Climate Risk in the American Financial System: a Bottom-Up Approach

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Abstract

Climate change will inevitably lead some companies to default on their debt, putting stress on banks and financial institutions. To ensure financial stability, financial institutions must prepare for climate risk appropriately. Although the first step to mitigating climate risk is quantifying that risk, researchers have not come to a consensus on the magnitude of climate-related credit risk. This thesis builds on prior research by taking a bottom-up approach to modeling climate risk in the American financial system. I find that risk is concentrated in certain companies, industries, regions, and financial institutions. Although these findings do not provide evidence that there is systematic climate risk in the American financial system, they do indicate that certain parts of the financial system are vulnerable and warrant regulation.

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Introduction

Climate change poses a severe threat to ecosystems, cities, and economies. Climate change poses two types of generic risk to corporations and the broader economy: physical risks and transition risks. Physical risk includes the direct impact of climate change on ecosystems and environments, whereas transition risk is risk to corporations or the broader economy that is created by humans' attempts to mitigate physical risks.

Since financial institutions do not have expansive physical operations and do not emit large quantities of greenhouse gases, they are primarily exposed to climate risk through their lending portfolios. If climate change is severe enough to cause companies to default on their loans, financial institutions will face losses.

If the companies to which financial institutions lend mitigate climate risk at the corporate level, they will not default on their loans. Unfortunately, although researchers project that the cost of climate change will be in the trillions of dollars, companies have only been planning for losses in the billions of dollars (Goldstein et al., 2018). Since companies are not sufficiently accounting for climate risk, financial institutions are exposed to climate risk through their lending portfolios.

Financial institutions also may not be sufficiently accounting for the climate risk that they are facing. The current supervisory framework, the Comprehensive Capital Analysis and Review (CCAR), is a scenario analysis that test financial institutions' abilities to withstand a distressed economy. Although CCAR ensures financial institutions can withstand generic stress, it does not address climate risk specifically. Financial institutions do not seem to factoring climate risk into their investment decisions on their own volition (Bolton & Kacperczyk, 2020). Therefore, financial institutions may face serious risk from climate change, meaning that climate change may create financial instability in the United States.

Researchers have attempted to quantify the risk that climate change poses to financial institutions globally employing both top-down and bottom-up approaches. Both top-down and bottom-up approaches start by modelling the real-world situations (e.g., climate mitigation goals and resulting government regulations). Top-down approaches then map those climate scenarios onto macroeconomic variables such as labor productivity or interest rates and predict macroeconomic performance. Macroeconomic performance is then distributed to individual firms and used to calculate marginal probabilities of default due to climate change. In contrast, bottom-up approaches distribute the impacts of real-world climate scenarios on businesses directly before calculating marginal probabilities of default. However, researchers have only applied a bottom-up approach to measuring the impacts of a carbon tax in Europe, and not the United States.

Methodology

My theoretical methodology consisted of three steps: predicting borrowers' exposures to transition risk in the form of a carbon tax, modeling a company's marginal probability of default due to that liability, and aggregating borrowers' probabilities of default at the industry and financial institution levels. I treated the assessed carbon tax as a liability on a company level in calculations of probability of default. I multiplied marginal probability of default (the increase in probability of default due to the carbon tax) by the loans quantum and a recovery rate to calculate financial institutions' loan losses and scale those numbers to match the size of capital markets.

Since carbon taxes depend directly on greenhouse gas (GHG) emissions, to calculate a borrower's exposure to transition risk from a carbon tax, I modelled the borrower's yearly GHG emissions. Because companies are not required to disclose their GHG emissions, I used incomplete self-reported data from the Carbon Disclosure Project (CDP) to project emissions. If the CDP dataset contained the borrower, I used the borrower's average reported emissions between 2008 and 2019 (for all years that there were data). Approximately 19.5% of borrowers were included in at least one CDP report. For the rest of the companies in the sample, I predicted carbon emissions using company characteristics such as their industry classifications

To calculate tax liabilities, I multiplied portfolio companies' taxable emissions by a hypothetical carbon tax. I chose to analyze the impact of a range of carbon taxes from $5/ton CO_2e to $150/ton CO_2e because the range of values that scientists and policy experts are predicting is large, and providing a range allows governments to assess the impact of different levels of taxation on financial stability or of a carbon tax in addition to other transition risks. I selected the specific range of carbon taxes to consider based on research on carbon pricing.

To calculate borrowers' marginal probabilities of default from a carbon tax, I calculated the probability of default using Merton's model (1974), before and after a carbon tax. Merton's model for probability of default treats a company's capital structure as a European call option (an option to buy an equity at a specified price on a specified date) and uses the Black-Scholes equation to find the probability that a company enters default. At its core, Merton's model (1974) assumes that a company is in default when the value of its liabilities exceeds the value of its assets. This assumption, (along with the assumptions that the equity does not pay dividends, assets grow at the risk-free rate, and there is no coupon on the debt) allows one to value a company's equity as a European call option where the value of the borrower's assets is analogous to the price of the option's underlying equity. Similarly, the value of the borrower's liabilities is analogous to the strike price. Just as the value of the option on the date it expires equals the difference between the value of the underlying equity and the strike price (or zero, if greater), the value of a company's equity equals the difference between the value of the company's assets and its liabilities (but no less than zero). Plugging liabilities into strike price, asset volatility into equity volatility, and equity value into option value in the Black-Scholes equations yields Formulas 1 through 3 where A is the asset value, L represents company liabilities, r is the risk-free rate, t is the time period, σ_A=Asset Volatility, and $N(x)$ is the cumulative normal distribution of x.

$$d1 = \ln\left(\frac{A}{L}\right) + \frac{r + \frac{\sigma_A{}^2}{2} * t}{\sigma_A * \sqrt{t}} \quad (1)$$

$$d2 = d1 - \sigma_A * \sqrt{t} \quad (2)$$

$$Equity\ Value = A * N(d1) - L * e^{-r*t} * N(d2) \quad (3)$$

For simplicity's sake, I assumed that borrowers would not change their behavior to decrease their GHG emissions and tax exposure over the one, two-, three-, four-, and five-year time horizons. I counted the carbon tax exposure in year one as short-term debt and the carbon tax exposures in years two through five (in scenarios that included those years) as long-term debt, because a carbon tax due in those years is similar to a debt instrument with a maturity date in those years. I only counted half of a company's long-term liabilities towards a company's liabilities in Merton's model to adjust for the possibility that long-term debt will be restructured or that assets might briefly exceed liabilities before the debt's maturity date. I then used Merton's model to calculate probability of default based on a risk-free rate of 2%, 252 trading days in a year, a company's assets, a company's liabilities (with and without carbon tax liabilities), and a company's asset volatility to calculate marginal probability of default on a company-by-company basis due to the carbon tax.

To calculate expected loan losses, I multiplied the marginal probabilities of default by loan quantum and a recovery rate (the percentage of loan a lender will be able to recover if a borrower goes into default). According to Ou et al. (2021), the average recovery rate on a secured loan (which most term loans are) was 69% in 2020. However, if a portfolio company is going into default because of a carbon tax, its assets are likely intended for use in emissions-intensive processes. This fact is likely to reduce the assets' resale value in a world with a carbon tax. To consider this risk, I examined a scenario with a 0% recovery rate and a 69% recovery rate, with the 0% recovery rate being my base case.

Results

The impacts of a carbon tax were concentrated in few companies, industries, and financial institutions.

I first analyzed the PDs for companies in my dataset without any carbon tax and compared those PDs to baseline values established in the literature. I found that that the average PD ranged from 8.46% over a time horizon of one year to 20.38% over a time horizon of five years. However, the elevated PDs should not have a very large impact on MPDs, because both the baseline PDs and carbon tax PDs will be elevated. I found that average MPD arising from the carbon tax ranged from 0.03% over one year with a tax of $5/ton of CO2e to 1.6% over five years with a tax of $150/ton of CO2e. . For my base case of $50/ton over five years, I found that the MPD averaged 0.60%. However, the distribution of MPD was skewed right, meaning that a few companies suffered a dramatic increase in PD while others suffered almost no increase in PD. This disparity is exemplified by the fact that the median MPD only ranged from 0.00001% in the one-year, $5/ton scenario to 0.0491% in the five-year, $150/ton scenario. . The fact that median MPD is so much lower than average MPD likely means that a few companies are accounting for most of the marginal probability of default. Similarly, the carbon tax burden was also focused heavily on a few industries, as is shown in the table below.

SIC Code	Industry Description	Percentage of Carbon Tax Burden	Average Carbon Tax as Percentage of Revenue	Percentage of All Loans	Average Revenue ($Bn)
49	Electric, Gas, and Sanitary Services	59.05%	12.14%	5.37%	6.89
50	Wholesale Trade – Durable Goods	12.78%	0.05%	2.13%	454.27
45	Air Transportation	5.19%	5.54%	2.34%	4.26
28	Chemicals and Allied Products	2.33%	0.51%	8.25%	6.08
16	Heavy Construction	1.96%	5.63%	0.31%	3.49
25	Furniture and Fixtures	1.95%	11.14%	0.19%	3.06
51	Wholesale Trade – Nondurable Goods	1.86%	0.68%	2.80%	21.86
44	Water Transportation	1.77%	7.11%	1.03%	6.62
13	Oil and Gas Extraction	1.71%	1.48%	0.70%	8.77
56	Apparel and Accessory Stores	1.42%	0.01%	0.10%	879.43

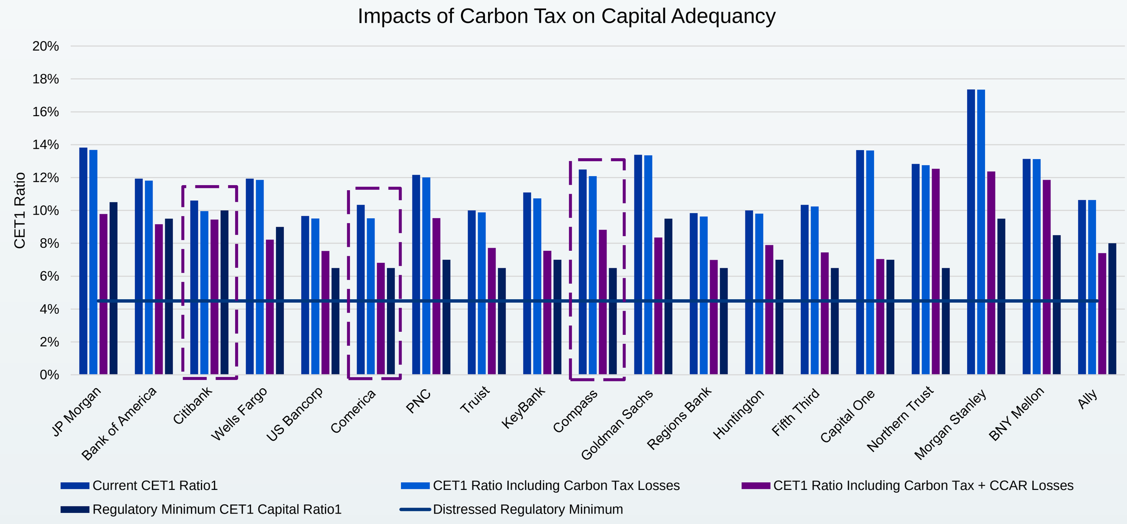
I multiplied MPDs by the value of loans and by a recovery rate, or the percentage of a loan that a lender will recover if the borrower defaults, to calculate projected loan losses. I then scaled projected loan losses to match market quantities of debt. Assuming a 0% recovery rate in my base case, I found that industry-wide losses would total $30.30Bn scaled to include commercial, industrial, and commercial real estate loans, and would fall to $9.39Bn scaled assuming the industry wide average recovery weight of 69%. However, I put more weight on the 0% recovery rate scenario, given that if a carbon tax is severe enough to force a company into bankruptcy, its assets are likely intended for use in emissions-intensive processes.
The losses by bank are shown below.

Financial Institution	Adjusted Losses ($MM)	Percentage Losses	Percentage Non-Performing Loans	Percentage Losses - Rank	Percentage Non-Performing Loans - Rank	Percentage Losses / Percentage Non-Performing Loans
JP Morgan	$2,058.46	0.42%	1.04%	9	3	39.90%
Bank of America	$1,729.86	0.39%	0.57%	11	12	68.35%
Citibank	$918.75	0.49%	1.00%	6	4	48.54%
Wells Fargo & Co	$896.30	0.26%	0.98%	14	5	26.26%
US Bancorp	$613.20	0.47%	0.41%	7	14	113.55%
Comerica Bank	$546.91	1.24%	0.67%	1	10	184.93%
PNC Bank NA	$482.92	0.29%	0.94%	12	6	30.57%
Truist	$464.03	0.27%	0.45%	13	13	61.22%
KeyBank	$428.99	0.61%	0.82%	4	8	74.36%
Compass Bank	$276.06	0.69%	0.20%	2	18	343.62%
Goldman Sachs & Co	$252.36	0.64%	1.46%	3	1	43.77%
Regions Bank	$228.16	0.43%	0.88%	8	7	48.27%
Huntington Bank	$164.80	0.40%	0.60%	10	11	66.13%
Fifth Third Bank	$144.79	0.23%	0.77%	16	9	29.68%
Capital One Bank	$81.85	0.11%	0.40%	17	15	27.31%
Northern Trust	$56.24	0.52%	0.39%	5	16	132.07%
Morgan Stanley Bank NA	$28.18	0.04%	0.24%	18	17	15.82%
Bank of New York Mellon	$27.31	0.23%	0.16%	15	19	146.59%
Ally Commercial Finance LLC	$1.33	0.01%	1.28%	19	2	0.43%

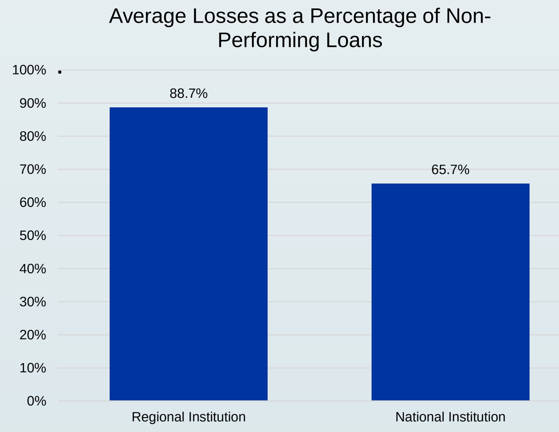
Conclusion

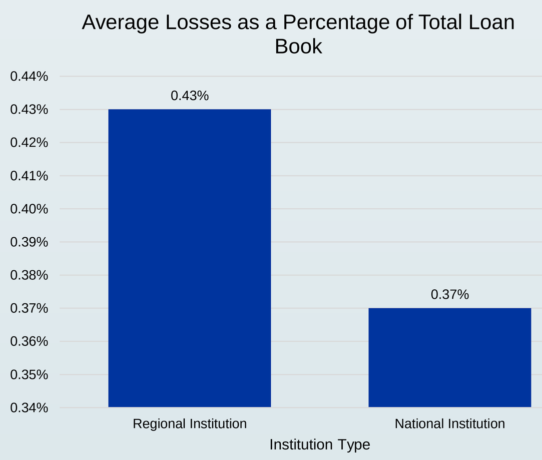
Overall, my findings support the proposition that a carbon tax would be minimally disruptive for most companies, industries, and financial institutions. However, outsized climate risk in regional banks means that there may be concentrated risk in certain regions or industries that could result in sub-systemic financial instability of those regions/industries. Additionally, concentration of climate risk in certain industries that are important to the American economy could have knock-on effects and cause financial instability. Taken together, my findings support increased oversight of financial climate risk in smaller financial institutions.

As shown in the chart below, the only bank that falls under its minimum reserve ratio is Citibank, while Comerica and Compass are the banks that are the hardest hit by a carbon tax.



Interestingly however, as shown below, regional banks suffer materially larger losses than do national banks. However, these smaller regional banks are not subject to the same levels of regulation as national banks. Namely, they do not undergo the yearly Comprehensive Capital Analysis and Review that ensures capital adequacy under distressed economic conditions. It is worrying that the least regulated financial institutions are exposed to the most risk





Therefore, regulators likely need not worry about he impacts of a carbon tax on the largest financial institutions in the U.S. However, my research indicates that regulators should consider expanding oversite over regional financial institutions. It also indicates that only certain industries and companies would be adversely impacted by a carbon tax.

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