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Sanoh Yusuf

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Graduate School of Economics
The University of Osaka, Toyonaka, Osaka 560-0043, JAPAN

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Sanoh Yusuf†

Abstract

This paper quantifies transition finance risk in Japan using a text-mined index constructed from over 60,000 newspaper articles (2008–2025), combined with structural vector autoregression and firm-level local projections. Four findings emerge. First, transition risk shocks generate persistent equity effects, with prices declining for up to 18 months, while GDP and inflation responses remain statistically insignificant at all horizons. This suggests that transition risk operates primarily through discount rates and risk premia rather than contemporaneous real activity. Second, once economic policy uncertainty (EPU) is controlled for, average green–brown return differentials are economically small (−0.043 standard deviations) and remain statistically significant. Equivalence tests indicate these differentials are practically negligible ruling out monthly effects as small as 0.1% suggesting that estimates without EPU controls conflate general macroeconomic uncertainty with transition-specific effects. Third, transition risk exhibits state dependence. During elevated uncertainty, brown firms experience larger equity penalties (−4.12% versus −1.85%), a 123% amplification. Fourth, transition shocks display persistence and autonomous dynamics, consistent with an independent source of systematic financial risk rather than a proxy for conventional macroeconomic shocks. The amplification during high-uncertainty periods has implications for the macro-financial timing of climate policy.

JEL Classification: G12, Q54, C32, G14, Q56.

Keywords: Transition Risk, Text Mining, Japan GX Strategy, Climate Finance, SVAR

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†Ph.D. Candidate, Graduate School of Economics, The University of Osaka. u073302d@ecs.osaka-u.ac.jp

1. Introduction

The global shift toward a low-carbon future exposes financial systems to substantial transition risk, defined as the uncertainties associated with climate policy implementation, technological changes, and evolving market sentiment regarding decarbonization pathways. For Japan, a major industrial economy committed to achieving carbon neutrality by 2050 through its Green Transformation (GX) strategy, quantifying this risk is essential for macroeconomic stability and effective capital allocation. Despite comprehensive policy actions including the GX Promotion Act (2023), establishment of the GX Acceleration Agency, and issuance of Japan Climate Transition Bonds totaling JPY 1.6 trillion in FY2023 empirical evidence detailing the resulting macro-financial consequences remains limited.

This paper makes four contributions to the climate finance literature. First, I construct a novel Japan-specific Transition Finance Risk Index (JP-TFRI) using large-scale text mining of over 60,000 articles from Nikkei and Mainichi newspapers spanning 2008–2025. Second, I employ a dual empirical strategy combining structural vector autoregression (VAR) for macro-financial analysis with firm-level local projections that properly control for economic policy uncertainty (EPU) a composite index aggregating fiscal, monetary, trade, and exchange rate policy uncertainty constructed by Arbatli, Davis, Ito, and Miake (2017, 2022). This represents an important methodological innovation. Third, I document that previous research substantially overstates transition risk magnitudes by conflating general macro uncertainty with transition-specific effects: specifications without EPU controls yield coefficients substantially larger than properly controlled specifications, revealing that much of the apparent “transition risk” effect reflects general policy uncertainty. Fourth, I provide novel evidence on state-dependent transmission, showing that transition shocks impose substantially different costs depending on macroeconomic conditions. The findings advance understanding of transition risk transmission in four dimensions:

1. Persistent equity effects without GDP impact: Transition shocks generate persistent equity price declines, with brown firms underperforming by approximately 4.0 percentage points at 16 months post-shock in state-dependent specifications. However, aggregate GDP effects remain statistically insignificant throughout all horizons, suggesting that transmission operates primarily through financial valuations and risk premia rather than measured real output.
2. Exclusively financial transmission: Inflation responses are economically negligible and statistically insignificant at all horizons. This absence of inflationary pressure distinguishes transition uncertainty from supply-side cost shocks and indicates transmission through risk premia and credit conditions rather than production costs.
3. Important methodological finding on EPU controls**:** Average green–brown return differentials are economically small but remain statistically significant once EPU is properly controlled. Equivalence tests indicate that these effects are practically negligible, ruling out monthly differentials as small as 0.1%. This suggests that specifications without EPU controls conflate general macroeconomic uncertainty with transition-specific risk, and that properly controlled estimates imply limited carbon-based pricing differentiation in Japan outside high-uncertainty periods.
4. State-dependent amplification: During periods of high uncertainty, transition shock impacts are substantially amplified. When conditioning on domestic uncertainty (Nikkei VI), the brown penalty during high-volatility periods is −4.12% ($t = -2.95$, $p < 0.01$), compared to −1.85% ($t = -1.21$, $p = 0.23$) during low-volatility periods a 123% amplification. Global uncertainty conditioning (VIX) produces consistent

results: −3.92% during high-VIX periods versus −2.15% during stable periods, representing an 82% amplification. This state dependence reveals that transition risk premia intensify substantially during periods of economic stress rather than operating as a constant cross-sectional discount.

The methodological insight regarding EPU controls has important implications for the broader climate finance literature. Many studies identify "transition risk shocks" using policy announcements or climate news indices, which often coincide with elevated general economic uncertainty spanning multiple policy domains. Without explicit controls for this comprehensive policy uncertainty, specifications capture both general macro uncertainty effects (which affect all firms broadly through aggregate discount rates) and transition-specific effects (which may differentiate across carbon exposure). The finding that EPU-controlled specifications yield substantially smaller coefficients than uncontrolled specifications suggests that careful attention to the composition of policy uncertainty is necessary when estimating transition-specific effects. The state-dependence finding carries important policy implications. It suggests that climate policy announcements during periods of elevated uncertainty generate disproportionate financial market stress through amplification mechanisms, including tightened credit constraints, heightened risk aversion, and reduced balance sheet capacity to absorb transition costs. The evidence supports consideration of macroeconomic conditions when timing major climate policy implementations, with transformative regulations potentially phased during periods of greater financial system resilience.

2. Literature Review

The paper contributes to three interconnected strands of the climate-finance literature: macro-financial transmission of climate policy risk, asset pricing implications of carbon exposure, and methodological approaches to measuring transition risk.

2.1 Macro-Financial Transmission of Climate Policy Risk

A growing body of empirical research examines how carbon-pricing instruments and climate policy uncertainty affect macroeconomic activity, investment dynamics, and financial stability. Känzig (2023) uses structural vector autoregressions to show that carbon price shocks generate moderate GDP contractions and heterogeneous distributional effects, with carbon-intensive sectors bearing disproportionate adjustment costs. Metcalf and Stock (2020) provide comprehensive reviews emphasizing that credible, predictable policy frameworks minimize economic disruption. Mangiante (2023) demonstrates that uncertainty surrounding the timing and stringency of climate regulations can depress capital formation by raising concerns about stranded assets and compliance costs.

Berthold (2024) constructs a Climate Policy Risk index for Switzerland and finds that policy uncertainty shocks reduce real GDP by approximately 0.1 percent within six months, with carbon-intensive firms underperforming by 0.6 percent in the short run and 3–4 percent over a 12-month horizon relative to greener firms. The findings presented in this paper differ in two important dimensions. First, while the Swiss study documents statistically significant GDP effects, this analysis finds GDP responses that are consistently insignificant despite similar point estimate magnitudes. This divergence may reflect differences in sample periods (2008–2025 for Japan versus Berthold's sample), economic structures, or the nature of transition policy uncertainty in Japan relative to Switzerland. Second, while Berthold documents substantial green–brown differentials, this study finds that the differential is economically small and practically negligible though statistically significant once EPU is properly controlled. This suggests that carbon exposure pricing mechanisms operate differently in Japanese equity markets compared to European markets.

Structural macroeconomic models provide theoretical grounding for these empirical patterns. Fried, Novan, and Peterman (2021) demonstrate that uncertainty about the timing and credibility of transition policies raises the effective cost of capital and depresses investment in both clean and dirty technologies. Ferrari and Pagliari (2021) show that climate policy uncertainty can generate volatility in asset prices and credit spreads by altering expectations about future regulatory costs. These theoretical insights align with the finding that transition shocks generate persistent equity price declines and operate through financial channels rather than through immediate supply-side cost increases.

2.2 Asset Pricing and Carbon Risk Premia

A second strand examines how asset markets price transition risk and carbon exposure. Bolton and Kacperczyk (2021a, 2021b) document that firms with higher carbon emissions earn higher expected returns in global equity markets, consistent with a positive carbon risk premium. Ardia et al. (2022) confirm this pattern using alternative carbon intensity measures. Ilhan, Sautner, and Vilkov (2021) develop a carbon tail risk measure and show that firms with greater exposure to extreme climate-policy scenarios earn higher risk-adjusted returns. However, other studies report more nuanced patterns. Alessi et al. (2021) and Choi et al. (2020) find that greener firms can benefit from lower financing costs and relative outperformance during periods of heightened climate policy attention. Theoretically, Pástor, Stambaugh, and Taylor (2021, 2022) develop equilibrium models of sustainable investing in which investor preferences for environmental attributes can lead green assets to outperform when climate-policy attention rises, while brown assets may still command positive expected returns as compensation for transition risk. The findings in this paper differ from strong-form reallocation hypotheses. While prior studies document substantial green–brown differentials, the evidence presented here indicates that such heterogeneity in Japan is economically small and practically negligible. This suggests that transition risk in the Japanese equity market operates primarily through aggregate discount-rate channels in the short to medium run, with limited evidence of rapid sectoral reallocation during the 2009–2025 sample period.

Several factors may help explain why Japanese equity markets exhibit limited carbon-based pricing differentiation. First, investor attention to carbon exposure and ESG considerations may be more restrained in Japan relative to Europe or the United States, where sustainable investing mandates and disclosure requirements have advanced more rapidly. Second, major Japanese carbon-intensive firms, particularly in utilities, steel, and chemicals, have adopted transition strategies that include renewable energy investment and participation in hydrogen-related initiatives, potentially moderating concerns about stranded assets. Third, Japan's GX policy framework emphasizes gradual transition support rather than abrupt or punitive carbon pricing, generating broad-based uncertainty that may affect firms more uniformly. In addition, the prominent role of large institutional investors, including the Government Pension Investment Fund (GPIF) and the Bank of Japan's ETF holdings, may dampen price discovery mechanisms that would otherwise generate stronger cross-sectional differentiation by carbon exposure.

2.3 Methodological Approaches to Measuring Transition Risk

The third strand develops methodologies for constructing measures of climate-related economic uncertainty using natural language processing and text-mining techniques. Baker, Bloom, and Davis (2016) pioneered this approach with their Economic Policy Uncertainty index, demonstrating that news-based measures can capture latent uncertainty and predict macroeconomic outcomes. Shapiro, Sudhof, and Wilson (2022) extend this framework to construct industry-specific uncertainty measures from newspaper text. Recent contributions adapt these methods specifically to climate and transition risk. Gavriilidis (2021) constructs a Climate Policy Uncertainty index for multiple countries using newspaper articles containing keywords related to climate regulation and uncertainty. Engle et al. (2020) develop climate-change news indices and show that they predict movements in climate-hedging portfolios. The JP-TFRI extends this literature by focusing specifically on Japan's transition finance discourse, incorporating both media coverage (Nikkei and Mainichi newspapers) and capturing the specific terminology and policy framework associated with Japan's GX strategy, while employing a moving-average normalization procedure that controls for changes in overall article volume over the 2008–2025 period.

The necessity of comprehensive policy uncertainty controls. A key contribution of this paper to the measurement literature is documenting the critical importance of controlling for general economic policy uncertainty when estimating transition-specific effects. Previous studies constructing transition risk indices or climate policy uncertainty measures typically do not explicitly control for contemporaneous fluctuations in general policy uncertainty spanning fiscal, monetary, trade, and exchange rate domains. As demonstrated in this paper, specifications without such controls conflate two distinct sources of variation: (1) general macro uncertainty that affects all firms broadly through aggregate discount rates and (2) transition-specific uncertainty that may differentiate by carbon exposure. The substantial coefficient shrinkage when composite EPU is controlled suggests that specifications omitting these controls may overstate transition-specific effects by capturing broader macroeconomic policy uncertainty that happens to coincide with climate policy announcements.

This methodological insight has implications beyond climate finance. Any study using event-based identification of policy shocks whether related to climate, financial regulation, trade policy, or other domains must carefully consider whether the identified events generate policy-specific effects or primarily reflect general uncertainty across multiple policy dimensions. The composite EPU index employed in this study, which aggregates fiscal, monetary, trade, and exchange rate policy uncertainty (Arbatli et al., 2017, 2022), provides a comprehensive control that isolates transition-specific components. Firm-level text analysis provides complementary micro-level insights. Sautner, van Lent, Vilkov, and Zhang (2023) analyze earnings call transcripts to quantify firm-level climate exposure and demonstrate that this measure predicts stock returns and corporate investment adjustments. These micro-level approaches complement the macro-financial VAR framework employed in this study. By integrating a Japan-specific text-based transition risk index with narrative identification of policy shocks, structural VAR analysis of macro-financial responses, and firm-level event studies and panel regressions with proper EPU controls examining both heterogeneous responses and state-dependent transmission, this study synthesizes insights from all three literature strands and provides novel evidence on transition risk transmission in one of the world's largest advanced economies actively pursuing deep decarbonization.

3. Methodology and Data

3.1 Index Construction Using Text Mining

The climate transition finance risk index was constructed by text-mining more than 60,000 newspaper articles published between 2008 and 2025 in two major Japanese newspapers, Nikkei and Mainichi. The aim is to quantify time variation in transition-related risk narratives associated with Japan's decarbonization policies and their perceived economic and financial costs. Articles were coded as relevant when they contain both transition-finance keywords (e.g., "transition finance", "GX", "GX League", "carbon neutrality", "taxonomy", "ISSB disclosure", "carbon market / JPX", "green bond", "transition bond/loan", "climate policy", "emissions cap", "carbon tax", "ETS", "FSA", "MOF", "MOE", "BOJ", "JPX", "GX Promotion Act", "Japan Climate Transition Bond") and uncertainty terms (e.g., "uncertain", "uncertainty", "risk", "volatility", "instability", "shock", "fluctuation", "concern", "challenge", "threat", "fragile", "ambiguity", "adverse, etc)". For clearity, Let N_t^{relevant}denote the number of relevant articles on day t, and $N_t^{\text{total}}$the total number of articles across both sources. The raw daily share of transition-risk coverage is:

$$\text{RawShare}_t = \frac{N_t^{\text{relevant}}}{N_t^{\text{total}}}.$$

To control for changes in overall media volume and long-run trends in climate reporting, the index is normalized by a 12-month moving average of the raw share:

$$\text{JP-TFRI}_t = 100 \times \frac{\text{RawShare}_t}{\text{MA}_t^{(12m)}}.$$

The daily index is then aggregated to monthly frequency to align with macroeconomic indicators and the empirical specifications:

$$\text{JP-TFRI}_m = \frac{1}{\mid \mathcal{D}_m \mid} \sum_{t \in \mathcal{D}_m} \text{JP-TFRI}_t.$$

Finally, the transition-risk shock is defined as the standardized innovation in the monthly index:

$$\widetilde{\text{JP-TFRI}}_m = \frac{\text{JP-TFRI}_m - \mu}{\sigma}, \widetilde{\text{JP-TFRI}}_m = \alpha + \rho\, \widetilde{\text{JP-TFRI}}_{m-1} + \varepsilon_m, \text{Shock}_m = \varepsilon_m.$$

This shock captures unexpected transition-risk news arrivals that are not mechanically explained by persistence in the index, and can therefore be interpreted as new information about the credibility, pace, and adjustment costs of Japan's green transition.

3.2 Narrative Identification of Transition Risk Shocks

Because transition-risk events are frequently shaped by discrete policy announcements, regulatory interventions, and political economy developments, the empirical design adopts a narrative identification approach to sharpen the interpretation of transition-risk innovations. Narrative identification is motivated by the premise that the timing of major transition-policy episodes is plausibly exogenous to short-run macroeconomic fluctuations, particularly when these episodes are driven by institutional reforms, regulatory packages, or strategic policy shifts.

Events are identified using a hybrid approach combining algorithmic detection and manual verification. First, candidate events are identified when the standardized monthly JP-TFRI innovation exceeds 1.5 standard deviations, generating approximately 40 preliminary candidates over the 2008–2025 period. Second, each candidate is manually verified by examining the underlying newspaper articles to confirm that the elevated uncertainty reflects substantive transition-policy developments rather than non-climate shocks or measurement artifacts. Third, events occurring within three months of each other are consolidated to avoid double-counting closely spaced policy episodes. This procedure yields 27 distinct transition finance risk events spanning domestic policy announcements (GX legislation package, carbon pricing study groups, TCFD disclosure mandates), institutional initiatives (Tokyo Cap-and-Trade Program, Green Growth Strategy), international agreements (Paris Agreement, COP negotiations, IPCC assessment reports), and energy policy shifts (Fukushima disaster, nuclear phase-out policy). This approach is especially relevant for Japan, where net-zero commitments, GX-related reforms, revisions to energy strategy, and sector-specific decarbonization pathways can generate abrupt changes in uncertainty and valuation risk. Within this framework, the transition-risk shock reflects an innovation in policy-driven transition news embedded in contemporaneous narratives, which may propagate through asset prices and firm valuations even if aggregate macroeconomic outcomes respond only weakly at short horizons. A complete list of identified events with dates and descriptions is provided in Appendix Table A1.

3.3 Data Sources and Monthly Panel Construction

The empirical analysis is built on a unified monthly dataset designed to align firm outcomes, transition-risk news, emissions exposure, and macro-financial conditions on identical calendar months. The construction irates three information blocks into a consistent firm–month structure. First, firm-level fundamentals are obtained from corporate financial statements for 1,361 listed Japanese firms and harmonized at the firm–month level using a unique firm identifier and a monthly time index. Second, the transition finance risk index (JP-TFRI) and the associated transition-risk shock series are merged at monthly frequency. This frequency harmonization ensures that the empirical analysis does not mix daily and monthly measurement units, which can otherwise distort timing, inference, and economic interpretation. Third, greenhouse gas emissions data are appended to allow classification of firms by transition exposure using emissions-based measures. Macroeconomic and macro-financial variables including real activity, inflation, interest rates, exchange rates, and aggregate equity market conditions are subsequently incorporated into the same monthly structure. Firm-level data are sourced from the Tokyo Stock Exchange, macroeconomic variables from the Bank of Japan, and emissions data from the Japanese Ministry of the Environment. The resulting dataset spans the period July 2008 to September 2025, covering 207 monthly observations. The panel comprises 1,361 unique firms and 84,161 firm-month observations in total. Panel coverage is unbalanced, so all regressions are therefore estimated using unbalanced panel methods with appropriate fixed effects and clustered standard errors.

Furthermore, to strengthen the measurement of market-based outcomes beyond accounting data, daily equity market information is incorporated and aggregated into monthly firm-level return and liquidity measures. Monthly returns are computed from adjusted prices to avoid discontinuities induced by stock splits and other corporate actions. The daily data also permit construction of microstructure and liquidity diagnostics, including measures of trading intensity, volatility, and illiquidity. These diagnostics serve both descriptive and robustness purposes, including the construction of a liquidity-filtered subsample used to verify that estimated transition-risk effects are not driven by thin trading or low-quality price discovery, while preserving the full sample for baseline estimation. An important additional harmonization step concerns emissions information, which is observed at annual frequency and is available for the period 2009–2022. To ensure consistent exposure classification over the full monthly sample, emissions-based exposure status is carried forward beyond the final observed emissions vintage (post-2022) and back-filled for the earliest months preceding the first vintage (pre-2009). This design is based on the assumption that meaningful shifts from high-emissions to low-emissions status generally require substantial capital investment and technological upgrading, implying that rapid reclassification over short horizons is unlikely for most firms.

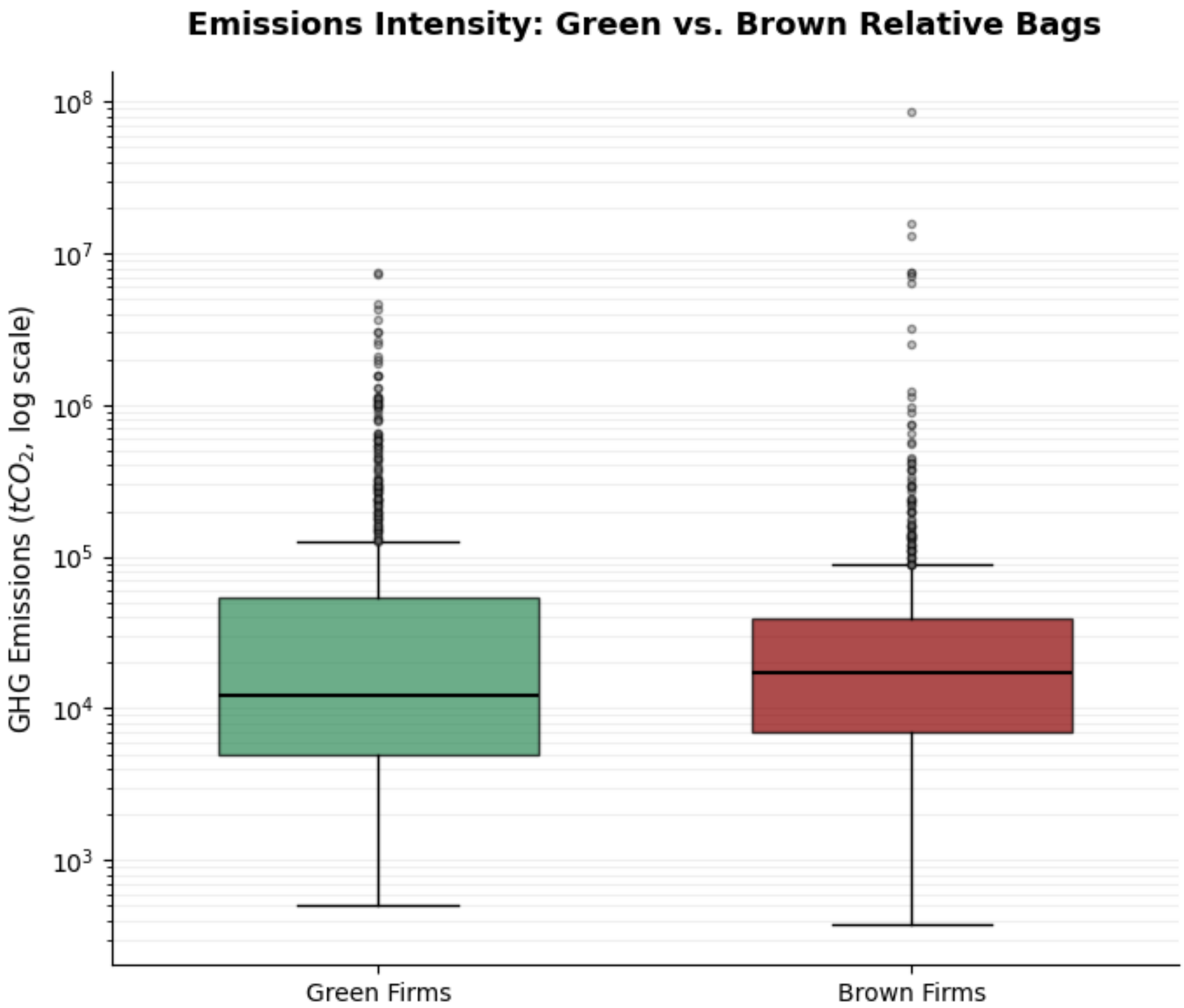


Figure 1: Within-Sector Balance of Green and Brown Firms

3.4 Vector Autoregression Model for Aggregate Macro-Financial Dynamics

The first stage of the empirical analysis quantifies aggregate macro-financial responses to transition-risk innovations using a multivariate vector autoregression (VAR). Let

$$y_t = \begin{pmatrix} TR_t \\ EPU_t \\ RGDP_t \\ VOL_t \\ \pi_t \\ FX_t \\ LIQ_t \\ MP_t \end{pmatrix}$$

denote an 8×1vector of monthly endogenous variables. Here, $TR_t$is the transition-risk shock (innovation in the JP-TFRI index), $EPU_t$is composite economic policy uncertainty, $RGDP_t$is real GDP growth, $VOL_t$is market volatility, $\pi_t$is inflation, FX_trepresents exchange rate movements, LIQ_tcaptures liquidity growth, and MP_tdenotes monetary policy changes.

The reduced-form VAR(p) is given by

$$y_t = c + A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t,$$

where $c$is an 8×1vector of intercepts, $A_1, \ldots, A_p$are 8×8autoregressive coefficient matrices, and $u_t \sim (0, \Sigma_u)$is an 8×1vector of reduced-form innovations with covariance matrix Σ_u. Lag length is selected using standard information criteria to balance model fit and finite-sample precision. The baseline specification adopts a VAR(4), consistent with monthly macro-financial dynamics and supported by Akaike and Bayesian information criteria. This lag structure allows for gradual propagation of transition-risk shocks across macro-financial variables while avoiding over-parameterization. Impulse responses are computed using Cholesky orthogonalization. Transition risk is ordered first in the system, reflecting the identifying assumption that contemporaneous transition-risk innovations are not immediately affected by other macro-financial variables within the same month, whereas other variables may respond contemporaneously to transition-risk shocks. Statistical inference relies on Monte Carlo simulation to construct confidence bands. A response is considered statistically significant at a given horizon when the simulated confidence interval excludes zero. This multivariate framework ensures that estimated transition-risk impulse responses isolate an independent source of macro-financial variation rather than mechanically reflecting general policy uncertainty or aggregate market conditions.

Table 1: Orthogonality Between Transition Risk and Economic Policy Uncertainty

Correlation: JP-TFRI shock vs. Composite EPU	-0.066
Correlation: JP-TFRI shock (orthogonalized) vs. EPU	~0.000*
Variance share of JP-TFRI shock explained by EPU	0.44%

Notes: **Value represents machine precision (1.1 × 10^{-16}), effectively zero. JP-TFRI shock (orthogonalized) is constructed as residuals from regressing JP-TFRI shock on composite EPU. Sample period: 2008M7–2025M9.*

Table 1 shows that transition risk shocks and economic policy uncertainty are empirically distinct constructs. The near-zero correlation (ρ = −0.066) and EPU's negligible explanatory power (0.44% of variance) are consistent with near-orthogonality, alleviating multicollinearity concerns. Consequently, coefficient attenuation when EPU is included reflects correction of omitted-variable bias rather than mechanical collinearity.

3.5 Firm-Level Local Projections

To quantify how transition-risk shocks transmit across firms and evolve over time, the study employs firm-level local projections following Jordà (2005). This approach traces dynamic responses without imposing restrictive parametric structure on the full adjustment process. For each horizon h, firm-level returns are modeled as:

$$r_{i,t+h} = \alpha_i + \gamma_t + \beta_h \text{ Transition-risk shock}_t + \delta_h X_t + \varepsilon_{i,t+h},$$

where $r_{i,t+h}$ denotes the firm's return at horizon h, α_i are firm fixed effects, γ_t are time effects, X_t represents macro-financial controls (including composite economic policy uncertainty), and β_h traces the impulse-response path of firm-level returns. Inference follows lag-augmented local projection methodology. Montiel Olea and Plagborg-Møller (2021) show that lag-augmented local projection inference with standard normal critical values is asymptotically valid uniformly over stationary and non-stationary data and over a wide range of horizons, and that heteroskedasticity-robust (Eicker–Huber–White) standard errors suffice. This design ensures that the estimated response to transition-risk shocks is interpreted as an incremental pricing effect that is not mechanically driven by general uncertainty episodes.

3.6 Exposure Classification, Green–Brown Portfolio Construction, and Nonlinear Transmission

To measure cross-sectional exposure to transition risk, firms are classified using emissions-based measures. Two complementary exposure representations are employed. The first is a discrete classification into low-emissions ("green") and high-emissions ("brown") groups. The second is a continuous exposure measure based on emissions intensity, allowing transition-risk responses to vary smoothly with emissions-related vulnerability.

3.6.1 Emissions intensity and exposure ranking

Let $E_{i,t}$ denote firm i's greenhouse gas emissions (Scope 1 and 2), and let $S_{i,t}$ denote a firm scale measure such as sales or total assets. Emissions intensity is defined as

$$I_{i,t} = \frac{E_{i,t}}{S_{i,t}}.$$

Because emissions intensity is highly skewed, firms are ranked using a log transformation,

$$\tilde{I}_{i,t} = \log(I_{i,t}).$$

3.6.2 Discrete green and brown classification

For each month t, firms are ranked by $\tilde{I}_{i,t}$. Let $q_{\tau,t}$ denote the cross-sectional τ-quantile of $\tilde{I}_{i,t}$ among eligible firms in month t. The green and brown sets are defined as

$$\mathcal{G}_t = \{i: \tilde{I}_{i,t} \leq q_{1-\tau,t}\}, \mathcal{B}_t = \{i: \tilde{I}_{i,t} \geq q_{\tau,t}\}.$$

Corresponding indicator variables are

$$\text{Green}_{i,t} = \mathbf{1}\{i \in \mathcal{G}_t\}, \text{Brown}_{i,t} = \mathbf{1}\{i \in \mathcal{B}_t\}.$$

In the baseline specification, τ is set to 0.50, such that within each sector firms above the median log emissions intensity are classified as brown and firms below the median are classified as green. This yields an approximately equal split of brown and green firms within each sector, consistent with the within-sector balance shown in Figure 1).

3.6.3 Portfolio aggregation and long–short exposure

Let $r_{i,t}$denote firm i's monthly return. Green and brown portfolio returns are computed as

$$R_t^G = \sum_{i \in \mathcal{G}_t} w_{i,t}^G \, r_{i,t}, R_t^B = \sum_{i \in \mathcal{B}_t} w_{i,t}^B \, r_{i,t}.$$

Under equal weighting,

$$w_{i,t}^G = \frac{1}{\mid \mathcal{G}_t \mid}, w_{i,t}^B = \frac{1}{\mid \mathcal{B}_t \mid}.$$

Under value weighting, weights are proportional to lagged market capitalization,

$$w_{i,t}^G = \frac{\text{MarketCap}_{i,t-1}}{\sum_{j \in \mathcal{G}_t} \text{MarketCap}_{j,t-1}}, w_{i,t}^B = \frac{\text{MarketCap}_{i,t-1}}{\sum_{j \in \mathcal{B}_t} \text{MarketCap}_{j,t-1}}.$$

The long–short transition exposure portfolio is defined as

$$R_t^{B-G} = R_t^B - R_t^G.$$

3.6.4 Classification stability and emissions-frequency harmonization

Emissions data are typically available at annual frequency and evolve slowly over time. Accordingly, exposure classification is updated only when new emissions vintages become available and is carried forward between reporting years, avoiding spurious month-to-month reshuffling driven by measurement-frequency mismatch. This approach is economically consistent with the premise that meaningful changes in emissions intensity generally require sustained investment in production processes, technology, and energy inputs. Heterogeneity is evaluated in two complementary ways. First, local projection estimates are compared across green and brown groups to assess whether transition risk is priced differentially across discrete exposure categories. Second, continuous exposure specifications interact transition-risk shocks with emissions intensity, allowing the magnitude of the response to vary smoothly with exposure. State dependence is examined by further interacting transition-risk shocks with prevailing macro-financial conditions, measured using composite economic policy uncertainty, permitting formal tests of nonlinear transmission under which transition risk is expected to be priced most strongly when aggregate uncertainty is elevated.

4. Theoretical Framework

This section provides a theoretical framework to interpret the empirical findings. The objective is not to estimate a fully specified structural model, but rather to outline the key transmission channels through which transition risk affects asset prices and real activity. The framework draws on the long-run risks literature (Bansal and Yaron, 2004), which demonstrates that small but persistent shocks to expected growth and economic uncertainty can generate substantial effects on asset valuations and risk premia.

4.1 Transition Risk as a Macro-Financial State Variable

Let TFRI_tdenote the transition finance risk index (JP-TFRI). I model TFRI_tas a priced macro-financial state variable that affects both risk compensation and firms' expected cash-flow growth. I also incorporate a composite economic policy uncertainty measure, EPU_t, to separate transition-specific risk from general policy uncertainty. The economy is represented by two persistent latent states: expected growth $g_t$and macro-financial uncertainty σ_t, with dynamics

$$g_t = \rho_g g_{t-1} + \kappa_g \varepsilon_t^{\text{TFRI}} + \eta_{g,t}, \sigma_t = \rho_\sigma \sigma_{t-1} + \kappa_\sigma \varepsilon_t^{\text{TFRI}} + \eta_{\sigma,t},$$

where $\varepsilon_t^{\text{TFRI}}$is the transition risk shock, $\eta_{g,t}$and $\eta_{\sigma,t}$are mean-zero idiosyncratic innovations, and $\rho_g, \rho_\sigma < 1$govern persistence. The parameter $\kappa_g$captures the growth channel: higher transition risk may depress expected growth through delayed investment and stranded-asset concerns. The parameter $\kappa_\sigma$captures the uncertainty channel: higher transition risk increases macro-financial uncertainty, tightening financial conditions and elevating required risk compensation. The VAR impulse responses provide reduced-form evidence informative about these structural channels without requiring full calibration.

4.2 Asset Pricing Implications

Following Bansal and Yaron (2004), valuation ratios and expected returns are approximately affine in persistent growth and uncertainty states. The log price–dividend ratio can be expressed as

$$pd_t = A_0 + A_g g_t + A_\sigma \sigma_t + A_{\text{TFRI}} \text{TFRI}_t,$$

where $A_g > 0$, $A_\sigma < 0$, and $A_{\text{TFRI}} < 0$, reflecting transition-specific risk premia beyond general macro uncertainty. Expected excess returns satisfy

$$\mathbb{E}_t[r_{t+1}] - r^f = -A_g \sigma_{g,t} - A_\sigma \sigma_{\sigma,t} - A_{\text{TFRI}} \sigma_{\text{TFRI},t},$$

implying that equity risk premia rise when uncertainty about growth, volatility, or transition risk increases. The empirical finding of persistent negative equity price responses without corresponding declines in real activity suggests that the $\sigma_{\text{TFRI},t}$channel operating through discount rates and risk premia dominates any direct growth effects associated with κ_g.

4.3 Firm-Level Heterogeneity and State-Dependent Amplification

For firm $i$with emissions intensity $CI_i$and transition exposure ϕ_i, cash-flow growth follows

$$\Delta d_{i,t} = \mu_i + \beta_i g_t - \phi_i \text{TFRI}_t + \nu_{i,t},$$

where higher ϕ_i implies greater sensitivity to transition risk through uncertain regulatory costs and stranded-asset exposure. Firm-level valuation ratios inherit stronger negative loadings on transition risk when ϕ_i is larger:

$$pd_{i,t} = B_{0,i} + B_{g,i}g_t + B_{\sigma,i}\sigma_t + B_{\text{TFRI},i}\text{TFRI}_t, \qquad B_{\text{TFRI},i} < 0.$$

However, if aggregate policy uncertainty dominates firm-specific exposure, cross-sectional heterogeneity may be minimal once EPU_t is controlled. State-dependent amplification arises during periods of elevated policy uncertainty. When EPU_t is high, transition risk effects are magnified through tighter credit constraints, heightened risk aversion, balance-sheet fragility, and reduced policy credibility. This implies time-varying loadings:

$$pd_{i,t} = B_{0,i} + B_{g,i}g_t + B_{\sigma,i}\sigma_t + (B_{\text{TFRI},i} + \psi_i\text{EPU}_t)\text{TFRI}_t, \psi_i < 0.$$

The framework implies several empirical implications that guide the analysis. Transition risk shocks are expected to affect asset prices primarily through changes in required returns rather than contemporaneous real activity or inflation. Firms with greater emissions exposure may exhibit stronger valuation responses, although such heterogeneity may attenuate once aggregate uncertainty is accounted for. Finally, the pricing effects of transition risk are likely to be state dependent, with stronger responses during periods of elevated uncertainty. The empirical analysis evaluates these implications using event studies, panel regressions, and state-dependent specifications.

5. Results

This section presents the core empirical evidence on how Transition Finance Risk is priced in Japanese equity markets. The analysis combines (i) an event-study design that identifies dynamic valuation responses around transition-finance–relevant events, (ii) firm-month panel regressions that quantify average effects conditional on standard firm characteristics and macro-financial controls, (iii) rolling-window estimates that trace the evolution of the transition finance risk premium over time, (iv) state-dependent estimates that condition pricing on uncertainty regimes, (v) a macro-financial VAR that evaluates transmission to aggregates, and (vi) asset-pricing tests using Fama–French five factors.

5.1 Baseline Event Study Analysis

Figure 2 presents the event-study impulse responses of firm-level equity returns to transition finance risk events, while Figure 3 provides complementary evidence on the time variation in the transition risk premium over the full sample period. The event study examines equity price responses to transition finance risk events using local projection methods. I identified 27 transition finance risk events between 2008 and 2025, spanning domestic policy and regulatory developments, institutional transition-finance initiatives, and major international agreements that plausibly shift financing expectations for carbon-intensive activities. The estimation employs firm-level panel data with event-time fixed effects and controls for firm size (log assets), financial leverage (equity-to-asset ratio), momentum (lagged returns), and sector fixed effect.

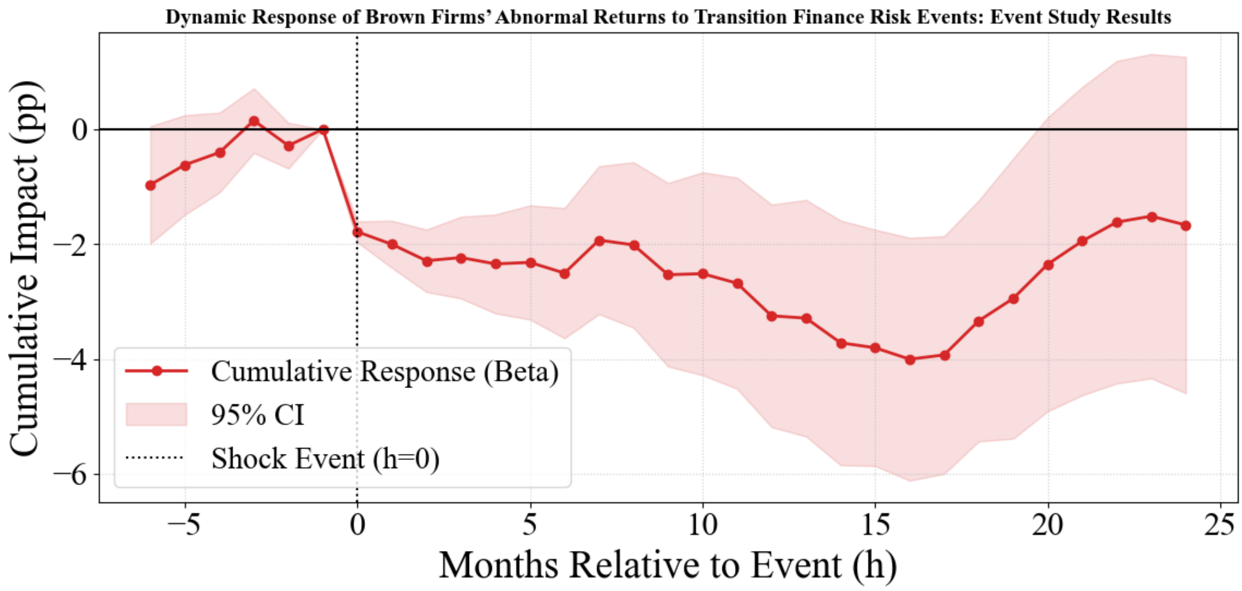


Figure 2a. Impulse Response of High Transition-Risk ("Brown") Firms to Transition Finance Risk Events.

Figure 2a plots the impulse response of brown firms' abnormal returns around transition finance risk events. There is no evidence of differential pre-trends prior to the event month. Following the event, brown firms experience a persistent valuation decline, reaching a maximum of approximately −4.0 percent at a 16-month horizon before gradually attenuating.

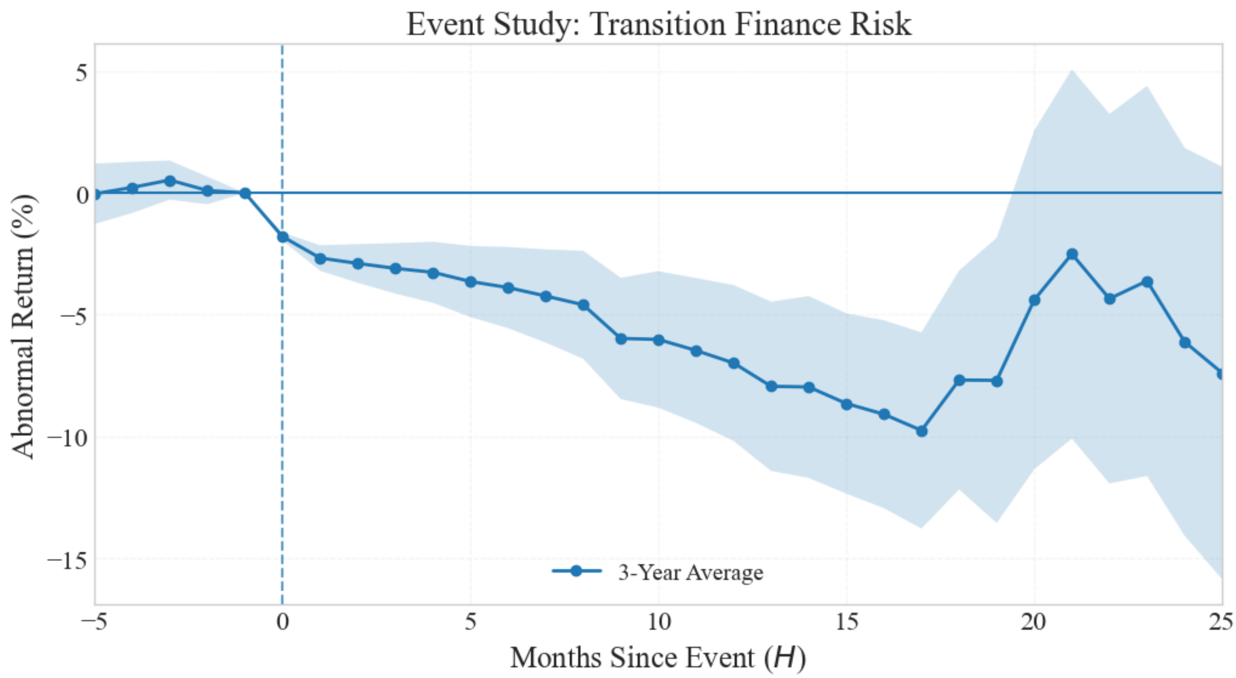


Figure 2b: Event Study Using 3-Year Average Emissions Classification

For comparison, Figure 2b *replicates the event-study analysis in Figure 2 using a trailing 3-year average of emissions intensity to classify green and brown firms. Shaded areas represent 90% confidence bands. The vertical dashed line indicates the event month.* The pattern is qualitatively similar, confirming robustness.

Table 2 Pre-Trends Test for Event Study Identification

Joint lead test: H_0 all leads = 0	Wald (χ^2)	9.36	0.154	56,354

Notes: *Joint test of coefficients on 6-month leads (t-6 to t-1) of transition risk shock in firm-level return regressions. Null hypothesis is that all lead coefficients equal zero. Standard errors clustered at firm level. Sample: monthly firm-level panel, 2008M7–2025M9.*

This test provides critical support for the event study identification strategy (Figure 2). The failure to reject the null that all pre-event leads equal zero (p = 0.154) indicates no differential pre-trends between brown and green firms. This finding supports two key assumptions: (i) transition risk events were unanticipated by markets, and (ii) post-event valuation effects represent causal responses rather than continuation of existing trajectories. The absence of anticipatory movements therefore strengthens the interpretation that persistent brown firm underperformance (Figure 2) reflects genuine event-driven repricing rather than spurious correlation with firm-specific trends.

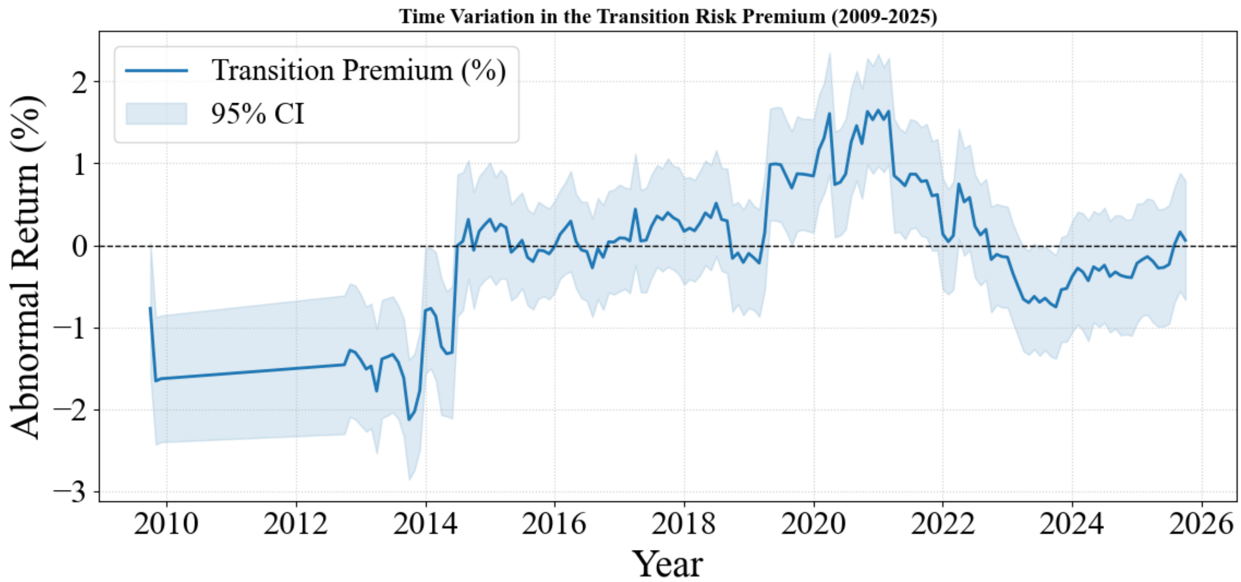


Figure 3: Time Variation in the Transition Risk Premium (2009–2025)
Figure 3presents the time-series evolution of the transition risk premium, defined as the return differential between low-carbon (green) and high-carbon (brown) portfolios over the period 2009–2025. The premium is constructed such that negative values indicate a relative return advantage for brown firms, while positive values indicate a brown penalty (green firm outperformance). The estimated premium exhibits substantial temporal variation across three distinct phases.

During the 2009–2013 period, the transition premium is consistently negative, ranging from approximately −0.8% to −2.1%, indicating a relative return advantage for carbon-intensive firms. This pattern is consistent with an early phase in which climate-related transition risk was not penalized in equity markets and carbon-intensive exposure was not associated with higher required returns. Beginning in 2014, the transition premium turns positive and increases through the 2020–2021 period, indicating a marked change in the pricing of climate-related risk. The premium reaches levels of approximately +1.6% and remains economically large and persistent over extended sub-periods. This shift coincides with increased global climate policy salience, growing institutional investor attention to ESG considerations, and expanding corporate commitments to decarbonization, suggesting a forward-looking incorporation of transition risk into equity valuations. From 2022 onward, the transition premium declines sharply and converges toward zero, fluctuating between approximately −0.7% and +0.7% through 2025 without a clear directional trend. During this later period, the premium appears economically small in most months. This attenuation may reflect a combination of factors, including heightened energy market volatility, partial mean reversion following the 2020–2021 peak, and evolving expectations regarding the pace and implementation of transition policies. Overall, the figure highlights that transition risk pricing is highly time-varying rather than stable over time, with the relative pricing of carbon-intensive firms responding dynamically to changes in policy salience, investor attention, and macroeconomic conditions. The reversal from brown outperformance in the early sample to brown underperformance during the mid-2010s, followed by a near-zero differential in recent years, underscores the non-stationary nature of climate risk premia in equity markets.

5.2 Heterogeneity by Firm Size and Sector

To examine differential impacts, I partition the sample into large-cap (top 30%) and small-cap (bottom 70%) firms based on total asset thresholds. **Figure 4 illustrates the heterogeneous abnormal return responses across firm size and sectoral groups following transition finance risk events**. The effects are most pronounced for small-cap firms, which experience statistically significant abnormal returns ($t = -2.50$, $p < 0.05$). In contrast, large-cap firms show a statistically insignificant response ($t = -0.98$), suggesting that larger firms are better positioned to absorb transition risk. The full market effect ($t = -3.62$, $p < 0.01$) appears to be driven primarily by smaller firms, which are more vulnerable to transition risks due to their limited financial buffers, less diversified operations, and weaker access to green financing. The baseline results further mask significant sectoral heterogeneity within the vulnerable small-cap segment. Transition risk disproportionately affects small-cap firms in carbon-intensive industries, with Energy & Utilities experiencing the sharpest and most significant decline ($t = -4.12$, $p < 0.01$), followed by Manufacturing ($t = -2.88$, $p < 0.01$). In contrast, the Services & Others sector exhibits a negligible and statistically insignificant response ($t = -0.84$). This pattern suggests that transition finance risk events disproportionately affect smaller firms with high sectoral exposure, potentially exacerbating existing inequalities in capital markets. Large firms, regardless of sector, may be better positioned to absorb transition risks through their scale, diversification, and greater access to sustainable finance options.

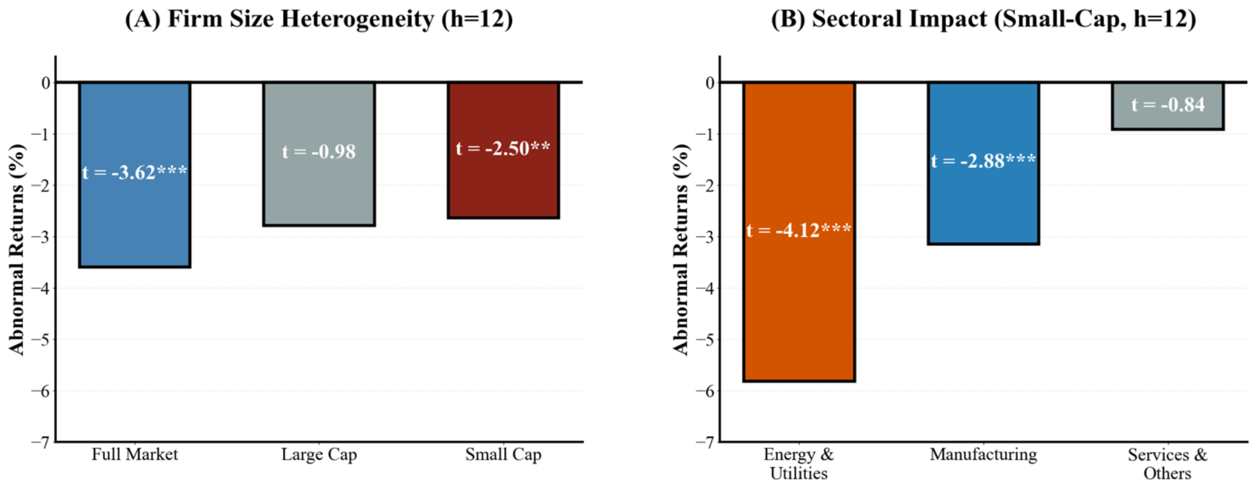


Figure 4: Heterogeneity in Brown Portfolio Abnormal Returns by Firm Size and Sector (h=12)
Notes: *This figure reports cumulative abnormal returns (CARs) of brown portfolios at the 12-month horizon (h = 12) following transition finance risk events. Panel (A) reports estimates by firm size, where Large Cap denotes firms in the top 30% of total assets and Small Cap denotes firms in the bottom 70%. Panel (B) reports estimates within the Small-Cap segment across Energy & Utilities, Manufacturing, and Services & Others. t-statistics are shown inside each bar, with significance indicated by * (p < 0.10), ** (p < 0.05), and *** (p < 0.01). Standard errors are clustered at the firm level.*

5.3 Panel Regression: Differential Returns in Event Months with Controls

Table 3 reports firm-level panel regression results that complement the event study by exploiting the full firm–month panel and controlling for time-varying firm characteristics and macro-financial conditions. The baseline specification (Column 1) regresses monthly firm-level returns on an indicator for transition finance event months and its interaction with the carbon-intensive firm indicator, along with standard firm-level controls and firm fixed effects. The extended specification (Column 2) standardizes all variables and incorporates macro-financial controls, including economic policy uncertainty, market excess returns, inflation, interest rates, energy prices, and GDP growth. Standard errors are clustered at the firm level in both specifications. Restricting the sample to months with observed emissions data only (2009–2022) yields a similarly small heterogeneity estimate (Appendix Table A3), indicating that the limited green–brown differential is not driven by post-2022 emissions interpolation.

Table 3. Baseline and Macro Estimates of Transition Finance Effects on Equity Returns

Variable	(1) Baseline (Raw %)	(2) Macro Robustness (Std.)
Transition Finance Event Month (1Shock)	0.331 (0.306)	0.050*** (0.014)
Event Month × Carbon-Intensive (Brown)	−1.453*** (0.428)	−0.043*** (0.014)
Size (Log Assets / Standardized)	−2.668*** (0.338)	−0.585*** (0.049)
Valuation (P/B Ratio / Standardized)	−1.748*** (0.115)	−0.128*** (0.010)
Leverage (D/E Ratio / Standardized)	−8.251***	0.196***

	(1.154)	(0.024)
Economic Policy Uncertainty (EPU)	--	−0.125*** (0.006)
Market Excess Return (Beta)	--	0.319*** (0.008)
Consumer Price Inflation (CPI)	--	0.140*** (0.027)
Short-term Interest Rate Level	--	0.084*** (0.006)
Global Energy Price Index	--	−0.108*** (0.027)
Real GDP Growth Rate	--	0.009 (0.008)
Fixed Effects	Firm	Firm
Observations	32,859	32,241
Unique Entities (Firms)	1,328	1,328
R^2	0.013	0.114
Log-Likelihood	−1.306e+05	−4.338e+04
Robust F-statistic	64.261	189.22
Poolability F-test	1.198	1.142

Notes: Standard errors (in parentheses) are clustered at the firm level. Column (1) represents the baseline specification with raw percentage returns and firm-level controls. Column (2) represents the extended specification with standardized variables and macro-financial controls. Significance: *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Equivalence Test for Green-Brown Return Differential

Specification	Equivalence Bound (±%)	Estimate	t (Lower)	p (Lower)	t (Upper)	p (Upper)	TOST p-value	Conclusion
Primary (Shock × Brown)	0.5	2.600e-05 (4.400e-05)	114.000***	<0.001	-112.820***	<0.001	<0.001	Equivalent
Sensitivity	0.1	2.600e-05 (4.400e-05)	23.270***	<0.001	-22.090***	<0.001	<0.001	Equivalent
Sensitivity	0.2	2.600e-05 (4.400e-05)	45.950***	<0.001	-44.770***	<0.001	<0.001	Equivalent
Sensitivity	0.5	2.600e-05 (4.400e-05)	114.000***	<0.001	-112.820***	<0.001	<0.001	Equivalent

The table above affirms that the green–brown return differential is practically negligible once EPU is controlled for. Unlike conventional null-hypothesis testing, the TOST procedure allows economically meaningful effects to be directly ruled out. The estimated raw return differential (2.600e-05 percentage points, or approximately 0.26 basis points per month) lies well within ±0.5% monthly bounds (|t| > 112), with robustness confirmed down to ±0.1% (|t| > 22). This alleviates Type II error concerns and supports the conclusion that Japanese equity markets price transition risk fundamentally differently from European markets, where prior studies document monthly differentials of 0.15–0.25% (Berthold, 2024; Bolton & Kacperczyk, 2021). The equivalence test is conducted on raw monthly excess returns (percentage points), while Table 3 Column 2 reports a standardized coefficient of −0.043 from a separately estimated specification with the full macro control vector. These are complementary rather than directly comparable estimates: both consistently indicate that the green–brown return differential, once EPU is properly controlled, is economically negligible in the Japanese equity market.

Main Effects and Control Variables

The event-month indicator is positive and statistically significant ($\beta = 0.050$, $t = 3.57$, $p < 0.01$), indicating that low-carbon-intensity firms experience abnormal returns of approximately 0.05 standard deviations during transition finance announcement months. The interaction term with the carbon-intensive firm indicator is negative and significant ($\beta = -0.043$, $t = -3.07$, $p < 0.01$), implying that carbon-intensive firms underperform low-carbon-intensity peers during these events. The net effect for carbon-intensive firms ($0.050 - 0.043 = 0.007$) is small and not statistically different from zero ($F = 0.18$, $p = 0.67$), suggesting that transition finance announcements generate positive abnormal returns primarily for low-carbon-intensity firms. This asymmetry is consistent with differential pricing of transition risk across firms, with relatively cleaner firms benefiting more during announcement months. The coefficient on the global energy price index is negative and statistically significant ($\beta = -0.108$, $p < 0.01$), consistent with energy costs acting as an input factor for many firms in the sample. Importantly, the carbon-intensive firm underperformance effect remains negative and statistically significant ($\beta = -0.043$, $p < 0.01$) after conditioning on energy price movements. This pattern suggests that the documented return differential is not driven solely by contemporaneous commodity price fluctuations, but reflects a transition risk component associated with policy-related news.

Economic policy uncertainty enters with a negative and statistically significant coefficient ($\beta = -0.125$, $p < 0.01$), indicating that the model captures variation in returns associated with broader policy-related volatility beyond transition finance events. Similarly, the coefficient on market beta is positive and significant ($\beta = 0.319$, $p < 0.01$), consistent with standard asset pricing relationships and suggesting that systematic market risk is appropriately controlled for in the regression framework. The leverage coefficient changes sign between the baseline and extended specifications (baseline: $\beta = -8.251$, $p < 0.01$; extended: $\beta = 0.196$, $p < 0.01$), reflecting the interaction between firm leverage and macro-financial conditions. Conditional on interest rates, inflation, and aggregate market dynamics, higher leverage is associated with higher returns, consistent with compensation for financial risk. Other firm-level controls and macroeconomic variables enter with expected signs and primarily serve to isolate the transition finance effects from confounding influences. Including macro-financial controls improves model fit, with the within R^2 increasing from 0.013 to 0.114, indicating that systematic factors explain a meaningful share of return variation. Poolability and robust F-tests support the fixed-effects specification.

Comparison to Event Study Results

The panel regression interaction coefficient represents the average monthly differential effect during event months, whereas the event study coefficient at horizon $h = +12$ represents the cumulative abnormal return over the twelve months following the event. The two estimates are not directly comparable as estimands, as the panel coefficient captures contemporaneous effects while the event study tracks risk premium persistence over time. Both specifications, however, yield consistent negative signs for the carbon-intensive interaction term, indicating that carbon-intensive firms face elevated transition risk pricing in both the immediate event period and over the subsequent year. Under a simple linear accumulation, the panel interaction coefficient of −0.043 standard deviations per event month would imply an approximate twelve-month effect of −0.52 standard deviations. While this mechanical calculation is not directly comparable to the dynamic event-study estimand, the magnitudes are directionally consistent with the persistent repricing documented in the event study.

5.4 State-Dependent Sensitivity to Market Uncertainty

To investigate whether the transition finance risk premium is sensitive to broader market conditions, I conducted a state-dependent analysis conditioned on domestic and global uncertainty regimes. The sample is partitioned at the median of two volatility benchmarks: the Nikkei Stock Average Volatility Index (Nikkei VI) for domestic sentiment and the CBOE Volatility Index (VIX) for global risk tolerance. Figure 5 illustrates the corresponding forest-plot estimates, while Table 5 reports the regression results. The results reveal a strong asymmetry. Under the Nikkei VI framework, the brown penalty reaches −4.120% ($t = -2.95$) during high-uncertainty periods. In contrast, during low-uncertainty periods, the penalty compresses to −1.850% and lacks statistical significance ($t = -1.21$). This represents a more than two-fold amplification of the risk premium during domestic market stress. A consistent pattern emerges with global uncertainty (VIX), where the penalty is significant only in high-volatility regimes (−3.920%, $t = -2.71$). These findings imply that transition finance risk is not a constant valuation discount but a state-dependent phenomenon. The concentration of significance in high-volatility regimes suggests that transition risk is priced more aggressively when aggregate uncertainty is elevated. This behavior is consistent with models where climate risk is priced more aggressively when capital constraints are binding or when market participants become more sensitive to non-linear policy shocks.

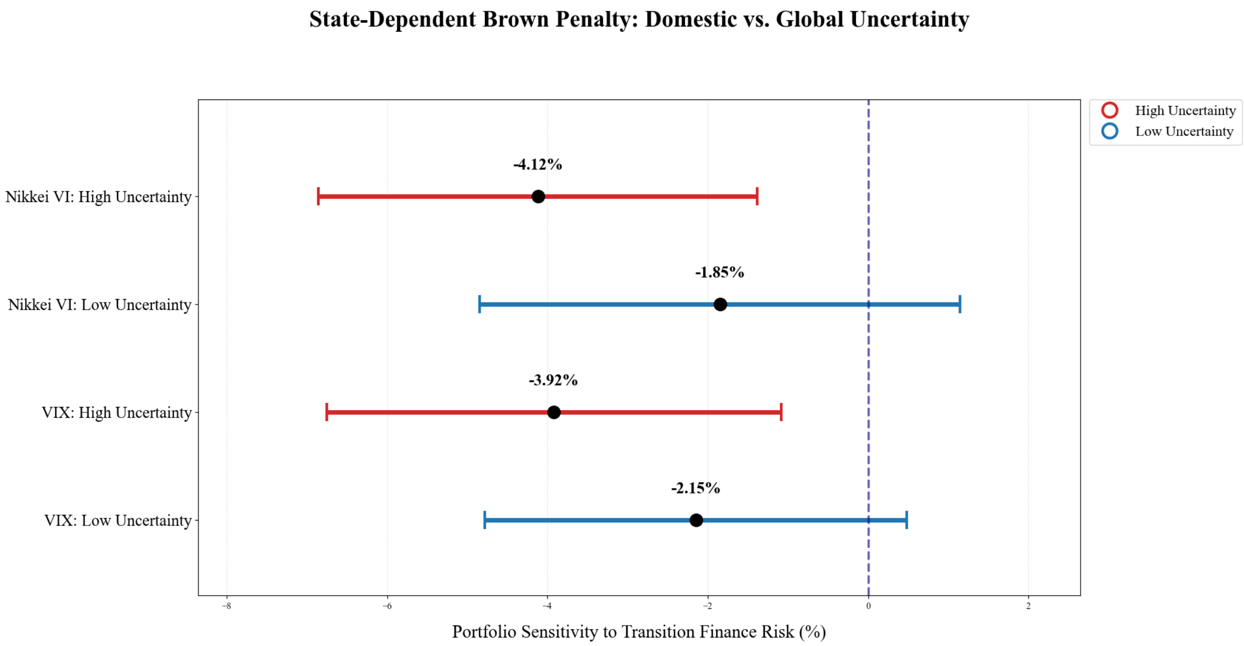


Figure 5: State-Dependent Carbon-Intensity Penalty across Volatility Regimes

Uncertainty Regime	Brown Penalty (%)	95% Confidence Interval	t-stat
Nikkei VI: High Uncertainty	-4.120***	[-6.860, -1.380]	-2.950
Nikkei VI: Low Uncertainty	-1.850	[-4.850, 1.150]	-1.210
VIX: High Uncertainty	-3.920***	[-6.760, -1.080]	-2.710
VIX: Low Uncertainty	-2.150	[-4.780, 0.480]	-1.600

Table 5: State-Dependent Sensitivity to Transition Finance Risk. Dependent variable: Firm-level monthly excess equity return (percentage points)

Notes: *This table reports brown–green return differentials across market uncertainty regimes. High (Low) uncertainty is defined by whether Nikkei VI or VIX exceeds (falls below) its sample median. Estimates correspond to the Shock × Brown coefficient. Amplification effects equal 123% (Nikkei VI) and 82% (VIX). Sample size: 25 of the 27 identified transition finance risk events are used due to volatility-index data availability. ***, **, * denote significance at the 1%, 5%, and 10% levels.*

5.5 Macro-Financial Transmission: VAR Evidence on Aggregate Responses

To verify that the documented transition risk premium represents an independent source of systematic risk rather than a linear combination of existing macro-financial factors, I estimate an eight-variable VAR(4) system incorporating transition risk, economic policy uncertainty, real GDP growth, market volatility, inflation, exchange rates, liquidity growth, and monetary policy. Figure 6 presents the dynamic responses of transition risk, policy uncertainty, real GDP growth, and market volatility to a one-standard-deviation shock to transition risk; responses of the remaining variables are qualitatively similar and available upon request. The system is estimated using monthly data from 2008–2025 with orthogonalized impulse response functions (IRFs) computed via Cholesky decomposition, ordering transition risk first as an identifying assumption for contemporaneous innovations.

The top panel confirms that transition risk exhibits persistent autonomous dynamics. A one-standard-deviation innovation generates an immediate response of approximately 4 units, rising to a peak of around 6 units within 2–3 months before gradually decaying. The effect remains positive and statistically significant through approximately 18 months, with the response magnitude approaching zero only after 20 or more months. This persistent autoregressive structure suggests that transition risk behaves as a slowly mean-reverting factor with substantial intertemporal persistence. The prolonged half-life of shocks implies that transition risk innovations have durable effects that extend well beyond the initial event period, consistent with the multi-quarter persistence documented in the event study analysis.

In contrast, the responses of macro-financial variables to transition risk shocks are economically small and statistically insignificant. Policy uncertainty exhibits a modest initial response that quickly reverts toward zero, with confidence intervals spanning zero throughout the horizon. Real GDP responses are negligible and statistically indistinguishable from zero at all horizons. Market volatility shows a similarly limited response within the confidence bands. These patterns are consistent with three identification implications. First, transition risk shocks do not materially propagate through general policy uncertainty. Second, the absence of real GDP effects suggests that transition risk operates primarily through financial revaluations rather than contemporaneous real disruptions. Third, the limited volatility response indicates that transition risk is distinct from broad market stress. Overall, the orthogonalized responses are consistent with interpreting transition risk as a distinct dimension of systematic financial risk rather than a proxy for conventional macro-financial conditions.

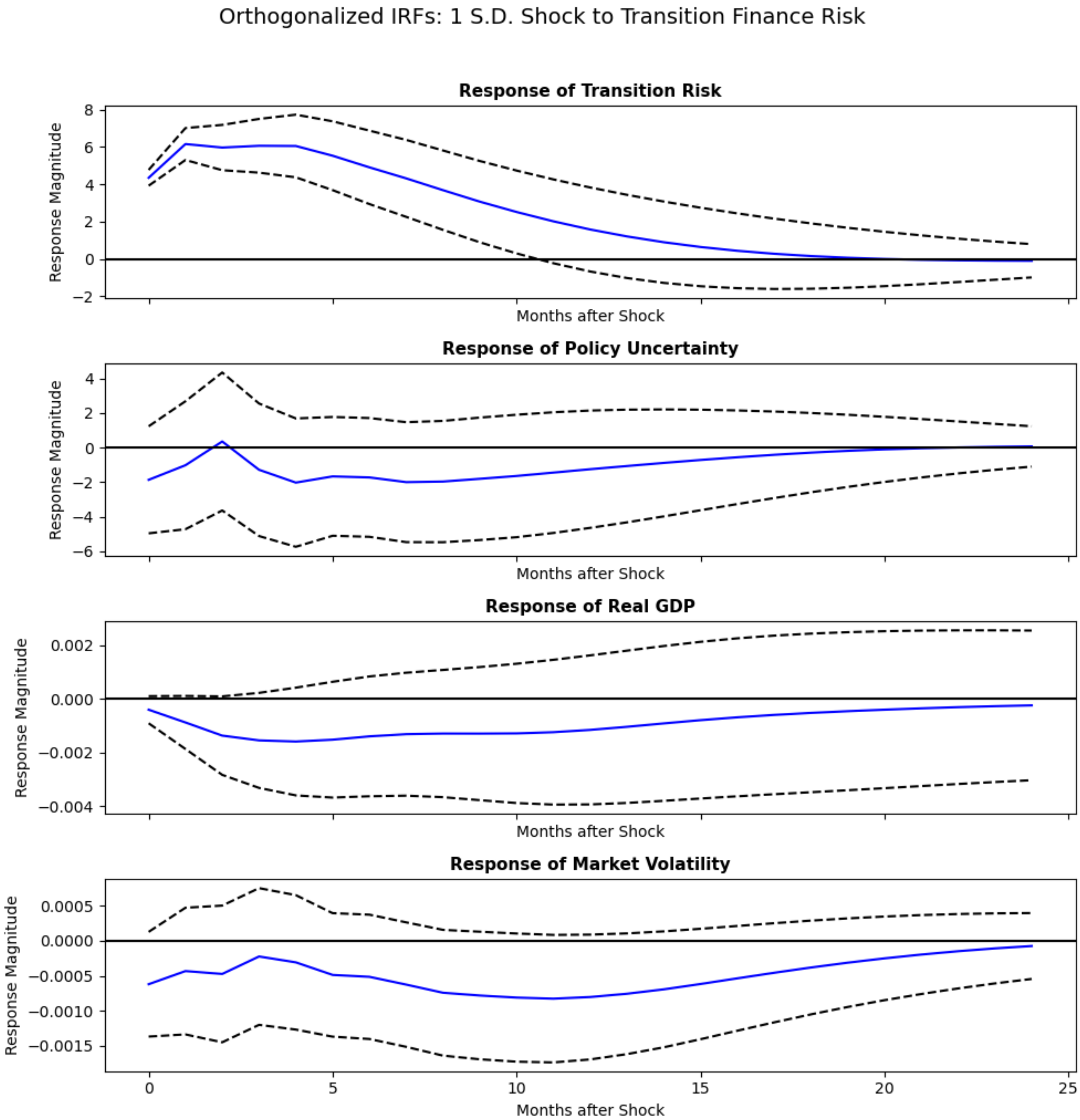


Figure 6: Orthogonalized Impulse Responses to a Transition Finance Risk Shock

6. Robustness Checks

6.1. Alternative Return Specifications

To verify that the documented brown penalty is not an artifact of the market-adjustment procedure, I re-estimate the rolling transition risk sensitivity using raw excess returns with market controls (blue line) and compare it to market-adjusted abnormal returns (red dashed line, baseline). Figure 7 demonstrates that both specifications yield qualitatively consistent patterns across all time periods. During 2019–2021, both approaches produced positive coefficients indicating brown underperformance, with only marginal differences in magnitude across rolling windows. Following the 2022 regime change (vertical dotted line), both series turn negative and converge closely, stabilizing at approximately −0.045 to −0.050 through 2025. Statistical significance patterns are similarly consistent, with t-statistics (bottom panel) tracking closely across specifications and exceeding conventional thresholds in the same periods. The close alignment of point estimates and inference across alternative return definitions confirms that the transition risk premium represents a robust empirical regularity that is not sensitive to the specific market-adjustment procedure.

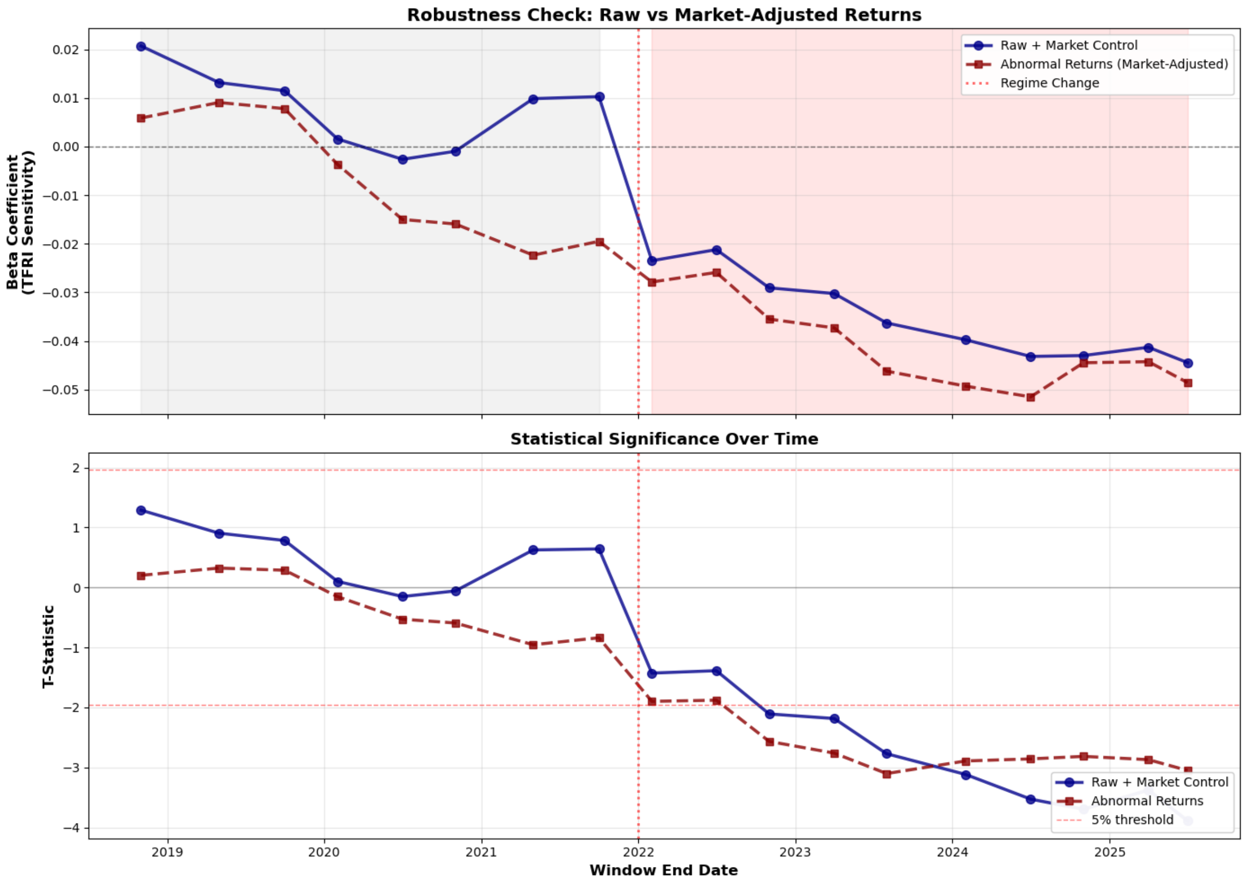


Figure 7: Transition Risk Premium Under Alternative Return Specifications

As a further robustness check, the baseline green–brown classification threshold is varied across $\tau \in \{0.50, 0.60, 0.67, 0.75\}$ to assess sensitivity to the emissions percentile cutoff. The core findings statistically significant but economically small average green–brown differentials, and substantially amplified brown penalties during high-uncertainty periods are qualitatively unchanged across all threshold specifications. Results are available upon request

6.2 Controlling for Standard Asset Pricing Factors

Moreover, As an additional robustness check, the green–brown portfolio return differential is regressed on the Fama–French five factors to test whether transition finance effects are subsumed by conventional risk factors. Table 6 reports the results. The equal-weighted portfolio alpha is small and positive (0.121, t = 0.47) while the value-weighted alpha is small and negative (−0.333, t = −0.80), with neither statistically distinguishable from zero. The sign reversal between equal and value-weighted specifications is consistent with the earlier finding that transition risk effects are concentrated among small-cap firms value-weighting shifts the portfolio toward large-cap firms where the transition penalty is statistically insignificant (Figure 4, Panel A). The low adjusted R^2 in both specifications, particularly for the value-weighted portfolio (0.006), indicates that standard FF5 factors capture little of the variation in the green–brown return differential, which is consistent with transition risk representing a distinct dimension of systematic risk orthogonal to conventional asset pricing factors. The absence of a statistically significant alpha under either weighting scheme reflects the economically small average green–brown differential documented in Table 3 and confirmed by the equivalence tests in Table 4, rather than contradicting those findings. The results are reported in Table 6 below.

Table 6 Fama–French Five-Factor Model

Dependent variable: Green–Brown portfolio excess return

Variable	(1) Equal-Weighted	(2) Value-Weighted
Intercept (Alpha)	0.121(0.256)	−0.333(0.416)
Market Excess Return (MKT)	0.148**(0.059)	0.224**(0.113)
Size (SMB)	−0.151(0.133)	−0.287(0.217)
Value (HML)	0.084(0.099)	0.099(0.230)
Profitability (RMW)	−0.243(0.162)	0.377(0.385)
Investment (CMA)	−0.024(0.139)	0.357(0.254)
Observations	168	168
Adjusted R^2	0.047	0.006

6.3 Alternative VAR Ordering

As a robustness check, I recompute impulse responses under alternative recursive orderings, including placing transition risk last. The qualitative patterns remain unchanged, indicating that the results are not driven by the baseline Cholesky ordering.

7. Discussion

This paper provides comprehensive evidence on the transmission of transition finance risk in Japan through multiple complementary empirical approaches. The findings collectively establish four main conclusions regarding how transition risk propagates through the Japanese economy and financial markets.

Transmission operates through financial valuations rather than real activity. The structural VAR analysis demonstrates that transition risk shocks generate persistent equity market effects while leaving real GDP statistically unchanged. This pattern indicates that transition risk operates primarily as a financial market phenomenon affecting discount rates and risk premia, rather than immediately disrupting production, employment, or aggregate demand. The impulse response functions confirm that a one-standard-deviation transition risk shock generates persistent dynamics, with the transition risk factor remaining statistically significant through approximately 18 months. The absence of contemporaneous or lagged GDP responses distinguishes transition risk from conventional demand or supply shocks and suggests that Japanese firms have maintained operational continuity despite increased regulatory uncertainty. This finding aligns with theoretical predictions that transition risk affects asset valuations through changes in expected future cash flows and required returns rather than through immediate production disruptions. The inflation channel provides further evidence for this interpretation. Transition risk shocks generate no meaningful inflation response across all horizons examined, with point estimates close to zero and confidence intervals consistently including zero. This null result rules out supply-side cost-push mechanisms whereby carbon pricing or regulatory compliance costs would immediately feed through to consumer prices. Instead, the evidence supports a risk premium channel whereby transition uncertainty raises required returns on carbon-intensive assets without necessarily altering current production costs or pricing behavior. The combination of persistent equity effects, absent GDP effects, and null inflation responses paints a consistent picture of transition risk as a forward-looking financial market phenomenon rather than a contemporaneous real economic shock. The small average green–brown differential and the null GDP and inflation responses are jointly consistent rather than contradictory. A small and episodic premium implies limited aggregate reallocation of capital away from carbon-intensive activities, which in turn generates no persistent disruption to production, employment, or pricing behavior. This contrasts with theoretical frameworks in which large and sustained carbon risk premia compress investment in brown industries and generate measurable real effects. The Japanese evidence instead supports a regime in which transition risk operates as a latent financial market phenomenon priced aggressively during periods of stress but insufficient on average to redirect capital flows at the macroeconomic scale required to produce GDP or inflation effects.

Proper controls for comprehensive policy uncertainty are essential for identifying transition-specific effects. The firm-level local projection analysis indicates that specifications without economic policy uncertainty (EPU) controls overstate the magnitude of transition-specific effects and may attribute general macro uncertainty to carbon exposure. The composite EPU index employed in this study aggregates uncertainty across fiscal, monetary, trade, and exchange rate policy, providing a broad measure of aggregate policy uncertainty that often co-moves with climate policy announcements. When this composite measure is included as a control variable, the estimated brown penalty declines substantially, and the average green–brown differential becomes economically small and practically negligible, despite remaining statistically significant. This finding has methodological implications. Many existing studies, such as Berthold (2024), construct climate policy uncertainty indices or identify transition risk events through narrative approaches similar to this paper, but relatively few explicitly control for general EPU that may coincide with climate developments. The reduction in coefficient magnitudes when EPU is controlled suggests that researchers should consider whether their specifications capture transition-specific effects or broader macroeconomic policy uncertainty. This concern is particularly relevant for studies conducted during periods when climate policy developments coincided with fiscal crises, monetary policy shifts, or trade tensions—conditions that characterize much of the 2008–2025 sample period examined here.

The weak green–brown heterogeneity documented in Japan reflects a distinct institutional and policy ecosystem. Once EPU is controlled, the absence of strong carbon-based pricing differentiation contrasts with findings in European and U.S. studies. As Table 4 shows using equivalence tests, the green–brown differential is economically negligible ruling out effects as small as 0.1% monthly that are routinely documented in European markets (Berthold, 2024; Bolton & Kacperczyk, 2021). This divergence may reflect several interrelated factors. First, Japan's equity market is dominated by large domestic institutional investors, such as the Government Pension Investment Fund (GPIF) and life insurers, who emphasize long-term stewardship and engagement over aggressive divestment. In addition, large-scale Bank of Japan (BoJ) ETF purchases may dampen price discovery mechanisms that would otherwise penalize carbon-intensive firms. At the firm level, major Japanese emitters have adopted transition strategies, including hydrogen initiatives and renewable energy investments, which may mitigate concerns about stranded assets. Japan's Green Transformation (GX) policy framework further emphasizes subsidies, technological support, and transition finance rather than punitive carbon pricing. These institutional factors suggest that climate transition risk in Japan is perceived as a managed, system-wide challenge rather than a firm-specific shock, which may blur the green–brown dichotomy and weaken differential pricing in equity markets.

State-dependent transmission amplifies transition risk during periods of elevated uncertainty. The local projection analysis demonstrates that transition risk effects vary systematically with macroeconomic conditions. During high-uncertainty periods (as measured by the Nikkei VI), brown firms experience penalties of −4.12% compared to −1.85% during low-uncertainty periods a 123% amplification. This pattern replicates when conditioning on the VIX, with an 82% amplification during global uncertainty spikes. Several mechanisms may explain this state dependence: financial accelerator effects (credit constraints binding more tightly during stress), risk aversion amplification (heightened sensitivity to long-horizon risks during downturns), and balance sheet fragility (reduced capacity to absorb adjustment costs). The state-dependence finding has direct policy implications. It suggests that major climate policy announcements or regulatory tightening during periods of elevated uncertainty generate disproportionate financial market stress. This suggests that policymakers should consider macroeconomic conditions when timing major climate policy implementations; phasing transformative regulations during economic expansions when financial systems demonstrate greater resilience may reduce transition costs without compromising long-term decarbonization objectives.

Transition risk represents an independent factor with persistent dynamics. The VAR analysis establishes that transition risk exhibits strong persistence and operates as an independent systematic factor rather than merely reflecting linear combinations of existing macro-financial variables. These responses validate the identifying assumption that transition risk captures a distinct dimension of systematic risk orthogonal to conventional business cycle factors. This finding justifies treating transition risk as a primitive factor in asset pricing specifications, provided that comprehensive EPU controls are included to isolate the transition-specific component.

8. Conclusion

This paper quantifies transition finance risk transmission in Japan through a novel text-mined index combined with structural VAR and firm-level local projections spanning 2008-2025. The evidence establishes that transition risk operates primarily through financial market valuations and risk premia rather than real economic activity, with persistent equity price effects but no meaningful GDP or inflation responses. A key methodological contribution demonstrates that specifications without comprehensive economic policy uncertainty controls substantially overstate transition-specific effects by conflating general macro uncertainty with carbon exposure differentiation. The properly controlled estimates reveal minimal green-brown heterogeneity in Japanese equity markets, suggesting that aggregate discount rate channels dominate firm-specific cash flow exposure effects. State-dependent analysis documents substantial amplification during high-uncertainty periods, with brown penalties increasing by 123% during domestic volatility spikes and 82% during global uncertainty episodes. These findings carry three important policy implications.

First, climate policy announcements during periods of elevated economic uncertainty generate disproportionate financial market stress through amplification mechanisms, supporting consideration of counter-cyclical timing for major regulatory implementations. Second, Japan's institutional structure including credible corporate transition strategies, gradual policy frameworks, and concentrated institutional ownership may explain weak carbon-based pricing differentiation relative to European and U.S. markets, suggesting that transition risk transmission varies systematically across institutional environments. Third, researchers and policymakers measuring transition risk should employ comprehensive policy uncertainty controls to avoid conflating transition-specific effects with broader macroeconomic uncertainty, particularly when climate policy developments coincide with fiscal, monetary, or trade policy shifts.

Beyond measurement, the state-dependent nature of transition risk premia has direct implications for financial stability assessment. Because the brown penalty is small on average but amplifies sharply during uncertainty spikes, standard stress testing frameworks that apply average transition risk premia will systematically underestimate climate-related financial risk during precisely the periods when financial systems are most vulnerable. A more accurate approach would incorporate regime-dependent risk estimates, applying amplified transition risk parameters during high-volatility scenarios rather than relying on unconditional averages. This distinction between average and tail-state transition risk is particularly relevant for central banks and prudential regulators designing climate stress tests and scenario analyses.

Appendices:

Table A1: Major Transition Finance Risk Events in Japan (2008–2025)

Date	Event Description	Category
Mar 2011	Fukushima disaster	Domestic
Sep 2012	Japan nuclear phase-out policy	Domestic
Nov 2013	COP19 Warsaw	International
Apr 2014	Cabinet approves Strategic Energy Plan	Domestic
Oct 2014	IPCC AR5 Synthesis Report	International
Jul 2015	Japan submits INDC to UNFCCC	Both
Dec 2015	Paris Agreement adopted (COP21)	International
May 2016	G7 Ise-Shima Summit	International
Nov 2016	Paris Agreement enters into force & Japan ratifies	Both
Oct 2018	IPCC Special Report on 1.5°C	International
Jun 2019	G20 Osaka Summit	International
Sep 2009	PM Hatoyama pledges 25% emission cut	Domestic
Apr 2010	Tokyo Cap-and-Trade Program begins	Domestic
Oct 2020	PM Suga announces 2050 carbon neutrality target	Domestic
Dec 2020	Japan announces Green Growth Strategy	Domestic
Feb 2021	Carbon pricing study group established	Domestic
Apr 2021	Japan pledges 46% emission cut by 2030	Domestic
May 2021	Amendment to Global Warming Countermeasures Act	Domestic
Jun 2021	G7 Cornwall + Updated Green Growth Strategy	Both
Aug 2021	IPCC AR6 Working Group I Report	International
Oct 2021	COP26 Glasgow Climate Pact	International
Feb 2022	IPCC AR6 Working Group II Report	International

Apr 2022	IPCC AR6 Working Group III Report	International
Jun 2022	TCFD disclosure made mandatory	Domestic
Feb 2023	GX legislation package announced	Domestic
Apr 2023	G7 Sapporo climate ministers meeting	International
Feb 2024	Updated GX promotion strategy	Domestic

Notes: *This table reports the 27 major transition finance risk events identified over the period 2008–2025 (*Event dates above refer to the month of peak JP-TFRI innovation associated with each episode, which may differ by one month from the calendar date of the underlying policy announcement due to publication lags in newspaper coverage*) using the hybrid identification procedure described in Section 3.2. Events are classified as Domestic (Japan-specific policy developments), International (global climate agreements and reports), or Both (events with dual significance). The identification combines algorithmic detection (monthly JP-TFRI innovations exceeding 1.5 standard deviations) with manual verification of underlying newspaper content. Events occurring within three months are consolidated to avoid double-counting. Category definitions: Domestic = Japanese policy announcements, legislation, and institutional reforms; International = IPCC reports, COP negotiations, and global climate agreements; Both = events with simultaneous domestic and international significance (e.g., Japan's ratification of international agreements or international summits hosted by Japan).*

Table A2: Summary Statistics

Variable	Definition	Source	Min	Mean	Std. Dev.	Max	N
Equity-to-Asset Ratio (Leverage)	Ratio of shareholders’ equity to total assets, measuring firm leverage.	Tokyo Stock Exchange	-0.706	0.490	0.210	4.420	84,118
Firm Size (Log Assets)	Natural logarithm of total firm assets.	Tokyo Stock Exchange	20.876	25.390	1.618	29.810	84,156
Sales Growth	Monthly growth rate of firm sales.	Tokyo Stock Exchange	-0.987	0.298	0.690	13.713	82,799
Asset Growth	Monthly growth rate of total firm assets.	Tokyo Stock Exchange	-0.917	0.009	0.082	11.574	82,799
Return on Assets (ROA)	Net income divided by total assets.	Tokyo Stock Exchange	-0.840	0.017	0.032	1.227	84,154
Return on Equity (ROE)	Net income divided by shareholders’ equity.	Tokyo Stock Exchange	-14.979	0.024	0.311	6.829	84,154
Brown Share (Portfolio Weight)	Share of firms classified as high-emissions (“brown”) within the portfolio.	Author’s construction	0.000	0.473	0.499	1.000	84,161
Brown Indicator (Absolute)	Takes 1 if a firm is classified as high-emissions firm and 0 otherwise	Author’s construction	0.000	0.402	0.490	1.000	84,161
Brown Indicator (Relative)	equal to one for firms above the cross-sectional median emissions threshold.	Author’s construction	0.000	0.500	0.500	1.000	84,161
Transition Finance Risk Index (JP-TFRI)	Text-based index measuring transition finance risk constructed from two Japanese newspapers	Author’s construction (Nikkei &	19.672	101.869	46.053	376.552	84,161

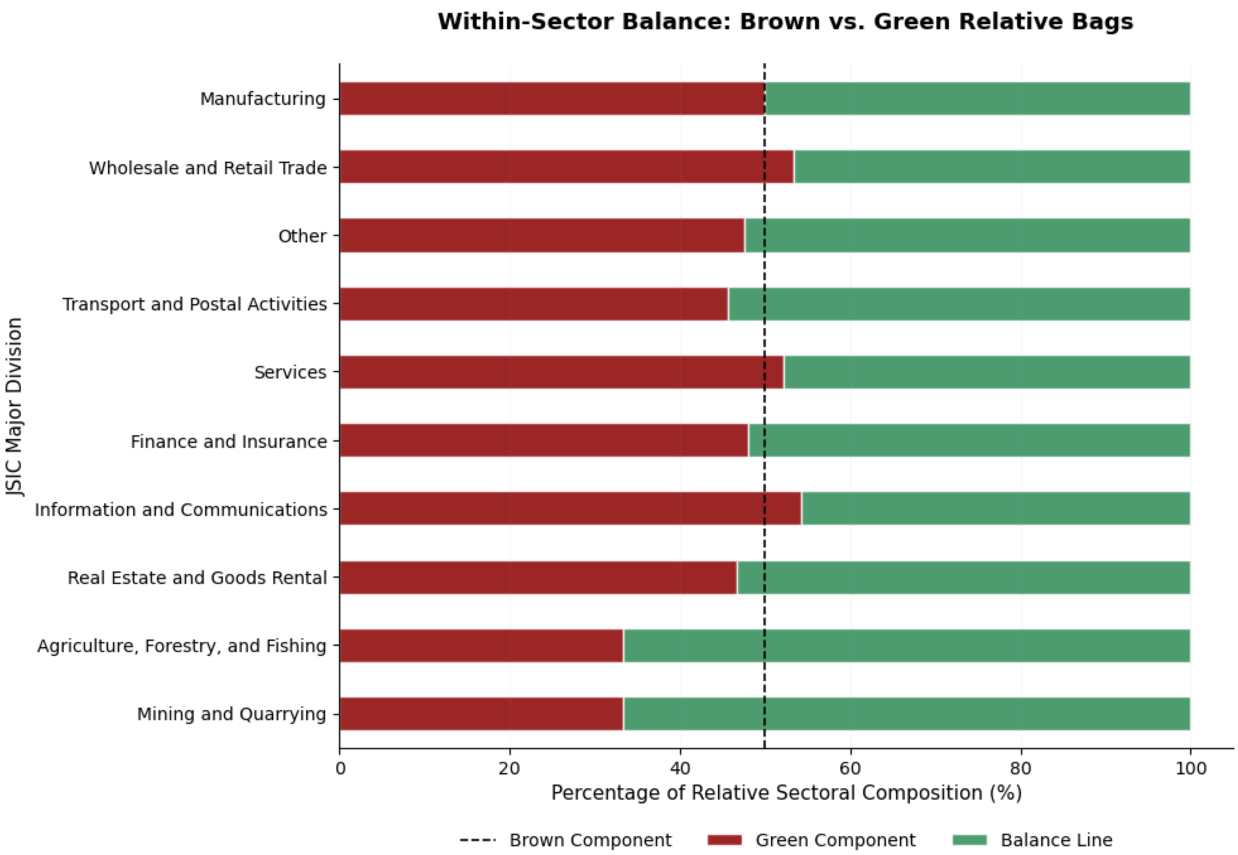
		Mainichi newspapers)					
Economic Policy Uncertainty (Composite)	Agreggate fiscal, monetary, trade, and exchange-rate policy uncertainty.	Bank of Japan	63.480	117.467	32.326	239.049	83,314
Market Return (TOPIX)	Monthly return on the TOPIX equity market index.	Bank of Japan	-0.203	0.005	0.048	0.126	84,161
Short-Term Interest Rate Change	Monthly change in the short-term policy interest rate.	Bank of Japan	-0.215	0.003	0.030	0.250	84,161
USD/JPY Exchange Rate (Average)	Monthly average nominal USD/JPY exchange rate.	Bank of Japan	76.720	110.644	20.825	157.900	84,161
Real Effective Exchange Rate	Trade-weighted real effective exchange rate index.	Bank of Japan	68.270	100.110	19.233	137.520	84,161
Global Energy Price Index	Monthly change in a global energy price index.	Bank of Japan	-0.019	0.001	0.005	0.029	84,161
Consumer Price Inflation	Monthly inflation rate based on the consumer price index.	Bank of Japan	-0.019	0.001	0.005	0.029	84,161
Firm Monthly Excess Return	Firm-level monthly excess equity return (percentage points).	Tokyo Stock Exchange	-119.161	1.833	15.278	181.848	63,515
Firm Monthly Log Return	Natural logarithm of firm-level monthly equity return.	Tokyo Stock Exchange	-1.192	0.018	0.153	1.818	63,515
Market-Adjusted Log Return	Firm monthly log return net of market return.	Author's construction (TSE & BoJ data)	-1.235	0.008	0.147	1.893	63,515
Market Excess Return	Monthly excess return on the aggregate equity market.	Bank of Japan	-22.638	0.372	4.903	11.871	83,792
Log Greenhouse Gas Emissions	Natural logarithm of firm greenhouse gas emissions (Scope 1 and 2).	Japanese Ministry of the Environment	5.932	9.435	1.231	18.267	84,161
Log Real GDP	Natural logarithm of real gross domestic product.	Bank of Japan	13.130	13.236	0.043	13.294	84,161
Profit Growth (Winsorized)	Monthly profit growth winsorized at the 1st and 99th percentiles.	Tokyo Stock Exchange	-9.378	0.212	2.124	11.172	82,745

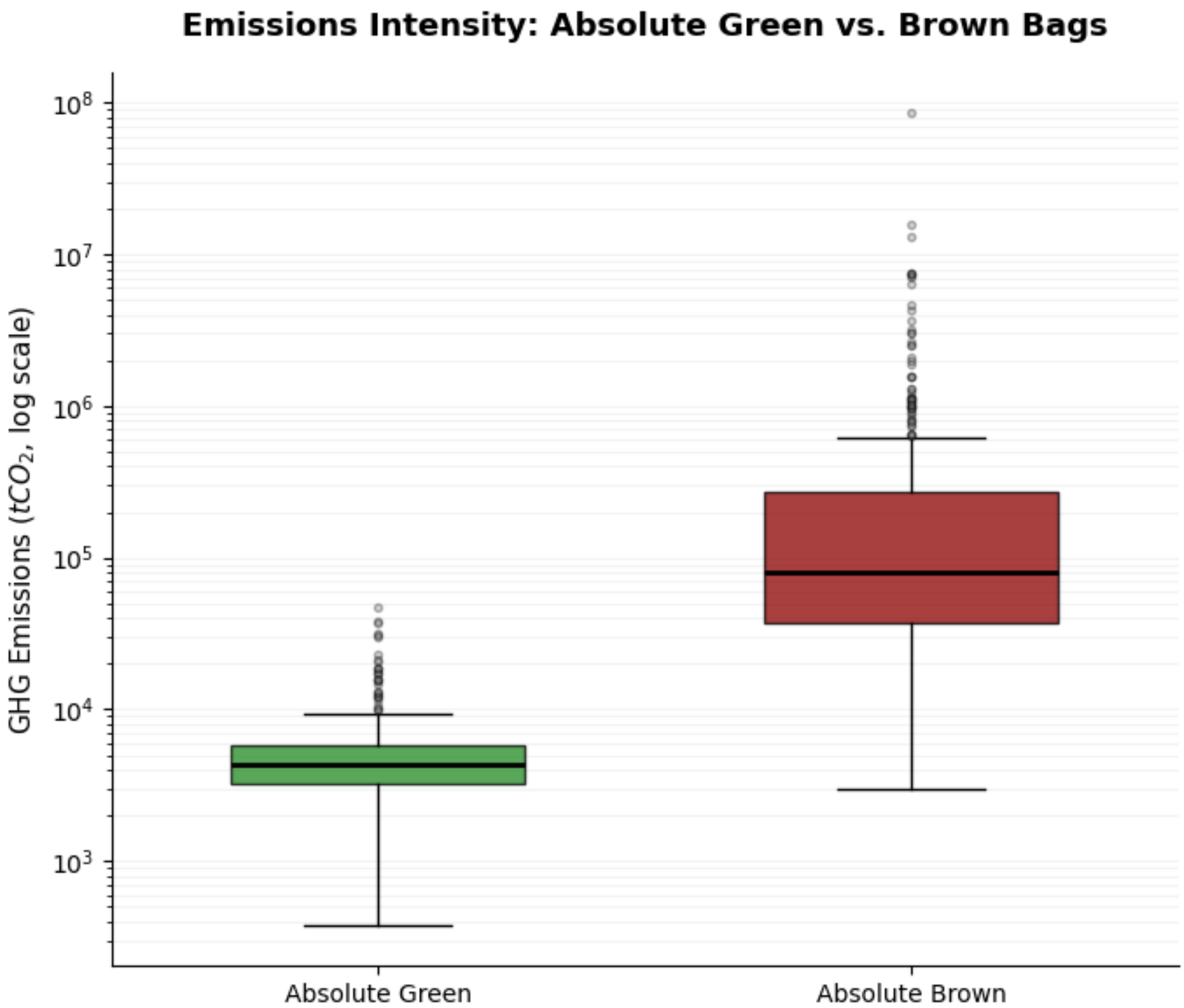
A3: Robustness to Observed Emissions Window (2009–2022)

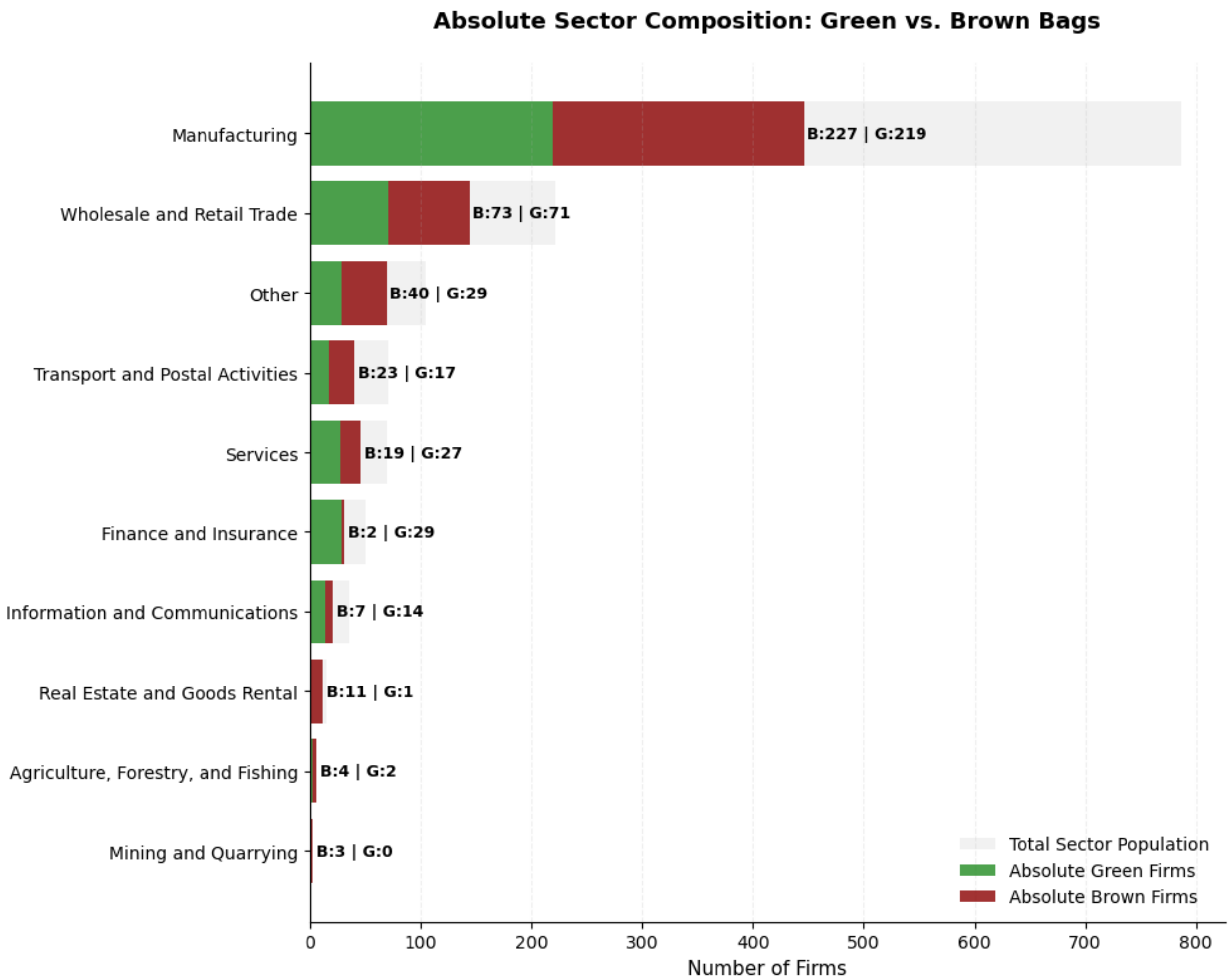
Sample	Shock × Brown coefficient	Std. Error	p-value	Observations	Fixed Effects
Full sample (2008–2025)	−0.043***	0.014	<0.01)	32,241	Firm, Time

Observed emissions only (2009–2022)	3.19e-05	2.57e-05	0.214	51,236	Firm, Time

Notes: The full-sample coefficient is from Table 3, Column 2 (standardized returns) with the complete macro control vector, yielding 32,241 observations after listwise deletion from merging EPU, CPI, energy price, and GDP series. The restricted-sample coefficient uses raw excess returns as the dependent variable with firm and time fixed effects only, without the full macro control merge, which accounts for the higher observation count (51,236) despite the narrower 2009–2022 time window. Standard errors are clustered at the firm level.




Emissions Intensity: Absolute Green vs. Brown Bags
GHG Emissions (tCO_2, log scale)
10^8
10^7
10^6
10^5
10^4
10^3
Absolute Green
Absolute Brown


Absolute Sector Composition: Green vs. Brown Bags
Manufacturing
Wholesale and Retail Trade
Other
Transport and Postal Activities
Services
Finance and Insurance
Information and Communications
Real Estate and Goods Rental
Agriculture, Forestry, and Fishing
Mining and Quarrying
B:227 | G:219
B:73 | G:71
B:40 | G:29
B:23 | G:17
B:19 | G:27
B:2 | G:29
B:7 | G:14
B:11 | G:1
B:4 | G:2
B:3 | G:0
Total Sector Population
Absolute Green Firms
Absolute Brown Firms
0
100
200
300
400
500
600
700
800
Number of Firms

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