The Review of Financial Studies

Banking on Carbon: Corporate Lending and Cap-and-Trade Policy

Ivan T. Ivanov
Federal Reserve Bank of Chicago, USA

Mathias S. Kruttli
Kelley School of Business, Indiana University, USA

Sumudu W. Watugala
Kelley School of Business, Indiana University, USA

We estimate the effect of carbon pricing policy on bank credit to greenhouse-gas-emitting firms. Our analyses exploit the geographic restrictions inherent in California's cap-and-trade bill and a discontinuity in the embedded free permit threshold of the federal Waxman-Markey cap-and-trade bill. Affected high emission firms face shorter loan maturities, lower access to permanent forms of bank financing, higher interest rates, and higher participation of shadow banks in their lending syndicates. These effects are concentrated among private firms, while credit terms of public firms are largely unaffected. Overall, we show that banks respond quickly to realizations of transition risk. (*JEL* G20, G21, G28)

Received: June 1, 2021; Editorial decision: July 16, 2023
Editor: Ralph Koijen
Authors have furnished an Internet Appendix, which is available on the Oxford University Press Web site next to the link to the final published paper online.

We are particularly grateful for the comments of two anonymous referees and the Editor, Ralph Koijen. We thank Ian Appel, Aymeric Bellon, Patrick Bolton, Sudheer Chava, Darwin Choi, John Coglianese, Piotr Danisewicz, Andrew Ellul, Emilia Garcia-Appendini, Vidhan Goyal, Matthew Gustafson, Florian Heider, Christoph Herpfer, Deniz Igan, Andrew Karolyi, Lorena Keller, Ryan Lewis, Tao Li, Kyle Meng, Justin Murfin, Borghan Narajabad, Phong Ngo, David Ng, Sanjay Patnaik, Diane Pierret, Alexander Popov, Nagpurnanand Prabhala, Tarun Ramadorai, Brigitte Roth Tran, Joâo Santos, Glenn Schepens, Hongyu Shan, Yu Shan, Mandeep Singh, and Chi-Yang Tsou and seminar participants at Cornell University, European Central Bank, Federal Reserve Bank of Chicago, Federal Reserve Board, Harvard University, University of Bristol, University of Houston, University of Zurich, UNPRI, Virtual Seminar on Climate Economics, NFA, System Energy Meeting, AFBC, Federal Reserve Week After Conference, MFA, SFS Cavalcade, FIRS, Sustainable Finance Forum, NBER Summer Institute Risks of Financial Institutions, Federal Reserve System Banking Conference, OFR Cleveland Fed Financial Stability Conference, Finance Down Under Conference, Swiss Winter Conference on Financial Intermediation, HEC-McGill Winter Finance Workshop, University of Oklahoma Energy and Climate Finance Research Conference, EBC Conference, Bank Regulation Research Conference, OCC Symposium on Climate Risk in Finance and Banking, CEMA, MoFiR, CICF, and Chatham House for helpful comments. We thank Kyle Meng for making data available on his website. Keely Adjorlolo provided excellent research assistance. Part of this work was completed while Ivanov and Kruttli were at the Board of Governors of the Federal Reserve System. The views stated herein are those of the authors and are not necessarily the views of the Federal Reserve Bank of Chicago or the Federal Reserve System. Supplementary data can be found on *The Review of Financial Studies* web site. Send correspondence to Mathias S. Kruttli, mkruttli@iu.edu.

The Review of Financial Studies 37 (2024) 1640–1684

https://doi.org/10.1093/rfs/hhad085 Advance Access publication December 7, 2023

Regulators and investors alike anticipate climate change to pose significant risks to the financial services industry, with potential adverse effects on systemic stability.[1] One source of risk is the adverse impact of climate change regulations on greenhouse-gas (GHG) emitting firms and their creditors. The implications of such "transition risks" are currently unknown because most jurisdictions have not implemented climate change regulations on a large scale.[2] To the extent that financial institutions have large exposure to GHG-emitting firms and limited flexibility to adjust such exposures, climate policies may adversely affect financial stability. Conversely, if financial institutions can quickly mitigate exposure to high-emitting firms in response to climate policies, then the minimal impact of such risks on systemic stability should not hinder regulatory action curbing GHG emissions.

We examine periods when major climate change policies in the United States move through the legislative process and exploit quasi-exogenous variation in regulatory requirements to identify their effect on corporate lending. To do so, we combine facility-level GHG emissions data from the Environmental Protection Agency (EPA) with comprehensive loan-level data on bank lending to private and public firms in the United States from the Federal Reserve's Y14 Collection (Y14) and the Shared National Credit (SNC) Program. Because cap-and-trade programs are arguably the most prominent climate policy solution for curbing GHG emissions, we focus on the two main cap-and-trade bills that passed or came close to passage in the United States: the California and the federal Waxman-Markey cap-and-trade bills. Both of these bills introduce a legally binding transition to a low-carbon economy and constitute two independent natural experiments in our study, occurring at different points in time, with emitting firms assigned to treatment and control groups along different dimensions.

We first examine the introduction of California's cap-and-trade bill. In December 2011, California enacted the first major cap-and-trade bill of any state in the United States, with the cap-and-trade program set to be implemented in January 2013. After the passage of but before the implementation of the program, GHG-emitting firms and their creditors face increased risks. These risks stem from an expected increase in operating costs as well as the uncertainty around such an increase due to the unknown impact of

[1] A survey conducted by the Bank of International Settlements in April 2020 reports that central banks expect climate change to have potential financial stability implications for the banking system (Bank of International Settlements, 2020).

[2] Carney (2015, p. 6) defines transitions risks as "the financial risks which could result from the process of adjustment towards a lower-carbon economy." Legislation considered in the U.S. Senate would require the Board of Governors of the Federal Reserve System to develop financial risk analyses relating to climate change. Transition risks are explicitly addressed in Section 3.8 of the bill (https://www.congress.gov/bill/116th-congress/senate-bill/2903/text).

the cap-and-trade program. Our analysis will capture these two effects jointly. Given this program only affects firms with GHG emissions in California, we estimate the response of firm financing to cap-and-trade policy by exploiting variation in the fraction of firm emissions in California. We study the response of both public and private firms using quarterly corporate loan data from Y14.

We find evidence consistent with lenders negotiating loan contracts following the passage of California's cap-and-trade bill in a manner that mitigates their exposure to affected firms. Firms with a large share of GHG emissions in California experience a reduction in loan maturities of approximately 5 months compared to firms with a small share of their emissions in California. This reduction is considerable given the average loan maturity of firms in our sample is about 30 months. The changes in loan maturity are driven by both a decline in maturity within loan type and a reduction in permanent forms of bank financing. Specifically, firms with substantial GHG emissions in California exhibit an increased reliance on credit line financing at the expense of term loan financing. The share of term loan financing decreases by about 25 percentage points. While treated firms also face higher loan interest rates, the total committed credit to these firms does not change significantly.

These debt structure changes provide lenders with the ability to quickly reduce exposure should firms face difficulties in operating under the cap-and-trade program. Short maturities allow lenders to frequently reevaluate credit relationships (Diamond 1991; Rajan and Winton 1995). Unlike term loans, the availability of credit lines is conditional on firms maintaining high cash flow and low credit risk (Jimenez, Lopez, and Saurina 2009; Sufi 2009; Acharya et al. 2014), and banks use discretion in preventing small firms from drawing on their credit lines in times of economic and financial stress (Greenwald, Krainer, and Paul 2021; Chodorow-Reich et al. 2022). Further, the higher interest rates are consistent with banks requiring direct compensation for exposure to risks associated with the climate policy.

We complement our results on California's cap-and-trade bill with an analysis of the Waxman-Markey cap-and-trade bill. To date, the Waxman-Markey bill is the federal cap-and-trade legislation that came closest to passage in the United States with a peak probability of passage implied by prediction markets at nearly 60% in 2009 (Meng 2017). The bill cleared the U.S. House of Representatives in June 2009, and was under consideration by the U.S. Senate until July 2010. Waxman-Markey carved out an exemption—a "free permit" to emit GHGs—for manufacturing firms with energy intensity at or above the prespecified 5% cutoff. This allows us to compare the financing outcomes of manufacturing firms just above and below the free permit threshold at the end of 2009 relative to 2008, when the bill had not yet passed the House. Our research design is similar to Meng (2017), who studies the economic cost of the Waxman-Markey cap-and-trade program using data on the equity valuations of public firms.

We conduct the Waxman-Markey analysis with data from the SNC as the Y14 data are not available prior to 2011. The SNC data provide comprehensive coverage of the U.S. syndicated loan market and allow us to measure the same loan contracting outcomes as with the Y14 data with the exception of loan interest rates. Importantly, although this empirical setting differs in terms of when treatment occurs and how firms are assigned to treatment, we find that lenders manage their exposure to covered firms in a qualitatively similar way. Firms just below the free permit threshold experience a reduction in loan maturities of up to seven months compared to firms just above the threshold after the bill passed the U.S. House of Representatives. Also, firms without free permits face a reduction in term loan share and a corresponding increase in credit lines. These results are significantly stronger for the most affected firms, that is, those closer to the 5% energy intensity cutoff.

We next examine the heterogeneity in the effects of these cap-and-trade programs on corporate credit. Virtually all of the documented effects are concentrated within the subsample of private firms. By contrast, we observe few significant changes in the debt structure of public firms. The differential effect of cap-and-trade policies on private versus public firms is consistent with banks expecting that private firms face relatively higher operating costs as a result of cap-and-trade policies. Both anecdotal evidence and our data suggest that private firms have lower GHG emissions efficiency than their public counterparts, which would make operating under a cap-and-trade program more costly.[3] The differential effects between private and public firms also could be driven by greater financial constraints among private firms (Hadlock and Pierce 2010; Saunders and Steffen 2011; Mortal and Reisel 2013; Erel, Jang, and Weisbach 2015; Ivanov, Pettit, and Whited 2022). Because private firms are typically smaller than public firms, both firm size and ownership may explain our results.

In addition to debt structure changes that are equilibrium outcomes of contracting between banks and firms, banks can also take more unilateral measures to reduce exposure to firms covered by impending cap-and-trade programs, such as selling loans on the secondary loan market or monitoring borrowers more closely. The SNC data allow us to analyze these two dimensions for the Waxman-Markey cap-and-trade bill. We show that lenders with large ex ante exposure to high GHG-emitting firms reduce syndicated loan exposure to firms below the free permit threshold by a greater extent. In response to this selling, some shadow banks, such as collateralized loan obligations (CLOs), take a significantly larger loan share in the syndicates of treated firms. Finally, firms below the free permit threshold are more likely to have cash flow covenants in their contracts.

[3] See, for example, Tabuchi (2021).

We also analyze whether firms experience significant changes in profitability, saving, and investment following the implementation of California's cap-and-trade program. Using the financial statement information for both private and public firms from Y14, we show that following program implementation, private firms face reductions in profitability. They also increase cash holdings, likely for precautionary reasons. In addition, private firms decrease capital expenditures, suggesting that there are large adverse real effects on the borrowers most affected by this cap-and-trade program.

Overall, by isolating periods around the passage of two major cap-and-trade bills, we show that the fluid nature of commercial lending relationships allows banks to adjust their exposure to covered firms quickly through loan renegotiation. In addition, our findings indicate that banks expect cap-and-trade policy to place a larger burden on private firms. For regulators concerned with financial stability, these results are reassuring as they show that bank lenders actively manage exposure to transition risk realizations stemming from climate policies. However, the results also show that financing conditions for covered firms tighten at the same time as these firms face a price on carbon. Taken together, these adverse effects may jeopardize the survival of some firms in polluting industries. Understanding heterogeneity in the effect of cap-and-trade programs on emitting firms is important for regulators designing climate policy.

The distinction our analysis documents between private and public firms adds to the existing literature that focuses on public firms. Meng (2017) finds that equity investors of public firms expect only modest economic costs as a result of the Waxman-Markey cap-and-trade bill, which are at the lower end of the distribution of estimates from government agencies and privately funded studies. Studying the California cap-and-trade program, Bartram, Hou, and Kim (2022) also document a modest impact on public firms as financially constrained public firms are likely to move their emissions out of California into other states. We complement these papers by showing that the effects of cap-and-trade programs on privately held companies' debt structure are large.

An emerging literature investigates how climate policy risks affect firm financing outcomes. Delis, de Greiff, Iosifidi, and Ongena (Forthcoming) show that fossil fuel firms with reserves in countries that score high on climate policy indices face higher interest rates on syndicated loans following the adoption of the Paris Climate Agreement of 2015. Seltzer, Starks, and Zhu (2022) find that the corporate bonds of firms with poor environmental profiles that operate in U.S. states with stricter environmental regulations pay higher yields and receive lower credit ratings after the Paris Climate Agreement.[4] Antoniou, Delis, Ongena, and Tsoumas (2022) show that when firms are able to store pollution permits, their cost of debt can decrease

[4] A separate asset pricing literature shows how equity and options markets price climate policy risks, for example, Engle, Giglio, Kelly, Lee, and Stroebel (2020); Ilhan, Sautner, and Vilkov (2021); Bolton and Kacperczyk

in the future if they preemptively acquire permits. Oehmke and Opp (2023) develop a theoretical model and find that capital regulations in response to climate risks can address financial risks but not necessarily reduce emissions. Kacperczyk and Peydró (2022) study bank lending to polluting firms following bank commitments to decarbonization. Other papers focus on the impact of physical climate risks on the municipal bond or bank lending markets (Painter 2020; Goldsmith-Pinkham et al. 2023; Correa et al. 2023).

Our paper contributes to this literature in two major ways. First, we study the response of firm financing to the introduction of two well-defined and legally binding regulatory frameworks intended for transition to a lower-carbon economy.[5] Second, our data allow us to distinguish between public and private firms and to comprehensively measure debt contract structure in addition to price for bilateral and syndicated bank lending, which is crucial for understanding how banks manage their exposure around climate change legislation.

1. Background

Cap-and-trade programs are a key policy tool for transitioning to a lower-carbon economy. Cap-and-trade programs cap total GHG emissions at a threshold that decreases over time. However, a cap-and-trade program does not explicitly set a price on carbon. Firms get allocated emission permits or need to purchase permits at auctions or the secondary market. The goal of a cap-and-trade program is to reduce total GHG emissions but let market mechanisms determine the price on carbon.

1.1 California cap-and-trade bill

The most significant cap-and-trade bill that has been implemented in the United States is California's cap-and-trade program (see, e.g., Bartram, Hou, and Kim (2022)). Another significant cap-and-trade program implemented in the United States in 2009 is the U.S. Regional Greenhouse Gas Initiative that covers a number of northeastern states but only caps emissions of utilities. California's cap-and-trade program is the only mandatory cap-and-trade program introduced in any state within the United States. that covers the majority of firms with high GHG emissions across industries.

The program requires all facilities with emissions of more than 25,000 metric tons of carbon dioxide equivalents (CO2e) per year to obtain allowances for

(2021); Pástor, Stambaugh, and Taylor (2022). Finally, Chava (2014); Chen, Hsieh, Hsu, and Levine (2022); Hsu, Li, and Tsou (2023) relate firms' financing to their general environmental profile.

[5] Papers that focus on nonenvironmental policies and firm financing are, for example, Alimon (2015); Qiu and Shen (2017); Ivanov, Pettit, and Whited (2022). They find that regulations introducing additional costs for corporate borrowers, such as labor protection laws or higher corporate taxation, lead to higher loan spreads, tighter nonprice loan terms, and more diffuse loan ownership structure. Bae and Goyal (2009) find that weaker legal protection is linked to tighter financial conditions.

their emissions. Carbon dioxide equivalents are defined as the quantity of carbon dioxide that for a given amount of GHGs or mixture of GHGs would generate the same global warming potential. The regulation was approved by the Office of Administrative Law on December 22, 2011.[6] The California Air Resources Board administers the cap-and-trade program and collects and verifies data reported by each emissions facility through the Mandatory Reporting Regulation program.[7] Each firm receives some quantity of free allowances to emit GHGs and must purchase the remaining allowances for their operations from quarterly auctions or through other secondary market means.

The first phase of the program was implemented on January 1, 2013, and covered all emitting firms other than fuel suppliers. Fuel suppliers were covered starting on January 1, 2015. The few fuel suppliers operating in California, such as Chevron and ExxonMobil, are generally large public firms. The covered facilities come from a wide range of industries, such as cement producers, electricity generation, and petroleum refining.[8] The program's emissions cap was set to decrease by 2% annually in 2013 and 2014 relative to the emissions level forecast for 2012. For subsequent years, the emissions cap was set to decrease by 3% annually relative to the realized emissions level in 2012. The goal of the cap-and-trade program was for California to return to 1990 emission levels by 2020.

At the time of regulation enactment at the end of 2011, the expected compliance costs for firms covered by the cap-and-trade program were highly uncertain. The California Air and Resources Board released an economic analysis ahead of the final vote stating on page 12 that: "Given the uncertainties about the nature of these factors [for example, ease of switching to low-GHG methods of production and pace of technological progress], it is impossible to predict with precision the allowance price. ... In 2010, ARB conducted a joint analysis of the AB 32 Climate Change Scoping Plan with Charles River Associates and Professor David Roland-Holst of the University of California Berkeley. The estimated price of CO2 in these three analyses ranged from about \$20/MTCO2e to \$100/MTCO2e in 2020."[9]

While this cap-and-trade program only covers a single state, the economic activity in California is considerable. California had a GDP of \$2.1 trillion in 2012, and if California was a sovereign country, its economy would have

6 See https://www.arb.ca.gov/regact/2010/capandtrade10/capandtrade10.htm.

7 See https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program.

8 Our conversations with the California Air Resources Board confirmed that the range of industries included in the cap-and-trade regulation is so wide that virtually all facilities in California that emit more than 25,000 metric tons of carbon dioxide equivalents per year are part of the cap-and-trade program. A list of the covered industries can be found online (https://ww2.arb.ca.gov/sites/default/files/classic//cc/capandtrade/guidance/chapter2.pdf).

9 The economic analysis can be found online (https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2010/capandtrade10/capv4appn.pdf).

ranked in the top 10 of the largest economies in the world.[10] Therefore, the introduction of the California cap-and-trade program allows us to study the response of corporate lending to a major economy transitioning away from fossil fuels.

1.2 Waxman-Markey cap-and-trade bill

At the U.S. federal level, no GHG cap-and-trade program has yet been implemented. The cap-and-trade program that came closest to passage was part of the American Clean Energy and Security Act of 2009, also known as the Waxman-Markey bill.[11] The bill passed the U.S. House of Representatives on June 26, 2009, and had a high probability of becoming law, while Democrats held both a filibuster-proof majority in the Senate and the presidency. The bill ultimately failed to pass in the Senate on July 22, 2010.

The centerpiece of the Waxman-Markey bill was a cap-and-trade program in which the total amount of GHG emissions in a given year would be capped relative to GHG emissions in 2005. The cap was set at 3%, 17%, 42%, and 83% below the 2005 emissions level by 2012, 2020, 2030, and 2050, respectively. Importantly for the identification strategy discussed in Section 3.2, approximately 15% of all emissions permits to emit GHG would be given for free to selected manufacturing firms covered by the cap-and-trade regulation.

At the time, the effect of the Waxman-Markey bill on firms as well as the associated economic costs were highly uncertain. While under consideration by the U.S. Congress, various sources reported widely diverging cost estimates, reflecting the high uncertainty of the impact of the bill on firms. For example, the Heritage Foundation estimated that: "Cumulative gross domestic product (GDP) losses are $9.4 trillion between 2012 and 2035."[12] In addition, the Congressional Budget Office estimated that "...the net annual economy wide cost of the cap-and-trade program in 2020 would be $22 billion or about $175 per household."[13]

1.3 Climate policy and bank lending

The passage of cap-and-trade legislation increases the credit risk of polluting borrowers. The credit risk framework, widely used in academia, industry, and

[10] This is based on data from the Bureau of Economic Analysis (https://www.bea.gov/data) and the International Monetary Fund (https://www.imf.org/en/Publications/WEO/weo-database/2022/October).

[11] See https://www.congress.gov/bill/111th-congress/house-bill/2454/text.

[12] The Economic Consequences of Waxman-Markey: An Analysis of the American Clean Energy and Security Act of 2009, August 6, 2009. (https://www.heritage.org/environment/report/the-economic-consequences-waxman-markey-analysis-the-american-clean-energy-and).

[13] Estimated Costs to Households From the Cap-and-Trade Provisions of H.R. 2454, June 20, 2009. (https://www.cbo.gov/publication/24918).

bank regulation,[14] defines expected loan loss from the perspective of the lender as:

$$ExpectedLoss = PD \times LGD \times EAD, \tag{1}$$

where PD denotes the firm's probability of default, LGD denotes the loss given default, and EAD denotes the lender's exposure to the firm at default. The cap-and-trade program can lead to a higher PD and LGD, which increase expected loan losses.

The cap-and-trade program can reduce a firm's cash flow because a price on carbon increases its operating costs. The cap-and-trade program could also increase the variance of cash flow. Importantly, both lower expected cash flow and higher cash flow variance increase the likelihood that a firm's cash flow falls below the default threshold, leading to higher PD (Trueman and Titman 1988; Minton and Schrand 1999; Acharya, Davydenko, and Strebulaev 2012).

These adverse changes in the distribution of cash flow are also likely to affect loan recovery rates in the event firms default. To the extent that the cap-and-trade program erodes the financial health of a large fraction of firms in polluting industries, the collateral value of these firms is also likely to decline due to a decrease in the resale value of, for example, equipment, which can also increase LGD, ultimately increasing expected losses to the lender (Shleifer and Vishny 1997; Benmelech and Bergman 2011).

Right after the passage but before the implementation of a cap-and-trade bill, it is unknown how binding the emissions cap would be for covered firms. Lenders and firms are not (fully) aware of the extent to which firms would have to modify production processes to reduce emissions, purchase emission allowances to maintain current levels of emissions, or do both. Additionally, the price of emissions allowances is still unknown at the time of bill passage, because the cap-and-trade program does not set an explicit price but lets the market determine it. As discussed in Sections 1.1 and 1.2, official cost estimates and public commentary suggest that the impact on firms was highly uncertain at the time of passage for both cap-and-trade bills.

Because of these unknowns, banks have to insure against the states of the world in which the adverse effects on cash flow are substantial. The passage of a cap-and-trade bill makes these states more likely. Lenders might cut credit or renegotiate the loan contracts of affected firms to gain flexibility to reduce exposure in the future, that is, to reduce EAD. The analysis in this paper focuses on how banks manage EAD in response to realizations of transition risk.

[14] See, for example, Plosser and Santos (2018) and Leitner and Yilmaz (2019), and a detailed description of the Basel II capital framework (https://www.bis.org/publ/bcbs107.pdf) and its application to the U.S. setting (https://www.federalreserve.gov/generalinfo/basel2/FinalRule_BaselII/).

2. Data

In this section, we discuss the data used to analyze the impact of the cap-and-trade bills on corporate lending. The variables in our analyses are also described in Table A1 in the appendix.

2.1 Credit data

Our analysis combines GHG emissions data from the EPA with corporate lending data from Y14 and SNC. Both data sets cover bank borrowing of a wide range of private and public firms. The California cap-and-trade program was signed into law in 2011 and implemented in 2013, which allows us to use the Y14 data, spanning 2011 to present, for this analysis. These data provide information on interest rates and capture bilateral lending in addition to syndicated lending (the SNC data only capture the latter). In other words, the Y14 data also allow us to observe smaller firms that are typically reliant on bilateral lending. We use the SNC data for the Waxman-Markey analysis as the bill was under consideration by the U.S. Congress in 2009-2010, when the Y14 data are not available. In addition, while we can utilize the longer-time series SNC data for the analysis of the California cap-and-trade bill, a number of high GHG-emitting firms in California borrow only bilaterally, and are thus not covered by the SNC Program.

The Y14 data come from Schedule H.1 of the Federal Reserve's Y14Q Collection, which covers 30 banks in the United States with total assets exceeding $50 billion during our sample period. Banks provide granular loan-level data on their corporate loans whenever a loan exceeds $1 million in commitment amount, together with associated financial statement information of the borrower (whenever available). For each loan facility, the Y14 reports the identity of the borrower, loan commitment amount and type, loan interest rate, origination date, maturity date, drawn amount in the case of credit lines, and bank internal borrower rating. We exclude government entities, financial firms, real estate firms, and offices of bank holding companies. We also exclude capitalized lease obligations, fronting exposures, commitments to commit, other real estate owned and other assets. Further, we discard loans that are guaranteed by the federal government, associated with special purpose vehicles, in default, not fully syndicated, for which the information on commitment amount is missing, which remain outstanding on banks books after maturity, or have remaining maturities exceeding 9 years. We winsorize the variables other than the term loans ratio at the 1% level. Table 1 presents the summary statistics for the Y14 data used in the analysis of the California cap-and-trade bill.[15]

[15] For more details of the Y14 data, see https://www.federalreserve.gov/apps/reportingforms/Download/DownloadAttachment?guid=c4ef7d8e-9242-4384-bd8c-fe458e753bb2.

Table 1
Summary statistics for the California cap-and-trade bill analysis

	Observations	Firms	Mean	SD	P10	P50	P90
A. Full sample							
Committed credit (in m US$)	2,929	878	327.960	549.367	7.400	109.089	953.498
Interest rates (in %)	1,418	538	3.126	1.660	1.360	2.750	5.500
Remaining maturity (in months)	2,929	878	34.234	18.389	7.061	37.553	56.200
Share of term loans	2,929	878	0.152	0.266	0.000	0.000	0.532
Private	2,929	878	0.518	0.500	0.000	1.000	1.000
CA emissions share	2,929	878	0.067	0.229	0.000	0.000	0.102
CapEx/Assets (in %)	1,046	699	3.496	10.116	−5.269	2.972	13.133
Cash/Assets (in %)	1,136	734	8.331	12.112	0.176	3.496	22.529
EBITDA/Assets (in %)	1,119	736	12.375	8.931	3.857	10.706	22.857
B. Firms with California emissions							
Committed credit (in m US$)	410	127	624.782	858.426	10.043	203.557	1,963.848
Interest rates (in %)	196	77	3.103	1.678	1.391	2.819	5.257
Remaining maturity (in months)	410	127	31.175	18.903	5.063	33.189	55.735
Share of term loans	410	127	0.172	0.292	0.000	0.026	0.633
Private	410	127	0.385	0.487	0.000	0.000	1.000
CA emissions share	410	127	0.480	0.419	0.017	0.309	1.000
CapEx/Assets (in %)	158	109	3.344	8.026	−5.116	3.093	10.046
Cash/Assets (in %)	166	112	11.362	16.792	0.247	4.329	29.414
EBITDA/Assets (in %)	165	112	11.992	8.253	3.315	10.802	21.164

This table reports the summary statistics of the firms included in our sample in our analysis of California's cap-and-trade bill. The data are quarterly, except the balance sheet variables, which are at an annual frequency. For each variable, the panels show the total observations and unique firm count, mean, standard deviation, and 10th, 50th, and 90th percentiles.

The SNC data come from regulatory reporting associated with the SNC Program, an inter-agency agreement among the three main federal banking regulators—the Federal Reserve System, the Federal Deposit Insurance Corporation, and the Office of the Comptroller of the Currency—to monitor the syndicated loan market.[16] The SNC program covers all syndicated commitments that exceed $20 million and are held by three or more supervised institutions as of the end of each calendar year, which accounts for virtually the entire syndicated loan market in the United States.

The SNC data set contains loan-specific information as of the end of each calendar year from 1992 through 2012. For each loan facility, the data provide the identity of the borrower, including name, industry, and location, loan type, loan commitment amount, origination date, maturity date, drawn amount in the case of credit lines, and bank internal borrower rating. The SNC data provide a unique opportunity to examine lender responses to cap-and-trade policies because they have complete coverage of the lending syndicate, including shadow bank participation over the life of each loan. Unlike the Y14 data, the SNC data do not contain information on whether a firm is publicly listed. We map SNC data to the historical Compustat data set to determine

16 SNC Program description and guidelines dated May 5, 1998, can be found online (https://www.occ.gov/news-issuances/bulletins/1998/bulletin-1998-21.html).

Table 2
Summary statistics for Waxman-Markey cap-and-trade bill analysis

A. Baseline bandwidth

	Obs.	Firms	Lead banks	Mean	SD	P10	P50	P90
Committed credit (in m US$)	414	236	60	467.161	671.574	45.000	216.915	1,279.458
Remaining maturity (in months)	414	236	60	34.993	17.064	13.510	34.775	56.327
Share of term loans	414	236	60	0.264	0.376	0.000	0.000	0.947
Cash flow covenant	143	105	38	0.441	0.498	0.000	0.000	1.000
Private	414	236	60	0.568	0.496	0.000	1.000	1.000

B. Wide bandwidth

	Obs.	Firms	Lead banks	Mean	SD	P10	P50	P90
Committed credit (in m US$)	805	469	75	470.035	684.228	47.153	211.491	1,250.000
Remaining maturity (in months)	805	469	75	34.741	15.978	14.093	34.500	54.720
Share of term loans	805	469	75	0.247	0.365	0.000	0.000	0.903
Cash flow covenant	264	196	49	0.496	0.501	0.000	0.000	1.000
Private	805	469	75	0.532	0.499	0.000	1.000	1.000

C. Lender-firm exposure (0 to 1)

	Obs.	Firms	Lenders	Mean	SD	P10	P50	P90
Baseline bandwidth	19,358	236	2,891	0.040	0.142	0.000	0.005	0.057
Wide bandwidth	38,121	469	3,975	0.035	0.127	0.000	0.005	0.054

This table reports the summary statistics of the firms included in our sample for the Waxman-Markey cap-and-trade bill analysis. The data are annual. Panels A and B show the data for the firm-level analysis within the two bandwidths described in Section 3.2. Panel C shows the data for the lender-firm-level analysis in Section 5.1. For each variable, the panels show the total number of observations, unique firm and lead bank/lender count, mean, standard deviation, and 10th, 50th, and 90th percentiles.

public status in 2009. We winsorize variables other than ratios at the 1% level. Table 2 presents the summary statistics for the SNC data used in the analysis on the Waxman-Markey bill.

2.2 Greenhouse gas emissions

Since 2010, the EPA requires each production facility emitting more than 25,000 metric tons of carbon dioxide equivalents per year to report their emissions. The covered GHGs are carbon dioxide, methane, nitrous oxide, and fluorinated GHGs. These data are publicly available (https://www.epa.gov/ghgreporting), cover a wide range of industries, and account for a substantial share of total U.S. emissions. Nearly 8,000 facilities that belong to direct GHG emitters are required to annually report their emissions, accounting for 3 billion metric tons of carbon dioxide equivalents or roughly 50% of total U.S. GHG emissions as of 2012.[17] To measure lending to high GHG-emitting firms, we map firms in the EPA data to firms in the loan

[17] The EPA data set also details the emissions of indirect GHG emitters. These facilities, such as large gas stations, produce materials resulting in more than 25,000 metric tons of emissions when combusted. We exclude indirect emitters (fuel suppliers) from our analysis because they were not covered at the start of the California cap-and-trade program (see Section 1.1).

data using the name and ZIP code of the parent company of each GHG-emitting facility. As we use a fuzzy name match technique, we verify each potential match manually. Internet Appendix Table IA-7 presents summary statistics by year for the matched sample.

The California cap-and-trade program also covers emissions from California electricity importers that occur out of the state and cannot be identified in the EPA data. To capture these emissions, we obtain data from the California Air and Resources Board.

Figure 1 depicts the county-level distribution of high GHG-emitting firms in our Y14 sample as of 2012. For each county, we sum up the GHG emissions of all facilities in that county. The figure shows that a substantial number of high GHG-emitting facilities are located in California, as indicated by the large number of darker-shaded counties. This geographic distribution suggests that our analysis of California's cap-and-trade regulation likely provides valuable insights into the effect of carbon pricing policies on firm financing.

3. Empirical Strategy

We examine the impact of the two cap-and-trade bills on firms' credit contracts along the following major dimensions: the firm's total loan commitments, commitment-weighted average remaining loan maturity, term loan commitments as a share of total commitments, and the commitment-weighted average interest rates. Loan interest rates are only available in the Y14 data used in the California analysis. Our analysis is conducted at the firm level because the renegotiation process typically affects all loans to a given borrower.

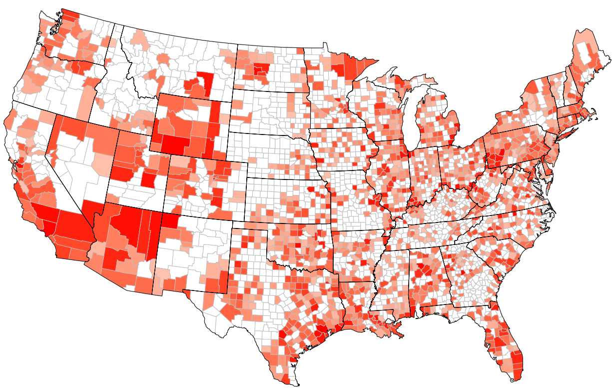


Figure 1
Emissions by county
This figure shows the 2012 GHG emissions by county based on the EPA data on high GHG-emitting firm facilities. Only GHG emissions from firms in the Y14 data are included. Darker-shaded counties represent higher emissions.

We test whether lenders reduce exposure to high GHG-emitting firms to limit the expected loss on loans. Second, we test whether banks gain additional flexibility to cut credit in the future. Shortening loan maturity allows banks to maintain flexibility and greater bargaining power during loan renegotiation (Flannery 1986; Diamond 1991; Rajan and Winton 1995). In addition, banks can gain additional flexibility by lending via credit lines instead of term loans, as credit lines generally have tight financial covenants and their availability is conditional on firms maintaining high cash flow (Sufi 2009; Acharya et al. 2014). Further, Greenwald, Krainer, and Paul (2021) and Chodorow-Reich et al. (2022) show that smaller firms may lose access to credit lines in times of stress. Finally, lenders could also increase loan interest rates as a compensation for lending to affected firms.

Bank lenders should have the ability to quickly respond to a cap-and-trade bill because loan renegotiation occurs frequently. Roberts and Sufi (2009) and Roberts (2015) show that, on average, commercial loans are renegotiated once every 9 months, significantly changing contract terms, such as amounts, maturities, interest rates, or financial covenants. Renegotiation is frequent for a number of reasons. Financial covenants in loan contracts are set tightly and are likely to be tripped, forcing renegotiations (Dichev and Skinner, 2002). Additionally, firms can initiate loan renegotiation to ensure the ability to take on investment projects. For example, capital expenditure covenants are typically set tight and frequently renegotiated to allow firms to change current investment projects or undertake new investments (Nini, Smith, and Sufi, 2009). Firms may also renegotiate debt contracts to relax borrowing base restrictions and ensure availability under credit lines tied to accounts receivable or inventory. We expect that whenever renegotiation happens around the passage of a cap-and-trade bill, lenders are likely to require stricter loan terms for firms covered by the cap-and-trade program. While firms may have incentives to renegotiate less during times of an impending cap-and-trade program, the highly state-contingent nature of bank loans described above is unlikely to allow firms to significantly reduce renegotiation.

Importantly, changes to loan contract terms represent an equilibrium outcome arrived at during the negotiation process between banks and firms. While banks might try to gain additional flexibility to renegotiate contracts in the future, firms would bargain for contract terms that are more likely to insulate them at least in part against the uncertainty of operating under a cap-and-trade program. Therefore, the direction and magnitude of changes in loan contract terms in response to the introduction of cap-and-trade programs is ultimately an empirical question.

3.1 Research design for the California bill

We first test how the passage of California's cap-and-trade bill affects the availability and the terms of credit extended to firms covered by the cap-and-trade program. We use a difference-in-differences specification, in which we split firms into a treatment group and a control group based on the geographic location of each firm's GHG-emitting facilities.

We define cap-and-trade program treatment in terms of each firm's GHG emissions in California as a share of total firm emissions:

$$CA\_Emissions\_Share_i = \frac{\sum_{k_i=1}^{K_i} FacilityEmissions_{k_i} \times I_{k_i \in CA}}{\sum_{k_i=1}^{K_i} FacilityEmissions_{k_i}}, \quad (2)$$

where k_i denotes a facility of firm i, and $I_{k_i \in CA}$ is an indicator variable for whether facility k_i is located in California. This variable measures treatment intensity as a firm with higher share of its total emissions in California would have to pay the carbon price for a greater share of its total emissions under the program. We also discretize the continuous variable to define treatment whenever a firm's GHG emissions in California are at least 50% of its total emissions. Figure 2 illustrates the identification strategy.

We estimate the following regression with data from the Y14 collection:

$$\begin{aligned} y_{i,q} =& \lambda CA\_Emissions\_Share_{i,q} \times I_{\text{Post CA bill}} + \beta_1 CA\_Emissions\_Share_{i,q} \\ &+ \beta_2 Controls_{i,q} + \psi_i + \phi_{q,ind} + \epsilon_{i,q}, \end{aligned} \quad (3)$$

where the dependent variable of interest, $y_{i,q}$ is one of the major loan contract terms described above for firm i in quarter q. We restrict the quarterly sample to a pre-period and a post-period that include the third and the fourth quarters of 2011 and 2012, respectively. As the coverage of our data starts in the third quarter of 2011, we exclude the first two quarters of 2012 to avoid quarterly seasonal variation in commercial lending as documented by Murfin and Petersen (2016). $CA\_Emissions\_Share_{i,q}$ denotes the emission share calculated using the annual EPA data for the year of quarter q. We show in Internet Appendix Table IA-5 that using only 2011 emissions data leads to qualitatively similar results. The coefficient of interest, λ, is employed to compare the changes in contract terms for treated firms around the bill's passage relative to those of the control firms. The second half of 2012 captures the time period when both firms and lenders faced significant uncertainty as to the effect of the cap-and-trade program on firms' future profitability. Importantly, because any bill that is passed by a legislative body is to some extent anticipated, our estimates around the passage of the California cap-and-trade bill should be considered a lower bound for the actual effects of the cap-and-trade program on loan terms.

Given that California's cap-and-trade bill covers fuel-supply emissions only starting in 2015 instead of 2013, we exclude fuel suppliers from our estimation sample. The control variables include borrower rating fixed effects representing the most conservative rating assigned to each firm by its bank lenders. Our rating measure relies on banks' internal ratings for each borrower converted to a five-grade S&P scale (AAA/AA, A, BBB, BB, and B or lower). We include industry-quarter fixed effects based on the four-digit NAICS code of each firm

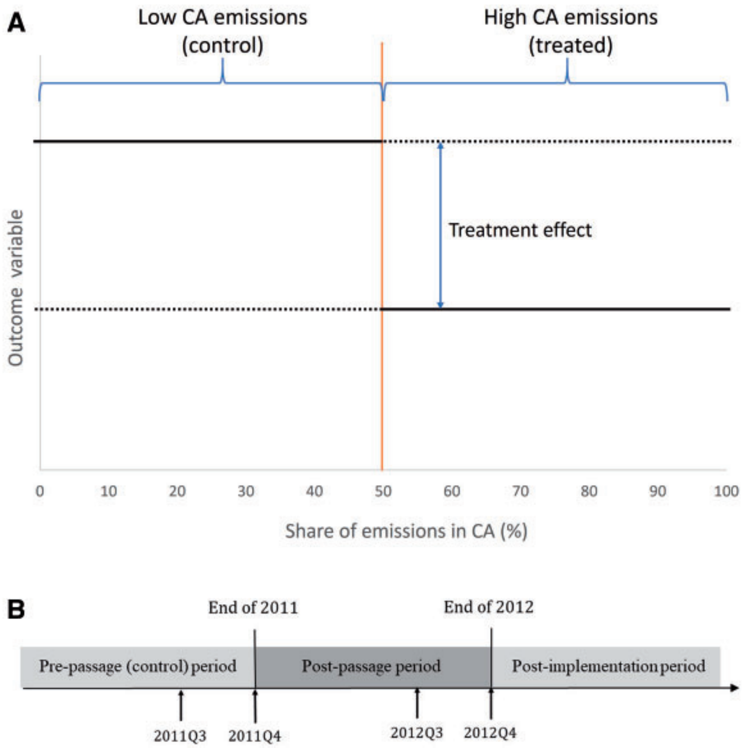


Figure 2
Identification strategy for the California cap-and-trade bill analysis
Panel A illustrates the identification strategy that assigns firm treatment by exploiting the share of GHG emissions in California for the analysis of California's cap-and-trade bill. In this example, we consider treated firms as those having at least 50% of their GHG emissions in California. In our empirical analyses, we also use a continuous measure of the share of GHG emissions in California. Panel B shows the relevant pre/post timeline for the analysis.

to estimate treatment effects within a given industry, which is important as the GHG emissions of a production process vary widely by industry. We use the four-digit NAICS code to ensure a sufficient number of observations in each industry.

3.2 Research design for the Waxman-Markey bill

A federal cap-and-trade program is likely to be more binding than a state-level program because firms may be able to avoid a state regulation by relocating activity out-of-state (Giroud and Rauh 2019; Bartram, Hou, and Kim 2022). Meng (2017) shows that after the bill passed in the House, prediction markets implied a considerable probability, close to 60%, of the bill also passing in the Senate. Under Waxman-Markey, a subset of manufacturing firms covered by the cap-and-trade regulation would have received approximately 15% of total permits of the cap-and-trade program for free. Following Meng (2017), we use this distinct feature of the bill granting free permits to manufacturing sectors (based on six-digit NAICS codes) that had an energy intensity of at least 5% and trade intensity of at least 15% between 2004 and 2006.[18] This feature of the bill allows us to estimate a difference-in-differences regression constructing the treatment and control groups with firms close to the 5% energy intensity threshold as certain manufacturing sectors fall just below and just above the 5% energy intensity threshold, while being above the 15% trade intensity threshold.[19] Specifically, firms that do not receive free permits should pose greater credit risks than firms that are granted free permits.[20] Figure 3 illustrates our identification strategy.

We use the SNC data for this analysis. Given these data are annual and reported as of year-end, we estimate a baseline regression with two time periods, 2008 and 2009. At the end of 2008, the Waxman-Markey bill had not been introduced in either chamber of the U.S. Congress. At the end of 2009, the Waxman-Markey bill had just passed in the House of Representatives and was under consideration by the U.S. Senate.

Our baseline regression is a difference-in-differences specification that takes the following form:

$$y_{i,t} = \lambda I_{i \in Treated} \times I_{t=2009} + Controls_{i,t} + \psi_i + \phi_t + \gamma_b + \epsilon_{i,t}, \tag{4}$$

where the sample is limited to 2008 and 2009 (the "pre" and "post" periods) and the coefficient of interest, λ, measures the relative change in the outcomes of interest between the treatment and control groups. Treatment, $I_{i \in Treated}$, takes the value of one if firm i does not receive free permits under Waxman-Markey and is zero otherwise. The dependent variables of interest are again a firm's remaining maturity, share of term loans, and the natural log of a firm's total loan commitments. We consider two bandwidths around the free permit threshold of 5% energy intensity. The baseline bandwidth includes firms in six-digit NAICS manufacturing industries that have an energy intensity between 2% and 8%. The wide bandwidth includes firms in six-digit NAICS manufacturing industries with an energy intensity between 1% to 9%. Internet Appendix Table IA-11 shows the energy intensity distribution across sectors.

The inclusion of firm and time fixed effects in the regression subsume the uninteracted terms $I_{i \in Treated}$ and $I_{t=2009}$. The controls differ slightly from those

[18] Energy intensity is defined in SEC.763(b)(2)(A)(ii)(II) of the Waxman-Markey bill as "... dividing the cost of purchased electricity and fuel costs of the sector by the value of the shipments of the sector, ...". Trade intensity is defined in SEC.763(b)(2)(A)(ii)(II) of the Waxman-Markey bill as "... calculated by dividing the value of the total imports and exports of such sector by the value of the shipments plus the value of imports of such sector, ...".

[19] The trade intensity threshold conditional on being above the 5% energy intensity threshold leaves too few observation for a separate analysis (Meng, 2017).

[20] The free permits are supposed to cover the firms cost from direct emissions and increased expenditures for electricity until 2026, when they would be phased out. To the extent that firms receiving free permits are affected by the cap-and-trade program through other channels, our estimates present a lower bound for the impact of the cap-and-trade program on loan terms. Further, the phase out of the free permits in 2026 is unlikely to affect creditor decisions in 2009, as the average maturity of syndicated loans is only around 3 years.

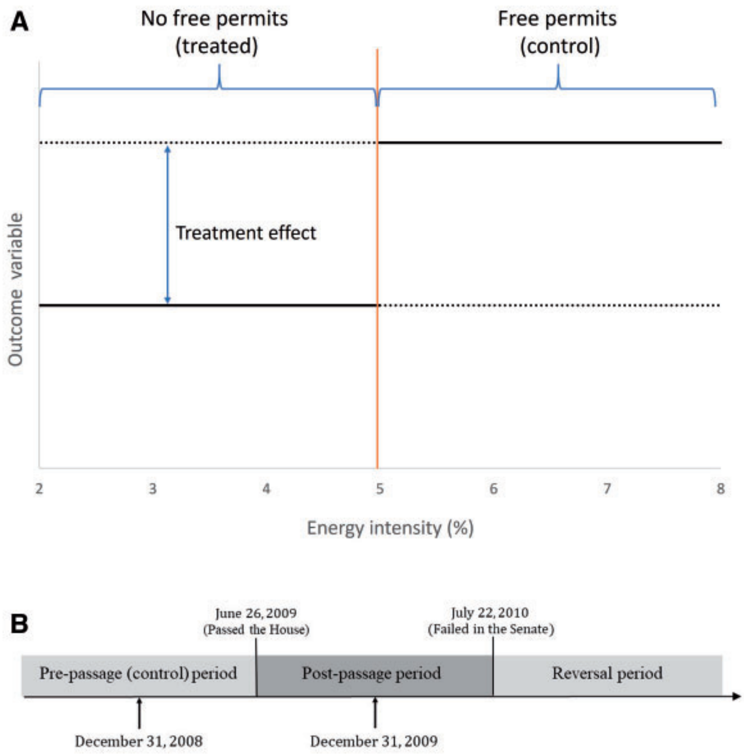


Figure 3
Identification strategy for the Waxman-Markey bill analysis
Panel A illustrates the identification strategy that assigns firm treatment by exploiting the free permit threshold based on energy intensity for the analysis of the Waxman-Markey cap-and-trade bill. Firms below the 5% energy intensity threshold do not receive free permits and are treated. We also conduct analyses allowing for differential effects by energy intensity across the treated firms. Panel B shows the relevant pre/post timeline for the analysis.

in Equation (3) due to differences in the underlying data. The annual SNC data only include firm ratings assigned by the lead lender (the administrative agent) in the supervisory five-grade ratings scale. Therefore, we include indicator variables that take the value of one whenever at least some fraction of the commitments to a borrower are rated “special mention,” “substandard,” “doubtful,” and “loss,” respectively, by the lead bank with “pass” being the omitted category. As the lead bank is the primary relationship-holder with the borrower in the syndicated loan market, we also include lead bank fixed effects. We show in Internet Appendix Table IA-9 that omitting the lead bank fixed effects leads to qualitatively similar results.

4. Baseline Results

In this section, we present our baseline estimates and discuss how the two cap-and-trade bills affect corporate lending to the covered firms.

4.1 California's cap-and-trade bill and credit terms

We first examine how the passage of California's cap-and-trade bill affects firms' loan contracting outcomes. Table 3 reports the estimates of Equation (3) for all three outcomes of interest. Panel A shows that the loan commitments coefficients are negative but insignificant with or without controls. This result suggests that banks do not manage their exposure by immediately cutting credit to firms with a high share of their GHG-emissions in California.

Panel B shows negative and significant estimates on the remaining maturity (in months) of affected firms after the passage of the bill. The remaining maturity of firms with a substantial share of their GHG emissions in California

Table 3
California's cap-and-trade bill and credit

	(1)	(2)	(3)	(4)
A. Log committed credit				
$CA\_Emissions\_Share_i \times I_{\text{Post CA bill}}$	−0.133		−0.119	
	(0.113)		(0.111)	
$I_{CA\_Emissions\_Share_i \geq 50\%} \times I_{\text{Post CA bill}}$		−0.122		−0.098
		(0.108)		(0.102)
Observations	2,929	2,929	2,929	2,929
Adj R^2	.937	.937	.938	.938
B. Remaining maturity (in months)				
$CA\_Emissions\_Share_i \times I_{\text{Post CA bill}}$	−4.514*		−4.723*	
	(2.715)		(2.641)	
$I_{CA\_Emissions\_Share_i \geq 50\%} \times I_{\text{Post CA bill}}$		−5.001**		−5.137**
		(2.506)		(2.391)
Observations	2,929	2,929	2,929	2,929
Adj R^2	.659	.660	.659	.660
C. Term loans share (0 to 1)				
$CA\_Emissions\_Share_i \times I_{\text{Post CA bill}}$	−0.220**		−0.225**	
	(0.102)		(0.099)	
$I_{CA\_Emissions\_Share_i \geq 50\%} \times I_{\text{Post CA bill}}$		−0.219**		−0.225**
		(0.096)		(0.095)
Observations	2,929	2,929	2,929	2,929
Adj R^2	.554	.558	.555	.559
For all panels				
Controls	No	No	Yes	Yes
Uninteracted variables	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry-quarter FE	Yes	Yes	Yes	Yes

This table reports estimates from Equation (3). The dependent variables are the log committed credit in panel A, maturity (in months) in panel B, and the term loans share of total committed credit (0 to 1) in panel C. $I_{\text{Post CA bill}}$ is an indicator variable that takes the value of one for the third or fourth quarter of 2012 and zero for the third or fourth quarter of 2011. $CA\_Emissions\_Share_i$ is a continuous variable (0 to 1) measuring a firm's California GHG emissions as a share of the firm's total GHG emissions. $I_{CA\_Emissions\_Share_i \geq 50\%}$ is an indicator variable that takes the value of one if the firm has at least 50% of its total GHG emissions in California and zero otherwise. Firm and industry-quarter fixed effects are included. Uninteracted independent variables are included in the regression or absorbed by fixed effects. Standard errors are clustered by industry and are reported in parentheses. *$p < .10$; **$p < .05$; ***$p < .01$.

decreases by 4 to 5 months. This decrease is economically significant as the average maturity in our sample is approximately 30 months, as shown in Table 1. We also find a negative and statistically significant effect on firms' reliance on term loans (panel C). Term loans as a share of total commitments decreases by about 0.23 for firms with substantial GHG emissions in California, which suggests that banks gain flexibility to potentially reduce exposure to such firms by substituting permanent financing with cash flow contingent financing.[21]

Importantly, the changes in maturity are not driven by the shift from term loans to credit lines. Internet Appendix Table IA-2 provides the results of the maturity regression with the sample restricted to term loans, and we find even stronger effects. This finding is consistent with banks perceiving their exposure to the term loans of firms with a large share of their GHG emissions in California as riskier than the credit lines of these firms.

Bartram, Hou, and Kim (2022) show that financially constrained public firms shifted some of their GHG emissions out of California after the implementation of the cap-and-trade program. Consequently, it is important to assess whether industries that are less able to "export" emissions across state lines face tighter loan terms. The industry for which avoiding the price on carbon is arguably the most challenging is electricity generation, because electricity imports—electricity generated outside of California but sold in California—are also covered by the cap-and-trade program. In Internet Appendix Table IA-4, we present results that show how for the subsample of electricity generators, the log commitment to electricity generators in California decreases by over 20% after the enactment of the cap-and-trade bill, and this decrease is statistically significant.

4.1.1 Private and public firms The results in Table 3 show that banks actively manage risks introduced by the cap-and-trade bill through the loan contracting process, leading to less borrower-friendly loan terms. When designing cap-and-trade programs, it is also important to understand potential heterogeneity in banks' responses. To do so, we examine whether private firms are differentially affected compared to public firms.

While data on public firms are readily available through mandatory public disclosures, our regulatory data sets are unique in their extensive coverage of private firms. To our knowledge, we are the first to study the effects of climate policy risks on corporate lending to private and public firms. In the emerging climate finance literature, private firms are typically ignored because of a lack of data. Exceptions are Shive and Forster (2020), who investigate private firms' emissions based on Capital IQ data, which are available for larger private

21 The vast majority of loans in the Y14 data are either term loans or credit lines, as well as other types of commitments, such as demand loans. To ensure that the reduction in term loans comes from an increase in credit lines, in unreported tests we estimate the regression in Equation (3) with credit line share as the outcome variable and find the increase in the credit line share to be very similar to the decrease in the term loans share.

firms that issue publicly traded debt. Our sample comprehensively covers a wider range of private firms regardless of public capital markets access. Also, De Haas and Popov (2023) analyze the emissions of Belgian firms around an exogenous shock to the cost of equity and find that they reduce their emissions after going public.

A cap-and-trade program is likely more expensive for private firms than for public ones for several major reasons. First, private firms could be significantly less emissions-efficient than their public counterparts due to limited disclosures and regulation. Anecdotal evidence is consistent with this notion. According to *The New York Times* in June 2021: "Oil and gas giants are selling off their most-polluting operations to small private companies. Most manage to escape public scrutiny."[22] Additionally, a report by the Environmental Defense Fund in May 2022 states: "Assets [oil and gas] are flowing from public to private markets at a significant rate."[23]

We corroborate this idea using balance sheet information on private and public firms from Y14. Based on these data, we construct three measures of emissions inefficiency: total firm emissions divided by net sales, total assets, or total debt. Figure 4, panels A–D, shows median emissions inefficiency as of 2012 for both public and private firms in the four industries that account for about 85% of our sample. All measures indicate that private firms are substantially more emissions inefficient, emitting more GHGs per dollar of revenue, assets, or debt than their public counterparts in the same industry. Normalized emissions are about three times higher for private firms than public firms across all four industries.

Second, size effects may also play a role in a differential impact of cap-and-trade programs on public and private firms. Private firms are smaller—the median private firm in our sample has $600 million in assets compared $5,000 million for public firms. Thus, to the extent that there are economies of scale in regulation compliance, such as upgrading old equipment or becoming more emissions efficient, private firms may be more adversely affected by cap-and-trade programs. Indeed, the California Air and Resources Board concluded that covered firms implemented process and efficiency upgrades in response to the cap-and-trade program.[24]

Finally, private firms tend to be more financially constrained than public firms (Hadlock and Pierce 2010; Saunders and Steffen 2011; Mortal and Reisel 2013; Erel, Jang, and Weisbach 2015; Ivanov, Pettit, and Whited 2022). Therefore, cap-and-trade programs are likely to adversely affect the already limited ability of private firms to obtain the necessary funding from their lenders for their transition to a low emissions

22 See Tabuchi (2021).

23 See https://business.edf.org/insights/transferred-emissions-risks-in-oil-gas-ma-could-hamper-the-energy-transition/.

24 See https://ww2.arb.ca.gov/resources/documents/faq-cap-and-trade-program#ftn24.

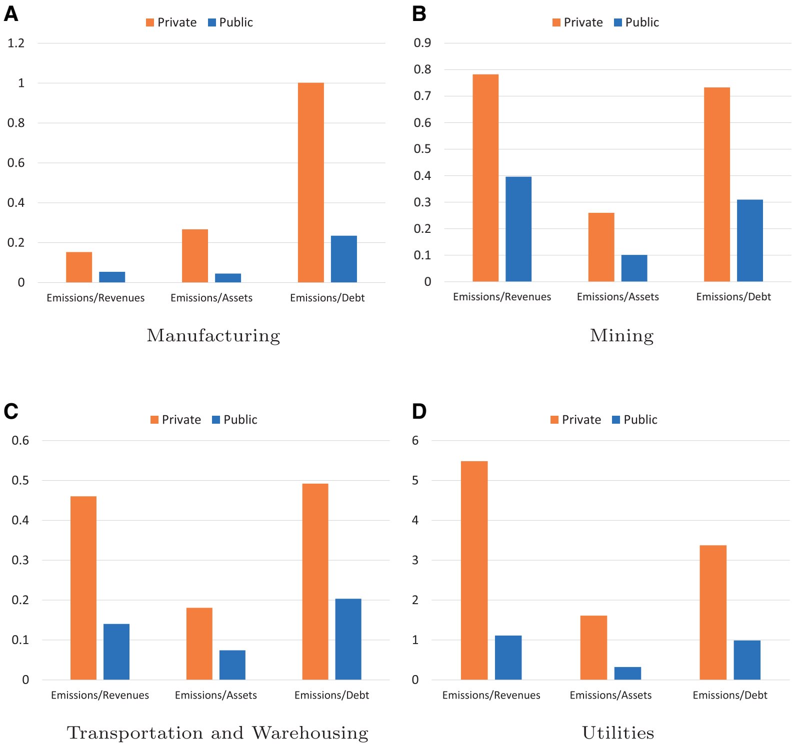


Figure 4
Firm emissions inefficiency
This figure shows the median firm CO2e emissions (in kg) divided by revenues, assets, or debt (in $) in 2012 by sector, for private and public firms separately.

regime. This can lead to additional bargaining power for bank lenders over private firms during the loan negotiation process.

Given these substantial differences between private and public firms, in Table 4 we present results separately for these two types of firms. We show that the effects in Table 3 are concentrated within the subsample of private firms. Private firms exhibit a weakly significant decrease in commitments (panel A) but large and significant decreases in maturity (panel B) and term loan share (panel C). Maturity decreases by 11 to 12 months for private firms with substantial emissions in California as compared to 4 to 5 months for the full sample. Similarly, the passage of the cap-and-trade bill translates to over 0.5 reduction in term loan share for private firms, roughly twice as large as in the full sample.

By contrast, public firms see no change or even some improvement in credit terms after the passage of the cap-and-trade program. For example, term loan share increases significantly, while both commitments and remaining maturity increase but are not statistically significant. These results are consistent

Table 4
California's cap-and-trade bill and credit for private and public firms

	Private firms				Public firms			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A. Log committed credit								
$CA\_Emissions\_Share_i \times I_{\text{Post CA bill}}$	−0.334* (0.170)		−0.265 (0.161)		0.067 (0.204)		0.080 (0.195)	
$I_{CA\_Emissions\_Share_i \geq 50\%} \times I_{\text{Post CA bill}}$		−0.331** (0.167)		−0.255 (0.157)		0.117 (0.160)		0.130 (0.150)
Observations	1,532	1,532	1,532	1,532	1,397	1,397	1,397	1,397
Adj R^2	.902	.902	.909	.909	.928	.923	.928	.924
B. Remaining maturity (in months)								
$CA\_Emissions\_Share_i \times I_{\text{Post CA bill}}$	−11.737*** (3.759)		−11.788*** (3.914)		1.642 (2.857)		1.984 (2.737)	
$I_{CA\_Emissions\_Share_i \geq 50\%} \times I_{\text{Post CA bill}}$		−11.556*** (3.640)		−11.461*** (3.740)		0.203 (3.073)		0.593 (2.981)
Observations	1,532	1,532	1,532	1,532	1,397	1,397	1,397	1,397
Adj R^2	.724	.725	.725	.725	.567	.567	.569	.569
C. Term loans share (0 to 1)								
$CA\_Emissions\_Share_i \times I_{\text{Post CA bill}}$	−0.522*** (0.142)		−0.556*** (0.126)		0.060** (0.024)		0.060** (0.026)	
$I_{CA\_Emissions\_Share_i \geq 50\%} \times I_{\text{Post CA bill}}$		−0.479*** (0.135)		−0.510*** (0.122)		0.050** (0.025)		0.052** (0.024)
Observations	1,532	1,532	1,532	1,532	1,397	1,397	1,397	1,397
Adj R^2	.582	.586	.593	.596	.549	.549	.547	.547
For all panels								
Controls	No	No	Yes	Yes	No	No	Yes	Yes
Uninteracted variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

This table reports estimates from Equation (3). The dependent variables are the log committed credit in panel A, maturity (in months) in panel B, and the term loans share of total committed credit (0 to 1) in panel C. $I_{\text{Post CA bill}}$ is an indicator variable that takes the value of one for the third or fourth quarter of 2012 and zero for the third or fourth quarter of 2011. $CA\_Emissions\_Share_i$ is a continuous variable (0 to 1) measuring a firm's California GHG emissions as a share of the firm's total GHG emissions. $I_{CA\_Emissions\_Share_i \geq 50\%}$ is an indicator variable that takes the value of one if the firm has at least 50% of its total GHG emissions in California and zero otherwise. Firm and industry-quarter fixed effects are included. Uninteracted independent variables are included in the regression or absorbed by fixed effects. Standard errors are clustered by industry and are reported in parentheses. $^*p < .10$; $^{**}p < .05$; $^{***}p < .01$.

with lenders anticipating that private firms face a disproportionately larger increase in operating costs than public firms as a result of the cap-and-trade program, and that public firms are largely unaffected or might even benefit from the adverse impact of the cap-and-trade program on their privately held competitors.

It is difficult to empirically disentangle the extent to which the differential effects between public and private firms are driven by firm ownership or size. Private ownership may allow firms to avoid market and regulatory scrutiny, thereby reducing the incentives of private firms to improve emissions efficiency. Also, private firms are more likely to be dependent on bank financing because of a lack of access to public equity and bonds markets. However, larger firms might be more emissions efficient because of the economies of scale in production processes. Thus, the lack of adverse bank financing effects among public firms may be a by-product of their size. While the high correlation of size and public ownership makes it difficult to disentangle the effects of the two, we show in Internet Appendix Table IA-6 that even the smallest public firms exposed to California's cap-and-trade program do not experience adverse changes to their lending terms. This finding suggests that the results in Table 4 are at least partially driven by public status.

4.1.2 Interest rates Another key loan contract variable is the loan interest rate. A bank might not only manage the expected loss of its loans to high GHG-emitting firms by adjusting contract terms that allow them to mitigate exposure at default if necessary but also require higher interest rates for such loans. Given that the Y14 data provide information on loan interest rates, we also estimate Equation (3) with weighted average loan interest rates paid by a given borrower as the dependent variable. As interest rates in the Y14 data are only reliably available for term loans, we estimate the interest rate regression only for term loans. Table 5 shows that creditors price loans to private firms with exposure to California's cap-and-trade program higher, but we do not find any effect for the subsample of public firms. The effect for private firms is economically large with an estimated interest rate increase of up to 1.7 percentage points. For public firms, the interest rates stay the same, which again suggests that banks expect public firms to be largely unaffected by the cap-and-trade program. Overall, this result implies that banks require direct compensation for bearing the risks related to the legislation in addition to the increased contract flexibility.

4.2 The Waxman-Markey cap-and-trade bill and credit terms

In this section, we examine how loan contract terms respond to the passage of the Waxman-Markey cap-and-trade bill in the House of Representatives as described in Section 3.2. We report the estimates of Equation (4) in Table 6. Overall, the difference-in-differences estimates of total credit commitments, remaining maturity, and term loans share in panels A, B, and C, respectively, are comparable to the effects we find in the California analysis and driven by private firms. Credit commitments do not exhibit a differential response to the bill for firms that fall below the free permit threshold. By contrast, private firms just below the free permit threshold face a shortening of maturities of up to 10 months relative to firms just above the threshold, which is considerable given that the average maturity of loans to firms in the manufacturing sectors near the free permit threshold is approximately 35 months over our sample

Table 5
California's cap-and-trade bill and interest rates

	Full sample				Private firms				Public firms			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$CA\_Emissions\_Share_i \times I_{\text{Post CA bill}}$	0.858 (0.542)		0.798 (0.531)		1.606** (0.773)		1.661** (0.772)		0.373 (0.947)		0.345 (0.838)	
$I_{CA\_Emissions\_Share_i \geq 50\%} \times I_{\text{Post CA bill}}$		0.577 (0.426)		0.608 (0.420)		1.567** (0.689)		1.598** (0.696)		0.022 (0.534)		0.069 (0.487)
Observations	1,418	1,418	1,418	1,418	688	688	688	688	730	730	730	730
Adj R^2	.729	.727	.733	.731	.820	.821	.834	.835	.634	.633	.636	.634
Controls	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes
Uninteracted variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

This table reports estimates from Equation (3) with the interest rate (in %) as the dependent variable. $I_{\text{Post CA bill}}$ is an indicator variable that takes the value of one for the third or fourth quarter of 2012 and zero for the third or fourth quarter of 2011. $CA\_Emissions\_Share_i$ is a continuous variable (0 to 1) measuring a firm's California GHG emissions as a share of the firm's total GHG emissions. $I_{CA\_Emissions\_Share_i \geq 50\%}$ is an indicator variable that takes the value of one if the firm has at least 50% of its total GHG emissions in California and zero otherwise. Only term loans are included in the sample. Firm and industry-quarter fixed effects are included. Uninteracted independent variables are included in the regression or absorbed by fixed effects. Standard errors are clustered by industry and are reported in parentheses. *$p < .10$; **$p < .05$; ***$p < .01$.

Table 6
Waxman-Markey cap-and-trade bill and credit

	All firms				Private firms				Public firms			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
A. Log committed credit												
$I_{i \in Treated} \times I_{t=2009}$	0.057		0.046		−0.035		−0.044		0.120		0.128	
	(0.073)		(0.073)		(0.069)		(0.065)		(0.101)		(0.103)	
$I_{i \in TreatedWide} \times I_{t=2009}$		0.063		0.071		0.056		0.056		0.068		0.083
		(0.057)		(0.055)		(0.068)		(0.066)		(0.076)		(0.074)
Observations	414	805	414	805	223	393	223	393	191	412	191	412
Adj R^2	.926	.930	.926	.930	.929	.913	.930	.911	.873	.913	.871	.917
B. Remaining maturity (in months)												
$I_{i \in Treated} \times I_{t=2009}$	−5.848		−6.062		−9.995		−10.478*		0.734		0.213	
	(4.001)		(3.814)		(5.945)		(5.230)		(2.857)		(2.674)	
$I_{i \in TreatedWide} \times I_{t=2009}$		−4.122		−4.258		−8.115		−8.474*		2.265		2.287
		(3.708)		(3.676)		(5.422)		(4.966)		(2.588)		(2.675)
Observations	414	805	414	805	223	393	223	393	191	412	191	412
Adj R^2	.656	.703	.659	.704	.581	.683	.603	.691	.803	.740	.831	.742
C. Term loans share (0 to 1)												
$I_{i \in Treated} \times I_{t=2009}$	−0.138**		−0.123*		−0.279***		−0.247***		0.021		0.018	
	(0.066)		(0.069)		(0.073)		(0.068)		(0.092)		(0.097)	
$I_{i \in TreatedWide} \times I_{t=2009}$		−0.113*		−0.116*		−0.238***		−0.230***		0.035		0.023
		(0.064)		(0.061)		(0.065)		(0.060)		(0.080)		(0.081)
Observations	414	805	414	805	223	393	223	393	191	412	191	412
Adj R^2	.640	.641	.676	.643	.653	.662	.704	.664	.655	.630	.654	.659
For all panels:												
Controls	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lead bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

This table reports estimates from Equation (4). The dependent variables are the log committed credit in panel A, maturity (in months) in panel B, and the term loans share of total committed credit (0 to 1) in panel C. $I_{i \in Treated}$ is an indicator variable that takes the value of one if the firm would not receive free permits under Waxman-Markey and zero otherwise. $I_{t=2009}$ is an indicator variable that takes the value of one for year 2009 and zero for year 2008. The results are shown for all firms and the subsamples of private and public firms. Firm, year, and lead bank fixed effects are included. Uninteracted independent variables are absorbed by fixed effects. Standard errors are clustered by industry and reported in parentheses. *$p < .10$; **$p < .05$; ***$p < .01$.

period, as shown in Table 2. Additionally, for private firms below the free permit threshold reliance on credit lines increases at the expense of term loans. The difference is again economically significant as term loans share (credit line share) is approximately 22-28 percentage points lower (higher) for firms just below the free permit threshold than for those just above the threshold. Syndicated loans in the SNC database are almost exclusively credit lines or term loans, so an increase in the term loans share implies a lockstep decrease in the credit lines share.

We also examine potential heterogeneity in the impact of the Waxman-Markey bill on firms below the 5% free permit cutoff. Within the set of firms that are just below the cutoff, those with higher energy intensities are more likely to be affected by the cap-and-trade program as carbon pricing increases energy expenditures for fuel and electricity. We estimate two specifications that include separate coefficients for each energy intensity bucket below the free permit threshold:

$$\begin{aligned} y_{i,t} =& \lambda_1 I_{EI_i \in [1,2)} \times I_{t=2009} + \lambda_2 I_{EI_i \in [2,3)} \times I_{t=2009} + \lambda_3 I_{EI_i \in [3,4)} \times I_{t=2009} \\ &+ \lambda_4 I_{EI_i \in [4,5)} \times I_{t=2009} + Controls_{i,t} + \psi_i + \phi_t + \gamma_b + \epsilon_{i,t}, \end{aligned} \tag{5}$$

$$\begin{aligned} y_{i,t} =& \lambda_1 I_{EI_i \in [1,3)} \times I_{t=2009} + \lambda_2 I_{EI_i \in [3,5)} \times I_{t=2009} \\ &+ Controls_{i,t} + \psi_i + \phi_t + \gamma_b + \epsilon_{i,t}. \end{aligned} \tag{6}$$

Panel A in Table 7 shows that firms in the 4% to 5% energy intensity bucket face large and significant changes in maturity and insignificant impact on term loan share, while firms in the lower energy intensity buckets face large changes in term loan share and limited effect on loan maturity. Panel B shows that the results are substantially stronger among private firms for both regression specifications shown in Equations (5) and (6), respectively. Private firms with the highest energy intensity below the free permit threshold face reductions in both maturity and term loan share in addition to reductions in loan commitments. These results are consistent with banks using different tools to reduce exposure that vary with the expected impact of the cap-and-trade program. Banks cut commitments to the most affected firms, while applying reductions in term loans share and maturity more broadly to most other covered firms.[25]

Because firms in our sample receive free permits based on energy intensity, our difference-in-differences estimates could be confounded by developments in the price of energy between 2008 and 2009. The narrow bandwidth around

[25] Banks are known to actively and closely monitor firms, and thus, possess information unavailable to other stakeholders (Diamond, 1984). We test whether the industries with the largest decrease in stock market valuations due to the Waxman-Markey cap-and-trade bill, as measured by Meng (2017) and Meng and Rode (2019), also experience the most stringent loan contracts and show in Internet Appendix Table IA-8 that the expectations of the banks and stock market differ. To be able to conduct this analysis for private and public firms, we assume that the heterogeneity of stock market expectations across industries is similar for private and public firms.

Table 7
Waxman-Markey cap-and-trade bill and credit by energy intensity

	Log committed		Remaining Maturity		Term loans share	
	(1)	(2)	(3)	(4)	(5)	(6)
A. All firms						
$I_{EI_i\in[1,2)}\times I_{t=2009}$	0.079		−3.420		−0.115*	
	(0.056)		(3.727)		(0.065)	
$I_{EI_i\in[2,3)}\times I_{t=2009}$	0.077		−5.268		−0.111*	
	(0.072)		(3.762)		(0.064)	
$I_{EI_i\in[3,4)}\times I_{t=2009}$	0.023		−4.812		−0.189***	
	(0.078)		(4.138)		(0.061)	
$I_{EI_i\in[4,5)}\times I_{t=2009}$	−0.111		−7.380*		−0.058	
	(0.084)		(3.759)		(0.154)	
$I_{EI_i\in[1,3)}\times I_{t=2009}$		0.078		−4.148		−0.113*
		(0.055)		(3.684)		(0.063)
$I_{EI_i\in[3,5)}\times I_{t=2009}$		−0.014		−5.578		−0.153**
		(0.078)		(3.937)		(0.072)
Observations	805	805	805	805	805	805
Adj R^2	.930	.930	.702	.703	.641	.642
B. Private firms						
$I_{EI_i\in[1,2)}\times I_{t=2009}$	0.149*		−7.188		−0.217***	
	(0.085)		(4.831)		(0.067)	
$I_{EI_i\in[2,3)}\times I_{t=2009}$	−0.053		−8.928*		−0.240***	
	(0.070)		(5.301)		(0.067)	
$I_{EI_i\in[3,4)}\times I_{t=2009}$	0.036		−15.208***		−0.281***	
	(0.090)		(5.741)		(0.077)	
$I_{EI_i\in[4,5)}\times I_{t=2009}$	−0.189***		−11.312**		−0.234***	
	(0.050)		(4.823)		(0.053)	
$I_{EI_i\in[1,3)}\times I_{t=2009}$		0.068		−7.854		−0.226***
		(0.070)		(4.888)		(0.062)
$I_{EI_i\in[3,5)}\times I_{t=2009}$		−0.051		−13.991**		−0.266***
		(0.091)		(5.486)		(0.065)
Observations	393	393	393	393	393	393
Adj R^2	.913	.911	.690	.693	.657	.662
For all panels						
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Lead bank FE	Yes	Yes	Yes	Yes	Yes	Yes

This table reports estimates from Equations (5) and (6). The dependent variables are the log committed credit, maturity (in months), and the term loans share of total committed credit (0 to 1). $I_{EI_i\in[a,b)}$ is an indicator variable that takes the value of one if the firm would not receive free permits under Waxman-Markey and the energy intensity level of the firm is at least a% and less than b%, and zero otherwise. $I_{t=2009}$ is an indicator variable that takes the value of one for year 2009 and zero for year 2008. The results are shown for all firms and the subsample of private firms. Firm, year, and lead bank fixed effects are included. Uninteracted independent variables are absorbed by fixed effects. Standard errors are clustered by industry and reported in parentheses. *$p < .10$; **$p < .05$; ***$p < .01$.

the 5% energy intensity cutoff alleviates this concern because it ensures that we compare firms that do not differ substantially in terms of energy intensity. In addition, crude oil prices nearly doubled from December 2008 to December 2009—the Brent crude oil price increased from $43.72 on December 31, 2008, to $78.39 on December 31, 2009. Therefore, if anything, energy price changes during this period works against the results we document: firms receiving free permits—those with higher energy intensity—will see a greater increase in operating costs due to higher energy prices relative to firms without free permits, but obtain better financing terms according to our analysis, due to the impact of the cap-and-trade bill.

The Waxman-Markey bill went through the legislative process in the aftermath of the Global Financial Crisis, and thus, it is important to understand whether the crisis may have differentially affected corporate lending to manufacturing firms. Such confounding factors are likely to be differenced out because we compare manufacturing firms above and below the free-permit threshold. Additionally, the placebo tests discussed in Section 5.3 and shown in Figure 6 confirm that from the end of 2007 to the end of 2008—the height of the Global Financial Crisis, but before the introduction of the Waxman-Markey bill—we do not observe any differential effects around the 5% energy intensity threshold. Finally, we also assess this possibility using sales and employment data from the National Establishment Time Series database.[26] Internet Appendix Table IA-10 shows no differential impact on sales and employment around the energy intensity threshold during the height of the Global Financial Crisis, suggesting that these industries were similarly affected by that crisis.

The analyses presented so far show that firms' total commitments are largely unaffected by the passage of the cap-and-trade bills. However, this leaves the possibility that firms' outstanding (or utilized) commitments decrease as firms shift reliance from term loans to credit lines. Particularly, in response to cap-and-trade program uncertainty, firms may reduce leverage by increasing the share of their credit line financing and utilizing less of their credit commitments. To test for this possibility, Internet Appendix Table IA-1 shows estimates of Equations (3) and (4) with the total utilized credit normalized by total commitments amount as the dependent variable. For both the California cap-and-trade bill and the Waxman-Markey cap-and-trade bill, the coefficient estimates are economically small and statistically insignificant. These results suggest that the shift from term loans to credit lines is not driven by firms utilizing less credit.

As loan contract renegotiation between borrowers and lenders changes contracts terms, such as amounts, maturities, interest rates, and credit line share simultaneously with financial covenants (Roberts, 2015), it is important to examine how cap-and-trade bills affect financial covenants. Specifically, it is possible that banks relax the financial covenants of firms affected by cap-and-trade trade programs, while tightening remaining maturities and term loan shares, thereby rendering the effect on loan contracts ambiguous. The SNC

26 See, for example, Addoum, Ng, and Ortiz-Bobea (2020) and Kruttli, Roth Tran, and Watugala (2023) for a description of the database.

Table 8
Waxman-Markey cap-and-trade bill and cash flow covenants

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$I_{i\in Treated} \times I_{t=2009}$	0.319**		0.320**		0.275**		0.186	
	(0.129)		(0.136)		(0.130)		(0.114)	
$I_{i\in TreatedWide} \times I_{t=2009}$		0.264**		0.234**		0.289**		0.245**
		(0.100)		(0.098)		(0.116)		(0.113)
Observations	143	264	143	264	143	264	143	264
Adj R^2	.606	.643	.613	.642	.657	.629	.674	.624
Controls	No	No	No	No	Yes	Yes	Yes	Yes
Lead bank FE	No	No	Yes	Yes	No	No	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

This table reports estimates from Equation (4). The dependent variable is an indicator variable that takes the value of one if the firm has a cash flow covenant. $I_{i\in Treated}$ is an indicator variable that takes the value of one if the firm would not receive free permits under Waxman-Markey and zero otherwise. $I_{i\in TreatedWide}$ is the equivalent variable for the wide bandwidth sample. $I_{t=2009}$ is an indicator variable that takes the value of one for year 2009 and zero for year 2008. Firm, year, and lead bank fixed effects are included. Uninteracted independent variables are absorbed by fixed effects. Standard errors are clustered by industry and reported in parentheses. *$p < .10$; **$p < .05$; ***$p < .01$.

data allow us to measure whether any of the loans of a given borrower include cash flow covenants.

We estimate Equation (4) with the cash flow covenant indicator as an outcome variable. The sample is smaller than in our baseline Waxman-Markey results because the cash flow covenant measure is only available for the subset of loans/borrowers that are reviewed in the SNC exam. The SNC Program typically samples the largest and most complex syndicated loans for annual/semi-annual examinations to assess systemic stability risks in the syndicated loan market. During our sample period, this sample represents only up to 41% of the total dollar amount of total SNC loans (Gustafson, Ivanov, and Meisenzahl, 2021). Therefore, we are unable to conduct subsample analyses for these tests. The results in Table 8 show that firms just below the free permit threshold are more likely to have a cash flow covenant in their loan contracts following the passage of the Waxman-Markey bill in the House of Representatives. The coefficient estimates imply that firms without free permits face between a 19- and 32-percentage-point higher probability of having cash flow covenants in their contracts after the passage of the program. Therefore, the strictness of loan contracts increases even further once we consider financial covenants.

Overall, our analyses of the two independent natural experiments, the California and the Waxman-Markey cap-and-trade bills, yield qualitatively similar results. This is reassuring considering that both the time period and the treatment assignment are different. The magnitude of the estimates are also similar in the two sets of analyses, which might be surprising given that the California cap-and-trade bill became a law, while the Waxman-Markey cap-and-trade bill ultimately failed in the U.S. Senate. The significant effect of the Waxman-Markey bill on firm financing is likely due to the federal nature of the bill. A national cap-and-trade program is potentially more stringent to firms than a single-state program because shifting GHG emissions to less regulated jurisdictions is arguably more challenging and a larger share of firms' emissions would be covered. In line with this idea, Martin, Muûls, Preux, and Wagner (2014) find that program avoidance is limited for the Emissions Trading Scheme in the European Union.

5. Systemic Stability Implications and Robustness

This section presents analysis that helps us understand alternative ways for banks to manage exposure to affected firms and the impact of the cap-and-trade program on firms' balance sheets. Further, it shows robustness tests for our baseline results from Section 4. The analyses in this section rely on either the SNC or the Y14 data, depending on data availability.

5.1 Lenders' ex ante exposure and shadow banks

An important financial stability consideration is the extent to which risks are concentrated within specific types of lenders. If lenders with high ex ante exposure to the climate policy quickly transfer these risks to less exposed lenders, systemic stability concerns are likely to be mitigated when a realization of transition risk like the passage of a cap-and-trade bill occurs. We explore this idea using lender-firm level data and test whether overall lenders' total exposure to high-emission firms affects lenders' incentives to sell syndicated loans when a cap-and-trade bill is passed. A wide range of lenders trade syndicated loans on the secondary loan market and the richness of the SNC data allow us to trace the evolution of lenders' loan positions over time (Irani and Meisenzahl, 2017).

We first compute a lender's total exposure to a given firm as a fraction of the lender's total syndicated loans:

$$LenderFirmExposure_{i,l,t} = \frac{FirmLending_{i,l,t}}{TotalLending_{l,t}}, \tag{7}$$

where the numerator is the total syndicated commitments of firm i held by lender l at the end of year t, and the denominator is the total syndicated commitments across all borrowers held by lender l in year t.

We also compute a lender's exposure to high GHG-emitting firms as of 2008—the pre-period of the Waxman-Markey analysis:

$$LenderHighEmissionExposure_l = \frac{\sum_{i=1}^{N} FirmLending_{i,l,2008} \times I_{i \in HighEmissionFirms}}{TotalLending_{l,2008}}, \tag{8}$$

where $HighEmissionFirms$ are all the firms that are included in the EPA data set, as well as fuel suppliers from sectors covered by the proposed Waxman-Markey cap-and-trade program. The EPA data are as of 2010, the first available year in the data. Figure 5, panels A and B, shows the distribution of the

$LenderHighEmissionExposure_l$ variable for all the lenders in our sample. The median lender working with affected firms in the baseline or the wide bandwidth specifications has portfolio exposure to high GHG-emitting firms of about 9%.

We then test whether lenders with above median ex ante exposure to high GHG-emitting firms ("high emission lenders") are more likely to sell the syndicated loans of treated manufacturing firms after the House of Representatives passed the Waxman-Markey cap-and-trade bill using the following regression specification:

$$LenderFirmExposure_{i,l,t} = \lambda_1 I_{l \in HighEmissionLender} \times I_{i \in Treated} \times I_{t=2009} + \omega_{i,l} + \Omega_{i,t} + \epsilon_{i,l,t}, \quad (9)$$

where the indicator variable $I_{l \in HighEmissionLender}$ takes the value of one if lender l had an above median $LenderHighEmissionExposure_l$ as defined in Equation (8). We also include firm × lender fixed effects, $\omega_{i,l}$, to ensure that the estimates capture changes within a firm and lender, and firm × year fixed effects, $\Omega_{i,t}$. These fixed effects subsume lower order interaction terms as well as firm and lender fixed effects. The remaining variables are defined the same way as for Equation (4), and the standard errors are double-clustered by six-digit NAICS industry and lender.

Table 9 shows that the estimate of the high GHG emission exposure interaction term is consistently negative and strongly significant. The estimates range between −0.015 and −0.008 and imply a considerable economic magnitude in light of the average $LenderFirmExposure_{i,l,t}$ shown in Table 2, panel C, ranging between 0.035 and 0.040. These results show that lenders' current exposure to high GHG-emitting firms is an important factor in their decision to sell the syndicated loans of firms that would not receive free permits under the proposed Waxman-Markey cap-and-trade program.

Syndicated loans are held not only by banks but also by shadow banks, for example, CLOs, pension funds, and hedge funds. Shadow banks hold a significant share of syndicated loans (Irani et al., 2021), and may increase exposure to polluting firms after the passage of a cap-and-trade regulation because of different risk appetites. Understanding these dynamics is important, because risks may accumulate in certain pockets of the nonbank financial sector such as CLOs, pension funds, or other shadow banks, leading to a more fragile financial system.

To test which shadow banks increase their holdings of the syndicated loans of treated firms, we modify Equation (9) by including interaction terms between $I_{i \in TreatedWide} \times I_{t=2009}$ and indicators for each type of lender: bank, CLO, collateralized debt obligations (CDOs), pension fund, insurance company, bank-affiliated fund, nonfinancial company, investment fund (e.g., a mutual or a hedge fund), and other credit institutions. We limit the sample to term loans as shadow banks are unlikely to participate in credit lines. Firm-year fixed effects

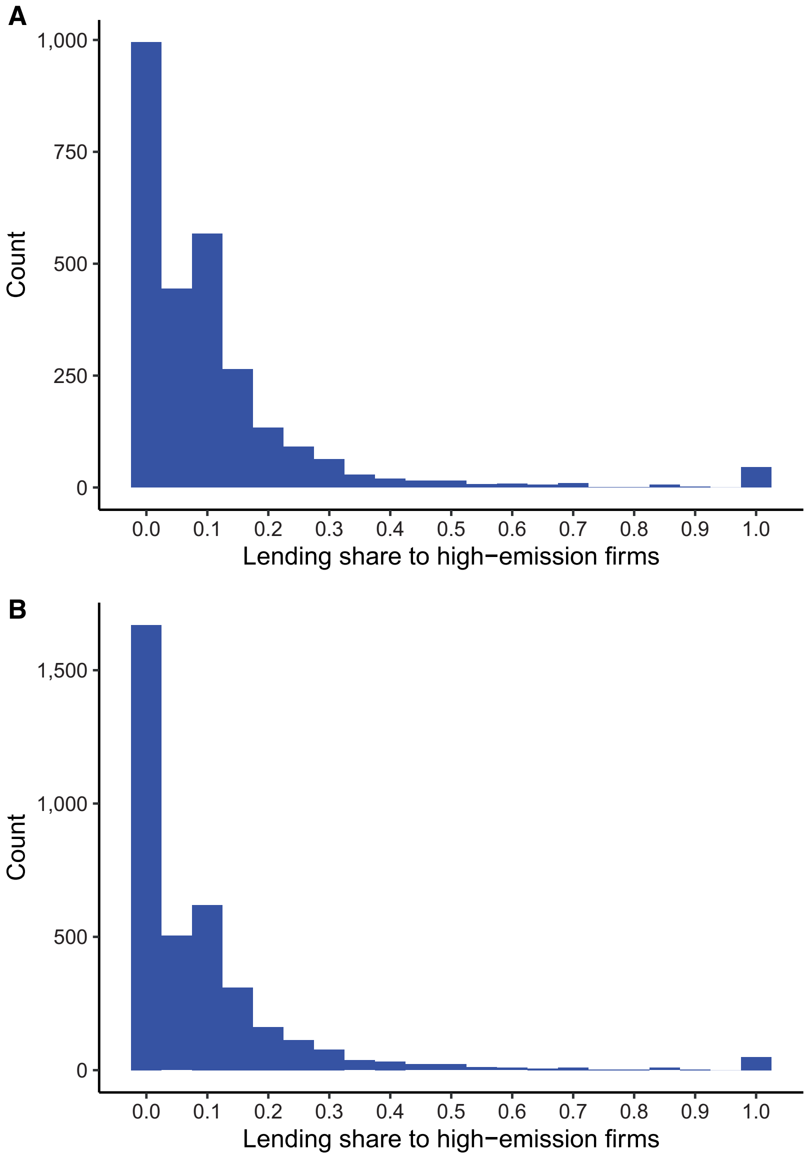


Figure 5
Lenders' exposure to high GHG-emitting firms
This figure shows the distribution in 2008 of the lenders' credit commitment to high GHG-emitting firms as a share of total credit commitment, $LenderHighEmissionExposure_l$, defined in Equation (8). Panels A and B include all lenders that lend to firms within the baseline and wide bandwidths of the Waxman-Markey analysis, respectively. This variable is used in Equation (9), the estimates of which are presented in Table 9.

Table 9
Waxman-Markey cap-and-trade bill and lenders' emission exposure

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$I_{i \in Treated} \times I_{t=2009}$	0.000		0.000					
	(0.009)		(0.008)					
$I_{i \in TreatedWide} \times I_{t=2009}$		0.000		−0.001				
		(0.010)		(0.009)				
$I_{i \in Treated} \times I_{t=2009}$	−0.014***		−0.015***		−0.008***		−0.012***	
$\times I_{l \in HighEmissionLender}$	(0.003)		(0.003)		(0.003)		(0.004)	
$I_{i \in TreatedWide} \times I_{t=2009}$		−0.013**		−0.013**		−0.009***		−0.012***
$\times I_{l \in HighEmissionLender}$		(0.005)		(0.005)		(0.003)		(0.005)
Observations	19,358	38,121	19,358	38,121	19,358	38,121	19,358	38,121
Adj R^2	.669	.598	.672	.600	.806	.769	.681	.611
Controls	No	No	Yes	Yes	No	No	No	No
Lender FE	No	No	No	No	Yes	Yes	No	No
Year FE	Yes	Yes	Yes	Yes	No	No	No	No
Firm-lender FE	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Firm-year FE	No	No	No	No	Yes	Yes	Yes	Yes

This table reports estimates from Equation (9). The dependent variable is a lender-firm level variable given in Equation (7), which measures the credit commitment between a firm and a lender as a share of the total credit commitments of the lender. $I_{i \in Treated}$ is an indicator variable that takes the value of one if the firm would not receive free permits under Waxman-Markey and zero otherwise. $I_{i \in TreatedWide}$ is the equivalent variable for the wide bandwidth sample. $I_{t=2009}$ is an indicator variable that takes the value of one for year 2009 and zero for year 2008. $I_{l \in HighEmissionLender}$ is indicator variable that takes the value of one if the lender has above median exposure to high GHG-emitting firms in 2008. Lower order interaction terms that are not shown are absorbed by fixed effects. Firm, year, and lender fixed effects are included separately or interacted. Standard errors are double-clustered by industry and lender and reported in parentheses. *$p < .10$; **$p < .05$; ***$p < .01$.

account for time-varying firm-specific factors, such as the reduced term loan reliance of firms without free permits under the proposed Waxman-Markey cap-and-trade program, while the interaction terms help isolate how different types of lenders change exposure to treated firms.

Table 10 shows that shadow banks, such as CLOs and CDOs, significantly increase their holdings of the syndicated loans of firms without free permits across specifications by nearly 3 percentage points. By contrast, insurance companies sharply decrease their holdings of firms without free permits although this result becomes insignificant once we compare insurance companies only to banks (column 10). Overall, these results suggest that banks not only change the loan terms of high GHG-emitting firms in light of pending cap-and trade regulations but also transfer their risk exposure to other participants in the syndicated loan market.

5.2 Balance sheet effects

The results presented in the previous sections are consistent with banks tightening loan terms in response to the expected adverse cash flow effects of carbon pricing. While the ultimate impact of a cap-and-trade program on firms' cash flow is unclear prior to implementation, banks are likely to insure against the states of the world in which firms' cash flow is substantially lower

Table 10
Waxman-Markey cap-and-trade bill and shadow bank types

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$I_{i\in TreatedWide}\times I_{t=2009}$ $\times I_{l\in Bank}$	−0.011 (0.011)									
$I_{i\in TreatedWide}\times I_{t=2009}$ $\times I_{l\in CLO}$		0.025*** (0.006)								0.028*** (0.009)
$I_{i\in TreatedWide}\times I_{t=2009}$ $\times I_{l\in CDO}$			0.018** (0.007)							0.027*** (0.007)
$I_{i\in TreatedWide}\times I_{t=2009}$ $\times I_{l\in PensionsFunds}$				−0.001 (0.022)						0.008 (0.028)
$I_{i\in TreatedWide}\times I_{t=2009}$ $\times I_{l\in Insurance}$					−0.050** (0.020)					−0.038 (0.026)
$I_{i\in TreatedWide}\times I_{t=2009}$ $\times I_{l\in BankAffiliatedFunds}$						−0.002 (0.014)				0.008 (0.014)
$I_{i\in TreatedWide}\times I_{t=2009}$ $\times I_{l\in NonFinancialCompanies}$							−0.035 (0.066)			−0.028 (0.069)
$I_{i\in TreatedWide}\times I_{t=2009}$ $\times I_{l\in InvestmentFunds}$								−0.015*** (0.005)		0.001 (0.012)
$I_{i\in TreatedWide}\times I_{t=2009}$ $\times I_{l\in Others}$									0.010 (0.011)	0.020** (0.010)
Observations	24,138	24,138	24,138	24,138	24,138	24,138	24,138	24,138	24,138	24,138
Adj R^2	.561	.562	.561	.561	.562	.561	.561	.561	.561	.563
Firm-lender FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

This table reports estimates from Equation (9) but interacting the independent variable with lender type. The dependent variable is a lender-firm level variable given in Equation (7), which measures the credit commitment between a firm and a lender as a share of the total credit commitments of the lender. $I_{i\in TreatedWide}$ is an indicator variable that takes the value of one if the firm would not receive free permits under Waxman-Markey and zero otherwise. $I_{t=2009}$ is an indicator variable that takes the value of one for year 2009 and zero for year 2008. $I_{l\in A}$ is an indicator variable that takes the value of one if the lender is of type "A" and zero otherwise. In column 10, the reference lender type is "Bank," which is thus dropped from the regression. Only term loans are included in the sample. Lower order interaction terms are included in the regression or absorbed by fixed effects. Firm fixed effects are interacted with year and lender fixed effects, respectively. Standard errors are double-clustered by industry and lender and reported in parentheses. *$p < .10$; **$p < .05$; ***$p < .01$.

and more volatile. As discussed in Section 1.3, a lower or more volatile cash flow increases the probability of default and the loss given default.

The Y14 data allow us to analyze how cap-and-trade programs affect cash flow and other balance sheet outcomes in the context of California's cap-and-trade program. As these financial statement information are updated annually or biennially, the data are well suited for studying the evolution of firm balance sheet outcomes around the implementation of California's cap-and-trade program. Consequently, we define the pre-period as 2011 and the post-period as 2013, the first year of the implementation. We measure cash flow with firms' earnings before interest, taxes, depreciation, and amortization (EBITDA) normalized by total assets and estimate the regression in Equation (3) with this measure as the dependent variable.

Table 11, panel A, shows a significant reduction in EBITDA/Assets for firms with a large emissions share in California after the implementation of the

Table 11
California's cap-and-trade program implementation and firm balance sheets

	All firms		Private firms		Public firms	
	(1)	(2)	(3)	(4)	(5)	(6)
A. EBITDA/Assets						
$CA\_Emissions\_Share_i \times I_{\text{Post CA Implementation}}$	−3.940* (2.221)	−3.891* (2.203)	−6.177*** (0.794)	−5.299*** (1.358)	−3.323 (3.924)	−3.358 (3.929)
Observations	1,117	1,117	480	480	637	637
Adj R^2	.525	.520	.421	.411	.567	.572
B. Cash/Assets						
$CA\_Emissions\_Share_i \times I_{\text{Post CA Implementation}}$	3.003* (1.805)	3.193* (1.923)	6.909** (3.339)	5.748 (4.118)	1.232 (2.143)	1.612 (2.333)
Observations	1,135	1,135	486	486	649	649
Adj R^2	.738	.738	.705	.711	.738	.731
C. CapEx/Assets						
$CA\_Emissions\_Share_i \times I_{\text{Post CA Implementation}}$	−2.666 (3.362)	−2.935 (3.480)	−4.738** (2.150)	−4.926* (2.693)	3.800 (2.760)	2.541 (2.748)
Observations	1,045	1,045	452	452	593	593
Adj R^2	.208	.200	.380	.354	.118	.116
For all panels:						
Controls	No	Yes	No	Yes	No	Yes
Uninteracted variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes

This table reports estimates from Equation (3) estimated with annual firm balance sheet data and 2013 as the post-period. The dependent variables are EBITDA/Assets (panel A), Cash/Assets (panel B), CapEx/Assets (panel C). $I_{\text{Post CA Implementation}}$ is an indicator variable that takes the value of one for 2013 and zero for 2011. $CA\_Emissions\_Share_i$ is a continuous variable (0 to 1) measuring a firm's California GHG emissions as a share of the firm's total GHG emissions. Firm and industry-year fixed effects are included. Uninteracted independent variables are included in the regression or absorbed by fixed effects. Standard errors are clustered by industry and are reported in parentheses. *$p < .10$; **$p < .05$; ***$p < .01$.

cap-and-trade program. This result is again driven by private firms in the sample. A one-standard-deviation increase in emissions in California is associated with a decrease in EBITDA/Assets between 1.39 and 1.62 percentage points for private firms depending on the specification.[27] While this decrease is economically relevant compared to the average EBITDA/Assets of around 12%, it might be lower than the banks expected as the ultimate price on carbon was close to the price floor set by the California Air and Resources Board. The settlement price of the auctions up to the end of 2013 ranged from \$10.09 to \$14.00, and was thus very close to the price floor of the auctions, which ranged from \$10.00 to \$10.71.

[27] The standard deviation of private firms' emissions share in California is 0.26.

This decrease in cash flow is consistent with higher firm operating costs as a result of the program, particularly for the emissions inefficient private firms. This effect is likely to have a direct component that comes from the price on emissions stemming from the combustion of fossil fuels in production processes. However, there is also an indirect supply chain effect where electricity and potentially other inputs become more expensive as a result of the price on carbon. While the supply chain effect is difficult to estimate, our estimates of the decrease in cash flow are roughly in line with auction prices of the emission allowances. Based on the coefficient estimates shown in Table 11, a one-standard-deviation move in a firm's California emission share is estimated to decrease EBITDA by around \$8.5 million for private firms. Up to the end of 2013, around \$1.4 billion in allowances were sold in auctions, which translates into about \$6 million per firm.[28]

As discussed in Section 1.3, an increase in cash flow variance also leads to an increase in the probability of default and the loss given default. However, conclusively testing for changes in cash flow variance is challenging because the low frequency of financial statements in our data do not allow us to compare a firm's cash flow variance around the implementation of the California cap-and-trade program. Overall, the relative stability of the quarterly auction settlement price on carbon and the limited year-to-year changes in firm emissions suggest that the adverse effect on mean cash flow is somewhat more pronounced than the effect on cash flow variance after program implementation.[29]

Panel B shows that the potentially higher uncertainty in obtaining external finance for private firms documented in Section 4.1 also translates to large increases in cash balances normalized by assets, indicating an increase in precautionary savings. A one-standard-deviation increase in emissions in California amounts to a 1.8-percentage-point increase in the cash-to-assets of affected private firms relative to the average and median cash-to-assets of private firms of 9% and 3%, respectively. Finally, we find that the higher uncertainty in accessing external capital markets and higher savings rates also leads to lower investment as proxied by net capital expenditures (in panel C) normalized by assets. Overall, we show that the highly uncertain environment in the bank financing market for firms covered by California's cap-and-trade program has adverse real implications for these firms. This reduction in investment and the increase in cash holdings could further impact the profitability of private firms.

The firm balance sheet data allow us to investigate the additional robustness of the baseline effects on total credit commitments in Section 4.1 as these results are based only on commitments from banks subject to Y14 reporting.

28 See https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program/cap-and-trade-program-data.

29 Auction settlement prices can be found here: https://ww2.arb.ca.gov/sites/default/files/2020-08/results_summary.pdf. The median absolute change in firm emissions year-to-year is around 8,000 MTs of CO_2e.

It is possible that private firms shift borrowing to nonbanks and small banks that do not report to Y14 around the passage of the cap-and-trade bill. Firms' total balance sheet debt includes borrowing from all sources, thereby allowing us to investigate whether such substitution occurs. We, therefore, compare firms' total debt in 2012 relative to total debt in 2011. In Internet Appendix Table IA-3, we show similar results for firms' total debt as in our baseline commitment specifications in Table 4—while total debt of private firms declines following the passage of California's cap-and-trade program, these results are not significantly different from zero—suggesting limited substitution of borrowing sources.

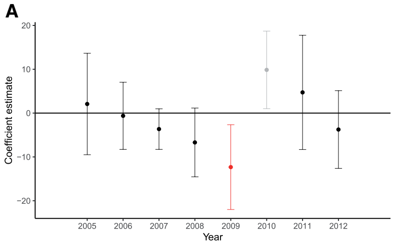
5.3 Robustness tests

In this section, we discuss additional robustness tests. We first examine the possibility of pre-trends in our difference-in-differences setting. This seems unlikely as our estimates rely on two distinct natural experiments, with treatment along different dimensions that occur at different points in time. Nevertheless, the longer time series dimension of the SNC data allow us to test for differences around the energy intensity threshold of the Waxman-Markey bill before the bill's passage by the House of Representatives in 2009. We also examine whether the treatment effects reverse in 2010 after the bill failed in the U.S. Senate.

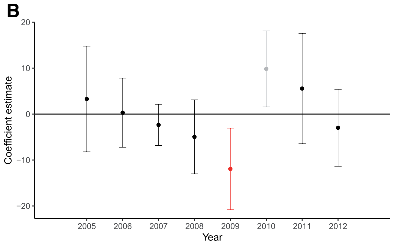
We reestimate Equation (6) over the following year pairs: from (2004, 2005) through (2011, 2012). The regression coefficients are plotted in Figure 6 with the "post" year of each test on the *x*-axis. The dependent variables are those for which we previously found a statistically significant effect: maturity, term loans share, and the incidence of cash flow covenants from Section 4.2. Covenants data are not available prior to 2006, so the first 2-year sample for which we can estimate covenants effects is (2006, 2007). Also, because of the smaller number of firms for which covenant data are available, Figure 6 plots the coefficient estimate of Equation (4) for cash flow covenants.

For all three variables, estimates for the coefficient of interest are not significantly different from zero in the placebo years prior to 2009. The coefficients only show a significant effect in 2009, which is the actual treatment year, when Waxman-Markey cleared the House of Representatives and was under consideration by the Senate. This result is reassuring as the effects in 2009 do not appear to be driven by violations in the parallel trends assumption. Interestingly, for all outcome variables, we find that the coefficient estimates revert to pre-2009 levels in the years after the bill failed in the Senate, with the reversion being statistically significant for the maturity and cash flow variables. This result suggests a rebound in borrowers' financial flexibility after the Waxman-Markey cap-and-trade bill failed in the Senate in July 2010.

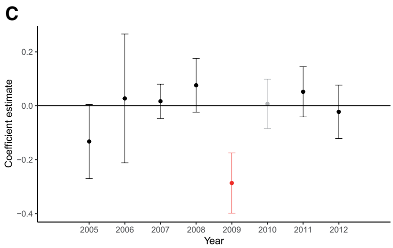
As the Y14 data coverage starts in 2011, we are unable to study pre-trends for the California cap-and-trade setting. To alleviate concerns that our difference-in-differences estimates may be driven by California-specific economic factors



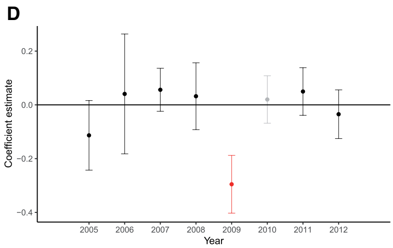
Remaining maturity (baseline bandwidth)



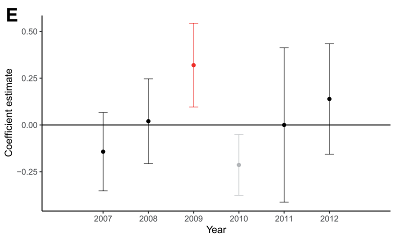
Remaining maturity (wide bandwidth)



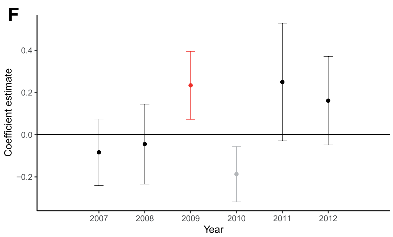
Term loans share (baseline bandwidth)



Term loans share (wide bandwidth)



Cash flow covenants (baseline bandwidth)



Cash flow covenants (wide bandwidth)

Figure 6
Placebo tests for the Waxman-Markey cap-and-trade bill
This figure shows the difference between treated and control firms in the Waxman-Markey analysis for a range of pre and post years based on the coefficient estimates from corresponding regressions using both the baseline and wide bandwidth samples. Panels A and B cover maturity (in months) and panels C and D cover the term loans share of total committed credit (0 to 1). They show coefficients for treated firms in the high energy intensity bucket for regressions on private firms as given in Equation (6). Panels E and F cover cash flow covenants (0 or 1) and show coefficients for treated firms based on regressions as given in Equation (4). The regressions are separately estimated for samples of 2 consecutive years: (2004, 2005), (2005, 2006), (2006, 2007), (2007, 2008), (2008, 2009), (2009, 2010), (2010, 2011), and (2011, 2012). The year shown on the x-axis is the "post" year in a specific test. The Waxman-Markey bill passed the U.S. House of Representatives in 2009 (red), but ultimately failed in the U.S. Senate in 2010 (gray). The cash flow covenant variable is not available prior to 2006. The bands show the 90% confidence interval.

that are unrelated to the cap-and-trade program, we estimate "falsification" style regressions in which nonpolluting firms are treated proportionally to the number of establishments they have in the state as a fraction of total establishments for each firm. The data on firm establishments comes from the National Establishment Time Series database. Similar to our main analysis, we compare the time series evolution of loan commitments, maturity, term loan

Table 12
California's cap-and-trade bill and non-polluting firms

	Log committed		Maturity		Term loans share		Interest rate	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A. All firms								
$CA\_Estab\_Share_i \times I_{\text{Post CA bill}}$	0.039**		−0.259		−0.157*		−0.161	
	(0.019)		(0.944)		(0.088)		(0.102)	
$I_{CA\_Estab\_Share_i \geq 50\%}$ $\times I_{\text{Post CA bill}}$		0.016		−0.530		−0.140*		−0.142
		(0.024)		(1.052)		(0.076)		(0.098)
Observations	40,907	40,907	40,894	40,894	40,894	40,894	11,931	11,931
Adj R^2	.952	.952	.897	.897	.757	.757	.892	.892
B. Private firms								
$CA\_Estab\_Share_i \times I_{\text{Post CA bill}}$	0.040**		−0.095		−0.162*		−0.112	
	(0.019)		(0.907)		(0.093)		(0.112)	
$I_{CA\_Estab\_Share_i \geq 50\%}$ $\times I_{\text{Post CA bill}}$		0.034*		−0.192		−0.151*		−0.108
		(0.020)		(0.937)		(0.083)		(0.109)
Observations	39,188	39,188	39,175	39,175	39,175	39,175	11,178	11,178
Adj R^2	.946	.946	.905	.905	.763	.762	.905	.905
For all panels								
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Uninteracted variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

This table reports estimates from Equation (3), but for firms in nonpolluting sectors. The dependent variables are the log committed credit, remaining maturity (in months), the term loans share of total committed credit (0 to 1), and the interest rate (in %), respectively. $I_{\text{Post CA bill}}$ is an indicator variable that takes the value of one for the third or fourth quarter of 2012 and zero for the third or fourth quarter of 2011. $CA\_Estab\_Share_i$ is a continuous variable (0 to 1) measuring a firm's California establishments as a share of the firm's total establishments. $I_{CA\_Estab\_Share_i \geq 50\%}$ is an indicator variable that takes the value of one if the firm has at least 50% of its total establishments in California and zero otherwise. Firm and industry-quarter fixed effects are included. Uninteracted independent variables are included in the regression or absorbed by fixed effects. Standard errors are clustered by industry and are reported in parentheses. Results are shown for all firms (panel A) and the subsample of private firms (panel B). *$p < .10$; **$p < .05$; ***$p < .01$.

share, and interest rates from the last two quarters of 2011 to those in 2012. We restrict the sample to nonpolluting firms, which we define to be firms in two-digit NAICS sectors with negligible GHG emissions. Each of these eight major sectors accounts for less than 0.01% of emissions in the EPA data set. We also exclude the agricultural sector because it is responsible for a considerable share of GHG emissions that are not covered by EPA data.

Table 12 shows the results for both the full sample (in panel A) and private companies (in panel B). The results in both panels paint a completely different picture from those in our main specifications—nonpolluting firms with larger presence in California do not see much of a change in maturity or interest rates between late 2011 and 2012. In addition, loan commitments of nonpolluting firms increase and term loans share decline between 2011 and 2012, albeit the respective statistical and economic significance is mixed across specifications. These patterns are consistent with debt contracts of nonpolluting firms in California not changing materially between 2011 and 2012. These estimates also stand in stark contrast with our main results in which high-emitting firms in California face substantially stricter loan terms.

6. Conclusion

Despite widespread discussions of climate policy risk, we know little about how lenders manage this risk and about the associated impact on emitting firms. We use specific features of the two major cap-and-trade bills implemented or considered in the United States thus far to identify effects and show that cap-and-trade programs lead to significant changes in corporate lending to affected firms. Firms face shortening in loan maturities, lower access to permanent forms of bank financing such as term loans, higher interest rates, and lower participation of banks in their lending syndicates with increased participation of shadow banks. These effects are mainly concentrated among private firms, suggesting banks are less concerned about the impact of cap-and-trade programs on public firms.

The fluid nature of commercial lending relationships allows banks to adjust their credit exposure quickly through loan renegotiation. This paper shows that they do so swiftly, in ways that mitigate their exposure to cap-and-trade legislation. These findings suggest that, at least in the bilateral and syndicated lending markets, legislation intended to curb GHG emissions and transition to a low-carbon economy is unlikely to pose large, unmanageable risks to the banking sector. The large differential response of private and public firms' loan terms implies that private firms simultaneously face tighter loan terms and a price on carbon, which has important implications for the design of such programs.

Appendix

Table A1
Variable descriptions

Variable name	Data source	Description
Borrower ratings SNC	SNC	Four indicator variables that take the value of one whenever at least some fraction of the commitments to borrower i in year t are rated "special mention," "substandard," "doubtful," and "loss," respectively, by the lead bank. Otherwise, the value of the indicator variables are zero. "Pass" is the omitted category.
Borrower ratings Y14	Y14	Four indicator variables based on the borrower i's credit rating in quarter q. The borrowers's credit ratings are issued by the banks and aggregated across banks for each borrower. As banks use different internal rating scales, banks in the Y14 also convert their own internal rating scale to an S&P scale in order for the measure to be comparable across banks. AAA/AA is the omitted category.
CA emissions share	EPA; Y14	The emissions in California normalized by total emissions of firm i in year y.

Table A1
(Continued)

Variable name	Data source	Description
CA establishment share	NETS; Y14	The number of establishments in California normalized by total number of establishments of firm i in year y.
CapEx/Assets	Y14	Net capital expenditure normalized by assets of firm i in year t.
Cash/Assets	Y14	Cash normalized by assets of firm i in year t.
Cash flow covenant	SNC	An indicator variable that takes the value of one when a cash flow covenant is present in any of the commitments to borrower i in year t.
Committed credit	SNC; Y14	Defined as the total dollar amount of loan commitments (in millions of US$) of borrower i in year t (quarter q).
EBITDA/Assets	Y14	EBITDA normalized by assets of firm i in year t.
EI	Meng (2017); SNC	Energy intensity based on firm i's 6-digit NAICS industry.
Interest rate	Y14	The interest rate that borrower i pays on term loans in quarter q.
Lead bank fixed effects	SNC	These are indicator variables based on the different lead banks in the sample.
Lender firm exposure	SNC	The amount of firm i's syndicated loans held by lender l in year t normalized by the total amount of syndicated loans held by lender l in year t.
Lender high emission exposure	SNC	The amount of high-emission firms' syndicated loans held by lender l in year t normalized by the total amount of syndicated loans held by lender l in year t.
Private	SNC; Y14	An indicator variable that takes the value of one when the borrower is private and zero when the borrower is public.
Remaining maturity	SNC; Y14	Defined as the average maturity of the loans of borrower i in year t (quarter q).
Term loans share	SNC; Y14	Defined as the share of total commitments to borrower i in year t (quarter q) in the form of term loans.
Treated	SNC	An indicator variable based on a firm i's industry that takes the value of one (zero) if the industry has an energy intensity of at least 2% and smaller than 5% (between 5% and 8%).
Treated wide	SNC	An indicator variable based on a firm i's industry that takes the value of one (zero) if the industry has an energy intensity of at least 1% and smaller than 5% (between 5% and 9%).

This table describes our variables. Some variables are in both the SNC and Y14 data sets, while others are only available in one data set.

References

Acharya, V., H. Almeida, F. Ippolito, and A. Perez. 2014. Credit lines as monitored liquidity insurance: Theory and evidence. *Journal of Financial Economics* 112:287–319.

Acharya, V., S. A. Davydenko, and I. A. Strebulaev. 2012. Cash holdings and credit risk. *Review of Financial Studies* 25:3572–609.

Addoum, J. M., D. T. Ng, and A. Ortiz-Bobea. 2020. Temperature shocks and establishment sales. *Review of Financial Studies* 33:1331–66.

Alimon, A. 2015. Labor protection laws and bank loan contracting. *Journal of Law and Economics* 58:37–74.

Antoniou, F., M. D. Delis, S. Ongena, and C. Tsoumas. 2022. Pollution permits and financing costs. Working Paper, Athens University of Economics and Business.

Bae, K.-H., and V. K. Goyal. 2009. Creditor rights, enforcement, and bank loans. *Journal of Finance* 64:823–60.

Bank of International Settlements. 2020. Climate-related financial risks: A survey on current initiatives. Available at https://www.bis.org/bcbs/publ/d502.pdf.

Bartram, S. M., K. Hou, and S. Kim. 2022. Real effects of climate policy: Financial constraints and spillovers. *Journal of Financial Economics* 142:668–96.

Benmelech, E., and N. K. Bergman. 2011. Bankruptcy and the collateral channel. *Journal of Finance* 66:337–78.

Bolton, P., and M. Kacperczyk. 2021. Do investors care about carbon risk? *Journal of Financial Economics* 142:517–49.

Carney, M. 2015. Breaking the tragedy of the horizon - climate change and financial stability. *Speech, Lloyd's of London,* September 29.

Chava, S. 2014. Environmental externalities and cost of capital. *Management Science* 60:2223–47.

Chen, J., P.-F. Hsieh, P.-H. Hsu, and R. Levine. 2022. Environmental liabilities, creditors, and corporate pollution: Evidence from the Apex oil ruling. Working Paper, National Bureau of Economic Research.

Chodorow-Reich, G., O. Darmouni, S. Luck, and M. Plosser. 2022. Bank liquidity provision across the firm size distribution. *Journal of Financial Economics* 144:908–32.

Correa, R., A. He, C. Herpfer, and U. Lel. 2023. The rising tide lifts some interest rates: Climate change, natural disasters and loan pricing. Working Paper, Board of Governors of the Federal Reserve System.

De Haas, R., and A. Popov. 2023. Finance and green growth. *Economic Journal* 133:637–68.

Delis, M. D., K. de Greiff, M. Iosifidi, and S. Ongena. Forthcoming. Being stranded with fossil fuel reserves? Climate policy risk and the pricing of bank loans. *Financial Markets, Institutions & Instruments*.

Diamond, D. W. 1984. Financial intermediation and delegated monitoring. *Review of Economic Studies* 51:393–414.

———. 1991. Debt maturity structure and liquidity risk. *Quarterly Journal of Economics* 106:709–37.

Dichev, I. D., and D. J. Skinner. 2002. Large-sample evidence on the debt covenant hypothesis. *Journal of Accounting Research* 40:1091–123.

Engle, R., S. Giglio, B. Kelly, H. Lee, and J. Stroebel. 2020. Hedging climate change news. *Review of Financial Studies* 33:1184–216.

Erel, I., Y. Jang, and M. S. Weisbach. 2015. Do acquisitions relieve target firms' financial constraints? *Journal of Finance* 70:289–328.

Flannery, M. 1986. Asymmetric information and risky debt maturity choice. *Journal of Finance* 41:19–37.

Giroud, X., and J. Rauh. 2019. State taxation and the reallocation of business activity: Evidence from establishment-level data. *Journal of Political Economy* 127:1262–316.

Goldsmith-Pinkham, P., M. T. Gustafson, R. C. Lewis, and M. Schwert. 2023. Sea level rise exposure and municipal bond yields. *Review of Financial Studies.* Advance Access published May 8, 2023, 36:4588–4635.

Greenwald, D., J. Krainer, and P. Paul. 2021. The credit line channel. Working Paper, NYU.

Gustafson, M. T., I. T. Ivanov, and R. R. Meisenzahl. 2021. Banks monitoring: Evidence from syndicated loans. *Journal of Financial Economics* 139:452–77.

Hadlock, C. J., and J. R. Pierce. 2010. New evidence on measuring financial constraints: Moving beyond the KZ index. *Review of Financial Studies* 23:1909–40.

Hsu, P.-H., K. Li, and C.-Y. Tsou. 2023. The pollution premium. *Journal of Finance* 78:1343–92.

Ilhan, E., Z. Sautner, and G. Vilkov. 2021. Carbon tail risk. *Review of Financial Studies* 34:1540–71.

Irani, R., R. Meisenzahl, R. Iyer, and J.-L. Peydró. 2021. The rise of shadow banking: Evidence from capital regulation. *Review of Financial Studies* 34:2181–235.

Irani, R. M., and R. R. Meisenzahl. 2017. Loan sales and bank liquidity management: Evidence from a U.S. credit register. *Review of Financial Studies* 30:3455–501.

Ivanov, I. T., L. Pettit, and T. Whited. 2022. Taxes depress corporate borrowing: Evidence from private firms. Working Paper, Federal Reserve Bank of Chicago.

Jimenez, G., J. A. Lopez, and J. Saurina. 2009. Empirical analysis of corporate credit lines. *Review of Financial Studies* 22:5069–98.

Kacperczyk, M., and J.-L. Peydró. 2022. Carbon emissions and the bank-lending channel. Working Paper, Imperial College London.

Kruttli, M., B. Roth Tran, and S. Watugala. 2023. Pricing Poseidon: Extreme weather uncertainty and firm return dynamics. Working Paper, Indiana University.

Leitner, Y., and B. Yilmaz. 2019. Regulating a model. *Journal of Financial Economics* 131:251–68.

Martin, R., M. Muûls, L. B. D. Preux, and U. J. Wagner. 2014. Industry compensation under relocation risk: A firm-level analysis of the EU emissions trading scheme. *American Economic Review* 104:2482–508.

Meng, K. C. 2017. Using a free permit rule to forecast the marginal abatement cost of proposed climate policy. *American Economic Review* 107:748–84.

Meng, K. C., and A. Rode. 2019. The social cost of lobbying over climate policy. *Nature Climate Change* 9: 472–6.

Minton, B. A., and C. Schrand. 1999. The impact of cash flow volatility on discretionary investment and the costs of debt and equity financing. *Journal of Financial Economics* 54:423–60.

Mortal, S., and N. Reisel. 2013. Capital allocation by public and private firms. *Journal of Financial and Quantitative Analysis* 48:77–103.

Murfin, J., and M. Petersen. 2016. Loans on sale: Credit market seasonality, borrower need, and lender rents. *Journal of Financial Economics* 121:300–26.

Nini, G., D. C. Smith, and A. Sufi. 2009. Creditor control rights and firm investment policy. *Journal of Financial Economics* 92:400–20.

Oehmke, M., and M. Opp. 2023. Green capital requirements. Working Paper, London School of Economics and Political Science.

Painter, M. 2020. An inconvenient cost: The effects of climate change on municipal bonds. *Journal of Financial Economics* 135:468–82.

Pástor, Ľ., R. F. Stambaugh, and L. A. Taylor. 2022. Dissecting green returns. *Journal of Financial Economics* 146:403–24.

Plosser, M., and J. A. C. Santos. 2018. Banks' incentives and inconsistent risk models. *Review of Financial Studies* 31:2080–112.

Qiu, Y., and T. Shen. 2017. Organized labor and loan pricing: A regression discontinuity design analysis. *Journal of Corporate Finance* 43:407–28.

Rajan, R., and A. Winton. 1995. Covenants and collateral as incentives to monitor. *Journal of Finance* 50:1113–46.

Roberts, M. R. 2015. The role of dynamic renegotiation and asymmetric information in financial contracting. *Journal of Financial Economics* 116:61–81.

Roberts, M. R., and A. Sufi. 2009. Renegotiation of financial contracts: Evidence from private credit agreements. *Journal of Financial Economics* 93:159–84.

Saunders, A., and S. Steffen. 2011. The costs of being private: Evidence from the loan market. *Review of Financial Studies* 24:4091–122.

Seltzer, L., L. Starks, and Q. Zhu. 2022. Climate regulatory risks and corporate bonds. Working Paper, Federal Reserve Bank of New York.

Shive, S. A., and M. M. Forster. 2020. Corporate governance and pollution externalities of public and private firms. *Review of Financial Studies* 33:1296–330.

Shleifer, A., and R. W. Vishny. 1997. A survey of corporate governance. *Journal of Finance* 52:737–83.

Sufi, A. 2009. Bank lines of credit in corporate finance: An empirical analysis. *Review of Financial Studies* 22:1057–88.

Tabuchi, H. 2021. Here are America's top methane emitters. Some will surprise you. *New York Times,* June 2.

Trueman, B., and S. Titman. 1988. An explanation for accounting income smoothing. *Journal of Acounting Research* 26:127–39.