# U.S. Banks' Exposures to Climate Transition Risks

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*The views expressed in this paper are those of the author and do not necessarily reflect the position of the Federal Reserve Bank of New York or the Federal Reserve System.

# Effects of Climate Transition Risk on Banks

- How does climate transition risk affect banks?
  - *Transition risk* arises from changes in policies as economies transition to less carbon-intensive environments.

- How much are banks exposed to a specific climate transition policy (e.g. \$50 carbon tax growing 5% annually)?

  $\Rightarrow$ We develop a measure to assess banks' credit portfolio exposure to a specific set of climate transition policies.

# Empirical Challenges

1. Existing approaches typically rely on backward-looking data (e.g. carbon emissions).
   - We propose a **forward-looking** measure that quantifies the effect of a specific set of climate transition policies on banks.
2. Reduced form approaches typically do not capture the general equilibrium effects.
   - We build on estimates from **general equilibrium** climate models.
3. Publicly available credit data may not accurately represent current exposure if the bank sells the loan after origination.
   - We employ a granular dataset (**Y-14**) that provides current loan-level credit exposure information for major U.S. banks.

# Our Approach in Brief

**General Equilibrium Climate Model Estimates**

E.g., How much does each industry's output fall if a carbon tax gets introduced?

| Industry | Change in Output |
|---|---|
| Coal | -30% |
| Renewable | +20% |

**Y-14 Data**

E.g., Bank's credit portfolio:

| Industry | Share of Lending |
|---|---|
| Coal | 50% |
| Renewable | 50% |

Study bank exposure to transition risk
- across time
- across banks
- across policies

Investigate how banks manage transition risk

# Key Findings

1. Banks' exposures to transition risk substantially vary across climate models.
   - The average bank credit exposure (as of 2022) ranges between -1% and 9.5%.
2. Across policies, banks' transition risk exposure is larger under stricter policies.
   - Relative to a $25 carbon tax, a $50 carbon tax increases banks' exposures by 1%.
3. In a severe scenario considering non-linearity, the loan portfolio of the average bank can lose up to 11% more than in the baseline scenario.
4. Banks appear to reduce the quantity and increase the price of loans made to borrowers in industries highly exposed to transition risk.

# Contribution to Literature

- How vulnerable is the financial system to climate transition risk?
  - Battiston et al (2017); Jung et al (2021); ECB (2021); Arseneau et al (2022)
  - We develop exposure measures capturing general-equilibrium effects of carbon policies, and find that the exposures are manageable.

- Do banks and investors price climate transition risk?
  - Studies of the equity market (e.g. Engle et al., 2020; Bolton and Kacperczyk, 2023; Pastor et al., 2021; Alekseev et al. 2022; Giglio et al., 2023), the corporate bond market (Seltzer et al, 2022) and the options market (Ilhan et al, 2021) suggest that investors factor in transition risk.
  - Ivanov et al (2022), Laeven and Popov (2022), Kacperczyk and Peydro (2022) find that banks price transition risk; however, Antoniou et al (2021) and Delis et al (2019) find weak evidence.
  - We find evidence of banks pricing climate transition risk.

# Climate Models: Overview

1. **Jorgenson et al. (2018)**
   - Estimates changes in industry-level output from 2015 to 2050, if a range of carbon tax policies are put in place in 2020.
   - e.g. Initial carbon tax rate of $50 and annual tax growth rate of 5%.

2. **Goulder and Hafstead (2018)**
   - Estimates changes in industry-level profits over infinite time horizon, if a range of carbon tax policies are put in place in 2017.
   - Considers renewable sector separately.

3. **NGFS G-Cubed Model (2022)**
   - Estimate changes in industry-level output from 2020 to 2050.
   - Considers NGFS scenarios (current, orderly, and disorderly transitions).

# Climate Model (1)

**Jorgenson et al. (2018)**

- Estimates industry-level decreases in output for 36 industries conditional on a specific carbon policy.
- Assumes a carbon tax is put in place in 2020, and grows from 2020 until 2050.
  - Provides estimates of change in industry-level output from 2015 until 2050.
  - Model estimates produced for several initial tax rates ($25 or $50) and tax growth rates (1% or 5%).
- Also models the redistribution of the tax proceeds.
  - Model outputs produced for redistribution as a lump sum dividend, a capital tax cut, or a labor tax cut.

Estimates: Carbon tax | Estimates: Redistribution | Model Flow | Mechanism

# Climate Model (2)

**Goulder and Hafstead (2018)**

- Estimates industry-level decreases in profit for 35 industries conditional on a specific carbon policy.
- Assumes a carbon tax is put in place in 2017, grows to $20 by 2019, and grows by 4% annually until 2048.
- Model output produced for several redistribution schemes (lump sum dividend, corporate tax cut, individual income tax cut, and payroll tax cut).
- Unlike Jorgenson et al. (2018):
  - Estimates are provided as percentage changes in the present value of profits over an infinite time horizon.
  - One of these industries is the renewable sector.

Estimates

# Climate Model (3)

**NGFS G-Cubed Model (2022)**

- Estimates industry-level decreases in output for 12 industries from 2020 until 2050.
- Unlike the other models, the policy scenarios set a certain carbon tax conditional on achieving a desired policy outcome.
  - Current Policy
  - Orderly Transition – sufficient policies to achieve net-zero emissions by 2050 is immediately adopted
  - Disorderly Transition – policy to limit end-of-century temperature rise to under 2 degrees adopted in 2031

Details Estimates

# Exposure Measure

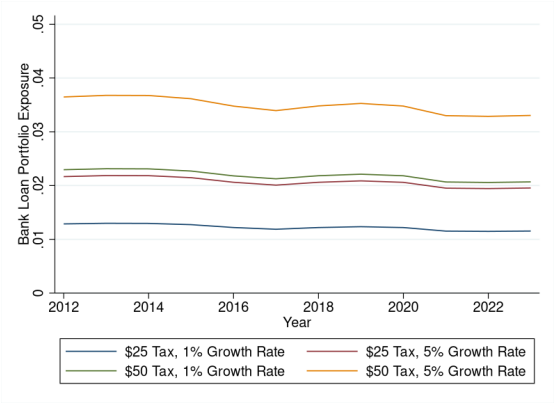
What proportion of bank $b$'s loan portfolio value would be lost if policy $P$ gets implemented?

$$Exposure_{b,t}^{P} = \sum_{j \in J} w_{b,j,t} \; Markdown_{j}^{P},$$

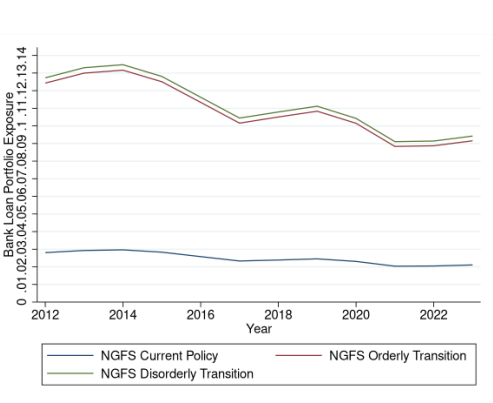
- $w_{b,j,t}$ is proportion of bank $b$'s loan made to industry $j$ at time $t$.
- $Markdown_{j}^{P}$ is the drop in the output or profits of industry $j$ under policy $P$.

- **Key Assumptions:**
  1. Banks lose the value of loans proportionally to the drop in the output or profit of the borrower's industry.
  2. Bank $b$ maintains their allocation of loans across industries as of time $t$.

# Average Exposure over Time




(a) Jorgenson et al.




(b) NGFS

- The maximum average exposure is less than 4% based on Jorgenson et al., while it is 13% based on NGFS.

# Which Policies Yield the Highest Exposures?

- Regression analysis to formally examine which policies yield highest exposures *within the same model*:

$$Exposure_{b,p,t} = \sum_{p \in P} \beta_p \mathbb{1}(Policy = p) + \Gamma X_{b,t} + \epsilon_{b,p,t}$$

- $Exposure_{b,p,t}$ is the transition risk exposure for bank $b$ under policy $p$ at time $t$.
- $X_{b,t}$ is a vector of bank-by-quarter level controls.
- Control for the natural log of total bank assets, loan-to-assets ratio, the bank return on assets, the bank leverage ratio, the bank deposit ratio, the loan-loss-reserves ratio, and the ratio of non-interest income to net income.

Summary Statistics

# Which Policies Yield the Highest Exposures?

| | (1) exposure | (2) exposure | (3) exposure | (4) exposure |
|---|---|---|---|---|
| 50 dollar tax | 0.01*** | | | |
| | (25.58) | | | |
| 5pp growth rate | 0.01*** | | | |
| | (26.73) | | | |
| 50 dollar tax and 5pp growth rate | 0.00*** | | | |
| | (28.84) | | | |
| Capital Income Tax Cut | | -0.01*** | | |
| | | (-57.68) | | |
| Labor Income Tax Cut | | -0.01*** | | |
| | | (-71.82) | | |
| Corporate Income Tax Cut | | | -0.02*** | |
| | | | (-78.18) | |
| Payroll Tax Cut | | | -0.00*** | |
| | | | (-161.18) | |
| Individual Income Tax Cut | | | -0.00*** | |
| | | | (-44.79) | |
| Orderly Transition | | | | 0.09*** |
| | | | | (8.36) |
| Disorderly Transition | | | | 0.09*** |
| | | | | (8.64) |
| Model | Jorgenson | Jorgenson | Goulder and Hafstead | NGFS |
| Policy Lever | Tax | Redistribution | Redistribution | Transition |
| Adjusted R2 | 0.66 | 0.60 | 0.24 | 0.34 |
| Observations | 5328.00 | 3996.00 | 5328.00 | 3996.00 |

$t$ statistics in parentheses

$^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

- Stricter policies yield higher exposures.
- Tax cuts have lower exposures than lump sum dividends.

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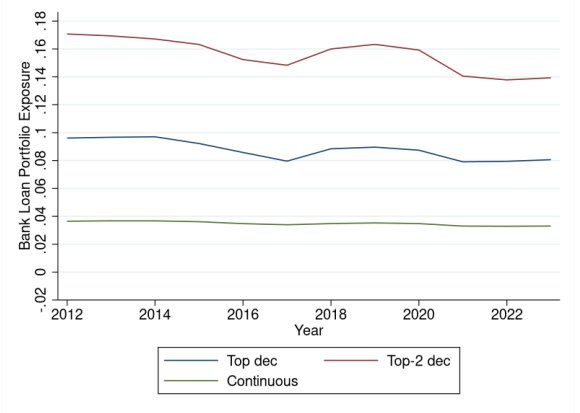
# Exposure Measure under Stress

Considering potential non-linear effects: what if banks are *more severely affected* by the riskiest industries?

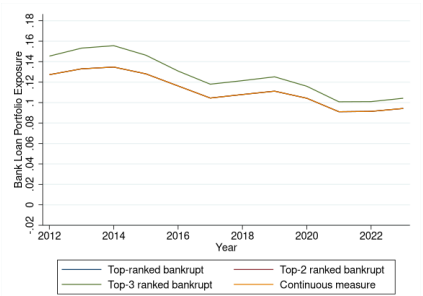
$$ExposureUnderStress^{P}_{b,t} = \sum_{j \in J} w_{b,j,t}\ \mathbb{1}(Markdown^{P}_{j} > x) + \sum_{j \in J} w_{b,j,t} \mathbb{1}\left(Markdown^{P}_{j} \leq x\right) \cdot Markdown^{P}_{j}$$

- $w_{bjt}$ is proportion of bank $b$'s loan made to industry $j$ at time $t$.
- $Markdown^{P}_{j}$ is the drop in the output of industry $j$ under policy $P$.
- $x$ is a cutoff where if the drop in industry output is above $x$, we assume the industry goes "bankrupt".
- Pick $x$ so we focus on either the top-decile or top-two-decile exposed industries.

# Average Exposure Under Stress over Time



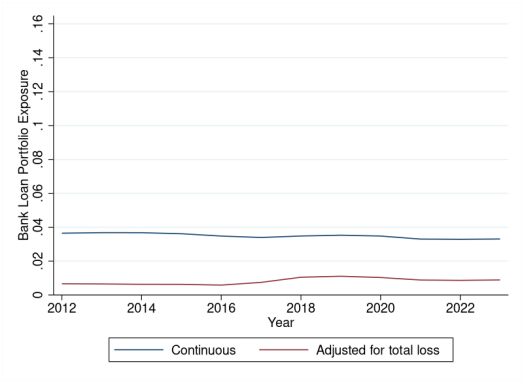

(a) Jorgenson et al.: \$50 initial tax, 5% annual tax growth rate



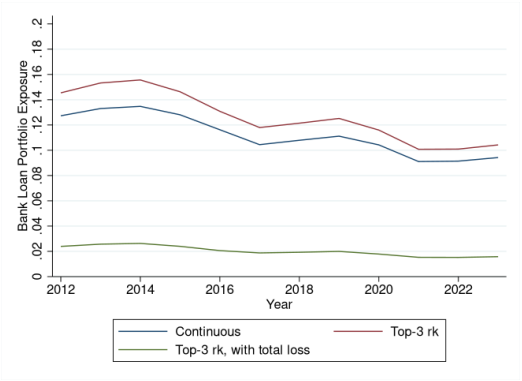

(b) NGFS: Disorderly transition

- Based on Jorgenson et al., the average *exposure under stress* is 11% higher than the average exposure.
- Based on the NGFS model, the average *exposure under stress* remains similar as the NGFS scenarios are already severe.

# Average Exposure Adjusted for Expected Loan Losses over Time



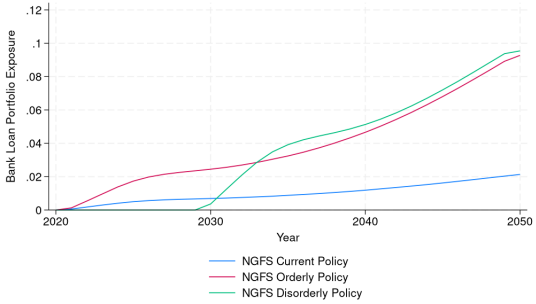

(a) Jorgenson et al (2018) $50 initial tax, 5% annual tax growth rate



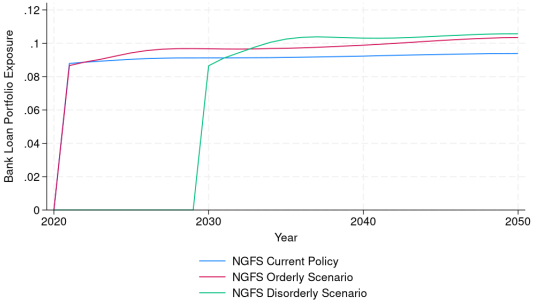

(b) NGFS disorderly transition

- Adjusting for the loss given default (LGD) and probability of default (PD) reduces exposures.

# Bank Exposure Paths



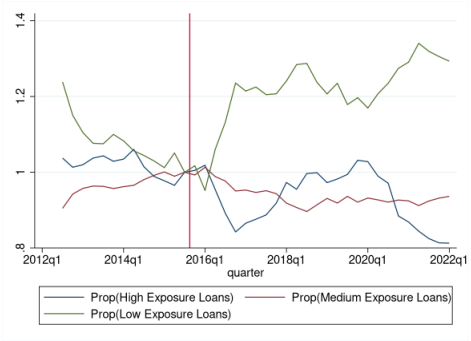

(a) NGFS Continuous Measure



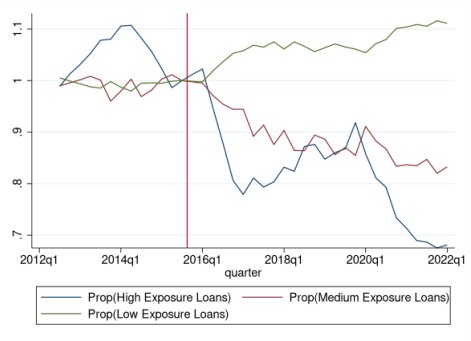

(b) NGFS Top-3 ranked bankrupt

Back

# Have Banks Adjusted Lending to Riskiest Borrowers?




(a) Jorgenson et al.




(b) NGFS

- Vertical line indicates Paris Agreement in 2015:Q4.
- Since Paris Agreement, banks have moved credit exposure from the riskiest to the least risky industries.

# Have Banks Adjusted Lending to Riskiest Borrowers?

$$Outcome_{i,t} = \beta_1 Post_t \times Exposure_i + \Gamma X_{i,t} + \gamma_i + \kappa_t + \epsilon_{i,t},$$

- $Outcome_{i,t}$ is the proportion of lending to the riskiest industries.
  - Riskiest industries are those most exposed to transition risks under the strictest scenario in each model. Definitions
- $Post_t$ is a dummy equal to one if after either the Paris Agreement or the Net-Zero Banking Alliance. Details
- $Exposure_i$ is the Exposure Under Stress the quarter before the Paris Agreement.
- $X_{i,t}$ are bank-level controls.
- $\gamma_i, \kappa_t$ are bank and quarter fixed effects.

# Have Banks Adjusted Lending to Riskiest Borrowers?

$$\textit{Share of Lending to Riskiest Industries}_{i,t} = \beta_1 Post_t \times Exposure_i + \Gamma X_{i,t} + \gamma_i + \kappa_t + \epsilon_{i,t} \quad (1)$$

| | (1) Pr(Exposed Lending) | (2) Pr(Exposed Lending) | (3) Pr(Exposed Lending) | (4) Pr(Exposed Lending) | (5) Pr(Exposed Lending) | (6) Pr(Exposed Lending) |
|---|---|---|---|---|---|---|
| Treated (Jorgenson) × Post Paris | -2.260** | | | | | |
| | (-2.63) | | | | | |
| Treated (Goulder) × Post Paris | | 0.018 | | | | |
| | | (0.27) | | | | |
| Treated (NGFS) × Post Paris | | | -0.201* | | | |
| | | | (-1.81) | | | |
| Treated (Jorgenson) × Post Alliance | | | | -0.945*** | | |
| | | | | (-2.82) | | |
| Treated (Goulder) × Post Alliance | | | | | 0.056 | |
| | | | | | (1.38) | |
| Treated (NGFS) × Post Alliance | | | | | | -0.079 |
| | | | | | | (-0.97) |
| Model | Jorgenson | Goulder and Hafstead | NGFS | Jorgenson | Goulder and Hafstead | NGFS |
| Scenario | 50d tax, 5p growth | Lump Sum | Disorderly Transition | 50d tax, 5p growth | Lump Sum | Disorderly Transition |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Bank Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Time Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Within-R2 | 0.138 | 0.030 | 0.087 | 0.084 | 0.032 | 0.040 |
| Observations | 1331.000 | 1331.000 | 1331.000 | 1331.000 | 1331.000 | 1331.000 |

$t$ statistics in parentheses

$^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

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# Have Banks Adjusted Interest Rates to Riskiest Borrowers?

$$Yield\ Spread_{l,t} = \beta_1 Treated_l + \beta_2 Post_t \times Treated_l + \Gamma X_{l,i,t} + \gamma_i + \kappa_t + \epsilon_{l,t}, \qquad (2)$$

| | (1) Interest Rate | (2) Interest Rate | (3) Interest Rate | (4) Interest Rate | (5) Interest Rate | (6) Interest Rate |
|---|---|---|---|---|---|---|
| Treated (Jorgenson) × Post Paris | 0.000 | | | | | |
| | (0.85) | | | | | |
| Treated (Goulder) × Post Paris | | 0.002** | | | | |
| | | (2.10) | | | | |
| Treated (NGFS) × Post Paris | | | 0.002 | | | |
| | | | (1.67) | | | |
| Treated (Jorgenson) × Post Alliance | | | | 0.002*** | | |
| | | | | (4.04) | | |
| Treated (Goulder) × Post Alliance | | | | | 0.004*** | |
| | | | | | (5.18) | |
| Treated (NGFS) × Post Alliance | | | | | | 0.003** |
| | | | | | | (2.55) |
| Model | Jorgenson | Goulder and Hafstead | NGFS | Jorgenson | Goulder and Hafstead | NGFS |
| Scenario | 50d tax, 5p growth | Lump Sum | Disorderly Transition | 50d tax, 5p growth | Lump Sum | Disorderly Transition |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Bank Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Time Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Within-R2 | 0.003 | 0.003 | 0.004 | 0.003 | 0.003 | 0.004 |
| Observations | 111731.000 | 104262.000 | 112317.000 | 111731.000 | 104262.000 | 112317.000 |

$t$ statistics in parentheses

$^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

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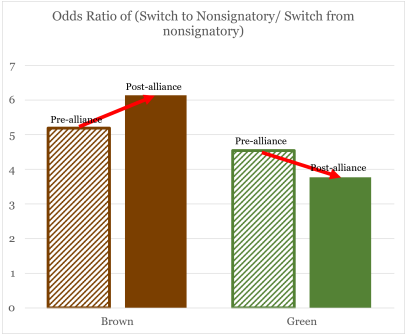
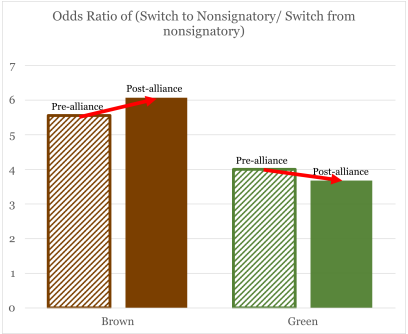
# Have Bank-Borrower Relationships Changed after the Net-Zero Banking Alliance?




(a) Jorgenson et al.




(b) NGFS

- **Brown** borrowers became more likely to switch to **non-signatory** banks.
- **Green** borrowers became more likely to switch to **signatory** banks.

# In Relation to Emission Funding

- Analyses so far build on the general equilibrium estimates.
- How much of our measure is explained by borrowers' carbon emissions, a commonly used backward-looking measure?
- Based on our methodology, are policy effects stronger for higher emitting firms?

# How Much of Exposure is Explained by Carbon Emissions?

| Model Scenario | I | II | III | IV |
|---|---|---|---|---|
| | *Panel A: Jorgenson et al (2018) Tax and Growth Rate Scenarios* | | | |
| | \$25 Tax, 1% Growth Rate | \$25 Tax, 5% Growth Rate | \$50 Tax, 1% Growth Rate | \$50 Tax, 5% Growth Rate |
| Emissions R2 | 0.572 | 0.577 | 0.582 | 0.588 |
| | *Panel B: Jorgenson et al (2018) Redistribution Scenarios* | | | |
| | Lump Sum Redistribution | Capital Tax Cut | Labor Tax Cut | |
| Emissions R2 | 0.577 | 0.595 | 0.577 | |
| | *Panel C: Goulder and Hafstead (2018) Redistribution Scenarios* | | | |
| | Lump Sum Redistribution | Corporate Tax Cut | Payroll Tax Cut | Individual Income Tax Cut |
| Emissions R2 | 0.257 | 0.257 | 0.257 | 0.258 |
| | *Panel D: NGFS Scenarios* | | | |
| | Current Policy | Disorderly Transition | Orderly Transition | |
| Emissions R2 | 0.496 | 0.411 | 0.416 | |

- Much of the variation in exposures is *not* driven by emissions.
- Based on the industry-level emissions data, $R^2$ is even smaller. Industry-Level

# Conclusion

- We develop a novel measure of US banks' exposure to transition risk building upon general equilibrium model estimates.
- We find that the estimated exposures are generally modest, and are no higher than 16% relative to current loan balances even in the most severe scenario.
- Banks' exposures to the riskiest industries appear to be mildly decreasing over time.
- Banks decreased lending and increased loan spreads for highly exposed industries in recent years.