Capital Budgeting and Climate Change:
Does Corporate Internal Carbon Pricing Reduce CO2 Emissions?

[redacted]

ABSTRACT

Internal carbon pricing by corporations is a relatively new tool in carbon management. Using a sample of 1,274 firms from 45 countries and across 43 industries reporting to the Carbon Disclosure Project (the CDP) during the years, 2015 to 2018, this study uses carbon emissions intensity ratios to compare the carbon emission reductions of firms that have engaged in carbon pricing for the most recent four years with other firms that do not employ internal carbon prices. Our univariate analysis for the entire sample shows no significant difference in either revenue or employee-based carbon intensities between firms using an internal carbon price and other firms. However, when we examine industry sectors with high CO2 emissions and which are capital-intensive, there is a significant difference: Carbon pricing firms reduce emissions more quickly based on both revenue intensity and employee-intensity measures. This subsample of firms is comprised of companies in the extractive, airline, ground transportation, cement manufacturing and utilities sectors, so represent firms that regularly make large capital investments. Our results are consistent with internal carbon pricing helping capital-intensive firms make investment decisions that lower carbon emissions. Multivariate regressions confirm that the effect of internal carbon pricing is additional to reductions realized from other carbon efficiency tactics pursued by sample firms. Our results are unaffected by the existence of national carbon tax plans.

Keywords: Carbon Pricing; Energy Finance, Capital Budgeting, Carbon Emissions, Cost of Carbon

JEL: Q51, Q56, Q58, G38

1. Introduction

Externalities, such as pollution, can be addressed in several ways, including command-control regulations, emissions trading and carbon taxes. Each of these approaches can be successful, but economists favor market-based approaches, such as cap-and-trade programs or Pigouvian taxes[1], because they are generally much more efficient than command-control regulations.

An externality that is garnering global attention is carbon dioxide from burning fossil fuels because of its role in accelerating anthropogenic climate change. Carbon taxes have been implemented - or are being considered - as a way to reduce CO2 emissions. Typically, carbon taxes are implemented as either national or regional taxes. These taxes can be narrowly targeted, for example, applying to only large-emitting stationary sources such as power plants; or they can affect a broad range of CO2 emitting activities if applied to the price of electricity, gasoline, diesel and aviation fuels.

At the firm level, internal carbon taxes have emerged as an increasingly popular tool for corporate climate management. Companies incorporate an internal price or shadow price of carbon in their investment analyses, as well as a means to analyze their climate change risk exposures. Firms as diverse as BP and Microsoft use internal carbon pricing. Adding a carbon tax to a financial analysis tilts the decision away from high CO2 emitting assets toward lower emitting alternatives. Over time, firms using an internal carbon price should reduce their carbon emissions faster than other similar, but non-carbon-pricing firms. While the precise method that companies use to apply an internal carbon tax will vary, from a capital investment perspective,

[1] For example, see Tietenberg (1985). Though, Stavins (1995) argues that the relative efficiency of market-based schemes depends on the details of specific plans.

the general approach is that the estimated CO_2 emissions (or CO_2 equivalent emissions based on different chemicals' global warming potential) become a cash outflow in the analysis that reduces that investment's Net Present Value (NPV). The reduction is greater for high carbon emitting investments compared to their low-emitting alternatives. Whether this adjustment causes the low-emitting investment to be accepted depends on other cost differences between the alternatives, as well as perceptions of risk and the discount rate applied to the future cash flows of the projects. For example, the carbon tax adjustment may not be sufficient to offset a much higher purchase price for the low-emitting asset. Since discounted cash flow investment analysis values future cash flows less than current or near-term cash flows, the present value of the carbon tax paid over time depends critically on the discount rate. Higher discount rates reduce the effectiveness of a carbon tax.

As with national or regional carbon taxes, whether an internal carbon tax accelerates a company's CO_2 emissions reduction depends on how the tax is designed, i.e., the price of carbon, the scope of activities to which the tax applies, how tax collections are used, the availability and cost of low carbon alternatives and what other CO_2 reduction activities the firm employs. The effectiveness of corporate carbon pricing mirrors that of national or regional programs. More effective policies are those with a higher price and/or that cover a broader set of emissions activities. How the entity uses the proceeds from the tax also affects its efficacy; carbon tax revenues invested in further emission reduction activities will have a greater impact than tax proceeds spent on more general expenses or returns to consumers.

The efficacy of a company-implemented carbon tax is likely to be much lower than a legislated national or regional tax. If an analysis incorporating a carbon tax indicates that a low-emitting alternative is superior, companies are not obligated to make that choice. That is, an organization's internal carbon price is only advisory, so unlike national or regional carbon taxes, corporate internal carbon taxes can be ignored. For a tax to direct a company to investment projects with lower emissions, such alternatives must exist and their costs must be less than the carbon tax penalty. That is, the effectiveness of an internal price on carbon emissions depends on technological innovation in developing emission-efficient alternatives. Since carbon taxes will often be applied to long-lived asset investment decisions, it may be several years before the results of investing in a low-emitting alternative appear in a company's carbon emissions reports. This time delay can occur because a company doesn't make such investments very often, or once a decision is made it can take an extended period of time for the asset to be built and put into operation. As this discussion suggests, an internal price on carbon may not appear to be effective in the short-term. Thus, our study should be considered a "first-look" at voluntary carbon pricing's effect on firm behavior and CO2 emissions, and consequently, on climate change.

For this study, we examine the proposition that firms utilizing carbon pricing will have greater carbon emission reductions, measured in terms of carbon intensity, than non-carbon pricing firms. To test this proposition, we use a sample of 1,274 firms that are included in each of the Investor CDP Public Data files for 2015 to 2018, which represents data for the years 2014 through 2017. This sample represents firms from 45 countries and 43 industry sectors. We study carbon emission intensity ratios because they are less likely to be affected by changes in company size than absolute emissions. We use both revenue intensity (Scope 1 and Scope 2 emissions divided by total revenue) and employee intensity (Scope 1 and Scope 2 emissions divided by the number of full-time employees). Using the entire sample, the empirical results initially suggest no significant differences between internal carbon-pricing firms and non-carbon pricing firms. However, when we examine industry sectors with high CO2 emissions and which are capital-intensive, there is a significant difference. Firms that report using an internal price on carbon to the CDP, have greater emission reductions, as measured by both revenue-intensity and employee-intensity measures, than other firms in the high CO2 emission capital-intensive subsmaple. Multivariate analysis shows that these results are not driven by countries using a national carbon tax, and are not diminished by other carbon reduction activities companies may pursue.

The paper proceeds as follows. Section two provides a brief overview of previous studies, followed by section three discussing the conditions needed for an internal carbon price to be effective. Section four describes the sample selection procedure and presents descriptive statistics. Section five reports our empirical results, and section six provides a summary and conclusion.

2. Overview of Related Studies

Internal carbon pricing is a recent addition to the carbon management tools available to corporations. Moreover, since it may take several years for the impact of internal carbon prices to appear, there is to our knowledge only one study examining the effectiveness of internal carbon pricing. Byrd and Cooperman (2019) examine 201 U.S. companies, with 52 that currently use an internal price of carbon and another 20 with plans to adopt a carbon price in the next two years. Examining changes occurring for the 2014 to 2016 period for industry-adjusted carbon emissions intensity measures, the authors find a significantly larger reduction for firms using carbon pricing versus the non-carbon pricing subsamples using an employee-based carbon intensity measure, but for the revenue-based measure, although the reduction was larger for carbon pricing firms, the difference was not statistically significant. The authors note that the mixed results could reflect the short period of time that companies have applied an internal carbon price and the range of ways it is being applied.

Other studies have looked at the effect of national or regional carbon taxes. Rafaty and Dolphin (2019) examine aggregate country data for 25 OECD countries from 1990 to 2012, employing a dynamic macro-panel model to estimate the cross-nationally heterogeneous relationship between carbon prices and per capita CO2 emissions. After controlling for average energy prices, non-pricing drivers of energy and carbon intensity, and various fixed effects, they find the relationship between changes in carbon prices and changes in per capita CO2 emissions to be negligible for about 84% of the countries analyzed. Based on non-linear relations, their results indicated carbon pricing was effective in just two countries, with a 10 percent price increase significantly associated with reduction of per capita CO2 emissions of 1.25% in Sweden and 0.067% in Finland. The authors suggest that their empirical results are consistent with a much larger carbon pricing performance gap for countries than that typically assumed.

Tietenberg (2013) provides an overview of carbon pricing programs implemented by countries and states, and a literature review of studies examining their effectiveness. Previous studies conventionally have assessed cost savings based on computer simulations and ex post analyses, with a substantial majority concluding that a change from more traditional regulatory controls to market-based policies, has the potential to achieve similar emission reductions at a much lower cost. Tietenberg points out weaknesses in some studies because historic baselines can be inaccurate benchmarks as well as the difficulty in attributing reductions in emissions solely to market-based mechanisms versus other exogenous factors. He notes several studies, summarized below, that had mixed results across countries.

Lin and Li (2011) attempted to control for other factors that could affect emissions in order to examine the effect of carbon taxes on the change in per capita CO2 emissions over time between countries that did, and did not, utilize a carbon tax. They found that carbon taxes reduced emissions for the countries with carbon taxes (except for Norway) but these reductions were only statistically significant for one country (Finland). The authors suggest that tax exemption policies in some countries for certain energy-intensive industries may have reduced the effectiveness of their carbon taxes.

A study by Summer, Bird, and Dobos (2011) found country carbon taxes to be related to lower carbon emissions, but only in high single digits, and not uniformly. They found that Norway actually reported a rise in emissions. As suggested by Bruvoll and Larsen (2004), the small or insignificant fall in emissions for studies examining countries with carbon taxes may be the result of tax exemptions and somewhat inelastic demand in sectors where the tax was implemented. Johansson (2000) similarly observed that insignificant results of studies of the effectiveness of Sweden's carbon tax likely reflect Sweden's many policy exemptions.

Although, there is a scarcity of studies examining the relationship between internal carbon pricing and carbon emission reductions for individual corporations, there is much anecdotal evidence for particular companies on the effectiveness of the use of internal shadow carbon prices for business decisions and risk mitigation strategies. This includes the use of an internal carbon price of $40 to $80 per metric ton of carbon dioxide equivalent (MTCO2e) for Shell Corporation's evaluation of investment decisions. Shell reports that the use of this shadow price, has contributed to a reduction of 2 million MTCO2e of its direct carbon emissions from its facilities over 2015 to 2016. Microsoft and Disney have also effectively used carbon fees for their business groups for the purpose of reducing their electricity consumption, air travel, and encouraging engagement in waste recycling, among other goals. Fees were also used to buy carbon offsets and in other ways designed to help the firms to reach their zero carbon emissions goals (Ahluwalia 2017a, b; Economist 2018).

3. The Conditions Necessary for an Internal Carbon Price to be Effective

A discounted cash flow analysis of a potential investment decision compares the cost of acquiring the asset to the present value of the future after-tax cash flows that the asset will produce over its life. If the discounted cash flows exceed the initial investment cost, the project has a positive net present value (NPV) and will add to the value of the company.

An internal carbon tax changes the future cash flows associated with an investment, and thereby changes its NPV. If the investment has any associated carbon emissions, then a carbon tax reduces the NPV, possibly enough to make the investment appear to dissipate shareholder value, implying that the company should not be make the investment.

The extent to which an internal price on carbon reduces an asset's future cash flows depends on the emissions produced, the price per ton of CO2 and the discount rate applied to the product of those two factors. The impact of a carbon tax increases as the price on carbon increases, emissions increase and/or the discount rate decreases.

The situation changes when there are alternative methods to accomplish the same goal. For example, a new office building could be built using standard methods or built to reduce energy use. Either design fulfills the required objective. Typically, we assume that energy-saving features increase the initial cost of a building. Without an internal carbon tax the present value of the energy savings for the more efficient building would have to be greater than the difference in the initial cost, for the energy efficient buildings to be selected. With a carbon tax the less efficient building has a larger tax burden than the more efficient alternative. To be the preferred choice, the present value of the energy savings plus the difference in the emission tax must be greater than the difference in initial cost. The tax on carbon emissions tilts decisions in favor of more efficient alternatives and the higher the price per ton of carbon dioxide emissions the better low carbon alternatives look. Although few companies report their internal carbon price, for those that do, prices range from $5 per ton of CO2 to $100 per ton. In the national context, the High-Level Commission on Carbon Prices (2017), chaired by Nicholas Stern and Joseph Stiglitz, recommends carbon prices of $40 to $80 per ton of CO2 by 20202 rising to $50 to $100 by 2030.

The effectiveness of a carbon tax in reducing emissions depends on low carbon alternatives being available. While some companies may still have 'low hanging fruit' to harvest, such as shifting to LED lighting systems, upgrading HVAC systems, and insulating buildings, many companies have captured those efficiencies. The next stage of emissions reductions will require redesigning products, changing manufacturing process and electrifying as many activities as possible and powering them with renewable energy. Some sectors such as aviation, may be able to make some marginal emission reductions, but will have to wait for technical advances to see significant improvements.

4. Sample Selection and Descriptive Statistics

The sample comprises all firms on the CDP public investor data-base that reported every year from 2015 through 2018 (reporting data for 2014 through 2017). The final sample contains 1,274 companies with 409 that reported using carbon pricing in 2018, 207 that reported using an internal price on carbon for all four years, and 265 used carbon pricing every year for the most recent three years. The sample includes companies from 45 countries (with the countries with the most observations shown in Table 1) and 43 GRI (Global Reporting Initiative) industry sectors (with the 15 sectors with the most observations listed in Table 2A). The sectors with the most companies reporting to CDP are led by Banking and Finance with 184 firms in the sample, 26 (14.1%) of which have used carbon pricing since 2015.

Table 2B shows the 15 sectors with the greatest proportion of companies using internal carbon pricing for all years from 2015 through 2018. The airline, gas, water and electric utilities sectors, comprising 92 firms, have 50 companies that reported using an internal carbon price for the sample. The airline sector has the largest proportion of firms using an internal price on carbon (63.6% of firms). Utilities, water, gas and electric, all had over 50% of firms reporting using an internal carbon price. In the oil and gas industry 42.9% of firms reported using carbon pricing.

Table 3A shows the average emissions of the 15 highest emitting sectors and the proportion of firms in an industry group that have their emissions verified by a 3rd party. These emissions include both Scope 1 (emissions from fuels combusted in company owned or controlled assets and refrigerants and solvents used in company equipment or factories) and Scope 2 emissions (primarily from electricity). If a company reported both location-based and market-based Scope 2 emissions the smaller number (location-based or market-based) was used. Location-based emissions are computed as if all electricity is taken from local grids. The market-based metric is based on actual emissions from electricity the company purchases through PPAs (Power Purchase Agreements), other purchases of green power, and electricity generated by the company. For more information, see, Greenhouse Gas Protocol, GHG Protocol Scope 2 Guidance, 2015).

The very high average emissions for the Construction Materials sector is due to many cement manufacturers in that sector. In 2018 cement production produced an estimated 4.1 billion tons of CO_2, or over 10% of the total global CO_2 emissions for that year (37.1 billion tons).

Table 3A shows how Scope 1 and Scope 2 emissions can vary across industrial sectors. This is potentially important for this study because Scope 1 emissions are largely under the control of the company, while Scope 2 emissions, which are mostly from purchased electricity, are controlled by the utilities providing the electricity not the firm using the electricity. This has implications about how much emissions can be reduced.

The next table, 3B, shows the Scope 1 and Scope 2 emissions (and 3rd party assurance percentages) for the 15 sectors with the most companies in the sample. Among the sectors average emissions vary widely. The opportunities and incentives to reduce emissions may also vary based on emission levels; that is, high emitting sectors are likely to want to reduce emissions more than low emitting sectors because of public scrutiny and criticism.

5. Methodology and Empirical Results

5.1 Methodology

We first do a univariate analysis to test whether companies using an internal carbon price have significantly larger reductions in their carbon emission intensity ratios than other companies. We measure change in terms of carbon intensity rather than absolute emissions. Absolute emissions (measured as metric tons of carbon dioxide equivalents) can change with company growth, as well as through acquisitions and divestments. Intensity measures address some of the data issues associated with companies growing or contracting. As a company grows we expect absolute emissions to increase. Emission intensity reflects improvements despite corporate growth or contraction. Carbon intensity ratios are calculated as carbon emissions divided by some company-level metric such as revenues or number of employees. So, a growing firm that emits more CO_2 would presumably have more revenues and employees, leaving intensity metrics relatively stable.

We find a few companies that report enlarging the boundary of activities over which they measure emissions. In this case, carbon intensity can change without any real change in a company's emission performance. This was reported by only a few companies and always as a broadening of the boundary, so contributes to a very slight bias against finding a reduction in emissions.

We measure changes in intensity metrics using the changes reported by companies for 2015 to 2017. CDP requests that companies provide revenue intensity metrics in their local currency. In years prior to 2017 CDP also requested emissions per full-time equivalents (FTE) or number of employees. Recently it has relaxed that request and asked instead for intensity measures relevant to the company's activities. About 60% of companies continue to report emissions per FTE, which means that measuring changes from 2016 to 2018 involves fewer firms than when using revenue intensity. Emissions include both Scope 1 and Scope 2 emissions. Scope 1 emissions are from fuels combusted in company-owned or company-controlled assets. These can include vehicles, heavy equipment, airplanes as well as factory equipment such as furnaces. Also included in this category are refrigerants such as CFCs and HFCs and some specialty chemicals including Sulfur Hexafluoride and Nitrogen Trifluoride. All gases are converted into CO_2 equivalents using their 100-year GWP (global warming potential) (IPCC, 2014). Scope 2 emissions are primarily from electricity purchased by the company but generated by utility separate from the company. In the last three years Scope 2 emissions have been reported as location-based and/or market-based. Where a company reports both types the lower amount is used in computing total emissions.

The data covers several reporting cycles. While most companies stay with their original format, some companies report revenue in billions of Yen or millions of Euros one year, but change units other years. As companies change the scope of their emissions collection efforts, intensity metrics can be affected. When faced with a significant change in an intensity metric we consulted accompanying notes and made adjustments whenever possible. We also compute carbon intensity measures using company provided data, to check entries that were likely typographic errors, such as reductions of over 100%. To ensure accuracy of any influential data points, we examined all large (greater than 50%) changes in intensity metrics from one year to the next.

In most cases large increases were the result of changes in the way emissions were measured or the acquisition/divestment of assets. In cases where changes did not appear to come from comparable metrics, we eliminated the observation. In a few cases large devaluation of the local currency reduced revenues and thereby increased the intensity ratio, though emissions levels had not changed, as mentioned by several Turkish companies. We kept these observations in the sample since currency rates moved both up and down over the time period we examine.

Large decreases were almost always associated with energy reduction investments or the purchase of zero-carbon electricity. If the explanation wasn't clear, we double-checked accuracy of reported numbers by computing annual changes in intensity factors using the data provided by the sample companies. There were several cases of companies simply entering data that was off by a factor of 10, such as 86% being entered when the calculated change was 8.6%.

5.2 Results for the Entire Sample

Tables 4A and 4B show the results from t-tests of carbon emission intensity reductions for the entire sample comparing companies using carbon pricing for 4 years to other companies. The intensity metrics are revenue intensity (metric tons of CO2 equivalents per currency unit of revenue) and employee intensity (metric tons of CO2 equivalents per number of full-time equivalent employees). As Table 4A shows, the changes in mean revenue intensity (reductions of 5.98% for the companies not using a carbon price for 4 years compared to 6.47% for the firms using a carbon price continuously for 4 years) show greater reductions in intensity, but the difference was not statistically significant. The t-statistic is 0.5262 with a p-value of 0.5990.

In Table 4B, FTE employee intensity changes are examined. The average reduction in FTE employee emissions intensity are 4.02% for the companies not using a carbon price compared to a 5.82% mean reduction for the firms using a carbon price continuously for 4 years. The difference between these average reductions is directionally consistent with internal carbon prices leading to greater reductions in intensity, but like revenue intensities the difference was not statistically significant (t-statistic = 1.393; p-value = 0.1659. Notice that the sample size for the FTE employee intensity test is much smaller than for the revenue intensity test (688 firms compared to 1,274 firms), reflecting the change in the data CDP requests.

5.3 Results for high-emitting, capital-intensive sectors

We posit that the sectors that will provide the best test of the efficacy of internal carbon pricing, are those that are capital-intensive and have high emissions. Capital intensity suggests companies make large investment regularly, and if a carbon price is used to analyze investments some should be low carbon emitting. Being a high emitter attracts more scrutiny and criticism, as well as risk exposure to future government mandated carbon taxes, so high emitting companies are likely to have an incentive to improve their carbon performance.

Table 3A shows the sectors with highest average emissions. To estimate capital intensity we used COMPUSTAT data for US companies to compute the average ratio of Net Plant, Property and Equipment to Total Assets for companies for the three years from 2016 through 2018, and then averaged these results by sector. We assume the average sector capital intensity of US companies is similar to that for other countries. The sectors that are capital-intensive and have high emissions include companies in the mining, oil and gas, utilities, cement (i.e., construction materials), ground transportation and airline industries. These are all industries that regularly make large capital investments, so are arguably sectors where carbon pricing could be particularly effective. This subsample includes 198 observations of which 87 satisfy the 4-year carbon pricing definition. For this group, 78 companies provided employee intensity measures. Firms in the subsample come from 33 countries.

Again, we use revenue and FTE employee carbon emission intensity changes. In Table 5A, examining revenue intensity, the average reduction for companies in these sectors that use carbon pricing is 5.46% compared to 1.97% for the non-pricing sector companies. This difference (3.49%) is statistically significant at the 5% level (p-value = 0.0455). Table 5B shows the results using FTE employee intensity. The average *reduction* for companies using carbon pricing is 5.84% compared to an *increase* over the period from 2015 to 2017 of 1.68% for the other companies. This difference (7.52%) is also statistically significant at the 5% level (p-value of 0.0270).

These results, utilizing a subset of industries with high CO2 emissions and which are likely to make major capital investments, is consistent with an internal carbon price affecting the analysis of investments, leading to carbon emission reductions.

Table 6 reports regression results using the subsample of capital-intensive, high CO2 emitting sectors. The dependent variable in each of the models is Revenue Carbon Intensity. For Model 1, similar to the univariate analysis for the high emitting capital-intensive subsample, the coefficient on the carbon pricing indicator variable is signed negative and significant at the 0.037 level. The carbon pricing indictor variable is 1 for all sample firms that reported using an internal price of carbon for all four years, 2014 through 2017, and 0 otherwise.

Internal carbon pricing is one of many emissions reduction activities that a company can pursue. Appendix A shows the different types of activities that corporations report to the CDP as other methods to reduce carbon emissions (e.g., employee engagement, having a dedicated budget for different carbon reducing activities, etc.). Given these alternative approaches being utilized by firms, we test whether carbon pricing explains carbon emission reductions or if it is a proxy for firms using several reduction methods.

Model 2 includes a variable for the number of other carbon emissions reductions methods, not including carbon pricing, that a company uses. The coefficient estimate for the carbon pricing variable is negative and significant at a 0.080 level, while the number of carbon emission reduction activities variable is negative, and significant at the 0.054 level. Thus, internal carbon pricing has a significant negative effect on carbon intensity measures beyond that of a company's other carbon reduction activities.

In Model 3, two groups of other activities – having a dedicated budget for various efforts and employee engagement for carbon reduction activities– are included in the model as dummy variables. The variable for a dedicated budget is equal to 1, if a company reported at least one of the three types of budgets (shown in Appendix A), and 0 otherwise. For this regression, the coefficient for the carbon pricing variable is negative and significant at a 0.047 level, while the coefficients for the dedicated budget and employee engagement variables are not statistically different than zero.

Model 4 tests whether the length of time a company has been using carbon pricing, rather than using carbon pricing for the most recent four years, explains carbon intensity reductions in this subset of firms. To create the variable for the number of years reporting a carbon price, we collected data from CDP reports from 2011 through 2018 and tallied the years a company reported using an internal carbon price. This variable takes on values ranging from zero (never used a carbon price: 35 of 198 firms) to 6 years (3 of 198 firms). This variable differs from our original carbon pricing variable because it doesn't require that companies used carbon pricing in the most recent four years. Several companies that reported using carbon pricing for 3 or 4 years, did not do so in the most recent four-year period, so they were categorized as non-pricers in our variable of continuous use during the most recent 4 year period. As shown in Model 4 of Table 6, the coefficient on the variable for the number of years a company has used carbon pricing is not statistically significant, suggesting that it is the continuous use of carbon pricing in recent years that is important for internal carbon pricing to reduce carbon emissions. The number of other (non-carbon-pricing) CO_2-reduction activities is also included in this model.

We estimated similar models using the employee carbon intensity measure as the dependent variable. These results are shown in Table 7. In all models the carbon pricing variable (used carbon pricing in the last 4 years) is statistically significant at the 5% level. This confirms the results in Table 6, that using an internal carbon price can be an effective tool for reducing carbon emissions. We found no other statistically significant results in models using employee intensity carbon reductions as the dependent variable. This might indicate that the number of full time employees is an unreliable measure of a firm's production, or the findings may have been affected by the small sample size (only 78 of the 198 high emitting capital-intensive firms reported employee intensity ratios).

6. Summary and Conclusion

To our knowledge, this study is the first to use a sample of international companies to examine the relationship between internal carbon pricing and carbon emission intensity reductions. Our evidence shows that for capital-intensive industries with high average emissions per company using an internal price on carbon emissions is associated with larger carbon emission reductions than for non-carbon pricing companies in those industries. This result is robust across both revenue intensity and employee carbon intensity metrics. The subsample of companies for which this result emerged are from the ground transportation cement, mining, oil and gas, airline and utilities sectors. Firms in most of these sectors regularly make major capital-intensive investments, so there may be many opportunities for the application of a carbon price as part of the capital budgeting process. Although our sample period is relatively short, looking at carbon intensity reductions from 2015 through 2017, we find evidence supporting a significant effect of carbon pricing in reducing carbon intensity ratios for our sample of high emitting capital-intensive industries reporting to the CDP.

Our evidence is consistent with carbon pricing having an effect on emissions beyond other carbon-reduction activities. We also find that the presence of a national carbon tax does not reduce the effect of an internal carbon price. Overall, our evidence supports the notion that internal carbon pricing can be an effective tool in mitigating carbon emissions.

The study is limited in several ways. First, carbon pricing is a relatively new tool in carbon management for many companies, so there is not a long time frame for evidence of its effectiveness to accumulate. As more data emerges its efficacy will become clearer. Second, the CDP databases do not provide details about how companies implement a carbon price. For example, rarely is the price of carbon emissions given nor is there information available that describes the extent to which the shadow price is applied. The effectiveness of an internal carbon price resides in the details of implementation. Therefore, finding any effect is somewhat surprising since some companies may have schemes that are weak in the sense they may set a low price per metric ton of carbon emissions, or carbon prices are being applied to only a few categories of investments. Third, while an analysis using a carbon price may signal that the company should invest in low-emitting alternatives, there is no obligation or immediate cash flow reasons to do so. Thus, while many companies may report including a carbon price in their analyses, we cannot know for sure whether the internal carbon pricing that they use is affecting their investments decisions. It may be that no cost-effective low-emission alternatives are available, or that other factors, such as uncertainty about whether a carbon tax or cap-and-trade system will be established, will offset the impact of the carbon price.

This first study of global companies using an internal carbon price as part of their carbon management activities provides preliminary evidence of its effectiveness, and points out important issues that will need to be addressed in future studies.

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Table 1: Geographic distribution for sample firms showing the countries with the largest percentage of firms in the sample.

Country	#Firms	% of sample
United States of America	291	22.8%
Japan	152	11.9%
United Kingdom of Great Britain and Northern Ireland	136	10.7%
Canada	69	5.4%
South Africa	58	4.6%
France	50	3.9%
Germany	41	3.2%
Brazil	40	3.1%
Switzerland	40	3.1%
Republic of Korea	36	2.8%
Australia	32	2.5%
Spain	32	2.5%
India	30	2.4%
Sweden	30	2.4%
Finland	26	2.0%
Norway	24	1.9%
Italy	21	1.6%
Turkey	20	1.6%
Netherlands	18	1.4%
Taiwan, Greater China	17	1.3%
Denmark	15	1.2%

Other countries in the sample, in the ordered by the number of firms are: Ireland, Austria, Belgium, China, Hong Kong Special Administrative Region, Portugal, New Zealand, Singapore, China, Colombia, Mexico, Thailand, Chile, Greece, Israel, Russian Federation, Guernsey, Argentina, Bermuda, Cyprus, Hungary, Luxembourg, Peru, Poland, and the United Arab Emirates.

Table 2A Largest GRI sectors in Sample

GRI Industry Sector	Count	Companies using an internal carbon price all 4 years	% of companies using an internal carbon price all 4 years
Banks, Diverse Financials, Insurance	184	26	14.1%
Electrical Equipment and Machinery	69	5	7.2%
Electric Utilities & Independent Power Producers & Energy Traders (including fossil, alternative and nuclear energy)	62	32	51.6%
Technology Hardware & Equipment	60	4	6.7%
Chemicals	57	15	26.3%
Food & Beverage Processing	56	5	8.9%
Oil & Gas	56	24	42.9%
Real Estate	52	4	7.7%
Pharmaceuticals, Biotechnology & Life Sciences	43	2	4.7%
Trading Companies & Distributors and Commercial Services & Supplies	43	4	9.3%
Telecommunication Services	42	3	7.1%
Software & Services	41	4	9.8%
Construction & Engineering	37	5	13.5%
Consumer Durables, Household and Personal Products	37	5	13.5%
Retailing	32	4	12.5%

Table 2B GRI Sectors with the largest percentage of companies using carbon pricing all 4 years of sample period.

GRI	Count	Companies using an internal carbon price all 4 years	% of companies using an internal carbon price all 4 years
Air Transportation – Airlines	11	7	63.6%
Gas Utilities	12	7	58.3%
Water Utilities	7	4	57.1%
Electric Utilities & Independent Power Producers & Energy Traders (including fossil, alternative and nuclear energy)	62	32	51.6%
Oil & Gas	56	24	42.9%
Mining - Iron, Aluminum, Other Metals	28	10	35.7%
Building Products	14	4	28.6%
Forest and Paper Products - Forestry, Timber, Pulp and Paper, Rubber	18	5	27.8%
Mining - Other (Precious Metals and Gems)	22	6	27.3%
Chemicals	57	15	26.3%
Automobiles & Components	29	5	17.2%
Construction Materials	12	2	16.7%
Ground Transportation - Highways & Railtracks	6	1	16.7%
Ground Transportation - Trucking Transportation	6	1	16.7%
Banks, Diverse Financials, Insurance	184	26	14.1%

Table 3A. Average 2018 Scope 1 and Scope 2 CO2 emissions and percent of firms using third-party assurance for emissions by sector for the 15 largest average emitting sectors. If companies provided both location-based and market-based Scope 2 emissions the smaller number was used.

	Average Scope 1	Average Scope 2 (lowest of location-based or market-based, if both are reported)	2018 Scope 1 Assurance	2018 Scope 2 Assurance
Construction Materials	32,076,805	2,772,758	83.3%	83.3%
Electric Utilities & Independent Power Producers & Energy Traders (including fossil, alternative and nuclear energy)	22,032,183	709,587	85.5%	72.6%
Mining - Iron, Aluminum, Other Metals	16,960,452	2,069,983	92.9%	92.9%
Air Transportation - Airlines	16,765,101	90,709	100.0%	90.9%
Oil & Gas	12,056,524	2,099,913	80.4%	71.4%
Water Transportation - Water Transportation	11,997,299	88,523	66.7%	66.7%
Water Utilities	5,421,245	1,214,278	71.4%	71.4%
Food & Staples Retailing	4,842,714	6,972,622	76.2%	81.0%
Gas Utilities	4,799,150	339,720	91.7%	91.7%
Chemicals	3,832,262	2,084,922	80.7%	78.9%
Forest and Paper Products - Forestry, Timber, Pulp and Paper, Rubber	3,172,133	1,215,288	77.8%	66.7%
Air Freight transportation and Logistics	2,713,369	381,774	84.6%	76.9%
Ground Transportation - Railroads Transportation	2,456,771	625,210	76.9%	76.9%
Ground Transportation - Trucking Transportation	2,118,461	202,005	83.3%	83.3%
Building Products	1,800,439	884,106	64.3%	57.1%
Average of entire sample	3,131,030	692,313	80.8%	79.0%
Median of entire sample	67,412	85,167		
Count	1,274	1,274	43	43

Table 3B. Average 2018 Scope 1 and Scope 2 CO_2 emissions in metric tons and percent of firms using third-party assurance for emissions by sector for the 15 sectors with the most firms in the sector. If companies provided both location-based and market-based Scope 2 emissions the smaller number was used.

	Number of firms in sector	Average Scope 1	Average Scope 2 (lowest of location-based or market-based, if both are reported)	2018 Scope 1 Assurance	2018 Scope 2 Assurance
Banks, Diverse Financials, Insurance	184	19,995	67,651	85.9%	86.4%
Electrical Equipment and Machinery	69	141,642	254,723	79.7%	79.7%
Electric Utilities & Independent Power Producers & Energy Traders (including fossil, alternative and nuclear energy)	62	22,032,183	709,587	85.5%	72.6%
Technology Hardware & Equipment	60	222,560	666,839	80.0%	80.0%
Chemicals	57	3,832,262	2,084,922	80.7%	78.9%
Food & Beverage Processing	56	671,628	427,724	85.7%	82.1%
Oil & Gas	56	12,056,524	2,099,913	80.4%	71.4%
Real Estate	52	374,706	72,180	90.4%	90.4%
Pharmaceuticals, Biotechnology & Life Sciences	43	209,812	216,726	81.4%	81.4%
Trading Companies & Distributors and Commercial Services & Supplies	43	895,239	116,417	55.8%	53.5%
Telecommunication Services	42	117,035	1,133,784	92.9%	92.9%
Software & Services	41	24,812	141,664	87.8%	87.8%
Construction & Engineering	37	335,041	68,278	81.1%	81.1%
Consumer Durables, Household and Personal Products	37	350,474	389,097	86.5%	86.5%
Retailing	32	83,372	333,647	78.1%	78.1%

Table 4A: T-test of changes in revenue intensity for the entire sample comparing companies that reported to CDP using a an internal carbon price for 4 continuous years and all other firms. Intensity measured as Emissions/Revenue and emissions/FTE Employees. Carbon emissions include both Scope 1 and Scope 2 emissions.

Two-sample t test of revenue intensity changes

Group	Obs	Mean	Std. Err.	Std. Dev.
Did not use a carbon price for 4 years	1067	-0.0598	0.00498	0.161
Used a carbon price for 4 years	207	-0.0647	0.0077	0.112

T-statistic = 0.5262

P-value Value = 0.5990

Table 4B: T-test of changes in FTE employee intensity for the entire sample comparing companies that reported to CDP using a an internal carbon price for 4 continuous years and all other firms. Intensity measured as Emissions/FTE Employees. Carbon emissions include both Scope 1 and Scope 2 emissions.

Two-sample t test of FTE employee intensity changes

Group	Obs	Mean	Std. Err.	Std. Dev.
Did not use a carbon price for 4 years	598	-0.0402	0.00529	0.129
Used a carbon price for 4 years	90	-0.0582	0.0119	0.112

T-statistic = 1.393

P-value Value = 0.1659

Table 5A: T-test of changes in revenue intensity for industry sectors reporting at least 30% of companies using a an internal carbon price for 4 continuous years compared to reductions for other firms in those sectors. The sectors included in this test are airlines, gas, water and electric utilities, oil & gas and metal mining. Intensity measured as Emissions/Revenue. Carbon emissions include both Scope 1 and Scope 2 emissions.

Two-sample t test of revenue intensity changes

Group	Obs	Mean	Std. Err.	Std. Dev.
Did not use a carbon price for 4 years	111	-0.0197	0.01299	0.137
Used a carbon price for 4 years	87	-0.0546	0.01045	0.0975

T-statistic = 2.013

P-value Value = 0.0455

Table 5B: T-test of changes in FTE employee intensity for industry sectors reporting at least 30% of companies using a an internal carbon price for 4 continuous years compared to reductions for other firms in those sectors. The sectors included in this test are airlines, gas, water and electric utilities, oil & gas and metal mining. Intensity measured as Emissions/FTE Employees. Carbon emissions include both Scope 1 and Scope 2 emissions.

Two-sample t test of FTE employee intensity changes

Group	Obs	Mean	Std. Err.	Std. Dev.
Did not use a carbon price for 4 years	52	0.0168	0.0193	0.139
Used a carbon price for 4 years	26	-0.0584	0.0271	0.138

T-statistic = 2.255

P-value Value = 0.0270

Table 6: Regression results using the subsample of 198 firms in the airline, cement, ground transportation, extractive and utility sectors, with 87 companies using carbon pricing. The dependent variable is Carbon Revenue Intensity computed as Total Scope 1 and Scope 2 emissions divided by total revenue. Standard errors are corrected for heteroscedasticity using White's procedure.

	Model 1	Model 2	Model 3	Model 4	Model 5
Used a carbon price continuously for the 4 sample years dummy variable	-0.0349	-0.028	-0.034		-0.029
t-statistic	-2.09	-1.76	-2.00		-1.76
p-value	0.037	0.080	0.047		0.080
Number of years reported using a carbon price in CDP filings				-0.0048	
t-statistic				-0.87	
p-value				0.385	
Number of carbon emission reduction activities other than carbon pricing that a firm reported doing to CDP (See Appendix A)		-0.006		-0.007	-0.0061
t-statistic		-1.94		-2.21	-1.93
p-value		0.054		0.028	0.055
Country has a national carbon tax dummy(1= yes)					0.0197
t-statistic					0.12
p-value					0.908
Employee Engagement dummy			0.006		
t-statistic			0.340		
p-value			0.734		
Dedicated Budget for various types of activities dummy			-0.019		
t-statistic			-0.970		
p-value			0.333		
Intercept	-0.0197	-0.0017	-0.012	0.002	-0.0027
t-statistic	-1.51	-0.010	-0.56	0.08	-0.13
p-value	0.132	0.924	0.578	0.940	0.900
Number of observations	198	198	198	198	198
F-Statistic	4.39	3.45	1.16	2.57	2.37
F-Statistic p-value	0.0375	0.0338	0.3312	0.0788	0.0720
R-squared	0.0203	0.0343	0.026	0.0257	0.0344

Table 7: Regression results using the subsample of 78 firms in the airline, cement, ground transportation, extractive and utility sectors, with 26 companies using carbon pricing. . Dependent variable is Carbon Employee Intensity computed as Total Scope 1 and Scope 2 emissions divided by number of full-time employees (FTEs). Standard errors are corrected for heteroscedasticity using White's procedure.

	Model 1	Model 2	Model 3	Model 4	Model 5
Used a carbon price continuously for the 4 sample years dummy variable	-0.075	-0.075	-0.0825		-0.077
t-statistic	-2.27	-2.23	-2.29		-2.25
p-value	0.026	0.029	0.025		0.028
Number of years reported using a carbon price in CDP filings				-0.0079	
t-statistic				-1.12	
p-value				0.265	
Number of carbon emission reduction activities other than carbon pricing that a firm reported doing to CDP (See Appendix A)		0.0003		-0.0006	-0.0026
t-statistic		0.06		-0.10	-0.05
p-value		0.956		0.922	0.964
Country has a national carbon tax dummy(1= yes)					0.0159
t-statistic					0.50
p-value					0.619
Employee Engagement dummy			0.035		
t-statistic			0.90		
p-value			0.371		
Dedicated Budget for various types of activities dummy			0.0103		
t-statistic			0.33		
p-value			0.739		
Intercept	0.0168	0.016	-0.008	0.015	0.011
t-statistic	0.87	0.79	-0.04	0.58	0.48
p-value	0.5389	0.433	0.970	0.561	0.631
Number of observations	78	78	78	78	78
F-Statistic	5.15	2.54	1.99	0.65	1.86
F-Statistic p-value	0.026	0.0854	0.1232	0.5346	0.1438
R-squared	0.0627	0.0628	0.0797	0.0111	0.0658

Appendix A

Carbon emission reduction activities reported to the CDP. This is item 3.3c on the 2017 CDP investor public database, which asks: What methods do you use to drive investment in emissions reduction activities? – Method.

1. Compliance with regulatory requirements/standards
2. Dedicated budget for energy efficiency
3. Dedicated budget for low carbon product R&D
4. Dedicated budget for other emissions reduction activities
5. Employee engagement
6. Financial optimization calculations
7. Internal finance mechanisms
8. Internal incentives/recognition programs
9. Internal price on carbon
10. Lower return on investment (ROI) specification
11. Marginal abatement cost curve
12. Partnering with governments on technology development
13. Other