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Carbon Costs and Credit Risk in a Resource-Based Economy: Carbon Cost Impact on the Z-Score of Canadian TSX 260 Companies

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Abstract

Climate risks and climate risk-related policies on carbon threaten the ability of economies to thrive and will impact the credit risk of many sectors, primarily high-emitting sectors. Higher credit risks will also affect lenders if their credit portfolios are exposed to climate change risks. The introduction of carbon pricing policies will exacerbate this threat in resource-based economies such as Canada. While some research exists on climate exposure and risks to lending portfolios, there is a knowledge gap on how carbon pricing impacts individual commercial credit risk. Consequently, this study analyzes the effect of different carbon pricing scenarios on Altman's z-score. Using the Canadian TSX 260 data between 2010 and 2020 as a sample, this paper applied the costs of different carbon prices using the Canadian Government's carbon price regime of $0 to $170 to analyze Altman's z-score variables until 2030. The results suggest that carbon price will significantly impact the credit risk of companies in high-emitting industries, such as the energy sector. We conclude that climate policy exposure in the form of carbon costs will have a real impact on credit risk and that lenders must consider carbon emissions as part of their credit risk assessment.

Keywords: climate risk, carbon pricing, climate risk policies, climate regulations, climate scenarios, climate risk impact, financial stability

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) (IPCC 6th Assessment Report) reinforced that human-induced climate change is causing rapid and irreversible change to our planet (IPCC, 2021). Countries and supranational unions, such as the European Union, respond to this threat through market-based instruments such as carbon taxes (Stavins, 2022). By putting a price on and increasing the cost of carbon, governments aim to curtail Greenhouse Gas (GHG) emissions (Trinks, Mulder, & Scholtens, 2022).

This paper analyzes how carbon price affect different economic sectors in a resource-based economy. With a specific focus on Canada but applicable to similar high carbon-dependent economies, we explored how the introduction of cost on carbon, such as carbon pricing, will impact carbon-intensive sectors that are significant contributors to the Gross Domestic Product (GDP) in such economies, and how this may expose the financial institutions that fund those sectors to increased costs and even bad debts. This is important as the full impact of regulatory climate transition risks, such as the introduction of carbon taxes on commercial credit risks, is not fully known, hence making it hard to predict how carbon control policies may play out in countries where essential sectors of the economy and substantial parts of the GDP comes from carbon-intensive sectors (Mukhtarov, 2022). For example, Canada's economy is strongly connected to carbon-intensive sectors such as mining and energy (Elder, 2021). These two sectors collectively contribute over 16% to the Canadian economy as of January 2023 (Statistics Canada, 2023). The percentage of carbon intensive secotor's contribution to the economy increases significantly when other sectors with significant carbon intensity, e.g., manufacturing and transportation, are added to the mix.

Research has shown that there is a direct correlation between climate transition efforts like carbon pricing regulations and systemic risk (Li, Wang, & Liu, 2022), which may negatively affect the financial industry's profitability and financial stability if not well managed (Weber & Oyegunle, 2019), though carbon pricing remains the most effective way to reduce carbon emissions (Baranzini et al., 2017). Considering this, our analysis of carbon price impact on commercial credit risk in a resource-based economy such as Canada will contribute to the academic knowledge in sustainable finance by addressing how such economies could react to carbon emissions pricing.

Our study differs from other studies conducted in this area because it addresses individual credit risks instead of analyzing the effect of climate exposure on lending and investment portfolios. For example, some studies investigated the impact of climate change exposure on the lending and investment portfolios of leading global banks and found that higher carbon exposure leads to higher financial risks (Battiston, Monasterolo, Riahi, & van Ruijven, 2021; Monasterolo, Battiston, Janetos, & Zheng, 2017). Other studies found that taking sustainability criteria, such as climate change, into account helps to identify and reduce commercial credit risks (Cui et al., 2018; Goss & Roberts, 2011; Mengze & Wei, 2015; Weber et al., 2015; Weber et al., 2010) while more recent studies found evidence that carbon price impacts the credit risk of companies (Bouchet & Le Guenedal, 2020; Capasso, Gianfrate, & Spinelli, 2020). However, these studies used financial income and balance sheet indicators or Merton's distance to default model (Merton, 1974) to model credit risk.

We addressed a gap in the literature by analyzing the influence of different carbon pricing scenarios on different sectors in a resource-based economy such as Canada using Altman's z-score (Altman, 1968) and to understand if introducing carbon price without proper regulatory rail guards could contribute to insolvency risk in high emitting sectors. Empirical studies demonstrated that the model is valid for manufacturing and non-manufacturing companies and publicly traded companies (Altman, 2018). Consequently, our research asks two questions:

(1) Do different carbon prices influence the credit risk score of Canadian companies, and

(2) is the credit score of different sectors affected differently by a carbon price.

Theoretically, the study is based on credit risk scoring and Altman's z-score model (Altman, 1968; Altman & Saunders, 1998) for publicly listed firms since our sample is based on TSX 260 firms, constituting the Canadian stock index. We applied the Canadian Government Climate Plan carbon tax policy plan to determine the different carbon price scenarios between \$0 to \$170 per tonne by 2030 (Environment and Climate Change Canada, 2020).

We used ANOVA to analyze differences between carbon prices and between industries. To analyze the latter, we used ANOVA for a difference-in-differences approach (Conley & Taber, 2011) that compared the differences between carbon-intensive and less carbon-intensive sectors' results with and without a carbon price. Our results suggest that carbon price influences credit default risks. We found that the carbon price mainly affects the default risk of high-emitting industries, such as energy and materials, that are important for the economy of resource-based countries such as Canada.

We contribute to the literature by showing the impact of different carbon pricing scenarios on Altman's z score, a widely used credit risk indicator that tests the likelihood of insolvency for publicly traded companies. Hence, we conclude that commercial lenders should assess carbon emission indicators and emission reduction strategies. Though carbon pricing probably does not lead to a significant credit risk increase overall, some industries could be affected more than others. Consequently, climate-exposed lending portfolios might be at risk.

The remainder of the paper includes a background section that discusses the theoretical approach and the methods followed by the study outcome. The paper concludes with a discussion of the results and conclusions.

2. Background

There is ample evidence that countries are struggling with meeting their Nationally Determined Contributions (NDCs) targets (Den Elzen et al., 2019) set as part of the 2015 Paris Agreement (UNFCCC, 2015). Based on the current emission trajectory, existing and new national climate pledges will lead to a 2.7°C temperature rise by the end of the 21st century instead of the targeted temperature increase of below 2°C (United Nations Environment Programme, 2021). This increase also extends beyond the United Nations's 1.5°C target increase above pre-industrial emission levels (Lawrence et al., 2018; Mahapatra & Ratha, 2017). To address this issue, there have been calls to halve annual GHG emissions by 2030 in line with the Paris Target to enhance the chances of fighting climate change (United Nations Environment Programme, 2021). Part of the response to this is exemplified by growing regulatory efforts (e.g., carbon tax regimes) targeted at addressing climate risks to the economy, with some of the likely impacts being the crux of this paper.

The connection between climate change and the financial industry is twofold. On one side, financial institutions finance activities that support climate change mitigation and adaptation, such as green energy. On the other hand, they finance activities that worsen climate change, such as fossil fuel projects (Furrer, Hamprecht, & Hoffmann, 2012). Unfortunately, the activities of the latter may lead to increased systemic risks for the financial industry, especially if it is exposed to significant sectorial or regional risks (Li et al., 2022). These risks could influence not only the financial risks of commercial borrowers, but also the stability of the financial sector (Alguindigue Ruiz & Weber, 2021).

Accomplishing these reduction goals needs a deliberate move towards a low-carbon economy at the regulatory level. This will directly impact the financial system and the economy (Monasterolo & De Angelis, 2019) since managing climate risk requires using various regulatory and other climate transition instruments such as macroprudential and monetary regulations targeted at enhancing the financial system's stability (Ojea Ferreiro, Reboredo, & Ugolini, 2022). This transition effort comes in the form of policy change (as exemplified by governmental carbon pricing) and technological or market changes. Policymakers in many jurisdictions have also used carbon pricing to address climate challenges (Harvey, Orvis, & Rissman, 2018). Though some researchers have argued that carbon pricing alone is insufficient to help curtail climate change (Rosenbloom et al., 2020), others have stated its effectiveness and ability to enhance innovation using a market-based approach (Baranzini et al., 2017). Regardless of whether placing a price on carbon is enough to fight climate change, it is still considered one of the most effective measures that regulators can employ to drive the transition to a low-carbon economy (Campiglio, 2016).

Carbon pricing is based on the assumption that climate change risks thrive because of markets' inability to adequately account for GHG emissions (Dafermos, 2021) and putting a cost on carbon is the most efficient way to reduce emissions (Beale et al., 2015). However, pricing carbon primarily impacts high-emitting companies and sectors. This might lead to unintended consequences, such as unexpected asset revaluation, debt default, and uncontrolled carbon bubbles across evolving industries (Semieniuk et al., 2021). The effect of carbon pricing will not only influence high carbon-emitting sectors, which may accelerate green investment, but it could put current bank loans and financial commitments to high-emitting sectors at risk (Dafermos et al., 2018). These risks may lead to extensive economic impacts, particularly in countries with a high ratio of resource-based industries. Managing these risks becomes critical as the financial sector strives to achieve net-zero portfolios (Robins et al., 2021). This will have direct implications for the loan exposures of banks and consequently asks for pricing climate-related credit risks of borrowers (Ehlers et al., 2021). This paper seeks to identify how carbon pricing will impact specific industries and what this means for credit risk in resource-based economies. Though some studies analyzed the impact of carbon taxes (Campiglio, 2016; Li et al., 2022; Zhang, Qi, Lin, Pan, & Sharp, 2022), there is a gap in the literature that addresses how different carbon prices may play out for different sectors, especially in economies where carbon-intensive sectors are critical. Our paper also addresses the indirect impact of climate risks, such as carbon pricing, from a theoretical perspective. We consider the credit risk that borrowers and lenders might face due to increasing price points of carbon in the transition to a low-carbon economy (Benedetti et al., 2021).

3. Canadian Banks and Cost of Carbon

Canada manages its climate change through two separate approaches. The first is a Federal-led national carbon pricing policy that sets a minimum price on carbon emissions nationwide. The second involves respective provincial climate change carbon policies that supplement the federal rule using various approaches such as cap-and-trade and carbon intensity reduction systems. This paper is based on the Federal Climate Emission Reduction Plan (Government of Canada, 2022), which addresses the legislated carbon pricing cost until 2030. Through this legislation, the Canadian government has adopted a carbon price policy that will yearly increase the price of carbon emissions up to CAD 170 per tonne of CO_2e by the Year 2030 (Environment and Climate Change Canada, 2020). This legislation represents a 467 per cent increase in cost for a tonne of CO_2e emissions for its duration, intending to add $15 each year to the cost of carbon. This paper investigates the implication of this and other similar policies and how they could increase the risk of default for commercial loans to high carbon-emitting industries.

Understanding the impact of carbon pricing is even more critical considering that the cost of carbon is expected to rise until at least the Year 2050 to help Canada meet its Net Zero target (Government of Canada, 2021). However, not much has changed in the financial sector's approach to lending to the most carbon-intensive sectors despite the enormous influence lenders and investors have on the carbon transition process (Dordi, Gehricke, Naef, & Weber, 2022). Research has shown that increased carbon disclosure aids operational efficiency and helps reduce the cost of debt (Wang et al., 2023). Also, financial institutions' climate disclosure has improved due to renewed commitments by banks, including the major Canadian chartered banks, to become net zero by 2050. Overall, it is unclear how banks intend to achieve their carbon emission reduction goal considering their current loan allocation, climate exposure to high emitting sectors and continued exposure of Canadian financial institutions to fossil fuel investments and lending (Carter & Dordi, 2021).

Canadian banks are deeply involved in lending to carbon-intensive clients, with increased lending since 2016 (Rainforest Action Network, 2019) despite their public commitments to support global climate goals. Unfortunately, this is not too different from the global reality. For example, between 2015 when the Paris Agreement was signed and 2022, the world's top 60 largest banks have provided fossil fuel companies with over $5.5 trillion in finance for investment in carbon-intensive fossil fuel projects, with Canadian banks providing $862 billion of that amount (Rainforest Action Network, 2023). Canadian chartered banks also dominated new investments in Canada's oil sands crude oil projects, with multiple years of commitment in some cases (Rainforest Action Network, 2023; Rijk, Van, Kaynar, Loenen, & Warmerdam, 2021). In view of these new investments in carbon and increasing carbon cost, an important question is how these exposures would increase Canadian banks' (and other global creditors') credit risks considering the introduction of a carbon price regime by the government.

To put this in perspective, between 2014 and 2020, lending to the fossil fuel industry increased by over 50% among Canadian chartered banks, with one of them increasing its exposure by as high as 160 per cent (Rijk et al., 2021). The banks also increased their investment in oil shares and continued underwriting fossil fuel stocks and bond issuances (Gutstein, 2021). Since COP 21, Canadian chartered banks have been some of the most prominent financiers of the fossil fuel industry globally. Reports show that three of the top five banks in the country are among the top 10 fossil fuel financiers globally in 2022 (Rainforest Action Network, 2023). As of 2021, Canadian chartered banks have collectively provided the coal and oil and gas industry with a combined value of over $694 billion in loans and underwriting services (Kirsch et al., 2021; Rijk et al., 2021). The implication of this increased carbon exposure could directly or indirectly affect the loan portfolio of banks as the cost of emitting carbon increases.

Also, Canadian banks continued exposure and investment in the fossil fuel industry contrast with the Bank of Canada's (BoC) classification of climate change as a critical risk to the economy and the stability of the Canadian financial system (Ens & Johnston, 2020). This poses a challenge as the Canadian economy is unique. The top six carbon-emitting industries contribute over 55 per cent of the economy's total emissions and more than 30 per cent of Canada's GDP (see Figure 1). A review of the five Canadian chartered banks' loans and acceptances for the 2022 full year reveals that their respective exposure to high carbon-intensive sectors ranges from 14% to over 44%. This makes them highly vulnerable to regulatory imposed carbon prices on these sectors, considering that a carbon price increase may significantly affect the performance of these loans, which could increase climate transition risk for the banks.

This paper assesses how carbon pricing affects the credit risk of commercial loans in different industries using the Canadian government carbon price regime, as adopted by the BoC (Ens & Johnston, 2020; Environment and Climate Change Canada, 2020). We explore how the price increase will impact commercial credit. We posit that introducing carbon price may have consequences for banks since it may lead to increased default rates and reduced liquidity for carbon-intensive firms (Dafermos et al., 2018). Our analysis is also applicable to banks in similar resource-based countries, which may face stiffer impacts in this regard, especially if the composition of their loan books is skewed to carbon-intensive sectors.

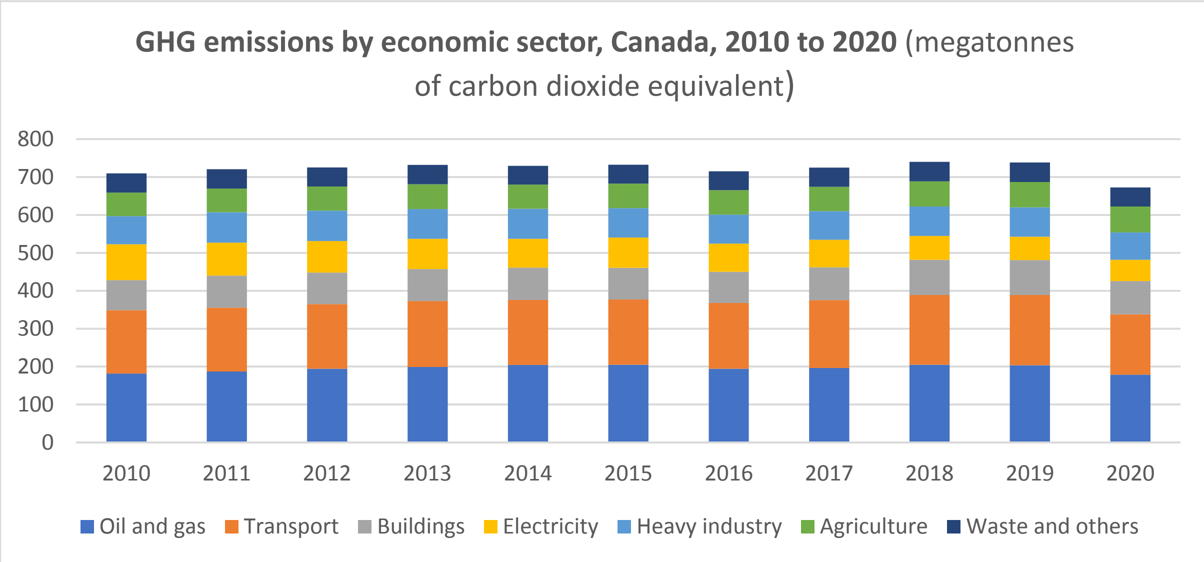

Figure 1. Canada's emission by sector adapted from environment Canada, 2023

4. Carbon Price Challenge for Resource-Based Economies

There is a growing body of work on the relationship between the economy and energy production in carbon-dependent countries and how climate mitigation efforts impact carbon-intensive sectors like oil and gas (Ike, Usman, & Sarkodie, 2020). This is important as studies have shown that climate transition efforts like the introduction of a carbon tax by major oil-producing countries like Norway and Canada have had little effect on oil production, but contributed to increased costs for consumers (Kopytin, Maslennikov, Sinitsyn, Zhukov, & Zolina, 2020). Studies have also shown that a carbon tax has material implications for the share price of publicly quoted companies (Bimha & Nhamo, 2017). The combination of these two factors and the fact that there is a direct relationship between economic growth and activities in the carbon-intensive natural resource sector (Bekun, Alola, & Sarkodie, 2019) places banks exposed to these sectors at risk due to their importance to resource-based economies.

Also, market-based carbon pricing and Emission Trading Systems (ETS) may be unsuccessful in transition economies and resource-dependent countries (Mukhtarov, 2022). Unlike what is obtainable in some parts of Europe where such measures are more established (Warwick & Ng, 2012), transition economies may struggle with adopting carbon prices due to issues of infrastructure, economic maturity and inadequate disclosure framework (Zheng, Zhou, & Wen, 2021; Zhou, Zhou, Peng, Chen, & Li, 2018). There is also a genuine concern over how carbon pricing will affect global competitiveness, especially for developing countries, and the price impact of the move on trade and the economy at large (Mukhtarov, 2022; Pradhan, Ghosh, Yao, & Liang, 2017) all of which could have an indirect impact on lending cost thereby increasing credit risk (Bouchet & Le Guenedal, 2020) for the financial institutions operating in those sectors.

4.1 The Intersection of Climate Risk and Credit Risk

Several studies have been conducted to analyze the connection between environmental risks, such as climate change, and credit risk. Studies on environment-related credit risk suggest that integrating sustainability criteria, like carbon price decrease the default risk of commercial loans (Goss & Roberts, 2011; Weber et al., 2010). This is important considering that these risks should increase credit interest for high-emitting borrowers (Goss & Roberts, 2011), as well as reduce interest for low-emitters (Zeidan et al., 2015). Hence, there is an increasing credit spread between low and high environmentally conscious borrowers (Bae et al., 2017).

Concerning climate-related credit risk, Kabir et al. (2021) found that high-emitting companies have higher credit risks using Merton's difference-to-default approach (Merton, 1974). This study, however, did not consider a carbon price. In the European context, a study found that green portfolios have lower credit risks because of carbon-neutral obligors' low cash flow volatility (Umar et al., 2021) and because financial markets integrate carbon risks into their credit risk assessment (Caragnano et al., 2020). This study used the costs of carbon emissions but did not use a credit risk model. A US study found similar results and emphasized the effect of carbon-intensive borrowers on credit risk (Safiullah et al., 2021). A study in India suggests similar findings

(Kumar & Firoz, 2018). However, Jung et al. (2016) found that carbon awareness plays a significant role in helping to mitigate carbon-related risk and credit pricing. In line with Palea and Drogo (2020), they state that even high emitters aware of their emissions have to pay lower interest rates than others who are not transparent about their emissions.

We summarize that higher carbon emissions are associated with higher credit risk. However, since this is a fast-evolving field, no known studies use a carbon price and apply it to a credit risk assessment model, especially to consider sectoral peculiarity. Consequently, this study addresses this gap in the literature.

Hence, the main objective of this research is to understand the impact of carbon pricing on commercial credit risk. To address this objective, we ask two questions:

(1) Do different carbon prices influence the credit risk score of Canadian companies, and

(2) is the credit score of different sectors affected differently by climate pricing.

4.2 Theoretical Framework and Methods

We used Altman's z-score model as our theoretical framework. Altman's z-score indicates credit default risk (Altman, 1968; Altman & Saunders, 1998) and its relation to credit risk management (Caouette et al., 1998). Companies with values below 1.8 are considered in distress. The area between 1.8 and 3.0 is considered grey, and z-scores above 3.0 are considered safe. We used the standard version of the z-score because all companies in the sample are publicly traded. The z-score for non-industrial companies (z") is usually only applied if these companies are private. Furthermore, analyses demonstrated a high accuracy of the z score for mining companies (Altman, 2018). These companies are overrepresented in our Canadian sample. Moreover, studies suggest that mixing manufacturing and non-manufacturing firms in one sample does not change the results significantly (Altman et al., 1977). However, we calculated the correlation between the z and z "for non-industrial companies to understand whether using z" might make a difference. The correlation between both scores is $r = .98$ ($p < .0001$). The result demonstrates that there is no difference in using z" instead of z (see Figure 2).

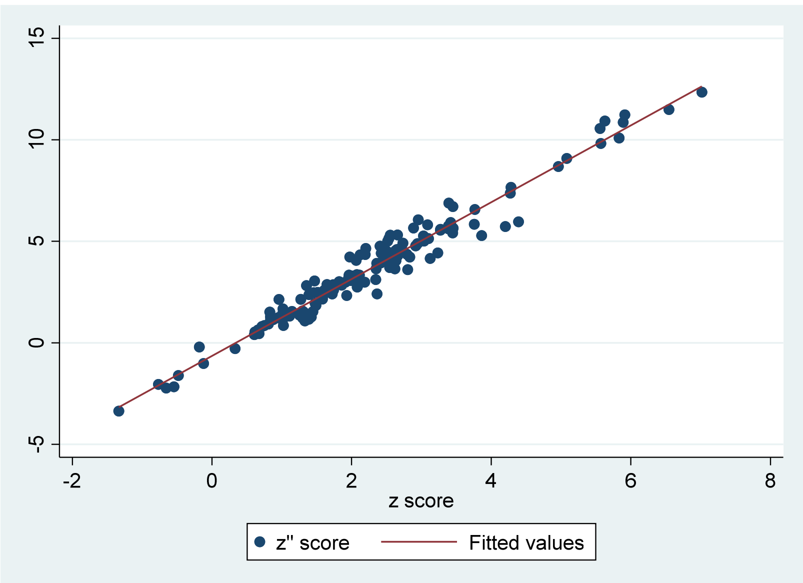

Figure 2. Correlation between z score and z" score

We used Altman's z-score model with the financial indicators and weights presented in Equation 1:

Equation 1. Altman's z-score

$$Z = 1.2A + 1.4B + 3.3C + 0.6D + 1.0E \quad (1)$$

Where:

- Z represents Altman's Z-score.
- A represents the Working Capital/Total Assets ratio.

- B represents Retained Earnings/Total Assets ratio.
- C represents Earnings Before Interest and Tax/Total Assets ratio.
- D represents the Market Value of the Equity/Total Liabilities ratio.
- E represents the Total Sales/Total Assets ratio.

Values above 3.0 are considered safe, the area between 1.8 and 3.0 is considered grey, and borrowers with values below 1.8 are considered in distress.

To assess the influence of carbon prices on the z-score, we employed different carbon prices that align with the 2°C consistent carbon price projection used by the Bank of Canada scenarios (Ens & Johnston, 2020). As described above, the different scenarios are based on the carbon price, \$30, \$50, \$100, \$150, and \$170 per metric tonne of CO_2e.

We gathered the financial data for companies listed on the Canadian Toronto Stock Exchange (TSX) from Wharton Research Data Services (WRDS). The data for the total carbon emissions were also gathered from Refinitiv ESG hosted by WRDS. Using the historical emission data from publicly quoted companies, we calculated how the increase in carbon price impacts commercial borrowers and, consequently, a sector's credit default probability.

We calculated the z-score with and without carbon pricing based on the functions presented in Equation 1 and the financial indicators. The carbon costs were calculated by multiplying the carbon price per tonne of CO_2e with the total carbon emissions. Then we subtracted the value from the Earnings Before Interest and Tax (EBIT) and the Retained Earnings. This change leads to a decrease in the z-score and, consequently, to an increase in default risk.

We only used the data for firms with a z-score and emissions data for the same year between 2010 and 2020. Furthermore, we removed the financial sector because they use different financial indicators that do not fit the z-score model. The sample consists of 19 companies in 2020 and 2021, 20 companies per year between 2010 and 2014 and in 2019, 21 between 2015 and 2017, 22 in 2018, and eight companies for 2022.

To analyze the consequences of different emissions-cost scenarios, we used analyses of variance (ANOVA) with sectors and the year as factors and t-tests for the differences in the z-scores overall between industries and the difference in differences (the difference between a no-cost scenario and a carbon cost scenario between different sectors). Furthermore, we applied ANOVA for the difference in differences analysis. Using GICSectors, we could categorize the respective companies into individual sectors. The sector distributions are presented in Table 1. Hence, the sector distribution is typical for a resource and heavy energy industry, such as Canada and other countries that rely on high carbon-emitting industries.

Table 1. Sector distribution

GIC Sector	N	Total assets (\$million)	Total debt (\$million)	Manufacturing
Energy	49	2190778	570131	0
Materials	48	271595	48991	0
Industrials	12	295119	77332	0
Consumer discretionary	17	145707	15703	23
Information technologies	14	77264	18070	10
Communication services	10	480961	172704	0
Utilities	5	128098	52709	0

5. Results

The distribution of the z-score categorized by sector is presented in Figure 3. Overall, 25.5 per cent of the sample is in the distress zone below 1.8. However, an ANOVA with the year and the sector as factors and the z-score as the dependent variable resulted in a significant difference between the industries regarding their z-score (ANOVA: df = 71, F = 3.40, p < .0001). The year did not have a significant effect, and there is no significant interaction between the year and the sectors. Consumer discretionary has a significantly higher z-score than the other sectors, according to a post hoc Scheffe test.

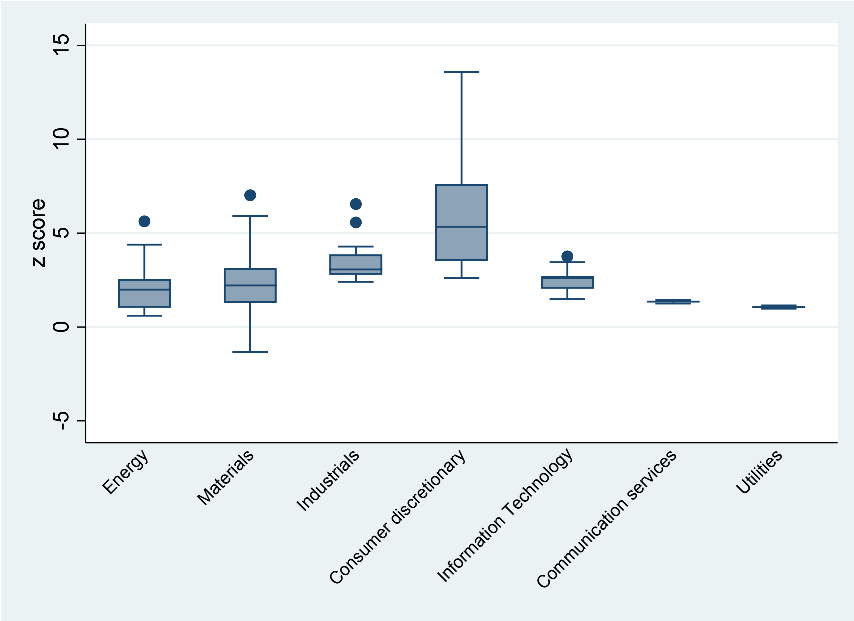

Figure 3. Box plots for the z-score without carbon price per sector

The average emission costs of $ million for the different pricing scenarios are distributed as presented in Table 2. Energy, Industrials, and Materials sectors have the highest carbon emissions and must bear the highest costs if GHG emissions are priced.

Table 2. Average carbon costs under the different cost scenarios per sector in $million

Sector	$30	$50	$100	$150	$170
Energy	318.00	530.00	1060.00	1590.00	1800.00
Materials	38.10	63.50	127.00	190.00	216.00
Industrials	121.00	202.00	404.00	607.00	687.00
Consumer discretionary	24.30	40.40	80.90	121.00	137.00
Information technology	3.64	6.07	12.10	18.20	20.70
Communication services	9.20	15.30	30.70	46.00	52.20
Utilities	10.00	16.70	33.40	50.10	56.80
Total	121.00	201.00	402.00	603.00	683.00

Next, the influence of carbon costs on the z-score was calculated. Figure 4 presents the difference between the z-score, including the carbon costs, and the z-score without carbon costs for the different sectors. The highest differences can be found in energy and materials, which already have relatively low z-scores compared to lower-emitting industries. The difference in the z score between all pricing scenarios, including a carbon price of $0, is significant (Hotelling test: $T = 112.54$, $p < .0001$).

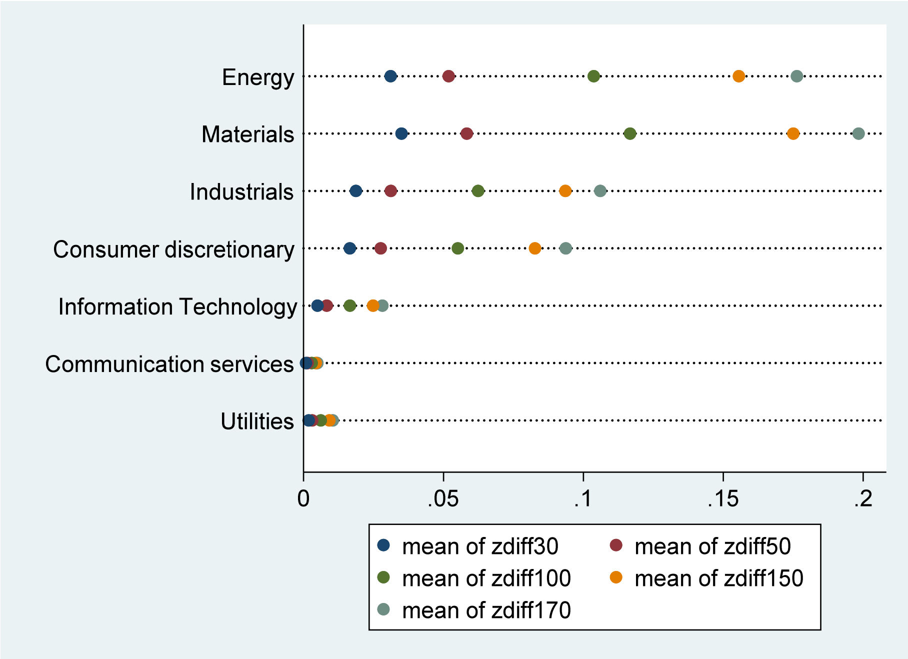

Figure 4. Difference in z-scores under different carbon price scenarios

On average, the z-score decreases by .024 for the $30 scenario and by .14 under a $170 scenario. Furthermore, the biggest change is for Materials with 0.20 and Energy with 0.18 for the $170 scenario. Hence, the difference in the highest emitting industry is 0.06 or 42 per cent higher than the average change induced by carbon pricing. The z-scores for materials and energy are already some of the lowest without carbon costs (see Table 3), so a carbon price can put high-emitting sectors in distress.

Table 3 demonstrates that the carbon price adjusted z score of firms from the Energy sector decreases to below 2.0, which is near the distress threshold. The low z score for utilities that are already in the distress zone decreases even more.

Table 3. Z-scores by sector for different pricing scenarios (no pricing, $30, $50, $100, $150, $170)

Sector	z score	z score $30	z score $50	z score $100	z score $150	z score $170
Energy	2.027	1.996	1.975	1.924	1.872	1.851
Materials	2.278	2.243	2.220	2.162	2.103	2.080
Industrials	3.567	3.548	3.536	3.504	3.473	3.461
Consumer discretionary	6.199	6.181	6.170	6.141	6.112	6.100
Information technology	2.521	2.515	2.512	2.503	2.494	2.491
Communication services	1.354	1.353	1.352	1.351	1.350	1.349
Utilities	1.068	1.066	1.065	1.062	1.059	1.057
Total	2.636	2.612	2.595	2.555	2.514	2.497

Consequently, we conducted a difference-in-differences analysis using ANOVA with the sector and the year as independent factors and the z score difference between the z score without carbon costs and the z score with a carbon cost of $30 per tonne CO_2e. The result of the model is significant ($p < .030$, df = 17, F = 1.81, $r^2 = .16$). On the factors, the sector is significant ($p < .0001$, df = 6, F = 4.89). The year is also not significant ($p < .9999$, df = 11, F = .10). The results show that the differences in z scores between sectors are different as presented in Figure 4.

6. Discussion

We analyzed the impact of different carbon pricing scenarios on the z-score of various industries in an economy that is highly exposed to carbon-emitting sectors. Our results showed a significant decrease in the z-score value of Canadian companies if a carbon price is introduced. Furthermore, the reduction is higher in high-emitting industries like materials and energy. This means that the default risk of banks' lending portfolios with considerable exposure to high-emitting industries increases under different carbon pricing scenarios. This is concerning, given that high-emitting industries already have lower z-scores than the average score of other sectors. It also underscores that carbon pricing would have different impacts on different industries, like studies on the environmental effects on various industries' financial performance (Semenova & Hassel, 2016). Consequently, there is a risk that specific sectors will find themselves in Altman's distress zone below 1.8, indicating a high risk of default. Thus, banks will need higher allowances for potential credit default.

In general, this study suggests that portfolios of banks in countries with high emitting industry exposure are exposed to higher financial risks than banks in economies based on lower emitting industries if carbon pricing is implemented since they are often more exposed to the high-emitting industries. This is prevalent in economies where such sectors are critically linked to other carbon-dependent sectors. Safiullah et al. (2021) and Kumar and Firoz (2018) found similar results for the United States and India respectively, in both instances, they concluded that there are higher risks for high-emitting sectors.

Regarding our research questions, the results suggest that carbon pricing influences Canadian companies' credit scores. Also, the analysis shows that carbon pricing affects different sectors differently. Hence, our study aligns with other studies that show the impact of environmental and sustainability criteria on credit risk.

Several studies have been conducted to analyze the connection between societal, environmental, and sustainability risks, such as climate change and credit risk. However, in contrast to studies by Goss and Roberts (2011) and Weber et al. (2010), we used different carbon prices and carbon emissions as our independent variables. Consequently, we could demonstrate the impact of carbon emissions based on financial indicators and not on the financial market or analysts' valuations.

Hence, carbon emissions and carbon price scenarios should be part of the credit risk assessment procedure because this study and others found an increase in credit risk for sustainability laggards (Bae et al., 2017; Zeidan et al., 2015). Our study, however, added the effect of carbon pricing to the analysis in contrast to studies that did not consider a carbon price but only GHG emissions (Kabir et al., 2021). High emissions that are not priced might not have a financial impact and might not influence credit risk. This might be the reason why many studies in Europe that have implemented carbon pricing find a connection between high carbon emissions and credit risk (Caragnano et al., 2020; Umar et al., 2021).

Furthermore, our study addresses a theoretical approach to credit risk using Altman's z-score (Altman, 1968). Hence, it is independent of real credit pricing, which might be biased. We conclude that whether lenders and financial markets consider GHG emissions and a climate price or not, there is a financial risk for high emitters due to increasing legislation on carbon price.

7. Conclusion

This paper addresses an important gap in carbon cost and credit risk research. By analyzing the impact of carbon cost on credit, this study provides insights into how carbon pricing policies affect credit risk. Of particular interest is the role of evolving climate regulations on carbon transition efforts and the need to develop necessary policy strategy for regulators and approach for lenders that will help drive a seamless transition to a low-carbon economy with minimal disruption to credit. Based on our results, we propose that lenders should start or continue to consider a real and a shadow carbon price that reflects pricing scenarios in their credit risk assessments. Perhaps, implementing an internal carbon price on credit will be a good starting point for financial institutions climate mitigation efforts against transition climate risk like government-imposed carbon tax impact that this study addresses. This will enable them to analyze carbon-related credit risks appropriately and set the appropriate interest rate. A consequence might be that high-emitting borrowers would have to pay higher interest.

Central Banks and other financial sector supervisors should also start introducing indicators that measure the financial sector's exposure to climate-related credit risks. Since introducing a carbon price is very likely in many countries, these risks might affect the financial industry. Consequently, supervisors and regulators should use carbon pricing scenarios proposed by Task Force on Climate-related Financial Disclosures (2017) to analyze portfolio climate risks (Nguyen et al., 2020). Finally, there is a need to improve GHG emissions reporting and disclosure as this will help the quality of data. A weakness of this study is missing data, as some firms do not even disclose their Scope 1 emissions. This issue is exacerbated when data for Scope 2 and Scope 3 emissions is considered. Though Downie and Stubbs (2013) discussed this problem in 2013, this challenge persists a decade later as the data for Scope 2 and 3 emissions are still largely unavailable and unreliable.

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