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Measuring the Effects of a Carbon Tax

Climate change poses risks to our economy, but so does the government's response to climate change.

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Climate change poses risks for households and businesses. The physical risks of climate change include, for example, damage caused by floods and wildfires. Less known are transition risks driven by how firms, households, and governments respond to climate change. Central banks in particular are interested in understanding how these transition risks will affect the economy and possibly the financial sector, including how it will affect small banks.

In this article, we quantify how one such transition risk, the enactment of a carbon tax, would affect firms, regional economies, and small banks in the U.S. Specifically, we study a permanent carbon tax of $100 per metric ton of greenhouse gas emissions (measured in CO_2-equivalent units). This tax rate is similar to the tax rates in Sweden ($130) and Switzerland ($125) but is on the low end of the estimates of the tax needed to limit a rise in the global temperature to 2 degrees Celsius.

We find that the effects of a carbon tax are heavily concentrated in a few sectors. Even though we follow emissions down the production chain all the way to the final-demand sector, industries that generate a large fraction of emissions at the source are still among the most affected. The effects are also highly concentrated in a few regions. The regional effects depend on how much the affected industries dominate the local economy, but the effects are more widespread when low-emitting firms can't easily substitute away from inputs that rise in price because of the carbon tax. A carbon tax would also burden community banks operating in counties with a large share of high-emitting industries.

Our findings provide a framework for assessing the impact of a carbon tax on the corporate sector, the regions where they operate, and small banks in those regions.

How a Carbon Tax Affects Firms' Profits

What does a $100 carbon tax mean for an individual firm's bottom line? We don't know how much carbon any one firm emits, but we do know how much each industry emits, so we use the industry-level emissions to derive emissions for the representative firm in the industry. This allows us to calculate the size of a representative firm's tax bill, industry by industry.

We assume that each firm passes the cost of the tax onto its customers. And because a firm can also be a customer, we must consider the amount of emitted carbon produced by each firm that provides inputs to any one firm. With all this information, we can calculate the carbon tax's effect on each firm's future profits.

With this information, we can finally quantify the transition risk posed by a carbon tax.[1] We discount the stream of a firm's future expected profits to calculate the firm's decline in market value due to the carbon tax. By doing so, we incorporate the risk that the firm may default and fail.[2]

Current estimates suggest that we need a $100 carbon tax to achieve the proposals agreed to in the 2015 Paris Agreement, so for this article we ask, what would happen if the U.S. government imposed a permanent $100 carbon tax (per metric ton of greenhouse gas emissions measured in CO_2-equivalent units)?[3] We assume that a firm's asset value will adjust immediately after the announcement of the tax, because informed investors will understand the likely impact of the carbon tax on firm profits—and thus the firm's stock price should fall to reflect their changed expectations.

However, a firm may also lose value if consumers avoid products with a large carbon footprint, if new technologies further lower the cost of green energy, and if other firms along the production chain default as a result of the carbon tax. With some adjustments, our methodology could capture the effect of these other factors, too.

Using Industry Linkages to Estimate Emissions and Firm-Value Losses

An economy is not just a collection of firms producing final goods for consumers. Many products are inputs for other firms. Therefore, the effect of the carbon tax on firm profits depends on the level of carbon emissions from firms in a particular industry. That's why we use an input-output model to account for interactions between firms that produce final goods and firms that produce inputs for other firms.

More specifically, our estimates of industry-level carbon use combine data on emissions at the source with an input-output table to account for the price effects down the production chain all the way to the final-demand sector.[4]

The input-output table helps us measure who ultimately pays

Production Model and Emission Estimates

We use information from EXIOBASE, a multiregional environmentally extended input-output table, to estimate emissions in the U.S. at the level of the three-digit National American Industry Classification System (NAICS) code. With its data on input-output transactions, labor inputs, energy supply and use, greenhouse gas (GHG) emissions, material extraction, land and water use, and emissions to air, water, and soil, EXIOBASE provides comprehensive up-to-date coverage of the global economy. EXIOBASE defines the GHG footprint of a particular country/product or final-demand sector as the total emissions of GHGs in kilograms of CO_2 equivalents (tCO_2-eq). EXIOBASE includes GHGs such as CO_2, CH_4, and N_2O, and it calculates each GHG's global warming potential (GWP).[11]

By using the input-output table to follow emissions along the entire production chain, from the source industry all the way to the final-demand sector, we capture the life cycle or "footprint" of emissions. This measure captures emissions associated with the production stage (that is, emissions that occur in the supply chain and are embodied in inputs from other sectors) and allocate them according to final demand. The measure also incorporates imports and exports of goods and services, so the total emissions when production linkages are incorporated do not necessarily equal the sum of emissions at the source. We assume that input suppliers along the production chain will increase their price by the full amount of the tax. In this case, a sector that is a heavy user of an input produced with a high-emission technology bears a relatively large share of the tax.

Recently, economists have developed general equilibrium models, paying particular attention to sectoral heterogeneity and how shocks propagate through production chains. These models are important for understanding the amplification and propagation of shocks via input-output connections while taking seriously sectoral elasticities of the substitution of intermediate inputs.[12] An important insight from the literature on production economies is that local economic shocks and shocks to individual industrial sectors can have significant aggregate effects when elasticities of substitution for intermediate outputs are low. Our framework (via the emission estimates) captures input-output linkages, but it is not as flexible as these models, in which it is possible to evaluate arbitrary elasticities of substitution and returns to scale.

for the tax only if we assume that demand for an emission-producing firm's product is perfectly inelastic—that is, we assume that consumers cannot find a substitute for the firm's product and can't minimize the use of this product, so they end up paying the full cost of the carbon tax. Of course, the real-world economy rarely works so simply. In the real world, firms and consumers eventually substitute away from goods that rise in price.[5] But our model helps us unpack how the carbon tax works its way through the economy.

See **Production Model and Emission Estimates**

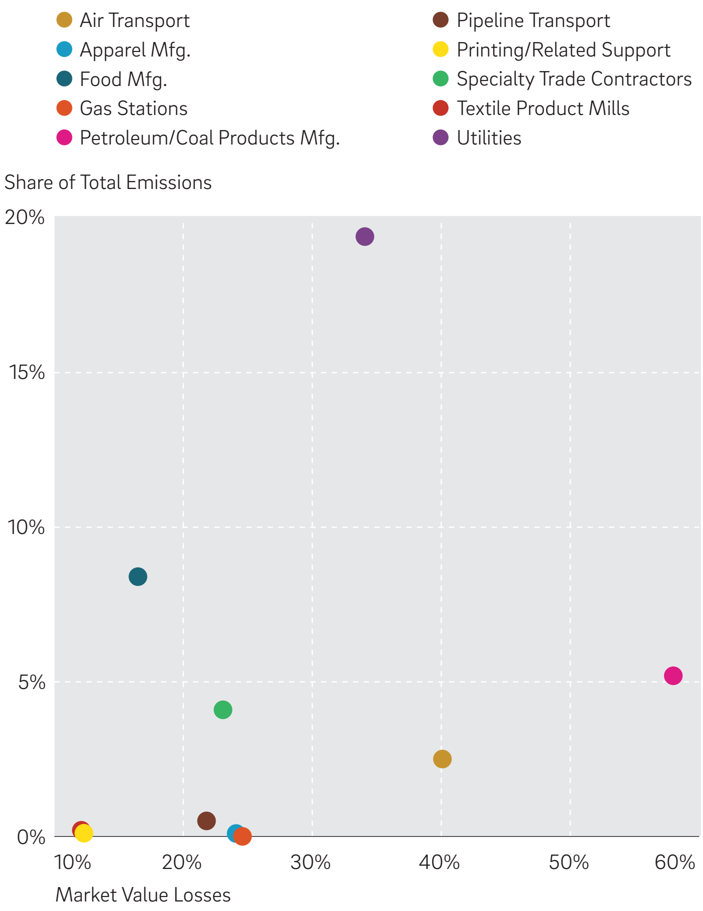
In summary, when we measure the exposure of firm revenues to the carbon tax, we account for both the rise in price that the firm charges customers and the rise in price that the firm pays to the suppliers of its inputs.

The market value losses we estimate are significant for some of the industries that account for a nonnegligible share of emissions (Figure 1). We find that even though our estimates consider industry linkages, several industries that account for a large fraction of emissions at the source are still at the top of our estimates. For example, we estimate that utility firms would see their value decline by 34.1 percent. Utilities account for about 43.2 percent of emissions at the source but only 19.4 percent of emissions when industry linkages are considered.[6]

FIGURE 1

High-Emission Industries Would See the Biggest Drop in Market Value Due to a Carbon Tax

Top 10 industries by industry losses



Data Sources: EXIOBASE, S&P Global Market Intelligence Compustat Data, and authors' calculations

Note: "Market Value Losses" correspond to our estimate of losses due to a $100 carbon tax. "Share of Total Emissions" refers to the fraction of total emissions accounted for by each industry. Compustat data copyright © 2021, S&P Global Market Intelligence (and its affiliates, as applicable). Obtained via Wharton Research Data Services (WRDS). No further distribution and or reproduction permitted.

How a Carbon Tax Affects the Rest of the Economy

To evaluate the effect of a carbon tax, we must consider regional differences in the economy (Figure 2). Regions heavily reliant on high-emission industries, such as manufacturing and fossil fuel extraction, would likely face increased costs, leading to shifts in employment and economic activity. For example, a county in the Texas oil patch is more likely to be heavily affected than a state capital and university town like Austin, TX.

To measure the transition risk at the regional level, we calculate how much the carbon tax would affect the value of all firms operating in each county, and we weight industry losses by the share of each industry's employment in each county.[7] Specifically, we calculate the effect of the carbon tax on the value of a hypothetical firm that has the same employment composition as the county it is in. This approach does not capture the migration of firms or workers across regions after the implementation of the tax. Nor does it consider local policies that encourage firms to shift toward new technologies, or national policies that mitigate the impact of a carbon tax. However, our approach is a good approximation of how a national carbon tax would affect the economy if stock prices respond quickly and correctly to news about the policy, and if it takes time for workers to relocate to different industries or regions and for firms to adjust their production processes.

In the real world, reduced profits would lead to further effects, such as declines in employment and the value of commercial real estate in regions where emitting firms have a large presence. We abstract from these considerations. Nonetheless, the methodology could be extended to evaluate how this tax would affect a county's employment, real estate prices, and other variables.

See **Regional Estimates**

We find that, across counties, firms would lose on average 4.3 percent of their value (the median loss is 4.0 percent), but there is significant dispersion, with values in some counties dropping by more than 10 percent (Figure 3). The most impacted counties tend to be highly exposed to the most affected industries. Many of these counties host sizable employment at gasoline stations, in utilities, as specialty trade contractors, and in food manufacturing. Even though these estimates consider production linkag-

Regional Estimates

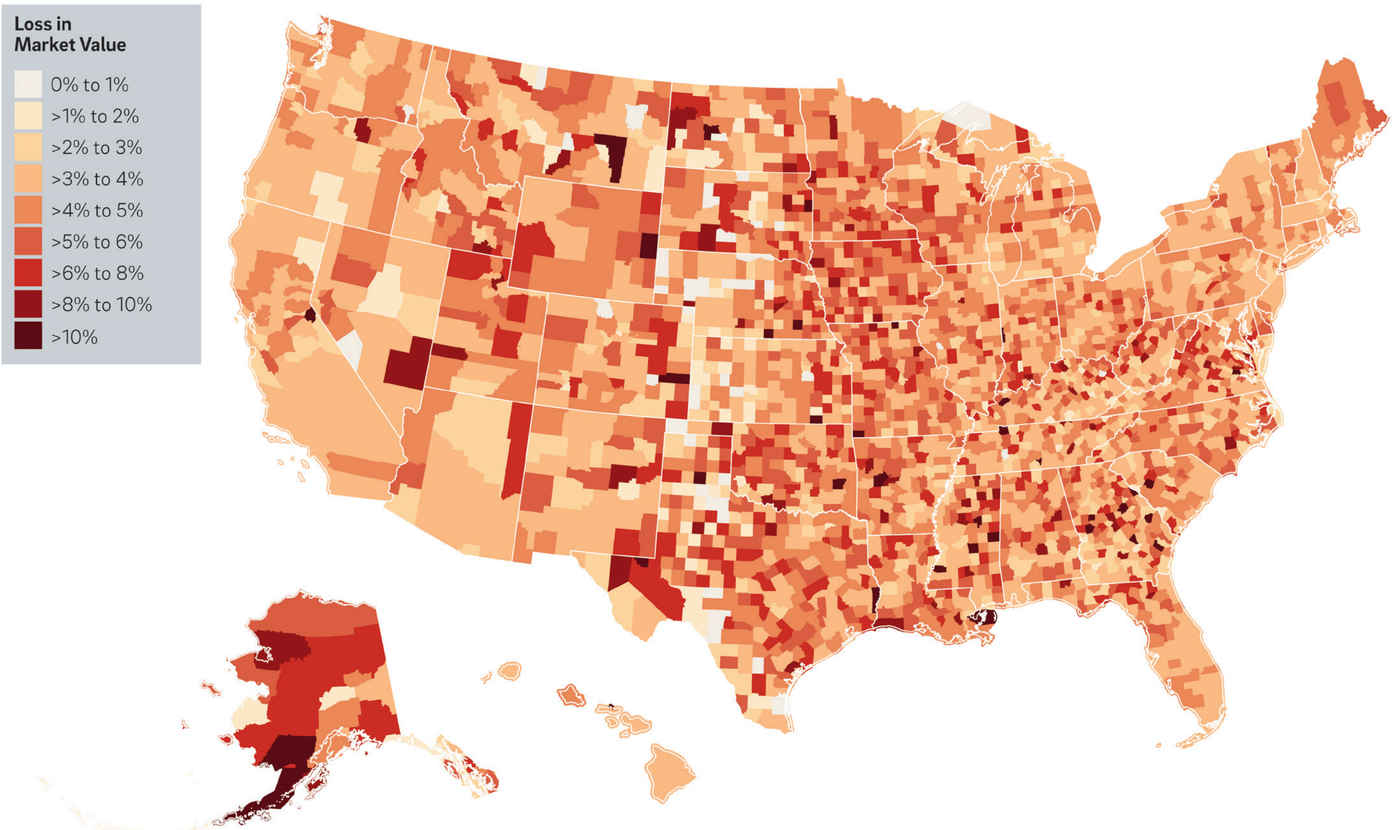
To estimate the regional impact of the carbon tax, we use the distribution of employment across counties at the three-digit NAICS level provided by the U.S. Bureau of Labor Statistics (BLS). We use the fraction of employees in a county that work for an industry as a proxy for that county's exposure to that industry. Then, we estimate the county-level exposure to the carbon tax by combining the county's industrial exposure with our estimates for industry-level value losses.

As we consider linkages across industries, we find that losses are broad in terms of geographical coverage: In about 91 percent of counties, the representative firm experiences a market value loss larger than 2 percent.[13] About 25 percent of those counties experience a loss larger than 5 percent.

FIGURE 2

A Carbon Tax Causes Losses Across the U.S.

The impact of a $100 carbon tax on a representative firm in each county



Data Sources: EXIOBASE, S&P Global Market Intelligence Compustat Data, U.S. Bureau of Labor Statistics' Quarterly Census of Employment and Wages (QCEW), and authors' calculations

Note: A representative firm has the same employment composition as the county that it is in. Compustat data copyright © 2021, S&P Global Market Intelligence (and its affiliates, as applicable). Obtained via Wharton Research Data Services (WRDS). No further distribution and or reproduction permitted.

es, most of the most-affected counties are relatively small, and all of them are below the median level of employment of 6,595.

How a Carbon Tax Affects Community Banks

In the U.S., community banks typically operate in one or just a few counties, so an oil patch community bank would be affected in ways that an Austin bank wouldn't be.[8] Although a community bank with branches spanning Texas might have a more diverse investment portfolio, enabling it to navigate a carbon tax more effectively, we anticipate a strong correlation between the regional economic impact of the carbon tax and the performance of smaller banks predominantly rooted in a specific area.

See *Climate Stress Tests* ↘

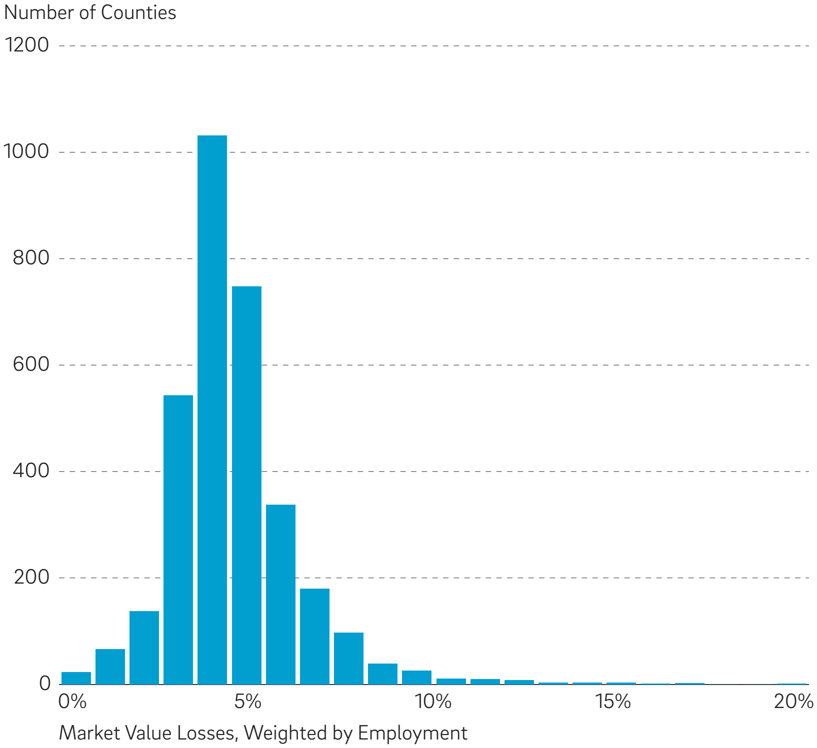
We use each bank's geographical footprint to capture the effect that the decline in the regional economy would have on that bank's portfolio. Because we want to focus on local assets, we

FIGURE 3

Across Counties, Firms Lose on Average 4.3 Percent of Their Value Due to a Carbon Tax

But there is significant dispersion.

Number of counties by market value losses (weighted by employment) due to a carbon tax



Data Sources: EXIOBASE, S&P Global Market Intelligence Compustat Data, U.S. Bureau of Labor Statistics' Quarterly Census of Employment and Wages (QCEW), and authors' calculations

scale the shock to each bank by its loan-to-asset ratio. This exercise is not a climate stress test but rather a rough measure of how the shock to the regional economy might affect different small banks.

To capture how a carbon tax affects community banks, we first use the location of bank branches to identify where each bank operates. We then weight the changes to the value of firms in a county by the share of the bank's deposits in that county. We use deposits to weight these market value losses at the county level because there is no comprehensive data to capture the regional coverage of the loan portfolio of small banks. We conclude by summing firm-value losses in all the counties in which each bank operates.[9]

To better understand this process, imagine that each county is a mutual fund comprising firms with operations in that county. We use the number of a firm's employees in the county to weight the firm's presence in this imaginary mutual fund portfolio. In turn, each bank owns shares in all the mutual funds (that is, counties) in which it operates. The carbon tax affects the value of all the firms in each mutual fund, and we measure the losses relative to the size of the bank's loan portfolio.[10]

See ***Estimating the Effects of Transition Risk on Small Banks***

We find that the impact of a $100 carbon tax on banks' portfolio losses accounts for about 2.5 percent of community bank assets, on average. That is, when we use the loan-to-asset ratio to scale the regional losses to which banks are exposed, a community bank experiences only a moderate loss.

Conclusion

For this article, we quantify the effects of one climate transition risk–a carbon tax–at the industry and regional levels. We then assess how a carbon tax would affect community banks in the U.S.

Initially, a carbon tax would fall more heavily on high-emission industries, but these industries might transmit some of these costs to final demand via production chains. To estimate the shock to each firm's value, we consider the linkages across industries and how emissions are transmitted from the source to final demand.

By leveraging these firm value shocks and considering the industry distribution of employment across geographical locations, we estimate the regional (county-level) consequences of a carbon tax. We find that, across counties, a $100 carbon tax leads to an average decline in firm value of 4.5 percent.

The county-level estimates of the shock to firm value allows us to estimate the potential effect of the tax on bank portfolios. We estimate that a $100 carbon tax results in losses to firm value that represent on average 2.5 percent of community bank assets.

Estimating the Effects of Transition Risk on Small Banks

To proxy for a bank's lending footprint, we use data on a bank's branch deposits, which we obtained from the Federal Deposit Insurance Corporation's (FDIC's) Summary of Deposits as of June 2019. The Summary of Deposits summarizes the results of the FDIC's annual survey of branch office deposits for all FDIC-insured institutions, including insured U.S. branches of foreign banks. All institutions with branch offices are required to submit the survey; institutions with only a main office are exempt.

Given our estimates for the county-level transition risk, we estimate the bank-level transition risk within its lending footprint. That is, for any given bank, we take the average of county-level losses across the counties where the bank operates and weight each county by the size of the deposit base of the bank in that county.

Once we have these bank-level estimates of market value losses, we quantify the potential impact on a community bank's operation by multiplying a bank-level estimate for the transition risk by a bank's loans, which we then scale by total assets.

Climate Stress Tests

Our exercise is not a climate stress test. However, there is a growing literature about—and central banks are becoming interested in—the link between financial stability and climate change.

In some ways, climate stress tests are different from the standard stress tests (that is, the tests that focus primarily on capital and liquidity levels during stress scenarios) performed by macroprudential supervisors. But in other respects, they are very similar.

A standard stress test is generally conducted for a horizon of two to three years, evaluates an extreme stress scenario, and uses detailed loan-level information. The bank must be able to meet capital and liquidity requirements under stressful conditions. A standard stress test also informs a bank's management about risks.

A climate transition risk stress test focuses on a much longer horizon of 10 years, and the scenarios often begin with a projection of future emissions. Common climate scenarios, provided by the Network for Greening the Financial System (NGFS), range from Current Policies to the most ambitious scenario: Net Zero 2050, which aims to limit global warming to 1.5 degrees Celsius through stringent climate policies and reaches net zero CO_2 emissions around 2050.

Because the primary goal of these exercises is to quantify the risks to financial institutions with different mixes of industry exposure, the next step is to link the aggregate outcomes to sectoral or regional effects. One approach expands the macroeconomic model to incorporate an input-output structure that provides sectoral effects.[14] The alternative approach, which goes directly from the increase in the carbon tax to either asset value or credit risk, evaluates the impact of these policies on each industry or region using a financial model.[15] When constructing these links, a key input is the estimates of carbon emissions at the industry level.

The final step in evaluating how the transition risk affects financial institutions is to establish a link between the industry or regional effects and the portfolios of these institutions. A direct approach can be used if loan-level data with industry information are available. If these data are not available, the researcher needs to infer the loan composition and the exposure of the loan portfolio to industry or regional losses.

Thus far, most central banks' climate stress tests have been informational—for the central bank to learn about climate risks and for firms to learn how to measure and control climate risks in their portfolios. They do not affect bank capital requirements.

Notes

1 See Berlin, Byun, D'Erasmo, and Yu (2022) for a detailed description of the methodology.

2 We use data on public firms to estimate the parameters of a standard asset pricing model—see Merton (1974)—as implemented by Bharath and Shumway (2008).

3 Analysts estimate an appropriate carbon tax based on different paths of CO_2 emissions required to keep global temperatures from rising above 2 degrees Celsius.

4 The input-output table describes the flow of products between industries as well as to final demand. We use the EXIOBASE input-output table and its direct-emissions estimates to calculate emissions. Direct emissions include only those emissions generated in the production stage. Our measure incorporates direct emissions for final demand and emissions generated in the production of the firm's inputs.

5 Consistent with our approach, elasticities of demand for inputs tend to be quite low. See Atalay (2017) for estimates of demand elasticities in a production economy. At the other extreme, we could assume that the carbon tax is levied on the emissions at the point of production, and final-goods producers face perfectly elastic demand. If this were the case, the profits of the final-goods producers would fall one-for-one with the tax, there would be no price effects along the production chain, and the effect of the tax could be measured using emissions directly at the source alone. See Berlin, Byun, D'Erasmo, and Yu (2022) for a comparison of these two approaches.

6 "Utilities" encompass a wide range of energy-generation industries, but fossil fuel electric power generation accounts for most of the utility industry's emissions.

7 Of course, employment composition is not the only determinant of how climate change or climate policies affect a county or region. Cruz and Rossi-Hansberg (2022) argue that the costs of climate change are extremely heterogeneous across locations due to different local temperature effects; differential effects on amenities, productivity, and natality; differential costs of migration; and trade across regions.

8 We adopt the definition of a community bank for year 2019 presented in the FDIC December 2020 Community Banking Study.

9 Because many small banks operate in only one county, the link between the regional impact and the performance of the bank as derived from the deposit base may not be as strong as it first seems. In our sample, about 92 percent of community banks operate in only one state and 42 percent operate in only one county. When we perform a robustness exercise using information on residential mortgage originations, we find similar results. (For the robustness exercise, we used the public version of the Home Mortgage Disclosure Act data for 2019, available from https://ffiec.cfpb.gov/.)

10 We assign the effects of the carbon tax to the bank's loan portfolio—not the asset portfolio as a whole—because the value of cash and securities is not sensitive to local economic shocks.

11 The GWP was developed to allow comparisons of different gases' impact on global warming. CO_2, by definition, has a GWP of 1 regardless of the period used, because it is the gas being used as the reference. Methane (CH_4) is estimated to have a GWP of 28–36 over 100 years. As in most of the literature, we focus on CO_2-equivalent emissions using GWP 100.

12 Some important examples in this literature include Horvath (2000), Atalay (2017), Baqaee and Farhi (2020), and Miranda-Pinto and Young (2022). See Devulder and Lisack (2020) for an example of a transition risk.

13 A representative firm has the same employment composition as the county where it operates.

14 See Vermeulen, Schets, Lohuis, et al. (2021) and Banque de France (2021).

15 Reinders, Schoenmaker, and van Dijk (2020) and Grippa and Mann (2020) estimate the value added for each industrial sector and assign a tax on carbon emissions.

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