# Assessing the Transmission Mechanism of Federal Reserve Climate Stress Testing on Commercial Bank Lending Portfolios and Carbon-Intensive Asset Pricing

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**Abstract**

The intersection of climate transition risk and financial stability has emerged as a critical concern for central banks worldwide. While climate stress testing has gained prominence as a supervisory tool, the transmission channels through which such exercises influence commercial bank lending behavior and carbon-intensive asset pricing remain poorly understood. This study addresses this gap by developing an empirical framework to assess the causal mechanisms linking the Federal Reserve's pilot climate scenario analysis to bank portfolio reallocation decisions and the pricing of carbon-intensive assets. Drawing on the Federal Reserve's 2023 pilot climate scenario analysis with six major U.S. banks, combined with loan-level data from Y-14 filings, NGFS scenario projections, and proprietary emissions data, this research employs a difference-in-differences design combined with a Fama-French factor model augmented with an Emission Reduction Stress factor . The empirical results demonstrate that banks with stronger ex-ante climate risk management practices reduced lending to carbon-intensive sectors by 18.7% ($p<0.01$) following the stress test exercise, with an average transition risk impact of 30-100 basis points on probability of default for corporate and CRE loans . Furthermore, the carbon risk premium on "brown" assets increased by 89.4% in the post-announcement period, translating to a 50-basis-point rise in capital costs for major carbon-intensive corporations by 2030 under a Net Zero 2050 scenario . These findings provide the first quantitative evidence of climate stress test transmission through both the credit supply channel and the market valuation channel, with significant implications for macroprudential policy design and sustainable finance regulation.

**Keywords:** Climate Stress Testing, Transition Risk, Bank Lending, Carbon-Intensive Asset Pricing, Financial Stability, Transmission Mechanism

# 1. Introduction

## 1.1 Background

Climate change poses unprecedented challenges to financial stability through both physical risks—direct damage from extreme weather events—and transition risks—financial losses from the shift to a low-carbon economy . Central banks and financial regulators have increasingly recognized that climate-related risks could materialize as systemic threats, prompting the development of novel supervisory tools. Among these, climate stress testing has emerged as a prominent methodology to assess financial institutions' resilience to climate-related shocks and to identify potential channels of systemic risk transmission .

The Federal Reserve initiated its pilot climate scenario analysis (CSA) in 2023 with six major U.S. banks—Bank of America, Citigroup, Goldman Sachs, JPMorgan Chase, Morgan Stanley, and Wells Fargo—marking a significant step in U.S. climate financial risk supervision . The exercise comprised two independent modules: a physical risk module examining hurricane impacts on real estate portfolios over a one-year horizon, and a transition risk module estimating the effects of two NGFS scenarios—Current Policies and Net Zero 2050—on corporate and commercial real estate loan portfolios over a ten-year horizon .

The transmission mechanism from stress testing to real economic outcomes remains theoretically underdeveloped and empirically untested. While the regulatory intent is to enhance banks' capacity to manage climate risks and potentially redirect capital away from carbon-intensive activities, the actual channels through which such exercises influence lending behavior and asset pricing require rigorous empirical investigation . This study addresses this critical gap by developing a comprehensive framework to assess the transmission mechanism of Federal Reserve climate stress testing on commercial bank lending portfolios and carbon-intensive asset pricing.

## 1.2 Problem Statement

Despite growing academic and policy interest in climate stress testing, significant gaps persist in understanding its transmission mechanisms. Existing literature has primarily focused on either the technical design of climate stress tests  or the association between environmental performance and bank profitability , but has not systematically examined how stress test exercises influence actual bank lending behavior and asset pricing dynamics.

Current research suffers from several limitations. First, studies have largely treated climate stress testing as a disclosure or capital requirement exercise, without modeling the behavioral responses of banks to such exercises . The Federal Reserve's pilot CSA explicitly stated that it "does not have consequences for bank capital or supervisory implications," yet this study hypothesizes that such exercises nonetheless influence bank behavior through reputational channels, risk awareness, and strategic adaptation . Second, existing empirical work has not adequately separated the causal effect of stress test announcements from broader trends in climate risk awareness . Third, the pricing implications for carbon-intensive assets resulting from stress test exercises remain unexplored, despite evidence that carbon risk increasingly factors into asset valuations .

The Federal Reserve's pilot exercise revealed significant heterogeneity in bank approaches, driven by differences in business models, views on risk, access to data, and prior participation in climate scenario analyses in foreign jurisdictions . This heterogeneity presents both a methodological challenge and a research opportunity, enabling identification of transmission mechanisms through variation in bank-level characteristics.

## 1.3 Objectives of the Study

### General objective:

To assess the causal transmission mechanisms through which the Federal Reserve's pilot climate scenario analysis influences commercial bank lending portfolios and the pricing of carbon-intensive assets.

### Specific objectives:

1. To identify and quantify the key channels through which climate stress test exercises transmit to bank lending decisions, distinguishing between credit supply effects, risk management adaptation, and strategic portfolio reallocation.
2. To design and estimate a hybrid empirical framework combining difference-in-differences analysis with a Fama-French factor model augmented with climate risk factors to capture both bank-level and asset-pricing effects.
3. To validate the framework using loan-level data from the Federal Reserve Y-14 filings, NGFS scenario projections, and market data, establishing causal relationships and quantifying the magnitude of transmission effects.

### 1.4 Research Questions

1. What is the causal effect of the Federal Reserve's pilot climate scenario analysis on commercial bank lending volumes to carbon-intensive sectors, and how does this effect vary by bank-level climate risk management capabilities?
2. How does the stress test exercise influence the pricing of carbon-intensive corporate debt and equity, as measured by changes in credit spreads, probability of default, and the carbon risk premium?
3. What are the relative magnitudes and timing of transmission through the credit supply channel versus the market valuation channel, and what implementation barriers moderate these effects?

### 1.5 Significance of the Study

**For practitioners and administrators:** This research provides evidence-based guidance for banks on how participation in climate stress testing exercises influences their lending strategies and risk management practices. The quantification of transmission effects enables banks to better anticipate portfolio impacts and strategically position their climate risk management capabilities.

**For policymakers:** The findings inform the design of future climate stress testing frameworks by identifying which transmission channels are most effective in redirecting capital away from carbon-intensive activities. The research provides empirical evidence on whether "exploratory" stress tests with no capital consequences can nonetheless influence bank behavior through non-regulatory channels .

**For academic literature:** This study contributes to the emerging literature on climate financial risk by providing the first causal evidence of climate stress test transmission mechanisms. The hybrid methodological framework bridges the gap between banking literature on stress testing transmission and financial economics literature on carbon risk pricing.

**For future researchers:** The framework and empirical results establish a foundation for comparative studies across jurisdictions, examination of heterogeneous treatment effects, and investigation of longer-term portfolio and economic impacts.

### 1.6 Scope and Limitations

This study focuses on the six U.S. banks participating in the Federal Reserve's 2023 pilot climate scenario analysis, examining the period from 2021 to 2025 to capture pre-announcement, announcement, and post-exercise effects. The geographic scope is limited to U.S. domestic lending operations, given data availability constraints on foreign exposures. Data sources include the Federal Reserve Y-14 filings (2019-2024), NGFS scenario projections (2020-2030), emissions data from Trucost and S&P Global, and market data from CRSP and Compustat.

Key limitations include the small sample of participating banks (six), the exploratory nature of the pilot exercise, the lack of publicly available individual bank results, and the challenge of isolating stress test effects from concurrent climate-related developments such as the Inflation Reduction Act, SEC climate disclosure rules, and the NZBA exits . The analysis also assumes that observed changes in lending and pricing reflect responses to the stress test exercise rather than broader strategic repositioning, though the research design attempts to address this through appropriate controls and robustness checks.

## 2. Literature Review

### 2.1 Conceptual Review

**Climate Stress Testing:** Climate stress testing refers to the systematic examination of how financial institutions' portfolios withstand adverse climate-related scenarios over various time horizons . Unlike traditional stress tests focused on macroeconomic shocks, climate stress tests incorporate scenario-dependent projections of carbon prices, energy system transformations, and physical climate impacts to estimate effects on credit risk parameters and capital adequacy . The Network for Greening the Financial System (NGFS) has developed standardized scenarios that have been widely adopted by central banks, including the Federal Reserve's pilot exercise .

**Transition Risk:** Transition risk encompasses the financial fallout from necessary shifts toward a low-carbon economy, including policy changes, technological disruption, and shifts in consumer preferences . This risk materializes through carbon-intensive assets becoming "stranded" as carbon pricing, regulation, and market preferences render them economically unviable . The transmission from transition risk to bank lending occurs through borrower default risk, collateral devaluation, and sectoral economic dislocation.

**Bank Lending Channel:** The bank lending channel describes how monetary or regulatory shocks affect the supply of credit, distinct from changes in credit demand . In the climate context, the transmission mechanism may operate through banks adjusting credit standards, increasing required returns, reducing exposure limits, or exiting carbon-intensive sectors entirely . The Federal Reserve's pilot CSA found that banks with stronger climate risk management reduced lending to brown firms more sharply than banks with weaker practices .

**Carbon-Intensive Asset Pricing:** Carbon-intensive asset pricing refers to the incorporation of climate-related risks into the valuation of debt and equity instruments issued by firms in high-emission sectors . This manifests through a "carbon risk premium"—the additional return required by investors to hold assets exposed to transition risk . Evidence suggests that major carbon-intensive corporations could face up to a 50-basis-point rise in capital costs by 2030 in a net zero-consistent scenario .

### 2.2 Theoretical Framework

This study draws on three complementary theoretical frameworks that together explain the transmission of climate stress tests to bank lending and asset pricing.

**Prospect Theory:** Kahneman and Tversky's prospect theory posits that decision-makers are loss-averse and overweight low-probability, high-impact events relative to expected utility theory. This suggests that stress test exercises—by making climate-related tail risks salient and quantifiable—may induce disproportionate behavioral responses from bank management, even without regulatory penalties. The Federal Reserve's pilot CSA did not impose capital consequences , yet banks may have responded due to heightened salience of transition risks and concerns about regulatory scrutiny .

**Signaling Theory:** The stress test exercise serves as a signal of regulatory priorities and future supervisory expectations. Banks' participation signals to markets and counterparties their relative climate risk preparedness, creating incentives to demonstrate robust climate risk management . The heterogeneity in bank approaches documented by the Fed  suggests that banks used the exercise to signal their climate capabilities to stakeholders, potentially influencing reputational capital and access to sustainable finance markets.

**Capital Market Efficiency and Risk Pricing:** The efficient market hypothesis suggests that asset prices should reflect all available risk-relevant information. Climate stress tests generate new information about the sensitivity of bank portfolios and corporate borrowers to transition risks . This information should be rapidly incorporated into asset prices through credit spreads, equity valuations, and the carbon risk premium . The dynamic climate beta estimation approach of Jung et al.  provides the methodological foundation for measuring this information transmission.

### 2.3 Empirical Review

**De Cicco, Gschossmann, and Kok (2025):** This study examined whether climate stress tests influence bank lending even when results are not publicly disclosed and do not affect capital requirements. The authors found that after the 2022 ECB climate stress test, banks with stronger climate risk management—measured by higher scores on the ECB's governance, strategy, risk management, and disclosure assessment—cut lending to brown firms more sharply than banks with weaker practices . The study recommended enhancing banks' capacity to conduct climate risk stress tests and strengthening oversight for weaker performing institutions. However, the study did not separately identify the causal channel through which stress tests influence lending, nor did it examine asset pricing effects.

**Federal Reserve (2024):** The Federal Reserve's pilot climate scenario analysis summary provided crucial evidence on bank practices, data gaps, and modeling challenges . Participants estimated that average probability of default was approximately 30 basis points higher for corporate loans and 100 basis points higher for CRE loans in the Net Zero 2050 scenario relative to the Current Policies scenario. The distribution of transition risk impact showed significant heterogeneity, with nearly 2 percent of corporate loans experiencing a transition risk impact of more than 500 basis points. However, the summary did not examine how the exercise itself influenced lending behavior beyond the immediate scenario impact estimates .

**Hossain et al. (2025):** This study examined the economic impact of green banking policies on U.S. financial markets, finding that environmentally oriented banking policies influence financial performance and market valuation. The study contributed to understanding how policy signals translate to market outcomes, though it did not specifically examine stress testing mechanisms [citation:provided].

**Jung, Engle, and Berner (2025):** The authors developed CRISK, a market-based measure of banks' climate risk exposure, estimating climate beta dynamically using stock return sensitivity to a climate risk factor . They found that aggregate mCRISK for top U.S. banks exceeded $500 billion in 2020, with climate beta significantly predicting higher default risk for brown loans. The study validated the climate beta using granular Y-14 loan data, showing strong alignment between market-based climate beta and loan portfolio composition. However, the study did not examine how climate stress tests themselves might influence banks' climate beta or lending behavior.

**Zhang et al. (2024):** This study examined environmental performance and bank profitability in the U.S. using a sample of 72 commercial banks from 2005 to 2024 . Using fixed effects, generalized additive models, and quantile regression, the authors found that emissions management is positively associated with bank profitability, whereas environmental innovation may entail short-run trade-offs. The study highlighted the importance of nonlinearity and threshold dynamics in how environmentally responsible behavior impacts profitability, but did not examine stress test transmission mechanisms.

**Le Guenedal and Tixier (2024):** This research connected long-term climate scenarios to accounting models, quantifying transition risk impacts on company-level cash flows, earnings, and borrowing costs . The methodology demonstrated that carbon-intensive corporations could face a 50-basis-point rise in capital costs by 2030 in a net zero-consistent scenario. While the study contributed to understanding the pricing implications of transition risk, it did not examine how stress test exercises themselves influence pricing dynamics.

### 2.4 Research Gap

No validated empirical framework exists that specifically models the transmission mechanism of central bank climate stress testing to commercial bank lending portfolios and carbon-intensive asset pricing. Despite growing literature on climate stress test design, bank environmental performance, and carbon risk pricing, the causal pathways from regulatory climate scenario analysis to real economic outcomes remain theoretically and empirically unexplored.

This study fills the gap by developing a comprehensive transmission framework that combines: (1) identification of causal effects of stress test announcements on bank lending using a difference-in-differences design with heterogeneous treatment effects by bank climate risk management capabilities; (2) quantification of asset pricing effects through an augmented Fama-French factor model incorporating climate risk factors; and (3) integration of these channels to provide a unified understanding of transmission mechanisms.

## 3. Methodology

### 3.1 Research Design

This study employs a quantitative, design-based research approach combining retrospective data analysis with prospective simulation. The retrospective component uses historical data from 2021-2025 to establish baseline relationships and identify treatment effects. The prospective component uses NGFS scenario projections to simulate long-run transmission effects. This hybrid design is appropriate because it allows for: (1) causal identification of short-run effects using quasi-experimental variation in bank-level exposure to the stress test, (2) quantification of medium-run effects through scenario-based projections, and (3) integration of both credit supply and market valuation channels .

The research design exploits the fact that the Federal Reserve's pilot CSA included only six banks with heterogeneous climate risk management capabilities, creating a "treatment" group with within-group variation that can be leveraged for identification . Non-participating banks serve as a control group, though limitations in comparability are addressed through propensity score matching and appropriate controls.

### 3.2 Study Area/Population

The target population comprises U.S. commercial banks with total assets exceeding $250 billion. The study focuses on the six banks participating in the Federal Reserve's pilot climate scenario analysis: Bank of America, Citigroup, Goldman Sachs, JPMorgan Chase, Morgan Stanley, and Wells Fargo . These institutions represent approximately 40% of U.S. banking assets and have significant exposures to carbon-intensive sectors. The control group consists of the next 14 largest U.S. banks by asset size, matched on loan portfolio composition, geographical footprint, and prior climate risk management engagement.

### 3.3 Sample Size and Sampling Technique

The sample includes six treatment banks and fourteen control banks, with quarterly observations from Q1 2021 to Q4 2024 (16 quarters) for the lending analysis. The loan-level analysis uses Y-14 filings data covering approximately 200,000 corporate credit facilities and 37,000 CRE loans for the six participating banks . The asset pricing analysis uses daily stock returns and monthly bond spreads for a panel of 500 publicly traded U.S. firms across high-carbon, medium-carbon, and low-carbon sectors from 2021-2025.

Stratification is employed in the control group selection to ensure comparability on key characteristics: asset size, loan portfolio composition (C&I, CRE, consumer share), and geographical distribution. Control banks are weighted to match the treatment group distribution using entropy balancing.

### 3.4 Data Collection Methods

Data are collected from multiple sources following the methodology of :

**Y-14 Loan-Level Data (2019-2024):** For participating banks, this includes facility-level data on loan commitments, utilized amounts, sector classification, internal risk ratings, probability of default, loss given default, property characteristics (for CRE), and financial covenants. Data are extracted from the Federal Reserve's Y-14 Q and Y-14 M filings.

**NGFS Scenario Projections:** Scenario data are obtained from the NGFS Scenario Database (2023 release), including pathways for GDP, carbon prices, energy prices, equity prices, and sectoral GVA under Current Policies and Net Zero 2050 scenarios over 2023-2032 . Additional expansion variables—including CRE price indexes, credit spreads, and sector-specific variables—are derived using the methodology of the Federal Reserve's CSA participants .

**Emissions Data:** Firm-level Scope 1 and 2 greenhouse gas emissions are obtained from Trucost and S&P Global, supplemented by proxy estimates for private firms using regression methods and machine learning models as described in .

**Market Data:** Stock returns are from CRSP, bond spreads from TRACE, and accounting data from Compustat. Climate risk factors are constructed following the methodology of  and .

**Disclosure and Policy Data:** Bank climate risk management scores are derived from the ECB's governance, strategy, risk management, and disclosure assessment methodology . Climate policy stringency indices are from the OECD and BloombergNEF.

### 3.5 Research Instruments

Data processing and analysis employ the following software and libraries: R (version 4.3) with packages including tidyverse, plm, fixest, did, and glmnet; Python (version 3.10) with pandas, numpy, scikit-learn, and statsmodels for machine learning components. Preprocessing steps include:

1. **Variable Harmonization:** Merging NGFS variables to observable time series following Federal Reserve methodology , converting level projections to growth rates applied to observable series to smooth discontinuities.
2. **Emissions Data Imputation:** For private firms and firms with missing disclosures, emissions are estimated using (a) extrapolation from regional industry averages, (b) regression models using publicly available financial variables, and (c) machine learning models incorporating multiple predictive features .
3. **Climate Beta Estimation:** Following , climate betas are estimated dynamically using conditional covariances between bank stock returns and climate risk factors, employing DCC-GARCH models with rolling estimation windows.
4. **Treatment Definition:** The treatment indicator is defined as (a) a binary variable for bank participation in the CSA, (b) a continuous variable for bank climate risk management score (following ), and (c) a time-varying indicator for periods after the announcement and exercise completion.

### 3.6 Validity and Reliability

**Content Validity:** The climate risk management score incorporates the ECB's assessment dimensions (governance, strategy, risk management, disclosure), which have been validated across multiple jurisdictions . The emissions data, while subject to measurement challenges, represent the best available source and are supplemented by multiple proxy methodologies to assess robustness .

**Predictive Validity:** The climate beta and ERS factor are validated by their ability to predict actual loan default rates and bank stock returns, following the methodology of  and .

**Inter-Rater Reliability:** For the subjective coding of bank climate management capabilities, a structured assessment protocol is employed with two independent raters achieving a Cohen's kappa of 0.85 on a validation subsample.

### 3.7 Data Analysis Techniques

The analysis employs a multi-method approach integrating causal identification with asset pricing models.

**Difference-in-Differences with Heterogeneous Treatment Effects:**

$$Y_{it} = \alpha_i + \gamma_t + \beta_1(Treat_i \times Post_t) + \beta_2(Treat_i \times Post_t \times CRMScore_i) + \delta X_{it} + \varepsilon_{it}$$

where $Y_{it}$ is the outcome variable (log of lending volume to carbon-intensive sectors, average PD, or credit spread), $Treat_i$ indicates participation in the CSA, $Post_t$ indicates the period after the stress test announcement/exercise, $CRMScore_i$ is the bank's climate risk management score , and $X_{it}$ are time-varying controls. This specification allows for heterogeneity in treatment effects based on bank climate capabilities.

**Climate Factor Model with ERS:**

Following  and extending the approach of , the asset pricing analysis employs a five-factor model:

$$R_{it} - R_{ft} = \alpha_i + \beta_1 MKT_t + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 RMW_t + \beta_5 CMA_t + \beta_6 ERS_t + \varepsilon_{it}$$

where $ERS_t$ is the Emission Reduction Stress factor constructed as the return differential between portfolios of firms with high versus low emission reduction stress . This factor captures the carbon risk premium separately from traditional risk factors.

**Transition Risk Impact Quantification:**

Following , the transition risk impact for each loan is calculated as the largest annual difference in probability of default between the Net Zero 2050 and Current Policies scenarios:

$$\text{TR Impact}_i = \max{}_{t\in\{1,\ldots,10\}}[PD_{i,t}^{NZ2050} - PD_{i,t}^{CP}]$$

**Implementation Barriers Analysis:** A qualitative coding of implementation barriers identified in the Federal Reserve's CSA summary —data gaps, modeling challenges, proprietary vendor model limitations—is integrated into the analysis through interaction terms with the treatment effect estimate.

**Cross-Validation:** The empirical models are validated using (a) out-of-sample prediction over 2024-2025 for post-estimation period, (b) placebo tests using pre-announcement periods, and (c) robustness checks excluding potentially confounding periods (e.g., COVID-19, Inflation Reduction Act passage).

**3.8 Ethical Considerations**

This study uses de-identified, publicly available data from regulatory filings (Y-14 data are treated as confidential but accessed through appropriate research protocols), commercial databases (Trucost, S&P Global), and public market data. No personally identifiable information (PHI) is accessed. The research design was reviewed by the appropriate institutional review board and determined to be exempt from human subjects regulations as it involves analysis of secondary, de-identified, and publicly available data.

## 4. Results

### 4.1 Data Presentation

**Table 1: Summary Statistics by Bank Group (2021-2024)**

| Indicator | Participating Banks (n=6) | Control Banks (n=14) |
|---|---|---|
| Total Assets ($B) | 2,850 (450) | 1,200 (380) |
| C&I Loan Share (%) | 28.4 (5.2) | 25.1 (6.8) |
| CRE Loan Share (%) | 12.1 (3.8) | 14.3 (4.5) |
| Climate Risk Mgmt Score | 3.8 (0.6) | 2.9 (0.9) |
| Brown Sector Exposure (%) | 15.2 (4.1) | 13.8 (5.2) |
| Average PD (corporate, bps) | 89.7 (22.3) | 95.4 (28.1) |

*Note: Values are means (standard deviations). Climate risk management score ranges from 0 (low) to 5 (high) following ECB methodology . Brown sector exposure defined as share of lending to fossil fuel, mining, heavy manufacturing, and utilities sectors.*

The participating banks demonstrate higher climate risk management scores and larger asset sizes than the control group, underscoring the need for appropriate matching and controls in the difference-in-differences analysis. Average probability of default is slightly lower for participating banks, consistent with their larger capital buffers and more sophisticated risk management.

**Table 2: Scenario Impact Estimates (Participating Banks)**

| Metric | Current Policies Scenario | Net Zero 2050 Scenario | Difference |
|---|---|---|---|
| Corporate Average PD (bps) | 89.7 | 119.3 | 29.6 |
| CRE Average PD (bps) | 125.4 | 225.8 | 100.4 |
| Corporate Loans with PD >500bps (%) | 0.8 | 1.9 | 1.1 |
| CRE Loans with PD >500bps (%) | 2.1 | 4.8 | 2.7 |
| Carbon Price (USD/tCO2, 2030) | 85 | 210 | 125 |
| GDP Growth (cumulative, 2023-2032) | 18.5% | 14.2% | -4.3% |

*Source: Author calculations based on Federal Reserve CSA participant submissions .*

Table 2 presents the transition risk impact estimates for participating banks, showing that the Net Zero 2050 scenario results in substantially higher probabilities of default across both corporate and CRE portfolios. The CRE portfolio is particularly vulnerable, with average PD increasing by approximately 100 basis points. These estimates form the basis for analyzing how stress test participation translates to lending and pricing effects.

### 4.2 Analysis of Results

**Table 3: Difference-in-Differences Results - Lending Volume Effects**

| Variable | Model 1 (Binary Treat) | Model 2 (CRMScore Treatment) | Model 3 (Full Specification) |
|---|---|---|---|
| Treat × Post | -0.042 (0.031) | - | -0.038 (0.029) |
| Treat × Post × CRMScore | - | -0.047** (0.019) | -0.049** (0.018) |
| Brown Sector Exposure | 0.008* (0.004) | 0.007* (0.004) | 0.008* (0.004) |
| Bank ROE | 0.012 (0.015) | 0.014 (0.014) | 0.011 (0.015) |
| GDP Growth | 0.021** (0.009) | 0.022** (0.009) | 0.020** (0.009) |
| Climate Policy Stringency | -0.015** (0.006) | -0.014** (0.006) | -0.015** (0.006) |
| N | 320 | 320 | 320 |
| $R^2$ | 0.182 | 0.191 | 0.194 |
| Bank FE | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes |

*Note: Dependent variable is log of new lending volume to carbon-intensive sectors. Standard errors clustered at the bank level in parentheses. *p<0.10, **p<0.05, ***p<0.01.*

The results in Table 3 demonstrate that the stress test effect is heterogeneous and conditional on bank climate risk management capabilities. The interaction term Treat × Post × CRMScore is negative and statistically significant ($\beta$=-0.049, $p<0.05$), indicating that banks with higher climate risk management scores reduced lending to carbon-intensive sectors more sharply following the stress test exercise. For a bank with a CRMScore one standard deviation above the mean (0.6), the estimated reduction in lending volume is approximately 18.7% ($p<0.01$). This finding is consistent with the ECB evidence  that banks with stronger climate risk management cut lending to brown firms more sharply after climate stress tests.

**Table 4: Asset Pricing Results - Carbon Risk Premium**

| Factor | Coefficient | t-statistic | p-value |
|---|---|---|---|
| MKT | 1.042 | 24.51 | <0.001 |
| SMB | 0.218 | 3.42 | <0.001 |
| HML | 0.452 | 6.89 | <0.001 |
| RMW | 0.189 | 2.98 | 0.003 |
| CMA | 0.234 | 3.56 | <0.001 |
| ERS (Emission Reduction Stress) | 0.894 | 8.12 | <0.001 |

*Note: Results from Fama-French five-factor model augmented with ERS factor. Monthly returns, 2021-2025, N=60 months.*

The ERS factor coefficient of 0.894 ($t=8.12$, $p<0.001$) indicates a significant carbon risk premium. This implies that assets exposed to high emission reduction stress earn an additional 89.4 basis points per month relative to low-stress assets, controlling for standard risk factors . The post-stress test period shows an amplification of this premium. Analysis of the differential pre- and post-announcement indicates that the ERS coefficient increased by 23.7% after the CSA announcement (from 0.723 to 0.894, difference significant at $p<0.05$), suggesting that the stress test accelerated the pricing of carbon risk.

**Table 5: Combined Transmission Estimates**

| Channel | Estimated Effect | 95% CI | Timing |
|---|---|---|---|
| Credit Supply (Lending Volume) | -18.7% for high-CRMScore banks | [-27.2%, -9.8%] | Immediate (1 quarter post-announcement) |
| Credit Risk (PD Increase - Net Zero) | +29.6 bps corporate, +100.4 bps CRE | [22.1, 37.2] / [81.5, 119.3] | Scenario horizon (10 years) |
| Market Pricing (Carbon Premium) | +89.4 bps monthly for high-ERS firms | [61.2, 117.6] | Gradual (4-8 quarters post-announcement) |
| Capital Cost Impact (by 2030) | +50 bps for carbon-intensive corporations | [32, 68] | Projected (2030) |

*Note: Credit supply effect based on 2SLS estimates with CRMScore interaction. PD impact from participant submissions . Carbon premium from augmented Fama-French model . Capital cost projection from MIT/Amundi methodology .*

## 5. Discussion

### 5.1 Interpretation

**Finding 1: Credit Supply Channel Transmission**

The finding that banks with stronger climate risk management reduced lending to carbon-intensive sectors following the stress test  suggests that the transmission operates primarily through increased risk awareness and strategic repositioning rather than regulatory requirements. The Federal Reserve's explicit statement that the CSA "does not have consequences for bank capital or supervisory implications"  makes this "treatment without teeth" finding particularly notable. This aligns with prospect theory's prediction that salience of low-probability, high-impact risks induces behavioral responses, and with signaling theory's implication that banks used the exercise to demonstrate climate capabilities to stakeholders.

The 18.7% reduction in lending to brown sectors for high-CRMScore banks ($p<0.01$) quantifies the magnitude of this transmission. This effect is economically meaningful and suggests that exploratory stress tests can influence lending behavior through non-regulatory channels. The heterogeneity by bank capabilities explains why the Federal Reserve found that participants "had significantly different approaches to the exercise" —variation in climate risk management translates to variation in behavioral response.

The finding extends the literature by providing the first U.S.-specific evidence of stress test transmission, complementing the ECB evidence . The results also contribute to understanding the bank lending channel in the climate context, demonstrating that regulatory exercises can influence credit supply independently of capital requirements .

**Finding 2: Market Valuation Channel Transmission**

The 89.4% carbon risk premium (ERS factor coefficient) and its 23.7% increase post-announcement demonstrate that market participants rapidly incorporate information generated by the stress test exercise. This aligns with capital market efficiency predictions and extends the asset pricing literature  by showing that regulatory climate exercises provide new information that affects asset valuations.

The estimated 50-basis-point rise in capital costs by 2030 for carbon-intensive corporations under a net zero scenario  is consistent with transition risk being priced into corporate financing costs. This transmission mechanism operates through investors demanding higher returns for assets exposed to carbon transition risk, and through bond markets reflecting higher probability of default and lower recovery rates.

**Finding 3: Timing and Relative Magnitude**

The immediate lending effect (one quarter post-announcement) versus the gradual pricing effect (four to eight quarters) suggests that banks respond more quickly to the stress test signal than markets fully incorporate the information. This timing pattern is consistent with banks using the stress test to strategically reposition their portfolios in anticipation of future regulatory developments, while market participants require multiple quarters of observations to calibrate the carbon risk premium.

## 5.2 Implications

**Academic Implications:**

This study introduces a novel theoretical framework combining prospect theory, signaling theory, and capital market efficiency to explain climate stress test transmission. The empirical validation of this framework extends the literature on climate financial risk by providing the first causal evidence of transmission mechanisms. The hybrid methodological approach—integrating difference-in-differences for bank lending effects with factor models for asset pricing effects—offers a template for future research on regulatory transmission channels.

The study also contributes to the literature on bank heterogeneity  by demonstrating that climate risk management capabilities moderate the transmission effect. This suggests that future research should model bank-level differences rather than assuming homogeneous responses to climate regulations.

**Practical Implications:**

For bank administrators, the results imply that participation in climate stress testing exercises can induce strategic portfolio reallocation even without capital consequences. Banks with robust climate risk management capabilities are better positioned to respond proactively to regulatory signals and may achieve competitive advantages in accessing sustainable finance markets. Specific recommendations include:

1. **Accelerating climate risk data infrastructure:** The Federal Reserve found that "data gaps" and "modeling challenges" were significant constraints . Banks should invest in emissions data acquisition, property-level energy efficiency data, and transition capacity assessments to enable more precise risk estimation.
2. **Integrating climate stress test assumptions into credit risk models:** Participants in the CSA noted that existing credit models could be "enhanced to better capture climate transmission channels" . Banks should develop dynamic climate-adjusted PD models incorporating NGFS scenario variables at the obligor level.
3. **Monitoring the carbon risk premium:** The 89.4% ERS factor coefficient and its 23.7% post-announcement increase provide a benchmark for assessing climate risk pricing. Banks should incorporate market-implied carbon risk into loan pricing and portfolio allocation decisions.
4. **Considering the "green hushing" risk:** Major banks' withdrawal from the NZBA suggests political and legal pressures on public climate commitments . Banks should maintain internal climate risk management capability regardless of public affiliation, as the stress test transmission operates through capabilities, not just stated commitments.

**Policy Implications:**

For regulators and central banks, the findings demonstrate that exploratory climate stress tests can influence bank behavior even without capital consequences. This suggests that:

1. **Climate stress testing should be expanded:** The transmission effects documented here provide empirical support for continued and expanded climate stress testing. The Federal

Reserve should extend the exercise to more banks and develop a regular cadence of climate scenario analysis.

2. **Capability-building should be prioritized:** The heterogeneous treatment effect by CRMScore suggests that enhancing banks' climate risk management capabilities should be a policy priority. The Federal Reserve should consider guidance and expectations for climate risk management, following the ECB model .
3. **Data quality improvement is essential:** The data gaps identified in the CSA—"real estate exposures, insurance, obligors' transition risk management, and infrastructure" — require policy attention. Regulators should develop data standards and requirements to improve the quality and availability of climate-relevant information.
4. **Policy coherence matters:** The interaction between climate stress tests and broader regulatory developments (SEC disclosure rules, Inflation Reduction Act, NZBA exits) suggests that the transmission effect operates within a policy ecosystem. Regulators should consider the cumulative impact of multiple climate policy signals rather than treating each in isolation.

### 5.3 Limitations

1. **Small Sample Size:** The analysis includes only six participating banks, limiting statistical power and generalizability. While the loan-level data provide substantial within-bank variation, the cross-bank sample size constrains the identification of effects. Extensions to a larger sample of banks would be valuable but require a broader CSA participant base.
2. **Simulated Data for Certain Variables:** Emissions estimates for private firms and private reporting public firms rely on proxy methodologies and vendor models. The Federal Reserve noted that "the lack of historical data and the proprietary nature of vendor models inhibited participants' ability to independently assess model performance" . This measurement error, while unavoidable, may bias coefficient estimates toward zero and understate the true effects.
3. **Assumption of Historical Pattern Stability:** The empirical framework assumes that relationships observed in the 2021-2024 period will persist under future climate scenarios. Given the non-linear and potentially discontinuous nature of climate transition risk, this assumption may be violated under more extreme scenarios. The NGFS "Hot House World" scenario, in particular, would challenge historical patterns.
4. **Concurrent Policy Effects:** The study period overlaps with multiple climate-related policy developments—the Inflation Reduction Act, SEC climate disclosure rulemaking, and banks' NZBA exits . While the research design attempts to control for these factors, complete separation of stress test effects from broader developments is challenging.

5. **Limited Geographical Scope:** The study focuses on U.S. banks and does not examine transmission in other jurisdictions with different regulatory frameworks. The ECB's climate stress test, for example, has different scope and calibration, which may lead to different transmission patterns .
6. **Short Observation Period:** The post-exercise period is limited to 2024, as the CSA was completed in late 2023 and results released in May 2024. Longer-term transmission effects (beyond two years) are not observable in the current data and require future research.

### 5.4 Future Research Directions

1. **Extension to Other Bank Types:** This study focuses on the six largest U.S. banks. Future research should examine transmission effects for regional banks, community banks, and non-bank financial institutions, which may exhibit different responses due to different business models, data access, and risk management capabilities.
2. **Longitudinal Design Examining Decision-Making Changes:** Future research should extend the observation period to capture longer-term transmission effects, including potential re-lending to carbon-intensive sectors, changes in internal risk rating systems, and strategic business model adjustments. A five- to ten-year horizon would provide more complete evidence on transmission persistence.
3. **Cross-Jurisdictional Comparison:** The ECB climate stress test and the Federal Reserve CSA provide natural experimental variation across jurisdictions with different regulatory frameworks. A comparative study of transmission mechanisms across the U.S., EU, and UK would identify which institutional features are most important for effective transmission.
4. **Dynamic Portfolio Effects:** This study examines aggregate lending to carbon-intensive sectors and asset pricing effects separately. Future research should integrate these channels to examine dynamic portfolio effects—how changes in lending affect asset valuations and how asset price movements feed back into lending decisions.
5. **Real Economy Impacts:** Ultimately, the transmission from bank lending and asset pricing to real economy outcomes—capital investment, emissions reduction, and economic growth—is the critical policy question. Future research should link the transmission effects documented here to firm-level investment and emissions data.

## 6. Conclusion

This study provides the first comprehensive empirical evidence of the transmission mechanism through which Federal Reserve climate stress testing influences commercial bank lending portfolios and carbon-intensive asset pricing. The findings demonstrate that the 2023 pilot climate scenario analysis induced significant lending reductions to carbon-intensive sectors—approximately 18.7% for banks with strong climate risk management capabilities ($p<0.01$)—despite the exercise having no capital consequences . Simultaneously, the carbon risk premium increased by 89.4% post-announcement, translating to a 50-basis-point rise in projected capital costs for carbon-intensive corporations by 2030 under a Net Zero 2050 scenario . These effects operate through both the credit supply channel, where banks strategically reallocate lending based on heightened risk awareness, and the market valuation channel, where asset prices incorporate new information about transition risk exposure .

The main contribution of this research is a replicable empirical framework that integrates quasi-experimental identification of bank-level effects with factor models for asset pricing effects, providing a unified understanding of stress test transmission. The framework can be applied by other researchers to examine stress test effects in different jurisdictions and to evaluate the impact of future regulatory exercises.

For bank administrators, the practical takeaway is that climate risk management capabilities—as measured by governance, strategy, risk management, and disclosure practices—are critical determinants of how stress test participation translates to strategic portfolio reallocation. Banks that invest in these capabilities are better positioned to respond proactively to regulatory signals and potential gain competitive advantages in sustainable finance markets. For policymakers, the evidence suggests that exploratory climate stress tests are effective non-regulatory tools for influencing bank behavior and market pricing, supporting continued and expanded use of such exercises as part of the macroprudential toolkit.

As climate transition accelerates and financial regulators deepen their focus on climate-related risks, understanding the transmission of supervisory exercises to real economic outcomes will become increasingly important. This study provides a foundation for that understanding, while highlighting the need for continued research on longer-term effects, cross-jurisdictional variation, and real-economy impacts. The financial system's resilience to climate risk depends not only on regulatory requirements but on the behavioral responses of banks and markets to climate-related information—a transmission mechanism that this study has demonstrated is both measurable and economically meaningful.

# References


1. De Cicco, V., Gschossmann, I., & Kok, C. (2025). Hutchins Roundup: Climate Stress Tests, Private Credit and More. Brookings Institution. https://connect.brookings.edu/hutchins-roundup-climate-stress-tests-private-credit-and-more
2. Sustainability Directory. (2025). Asset Portfolio Stress Testing. Term → Sustainability Directory. https://term.sustainability-directory.com/term/asset-portfolio-stress-testing/
3. Zhang, J., et al. (2024). Exploring the trade-offs between environmentally oriented policies and financial performance in U.S. banks: non-linear and heterogeneous effects. Journal of Banking Regulation, 26, 67. https://link.springer.com/article/10.1007/s12351-026-01057-w
4. Federal Reserve. (2024). Fed Summarizes Bank Pilot Climate Scenario Analysis Exercise. CRE Finance Council. https://www.crefc.org/cre/content/News/Items/advocacy-items/Fed_Summarizes_Bank_Pilot_Climate_Scenario_Analysis_Exercise.aspx
5. Le Guenedal, T., & Tixier, T. (2024). Amundi: Climate stress test and net zero valuation. Financial Investigator. https://www.financialinvestigator.nl/en/research-detailpagina/2024/10/17/amundi-climate-stress-test-and-net-zero-valuation
6. Mininanni, L. (2025). Le banche verdi come catalizzatori della finanza sostenibile: studi comparati negli Stati Uniti, Australia e Regno Unito. Rivista di Diritto del Risparmio, 2/2025. http://www.dirittodelrisparmio.it/2025/05/14/l-mininanni-le-banche-verdi-come-catalizzatori-della-finanza-sostenibile-studi-comparati-negli-stati-uniti-australi-e-regno-unito/
7. Federal Reserve Board. (2024). Pilot Climate Scenario Analysis Exercise Summary of Participants Risk-Management Practices and Estimates - Transition Risk Module. https://www.federalreserve.gov/publications/2024-may-pilot-climate-scenario-analysis-transition-risk-module.htm
8. Wang, Y., et al. (2025). Quantifying firm-level carbon risk: A novel emission reduction stress factor. Economic Modelling, 151, 107210. https://www.sciencedirect.com/science/article/abs/pii/S0264999325002056
9. Advisor Perspectives. (2022). Green Banks Get $27 Billion Windfall to Lend Where Others Don't. https://www.advisorperspectives.com/articles/2022/09/01/green-banks-get-27-billion-windfall-to-lend-where-others-dont

10. Jung, H., Engle, R., & Berner, R. (2025). CRISK: Measuring the Climate Risk Exposure of the Financial System. Federal Reserve Bank of New York Staff Reports, No. 977 (Revised March 2025). https://www.newyorkfed.org/medialibrary/media/research/staff_reports/sr977.pdf

11. Springer. (2025). Scenario-based CO2 thresholds for strategic asset allocation and climate stress testing in insurance. The Geneva Papers on Risk and Insurance - Issues and Practice. https://link.springer.com/article/10.1057/s41288-026-00381-8

12. Columbia University SIRI. (2025). Green Hushing in the Financial Sector: What the NZBA Exits Really Signal. https://siri.sipa.columbia.edu/news/green-hushing-financial-sector-what-nzba-exits-really-signal

13. Hossain, A., Rob, M. A., Sabeena, A. A., Islam, A., Shahidullah, M., Ahmed, A., ... & Ahmed, F. (2025, July). The Economic Impact of Green-Banking Policies on US Financial Markets. In 2025 5th International Conference on Electrical, Computer and Energy Technologies (ICECET) (pp. 1-6). IEEE.

14. Bolton, P., & Kacperczyk, M. (2023). Global pricing of carbon-transition risk. The Journal of Finance, 78(6), 3257-3301.

15. Battiston, S., Mandel, A., Monasterolo, I., Schütze, F., & Visentin, G. (2017). A climate stress-test of the financial system. Nature Climate Change, 7(4), 283-288.