80%	0.0%	0.0%	60.0%	82.3%
322130	Paperboard	5.78%	76.4%	79.4%	84.7%	89.6%
325211	Plastics	5.23%	0.0%	0.0%	0.0%	0.0%
325193	Ethyl Alcohol	4.92%	0.0%	0.0%	27.1%	41.4%
331312	Primary Aluminum	4.77%	86.6%	87.8%	92.0%	96.5%
325188	Inorganic Chem	4.21%	0.0%	0.0%	0.0%	26.6%
325181	Alkalies/Chlorine	4.18%	36.3%	52.5%	71.9%	84.5%
327410	Lime Manufacturing	3.95%	98.6%	98.9%	99.2%	99.2%
325110	Petrochem	3.34%	0.0%	0.0%	0.0%	0.0%
311221	Wet Corn Milling	2.31%	0.0%	36.8%	53.9%	58.8%
331311	Alumina Refining	1.80%	96.4%	96.4%	96.8%	97.3%
331419	Non-Fe Smelting	1.41%	0.0%	0.0%	5.8%	48.2%
331511	Iron Foundries	1.35%	0.0%	0.0%	0.0%	0.0%
322122	Newsprint Mills	1.06%	91.2%	92.2%	92.9%	93.6%
331112	Ferroalloy Product	0.88%	67.8%	70.5%	83.0%	83.0%
327213	Glass Containers	0.85%	33.3%	40.2%	45.0%	61.3%

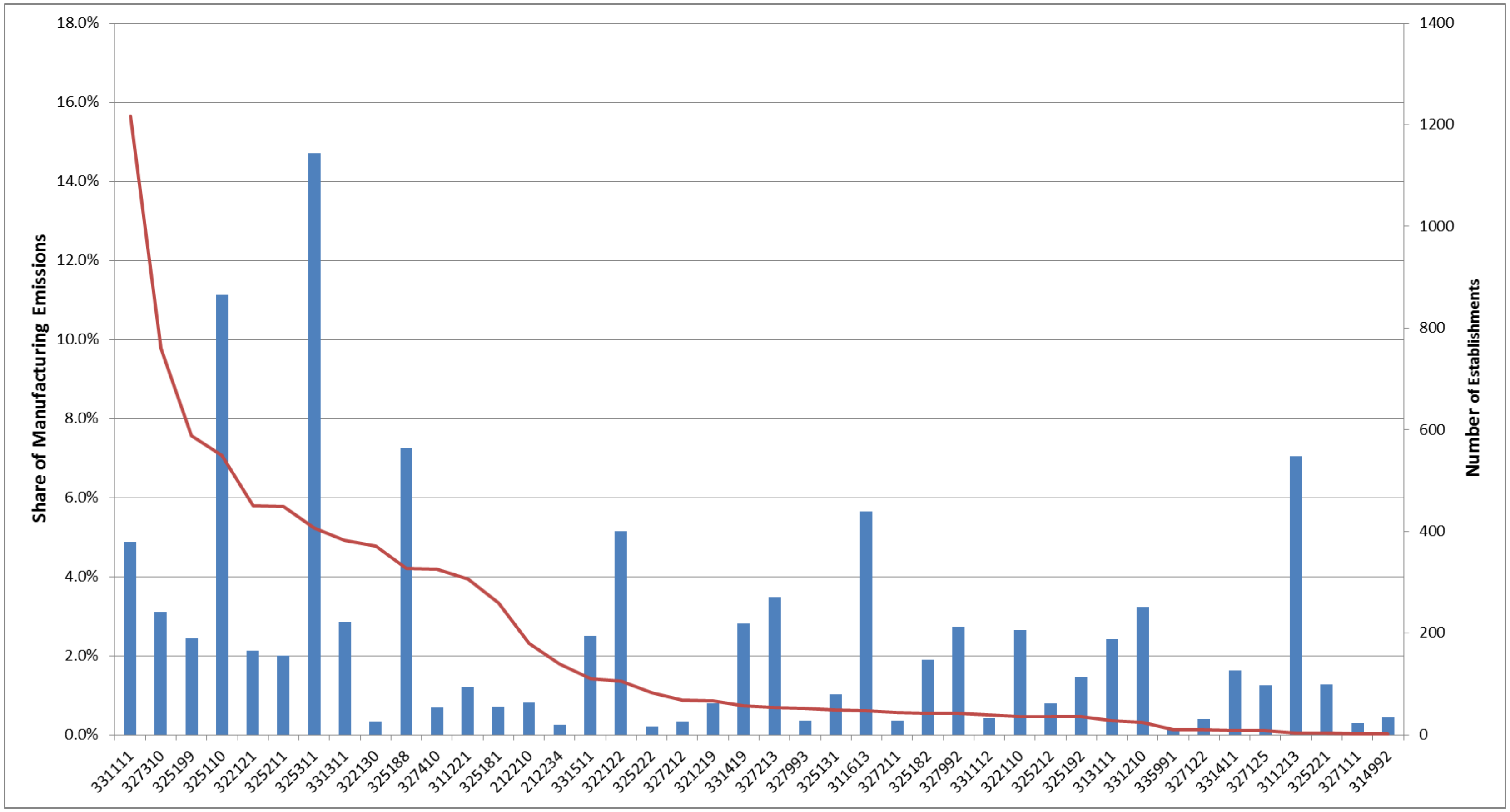
Notes: Fraction of carbon credits that would be unusable in the current year, based on sector level tax liability rates. See text for details. Top 20 emitting sectors.

Table 7. Unusable Carbon Credits based on QFR Data

NAICS	Sector	Number of QFR Firms	Unusable Credits 95% Cutoff	Unusable Credits 90% Cutoff	Unusable Credits 75% Cutoff	Unusable Credits 50% Cutoff
	All 42 EITE Sectors	**250**	39.3%	39.5%	43.0%	42.6%
331111	Iron+Steel	20	14.4%	14.7%	29.0%	43.0%
325199	Organic Chem	30	10.0%	10.2%	12.4%	18.4%
325211	Plastics	30	68.3%	69.7%	70.5%	71.2%

Notes: Fraction of carbon credits that would be unusable in the current year, based on firm-level tax liability data from Quarterly Financial Reports. See text for details. Only these 3 sectors have reportable data.

Figure 1. Emissions and Establishment Count in Sample



Notes: Sectors sorted by descending share of manufacturing emissions (higher emitters on the left); vertical bars show number of establishments per sector in the 2012 CMF data.

Figure 2. Hypothetical within Sector Emissions Intensity Variation