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Investigating the impact of climate-related risks: a regime-switching analysis of bond market dynamics and inflation expectations

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ABSTRACT

We examine how climate-related (transition and physical) risks impact European bond markets and inflation expectations, and identify their effects across distinct volatility regimes using a Markov-switching vector autoregression model. Our central finding is that the transmission of climate-related risk shocks is highly state-dependent and primarily affects short-term inflation expectations. Transition risks have a limited, disinflationary effect on short-term expectations, but only during low volatility periods. In sharp contrast, physical risks exert a destabilising, inflationary impact during high volatility periods, depressing bond returns and amplifying market stress. Additionally, we observe two more patterns: first, that long-term inflation expectations tend to remain largely anchored. Second, financial linkages and contagion tend to intensify in the high volatility state. Our findings matter for asset pricing and for monetary authorities. They support integrating climate-related risks into stability frameworks, as these shocks presumably intensify and complicate the trade-off between inflation-target credibility and financial stability.

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1. Introduction

As a global leader in climate regulation and sustainable finance, Europe is at the forefront of confronting the financial implications of climate transition policies and environmental shocks. These risks, broadly classified into transition risks arising from regulatory and technological shifts toward a low-carbon economy, and physical risks stemming from climate-induced disruptions, pose growing challenges for asset valuation, monetary policy, and market stability. In particular, concerns have emerged over how such risks interact with inflation expectations and bond pricing mechanisms in Europe's integrated financial markets, particularly under volatile conditions (Battiston, Dafermos, and Monasterolo 2021; Boissay et al. 2023). Additionally, concerns regarding financial stability have emerged due to these climate-related risk-induced cost-push inflationary dynamics (Ciccarelli, Kuik, and Martínez Hernández 2023; Jackson 2024). Indeed, in recent years, central banks have begun to identify the green transition and physical climate change as sources of financial stability risk (Battiston, Dafermos, and Monasterolo 2021).

If these pressures become more structural, they could amplify the trade-off between monetary policy and financial stability for central banks.¹ It is understood that climate change and related policies may trigger macroeconomic and financial instability by impairing the balance sheets of firms, households, banks, and insurers. Delayed or abrupt transitions may amplify risks, either through intensified physical damage or sudden reallocations of capital (Batten, Sowerbutts, and Tanaka 2016; European Systemic Risk Board 2016). Alongside these macroprudential considerations, the evolving landscape of climate-related risks presents significant challenges and opportunities for risk management and portfolio construction (Bertolotti 2020). Understanding

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how these risks manifest in European financial markets, particularly across different asset classes and volatility regimes, is crucial for institutional investors seeking to optimise risk-adjusted returns and build resilient portfolios (Krueger, Sautner, and Starks 2020).

While the literature has explored the effects of climate-related risks on equity markets, commodity prices, and credit risk premia (Cepni et al. 2023; Krueger, Sautner, and Starks 2020), and identified multiple transmission channels with emphasis on nonlinearities (Battiston, Dafermos, and Monasterolo 2021; Battiston et al. 2017; Semieniuk et al. 2021; Stolbova, Monasterolo, and Battiston 2018), relatively little is known about how these risks influence market-based inflation expectations and bond returns across different volatility regimes. This phenomenon remains under-investigated, despite its growing policy relevance for the euro area.

To address this gap, we examine how news-based measures of transition and physical climate risks transmit to inflation expectations and bond markets in Europe, with particular attention to regime-dependent dynamics during periods of financial stress. We employ a Markov-switching Vector Autoregression (MS-VAR) combined with the news-based Transition Risk Index (TRI) and Physical Risk Index (PRI) (Bua et al. 2024). While these indices are proxies for perceived rather than objective risk, their broad acceptance in recent literature (see, for example, Bua et al. 2024; Tilly and Livan 2022) supports their effectiveness at capturing market sentiment. The model allows us to capture time-varying responses and amplification effects across euro-denominated green and conventional corporate bonds, sovereign bonds, and German breakeven inflation rates (BEIRs), the benchmark for euro area inflation expectations. We present regime-dependent Generalised Impulse Response Functions (GIRFs) (Ehrmann, Ellison, and Valla 2003), which illustrate co-movement dynamics under shocks across regimes. By integrating bond class heterogeneity with regime shifts, this study provides the first empirical assessment of how climate-related risks shape both short- and long-term inflation expectations and bond market dynamics in Europe, contributing to ongoing policy debates about potential de-anchoring from the European Central Bank's (ECB) inflation target.

We address three research questions, namely, (i) How do inflation expectations and bond markets respond to shocks in news-based climate-related risk indices across different volatility regimes? (ii) How do bond returns react to short- and long-term inflation expectation shocks across regimes? (iii) Do shocks to different bond classes result in contagion or decoupling dynamics depending on volatility regimes?

Our findings suggest that bond markets are more sensitive to physical than transition risks, particularly during high volatility regimes. Moreover, only short-term inflation expectations respond significantly to climate-related shocks, while long-term expectations remain firmly anchored. Finally, contagion effects across bond classes are amplified during periods of stress, indicating that volatility intensifies financial linkages and market reactions to climate-related risks. These findings are especially relevant for European institutional investors managing inflation-hedging strategies and green finance mandates, as well as for central banks considering how to integrate climate-related risks into inflation models and financial stability toolkits, since climate-related risks are becoming increasingly structural drivers of macro-financial dynamics shaped not only by fundamentals but also by market sentiment and behavioural responses to volatility.

The remainder of this paper is structured as follows. Section 2 reviews the relevant literature on climate-related risk, inflation expectations, and bond markets. Section 3 outlines the data and econometric methodology while Section 4 presents the empirical findings. Section 5 concludes with a discussion of the results and derives implications for financial stability and monetary policy trade-offs.

2. Literature review

This work contributes to various strands of literature, specifically the effects of green transition and physical climate risks on inflation expectations and on bond markets, as well as bond market interactions under different volatility regimes.

To the best of our knowledge, inflation expectations have not yet been directly linked to news-based climate-related risks; however Tilly and Livan (2022) show that daily macro-financial news sentiment drives BEIRs across eight countries. Parallel research using survey-based evidence shows that both households and firms adjust their inflation expectations in response to climate concerns, though the direction and persistence of these effects vary across studies (Angelico 2024; Hensel, Mangiante, and Moretti 2024; Meinerding, Poinelli, and Schüler 2023).

Empirical evidence suggests that both physical climate risks and green transition risks can exert inflationary pressures through both supply-side disruptions and transition-related adjustments. Physical risks raise prices by disrupting production, damaging infrastructure, and reducing key inputs, with the magnitude depending on shock intensity, consumption shifts, and fiscal support (Beirne, Renzhi, and Volz 2021; Cantelmo 2022; Cevik and Jalles 2024; Kabundi, Mlachila, and Yao 2022; Qi et al. 2025). In contrast, transition risks affect inflation dynamics primarily via firms with high carbon intensity, which face stranded asset risks,² rising refinancing costs, and tighter regulation, while lenders face reputational and compliance risks (Chava 2014; Delis et al. 2024; Generation Foundation 2013). Beyond firm-level impacts, adaptation costs and supply-side adjustments can transmit these pressures more broadly across sectors, with the macroeconomic outcome shaped by an economy's structure and regulatory environment (Berthold et al. 2024; Cahen-Fourot et al. 2021; Konradt and di Mauro 2023; Moessner 2022; Santabárbara and Suárez-Varela 2022). These phenomena are increasingly referred to as *Greenflation* and *Climateflation* (Schnabel 2022a, 2022b).

Building on this literature, our study contributes by providing a direct analysis of news-based climate-related risks on BEIRs, which serves as a widely used market-based measure of inflation expectations (see e.g. Christensen, Lopez, and Rudebusch 2010; d'Amico, Kim, and Wei 2018; Gürkaynak, Sack, and Wright 2010; Strohsal and Winkelmann 2015). Furthermore, we contribute to the literature of the effects of inflation expectations on bond markets. Rising inflation expectations typically lower real interest rates and bond prices, consistent with Fisher's theory (Fisher 1930); however, in practice their effects depend on the inflation driver, the business cycle, and expected monetary policy (Chun 2011). In this vein, Pesci et al. (2022) find that inflation expectations have time-varying effects on corporate bonds, with weaker impacts on investment-grade and stronger sensitivity in high-yield bonds. When inflation is supply-driven, sovereign and corporate bonds tend to face higher risk premia due to worsening economic conditions and fears of prolonged monetary tightening. By contrast, when inflation is demand-driven, sovereign bonds remain more stable and corporate spreads narrower (Bonelli, Palazzo, and Yamarthy 2025; Cieslak and Pflueger 2023). Boeckx, Iania, and Wauters (2025) relate this to time horizons in that short-term expectations are more influenced by supply shocks whereas long-term expectations are driven more by demand-side factors.

The literature analysing climate-related risks on bond dynamics indicates varying effects across bond classes, raising financial stability concerns. For conventional and green corporate bonds, an important concept is the 'greenium', or the yield discount investors accept on green assets relative to conventional ones, reflecting their expected benefits from the green transition. Empirical evidence confirms the presence of such premia in several markets (e.g. Bolton and Kacperczyk 2023; Pástor, Stambaugh, and Taylor 2022).³

While the market for green bonds has grown significantly in recent years, the performance characteristics and drivers of these investments are still relatively under researched. Recent work by Baltas and Mann (2024) shows that green bond indices do not consistently outperform the broader market once financial and commodity factors are accounted for, suggesting limited performance differentiation versus conventional assets. Fernandes and Papadimitriou (2025) find that drought risk increases firm cash holdings in the euro area, especially for unlisted firms, supporting a precautionary motive. Understanding how specific environmental risks translate into corporate financial behaviour is crucial for assessing the broader economic impacts of climate change. The increasing risk of climate-related disasters has also raised awareness of the necessity for regulatory action, prompting policymakers to strengthen environmental regulations (Emam, Grebel, and Tudor 2020) and investors to anticipate stricter policies, thereby accelerating their transition toward green investments (Choi, Gao, and Jiang 2020). Conlon et al. (2024) show that borrower exposure to extreme weather raises lender systemic risk in syndicated loans, and Goodarzi and Meinerding (2025) highlight the value of regime shifts in dynamic allocation during high uncertainty.

Government bonds are similarly affected by climate-related risks, albeit through different channels, as exposure to climate hazards can weaken state finances, raise government risk profiles and borrowing costs, and depress bond prices (Beirne, Renzhi, and Volz 2021; Cevik and Jalles 2022; Klusak et al. 2023). Closely related to our work, a growing strand of literature employs the TRI and PRI to analyse bond market dynamics. These studies generally find that climate-related risk effects are time-varying and regime- or quantile-dependent, with the PRI exerting stronger and more consistent impacts on bond pricing than the TRI. Results also suggest heterogeneous resilience across bond classes: ESG corporate bonds tend to be more resilient to transition risks, while

ESG sovereign bonds are more sensitive to physical risks, and global green bonds exhibit reduced volatility under the PRI but heightened instability when transition risks are unexpectedly low (Bats, Bua, and Kapp 2024; Bourri et al. 2023; Cepni et al. 2023; Cepni, Demirer, and Rognone 2022).

This research therefore aligns with work that explores the transmission of shocks in different market volatility regimes. Financial markets are known to exhibit volatility clustering (Cont 2010), often amplified by behavioural factors such as herding (Schmitt and Westerhoff 2017; Shiller 1995), leverage effects (Brunnermeier and Pedersen 2009; Thurner, Farmer, and Geanakoplos 2012), and heightened risk aversion leading to safe-haven flows (Kindleberger and Aliber 1978; Tversky and Kahneman 1992). Based on Saliency Theory (Bordalo, Gennaioli, and Shleifer 2012), investors in stressed market environments also tend to overweight salient information, systematically under-weighting other risks.

Against this backdrop, several recent studies employ MS-VAR models to analyse regime-specific contagion dynamics in bond markets. Evidence generally shows that contagion across green, sovereign, and corporate bonds becomes stronger under high volatility regimes, with interdependence dominating in calmer periods (Flavin and Sheenan 2023; Reumkens and Sheenan 2024; Sheenan, Schweers, and Klein 2024). These findings underscore the usefulness of a regime-switching MS-VAR framework for capturing bond market interlinkages under stress, an approach our study extends by explicitly incorporating climate-related risks and inflation expectations.

3. Data and econometric method

This study explicitly focuses on European financial markets due to the region's regulatory leadership in climate policies and the availability of high-quality, standardised financial and climate-related risk data. The European Union's (EU's) stringent climate regulations and ambitious decarbonisation targets create a unique setting for evaluating the financial implications of climate-related risks (EC 2019), making it an ideal case for this analysis. However, we recognise that this framework is subject to political friction, exemplified by the recent 'Omnibus Simplification Package' (EC 2025; European Climate Neutrality Observatory 2025), which has attracted criticism for potentially undermining the effective scope of key corporate sustainability directives.⁴

The choice of a daily data frequency is a deliberate methodological decision, dictated by both the nature of our research question and the construction of our key explanatory variables. Our analysis aims to capture the high-frequency dynamics of financial market reactions to news-based climate risk sentiment. Lower frequencies, such as weekly or monthly, would mask these immediate impacts, as the market's response to information shocks is often short-lived. Conversely, an analysis at a higher, intraday frequency is precluded by the availability of the news-based TRI and PRI, which are constructed at a daily aggregation level. Therefore, daily frequency represents the most appropriate temporal resolution to investigate the research question at hand.

Our daily dataset, sourced from Refinitiv/LSEG Datastream, spans October 20th, 2014, to June 24th, 2024. It incorporates climate-related risk data alongside the log returns of five key financial indices: corporate bonds (S&P Euro Corporate Bond Index), green bonds (Bloomberg MSCI Euro Green Bond Index), government bonds (Bloomberg Euro Agg Treasury 10+ Year TR Index), and Break-Even Inflation Rates for Germany (two-year and ten-year maturities).

A key input are the news-based Transition Risk Index and Physical Risk Index developed by Bua et al. (2024), which serve as proxies for market perceptions of transition and physical climate risks. While these indices reflect perceived rather than objective risk exposure, their construction from aggregated news sentiment makes them well-suited to capture evolving market narratives. We acknowledge their limitations, including potential biases from the underlying news sources and the inherent challenges of Natural Language Processing. Nevertheless, their growing acceptance in the literature (e.g. Bua et al. 2024; Tilly and Livan 2022) underscores their value as indicators of climate-related risk sentiment.

Our analysis relies on bond indices rather than individual securities. While this approach effectively captures broad market-level dynamics, it abstracts from issuer-level effects and does not explicitly control for idiosyncratic bond characteristics. This design choice allows us to focus on macro-level interactions across major bond segments and inflation expectations. For BEIRs, we follow Pesci et al. (2022) and use German inflation-linked bonds as a reliable proxy for broader European implied inflation expectations due to their superior liquidity. To

capture both short- and long-term dynamics, we include the two-year BEIR and the ten-year BEIR, with the latter being a standard measure for long-term inflation compensation (Church 2019).

All series are transformed to ensure stationarity. Financial indices are in log returns, while BEIRs series are first-differenced.⁵ Augmented Dickey-Fuller (ADF) tests confirm that all series are stationary at conventional significance levels, ensuring their suitability for econometric modelling.⁶ Descriptive statistics and time series plots are presented in Appendix 1.

Finally, given the context-dependency of our empirical approach, our findings should be interpreted primarily within the European context and are not necessarily transferable to other regions with different economic structures, risk profiles, or policy frameworks.

The applied MS-VAR model effectively captures the non-linear, time-varying dynamics typical of financial markets (Cont 2010), enabling us to assess how climate-related risks and inflation expectations influence bond markets under different volatility regimes, an essential factor for risk management and portfolio allocation. Similar methods have also been applied to optimal portfolio strategy analysis, as shown in Goodarzi and Meinerding (2025).

The model is given by:

$$\begin{aligned}
 y_{i,t} &= \alpha(s_t) + \sum_{k=1}^K \beta_k(s_t) y_{i,t-k} + \epsilon_{i,t}^{s_t}, \\
 s_t &\in \{1, 2\}, \\
 \epsilon_{i,t}^{s_t} &\sim i.i.d.N(0, \sigma_s^2),
 \end{aligned} \tag{1}$$

where $y_{i,t}$ is an n -dimensional time series vector of dependent variables, given by the above presented time series. α is a matrix of state-dependent intercepts, $\beta_1.. \beta_k$ are matrices of the state-dependent auto-regressive coefficients and capture the relationships between our variables, and $\epsilon_{i,t}^{s_t}$ is a state-dependent noise vector, which has a zero mean and constant variance within each regime. s_t is an unobserved random variable that signals the switch from one regime to another. K is the lag length, following the suggestions of the Hannan–Quinn Information Criterion and is set to 1. Since the true regime cannot be observed, we must specify the paths by which the regimes transit from one to another. We assume s_t follows a first-order Markov process in which the current regime, s_t relies only on the regime one period in the past, s_{t-1} .

We estimate the model using a Bayesian Markov Chain Monte Carlo approach with specified prior distributions: a Wishart distribution for variances, a flat prior for VAR coefficients, and a weak Dirichlet prior for transition probabilities favoring state persistence. Employing Gibbs sampling, we estimate parameters and regimes by sequentially drawing sigmas given mean coefficients and regimes, then drawing mean coefficients (α and β) given sigmas and regimes, followed by drawing regimes given sigmas and mean coefficients, and finally drawing the transition parameters. This sequence is repeated 10,000 times after discarding an initial burn-in of 2,000 iterations. With the estimated parameters, we generate regime-dependent GIRFs and their associated confidence bands.

The model identifies two volatility regimes: low (Regime 1) and high (Regime 2), with high volatility periods occurring in distinct clusters. While the regime classification is based on European data, several international events triggered significant spillovers into European markets. Figure 1 presents the smoothed probabilities of the high volatility regime.

It is clear from Figure 2 that while the system predominantly remains in the low volatility regime, three distinct periods of significant volatility clustering are identified. The first volatility cluster emerges in 2015, with key events intensifying market fluctuations as the European Securities and Markets Agency (ESMA) reports. In January 2015, the Swiss Franc Shock caused a sudden appreciation of the franc, leading to losses for European exporters. By mid-2015, the Greek Debt Crisis triggered sovereign bond turbulence, particularly in Greece and peripheral EU nations (ESMA 2015). The Chinese Stock Market Crash (June–August 2015) resulted in a global selloff, culminating in Black Monday (August 24, 2015). Furthermore, the U.S. Federal Reserve rate hike (December 2015) increased capital outflows from emerging markets, adding to bond market instability

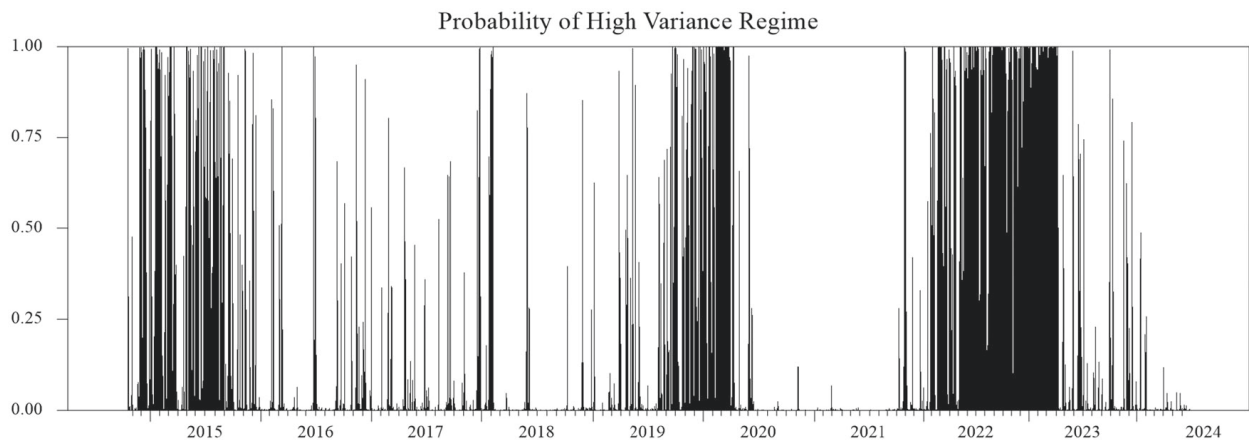


Figure 1. Smoothed probabilities of the high volatility regime (TRI and two-year BEIR).

Notes: Estimated using the MS-VAR model, this figure highlights periods of increased financial market stress and their alignment with major economic and geopolitical events.

(ESMA 2016). Meanwhile, the Paris Agreement was adopted in December 2015, with the EU showing great support for it (EC 2016).

A second, intense volatility period spans mid-2019 to mid-2020. In mid-2019, European sovereign bond yields hit historic lows, driven by ECB interest rate cuts and economic uncertainty (ESMA 2019). In December 2019, the European Commission (EC) announced the European Green Deal, also giving an outlook on the Green Financing Strategy and highlighting the role of the public sector in it (EC 2019). Following on this, (ESMA 2020a) acknowledges the growing importance of ESG considerations among investors. In March–April 2020, the COVID-19 market turmoil caused market stress (ESMA 2020b).

The most persistent volatility phase occurs between 2022 and mid-2023, corresponding to overlapping crises. The Russian invasion of Ukraine in February 2022 led to significant turmoil in energy markets (ESMA 2022). The subsequent European energy crisis, spanning from June to September 2022, saw gas prices peak in August due to supply shortages, prompting government interventions, as discussed in the same report. Following the announcement of the Fit for 55 initiative (EC 2023), increased volatility in carbon pricing and green investments were observed (ESMA 2023a). Throughout 2023, particularly in January and July–August, ongoing energy market instability continued to impact electricity, natural gas, and carbon credit markets (ESMA 2023b).

The summary statistics presented in Table 1 provide a detailed characterisation of these two distinct regimes identified in the MS-VAR model. The findings reveal differences in terms of persistence, volatility, and inflation expectation dynamics, depending on whether the model includes the TRI or the PRI in conjunction with the two-year or ten-year BEIRs.

We identify regimes according to volatility, with Regime 2 characterised by substantial increases in standard deviations of all variables, particularly in BEIRs. When the two-year BEIR is included in the model, its variance increases almost 50-fold. In contrast, the ten-year BEIR exhibits a more moderate rise in standard deviation, suggesting that shorter-term inflation expectations respond more aggressively to regime shifts. This disparity likely reflects differences in how inflation expectations are formed across horizons. Short-term expectations, as captured by the two-year BEIR, are more reactive to immediate shocks, such as supply chain disruptions, geopolitical events, or abrupt monetary policy adjustments (Boeckx, Iania, and Wauters 2025). In contrast, long-term expectations, reflected in the ten-year BEIR, tend to be more anchored, as they incorporate central bank credibility and structural inflation trends (Boeckx, Iania, and Wauters 2025; Diegel and Nautz 2021; Yetman 2020). Additionally, investors may adjust their short-term inflation outlook more frequently in response to market volatility, whereas long-term expectations remain relatively stable unless a fundamental shift in monetary policy or economic conditions occurs (Boeckx, Iania, and Wauters 2025; Diegel and Nautz 2021; Pesci et al. 2022).

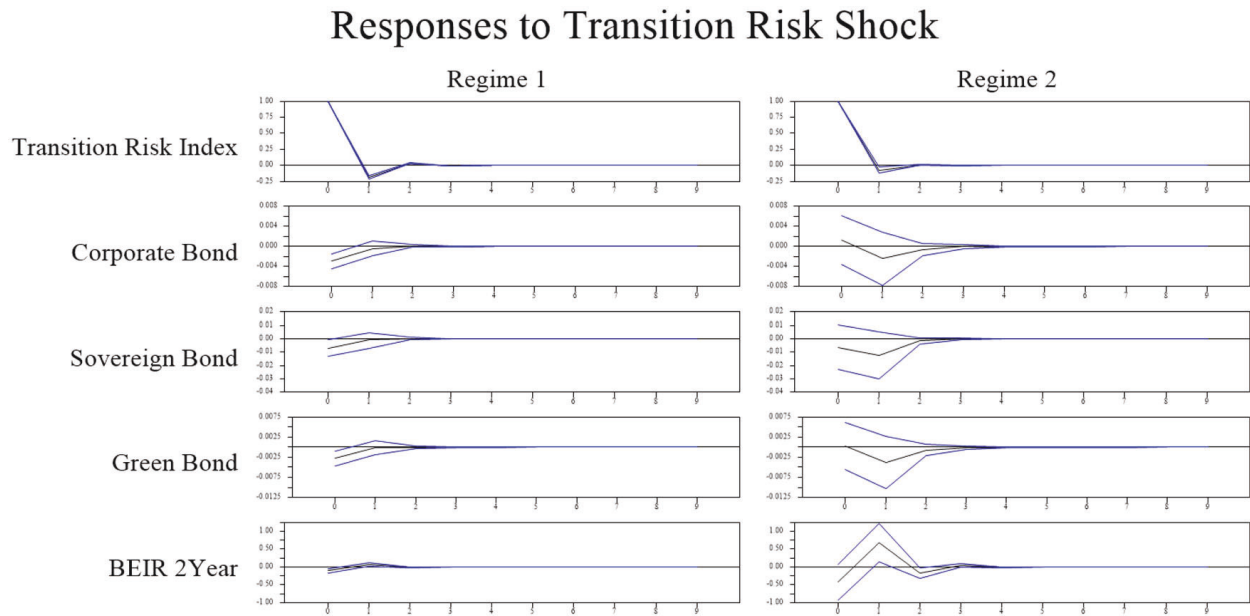


Figure 2. GIRFs illustrating the effects of an exogenous shock to the TRI on two-year BEIR, as well as various bond classes, under low- and high volatility regimes. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

Table 1. Regime-specific summary statistics for transition risk (Panel A) and physical risk (Panel B).

Parameters	2-Year BEIR		10-Year BEIR	
	Regime 1	Regime 2	Regime 1	Regime 2
	Panel A: Transition risk			
Probability to stay in regime	0.92	0.78	0.93	0.80
Regime Frequency (%)	73.41	26.59	71.86	28.14
Avg. Crisis Duration (Periods)	–	4.81	–	5.00
Standard deviation				
Transition Risk	0.0197	0.0253	0.0197	0.0255
Corporate Bond	0.0000	0.0032	0.0000	0.0032
Sovereign Bond	0.0045	0.0100	0.0045	0.0105
Green Bond	0.0000	0.0032	0.0000	0.0032
Two-year BEIR	0.0448	0.3062	–	–
Ten-year BEIR	–	–	0.0221	0.0418
	Panel B: Physical Risk			
Probability to stay in regime	0.93	0.78	0.93	0.80
Regime Frequency (%)	74.05	25.95	73.03	26.97
Avg. Crisis Duration (Periods)	–	4.39	–	5.58
Standard deviation				
Physical Risk	0.0197	0.0228	0.0200	0.0219
Corporate Bond	0.0000	0.0032	0.0000	0.0032
Sovereign Bond	0.0045	0.0100	0.0045	0.0105
Green Bond	0.0000	0.0032	0.0000	0.0032
Two-year BEIR	0.0452	0.3077	–	–
Ten-year BEIR	–	–	0.0226	0.0421

Notes: This table summarises regime-specific characteristics from the MS-VAR model. Regime 1 is the low volatility state; Regime 2 is the high volatility (crisis) state. The probability of remaining in each regime is derived from the transition probability matrix. The average duration of each state is computed as $1/(1 - P(i, i))$. Standard deviations are the square roots of the diagonal elements of the residual covariance matrix (Σ). *Column mapping:* Columns 2-3 report statistics for specifications that include the **two-year** BEIR; columns 4-5 refer to specifications that include the **ten-year** BEIR. Accordingly, the BEIR rows report regime-specific standard deviations only for the maturity included in the corresponding specification.

The standard deviation of transition risk and physical risk remains relatively stable across both regimes, indicating that while these risks contribute to the transition between states, their own volatility does not change substantially. However, bond market dynamics exhibit moderate shifts: the variance of sovereign bonds and green bonds increases by a factor of 5–10% in Regime 2, while corporate bonds show minimal variance changes, suggesting that sovereign debt instruments and green assets are more sensitive to shifts in market volatility. Across all specifications, Regime 1 (low volatility state) exhibits a high degree of persistence with an average duration of around five days. Conversely, Regime 2 (high volatility state) is less persistent with a shorter duration.

4. Results and discussion

To assess the impact of climate-related risks on inflation expectations and bond markets, we present the model's estimated results using GIRFs. These allow us to examine the shock transmission dynamics among the variables, revealing how a shock to one asset class or risk factor can impact others across different volatility regimes. Understanding these potential interdependencies and contagion effects (Dungey, Flavin, and Lagoa-Varela 2020) is crucial for financial market participants in managing portfolio risk and assessing systemic vulnerabilities.⁷ To improve interpretability and provide context, for each shock a short example relating to our data will be initially introduced.⁸

It is crucial to clarify that our use of GIRFs within the Bayesian MS-VAR framework provides a statistical characterisation of regime-dependent shock transmission and co-movement dynamics, rather than a structural identification of causal contagion channels. Shocks are treated as reduced-form innovations $\varepsilon_t | S_t = s$ drawn from the regime-specific covariance matrix Σ_s . No contemporaneous or sign restrictions are imposed, so the responses are invariant to variable ordering but remain model- and distribution-dependent, and should therefore not be interpreted as causal. This reduced-form perspective is well-suited to our objective of examining how TRI and PRI interact with bond market variables across volatility regimes. While structural identification schemes, such as recursive orderings or sign restrictions, are possible, they require strong and potentially contested priors and thus lie beyond the scope of this paper. From a risk-management standpoint, structural identification is not essential as GIRFs quantify the size, direction, and persistence of generalised shocks, offering robust insights into spillovers and connectedness without committing to a specific structural scheme. Accordingly, we emphasise predictive interdependence rather than causation. Significant lagged cross-effects indicate that variables help forecast one another conditional on regime, though formal Granger causality requires explicit, regime-specific testing. All GIRFs are conditional on the initial regime and the transition matrix, and we report the shock scaling (one standard deviation) and conditioning choices to make this dependence transparent.

We further examine how shocks transmit to inflation expectations and bond markets across regimes by analysing cross-regime changes in the comovement of variables. Following Dungey, Flavin, and Lagoa-Varela (2020), we classify these dynamics into three categories: contagion, where comovement among the shocked and other variables increases in the high volatility regime; interdependence, where comovement remains unchanged across regimes; and decoupling, where comovement decreases under high volatility. This classification captures whether climate-related and other shocks statistically intensify financial linkages (contagion), preserve their stability (interdependence), or weaken connections (decoupling). In our setting, comovement refers to both the strength and persistence of response activity relative to the shocked variable observed in the regime-dependent impulse responses.

This framework provides a rigorous description of observed co-movement patterns and helps to identify whether shifts in volatility regimes reflect structural market changes or heightened investor sensitivity to specific shocks. The dynamics across specifications generally display a high degree of similarity and are therefore described jointly, with explicit discussion of any deviations. Such deviations may signal evolving structural conditions or non-linear amplification effects during financial stress. Importantly, we emphasise that these are statistically observed co-movement dynamics rather than deeper structural contagion mechanisms, which we highlight as avenues for future research.⁹

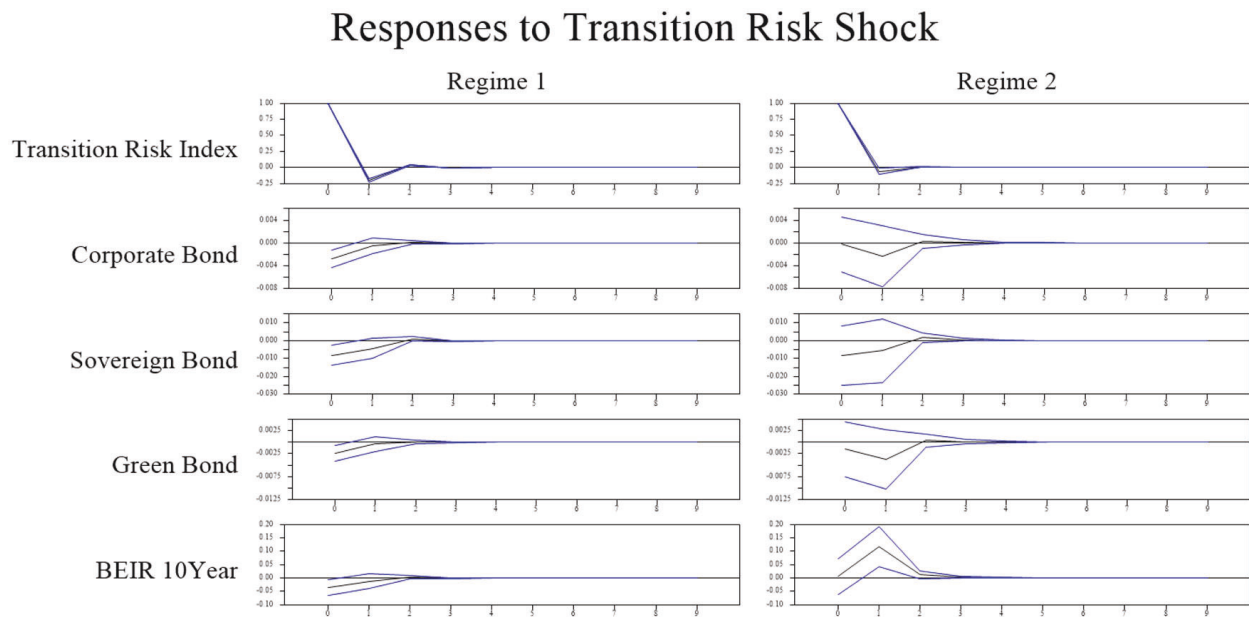


Figure 3. GIRFs illustrating the effects of an exogenous shock to the TRI on ten-year BEIR, as well as various bond classes, under low- and high volatility regimes. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

4.1. Shock transmission of transition risk to inflation expectations and bond markets

An example of a green regulatory shock occurred in July 2021 with the announcement of a more restrictive policy on carbon emission allowance supply within the EU Emissions Trading System under the Fit for 55 initiative, intending to raise carbon prices (European Commission 2021).

Figures 2 and 3 illustrate the regime-dependent response to a shock in the TRI.

In both Figures 2 and 3, in the low volatility regime (Regime 1), the TRI exhibits a negative rebound at period one before converging. Green bonds, corporate bonds, and sovereign bonds display nuanced but significant negative reactions. Additionally, the two-year and ten-year BEIRs show slight negative responses.

In the high volatility regime (Regime 2), the TRI response remains unchanged. However, green bonds, corporate bonds, and sovereign bonds no longer exhibit a significant reaction, indicating decoupling. In contrast, both BEIRs display a significant positive effect with widened confidence interval (CI) bands, with the two-year maturity reacting more strongly than the ten-year maturity, indicating contagion.

Our robustness checks in Figures A8 and A9 yield similar patterns. While the nuanced effects on bonds dissipate in the low volatility regime, the confidence intervals of the BEIRs widen further and encompass the zero line. Accordingly, regarding inflation expectations, we find that increased news coverage of the green transition leads to a slight but robust decline in two-year but not ten-year inflation expectations in the low volatility regime. This aligns with the intuition that inflationary effects are more pronounced in the short-term. Yet long-term inflation expectations remain more anchored, as markets anticipate that the ECB will guide inflation toward its target (Bernanke 2007; Christelis et al. 2020).

Our findings indicate that the bond classes analysed are at most negatively affected in the low volatility regime, while they show no significant effects in the high volatility regime. This suggests that in periods of heightened volatility, investors' attention may be more focussed on immediate or prominent risks, reducing the influence of transition concerns. This aligns with theoretical expectations that in turbulent markets, less salient risks receive less weight in decision-making (Bordalo, Gennaioli, and Shleifer 2012). The given high volatility periods align with key crises, such as the aftermath of the euro crisis, the COVID-19 pandemic, and geopolitical instability, including the Russian conflict, during which investors prioritised pressing financial and economic concerns over transition risks. In addition, the divergence between green and corporate bonds remains relatively subtle. This is in line with the assessment of European authorities that the taken policy measures facilitate a gradual, structured transition and should not cause sudden disruptions (European Central Bank 2022).

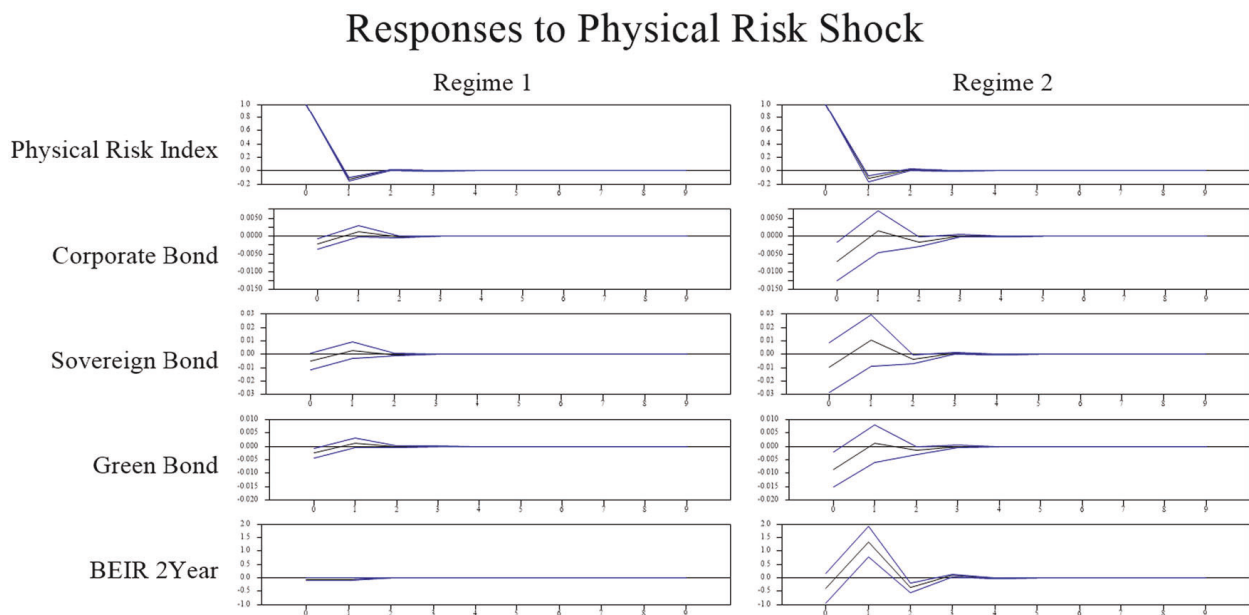


Figure 4. GIRFs displaying the effects of an exogenous shock to the PRI on two-year BEIR and bond markets under different volatility regimes. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

4.2. Shock transmission of physical climate risk to inflation expectations and bond markets

One example of a physical climate shock would be the summer 2022 heatwave, which triggered one of Europe's most severe droughts in recent history, leading to critically low water levels in major rivers. This event had far-reaching consequences across agriculture, energy production, and transportation (Toreti et al. 2022).

Figures 4 and 5 illustrate distinct regime-dependent dynamics following a shock to PRI.

In the low volatility regime (Regime 1), the PRI exhibits a negative rebound at period one before converging. Corporate bonds and green bonds exhibit nuanced but significantly negative reactions while sovereign bonds remain insignificant. The ten-year BEIR reacts negatively, whereas the two-year BEIR exhibits no significant response. In the high volatility regime (Regime 2), the PRI follows a similar pattern, converging at period two after a small negative rebound at period one. All bond classes exhibit marginal reactions in both specifications, though with slight variations.

In Figure 4, green and corporate bonds exhibit a slightly stronger negative response. Sovereign bonds initially show no significant reaction but all experience a marginal negative effect at period two, indicating contagion. In Figure 5, green and corporate bonds react like before, suggesting interdependence. Sovereign bonds show a slight negative response when the shock occurs, turning marginally positive at period one, suggesting contagion but with some correction effects. Additionally, the two-year BEIR exhibits a notable significant positive impact when the shock occurs. At the same time, the ten-year BEIR turns significantly positive at period one, indicating contagion for both BEIR horizons.

The robustness checks in Figures A6 and A7 broadly confirm these results, reinforcing the observed effect patterns for bond classes and the two-year BEIR. In contrast, the findings for the ten-year BEIR are not consistent. This pattern suggests that markets respond faster to physical climate risk news in the short-term while long-term inflation expectations remain more stable. This is consistent with the expectation that, while rising long-term expectations highlight their structural importance, markets retain confidence in the ECB's ability to ensure long-term price stability.

In terms of bonds, physical climate risk news has a negligible influence on sovereign debt across both regimes, reflecting their safe-haven status and lower sensitivity to non-systemic shocks. Green and corporate bonds are negatively affected in both regimes, but the impact is stronger in the high volatility regime, indicating contagion. This suggests that as firms face greater financial and operational risks, investors anticipate higher costs and weaker economic activity due to physical climate-related damages. Additionally, the increased systematic

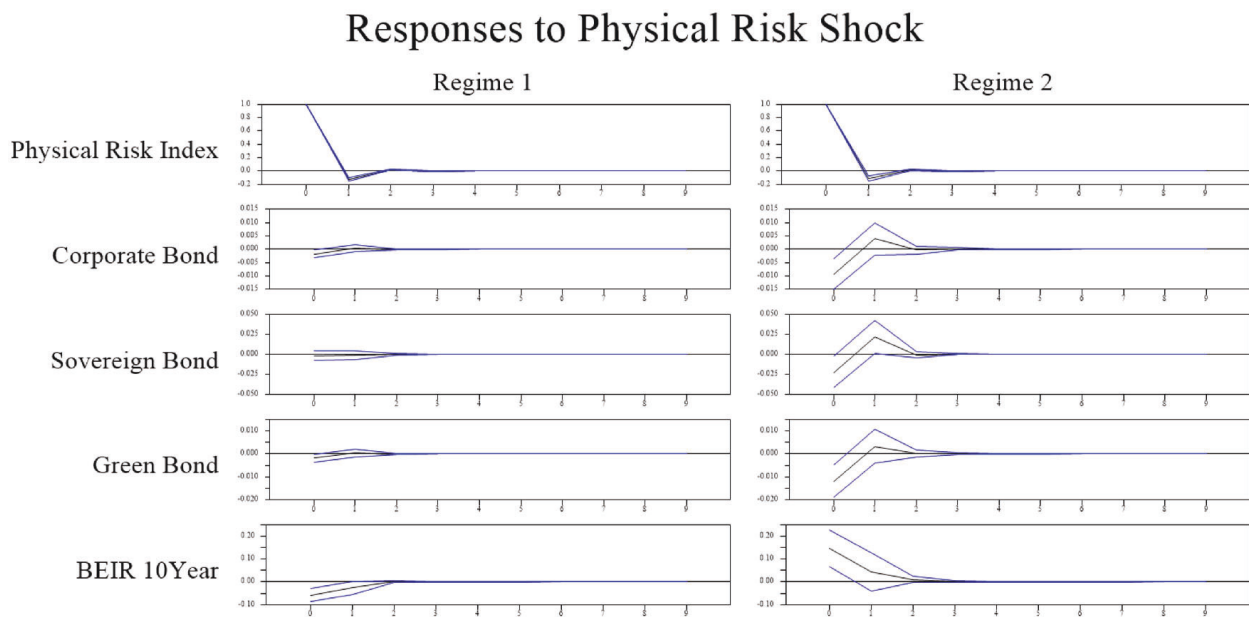


Figure 5. GIRFs displaying the effects of an exogenous shock to the PRI on ten-year BEIR and bond markets under different volatility regimes. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

risk exposure of these asset classes to physical climate events during market downturns, prompting investors to incorporate such risks into portfolio stress testing and scenario analysis, behavioural factors (see Schmitt and Westerhoff 2017; Thurner, Farmer, and Geanakoplos 2012) likely amplify the effects, leading to stronger market reactions in high volatility market regimes.

4.3. Shock transmission of inflation expectations to bond markets

Boeckx, Iania, and Wauters (2025) find that two-year inflation expectations are more sensitive to supply shocks, while ten-year inflation expectations are primarily influenced by demand factors such as economic growth and interest rate expectations. Accordingly, an appropriate example of an upward shock to short-term inflation expectations is the Russian invasion of Ukraine in early 2022. This event triggered severe disruptions in the energy supply, increased energy prices, and increased economic uncertainty, ultimately increasing short-term inflation expectations throughout Europe (Lane 2022). In the same vein, concerning a shock to ten-year inflation expectations, an example is the roll-out of COVID-19 vaccines in early 2021, which improved the economic outlook amid deflationary pressures and led to higher inflation forecasts (Arnold 2021).¹⁰

Figures 6 and 7 illustrate the dynamics following a positive shock to the two-year BEIR ahead.

In the low volatility regime (Regime 1), the two-year inflation expectation proxy converges directly at period one. Corporate bonds and sovereign bonds remain unaffected in all periods. Green bonds also do not exhibit a response in Figure 6; however, in Figure 7, they display a marginally significant positive effect in period one. The TRI follows a brief oscillatory pattern. The PRI does not exhibit any significant response.

In the high volatility regime (Regime 2), the two-year BEIR experiences a negative rebound at period one before returning to baseline at period two. Corporate bonds, sovereign bonds, and green bonds exhibit oscillatory patterns, showing no significant movement at the time of the shock, followed by a negative reaction at period one and full convergence at period two, indicating a stronger shock transmission, classified as contagion. The TRI's and PRI's relationship to the shocked variable remains unchanged across regimes.

Figures 8 and 9 illustrate the propagation of a positive shock to the ten-year BEIR.

In the low volatility regime (Regime 1), the ten-year BEIR converges at period one. Corporate bonds and green bonds remain insignificant at the time of the shock but exhibit a positive reaction. Sovereign bonds show no measurable reaction. The TRI and PRI display no significant response across all periods.

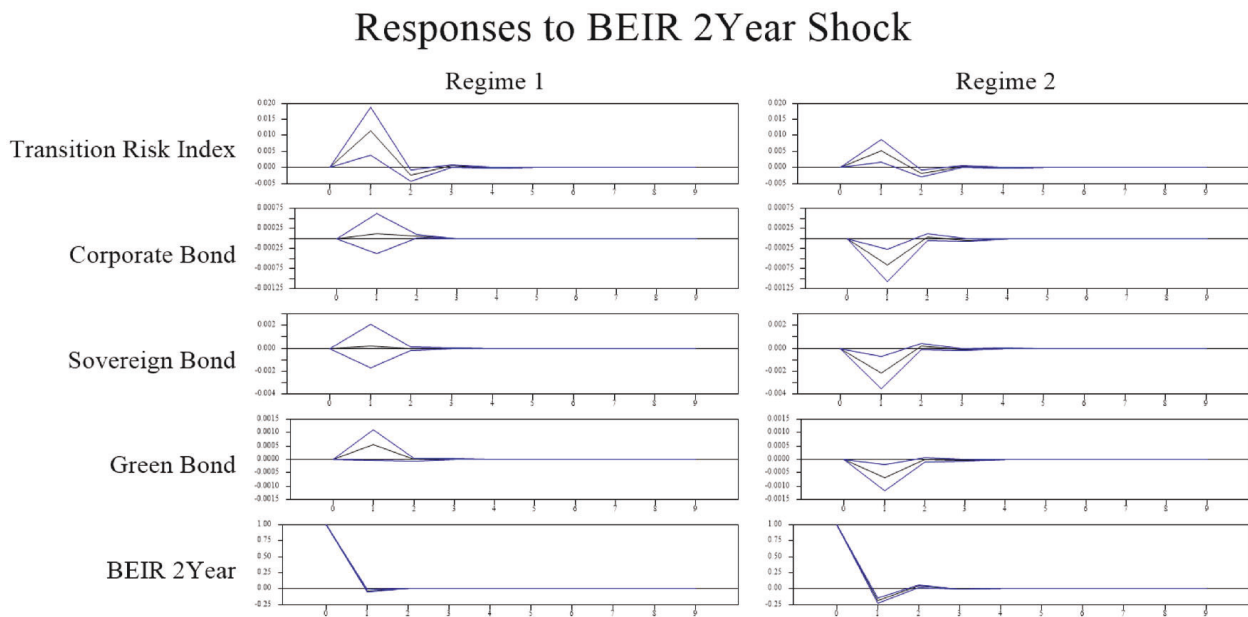


Figure 6. GIRFs illustrating the impact of an exogenous shock to the two-year BEIR on TRI and bond markets across volatility regimes. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

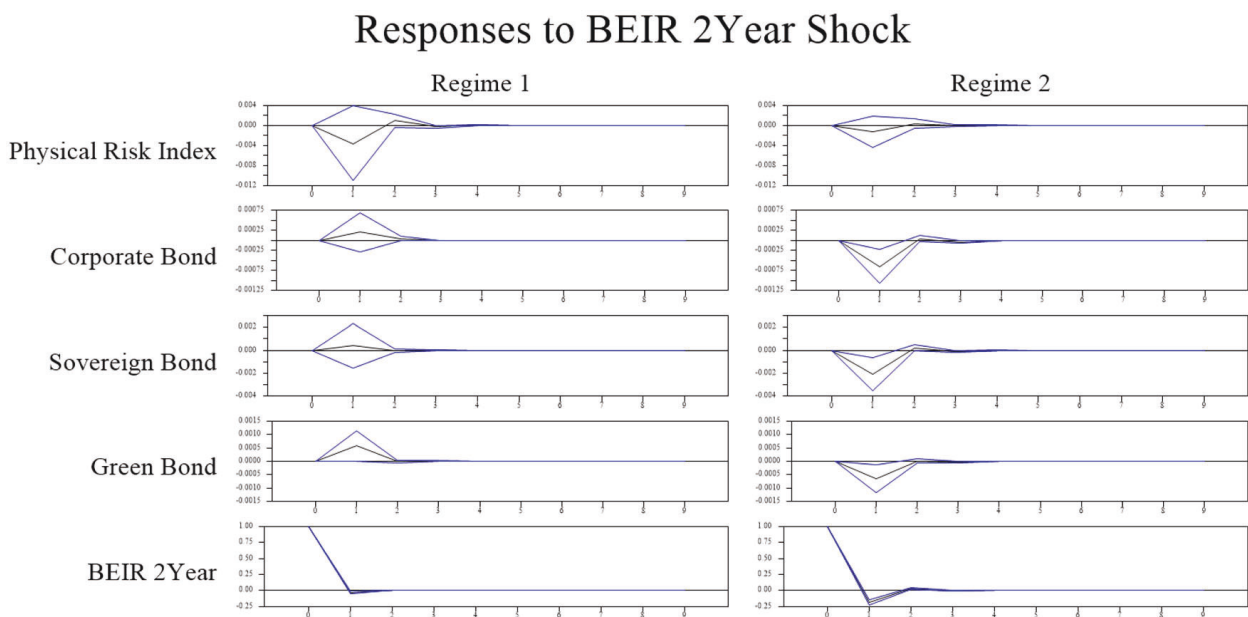


Figure 7. GIRFs illustrating the impact of an exogenous shock to the two-year BEIR on PRI, and bond markets across volatility regimes. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

In the high volatility regime (Regime 2), the ten-year BEIR undergoes a more prolonged adjustment. Corporate bonds, sovereign bonds, and green bonds exhibit a delayed response and an extended adjustment period, classified as contagion. The TRI and PRI remain insignificant throughout.

Regarding the effect of a shock on short-term inflation expectations the robustness checks in Figures A10 and A11 support all findings. There are negligible responses in the low volatility regime but in the high volatility regime there are significant yet nuanced negative effects across bond classes. This suggests that, in high volatility regimes, bond markets price in inflationary risks more sharply, potentially due to concerns over monetary tightening and increased discounting of future bond payments (Cochrane 2022; Dai, Singleton, and Yang 2007;

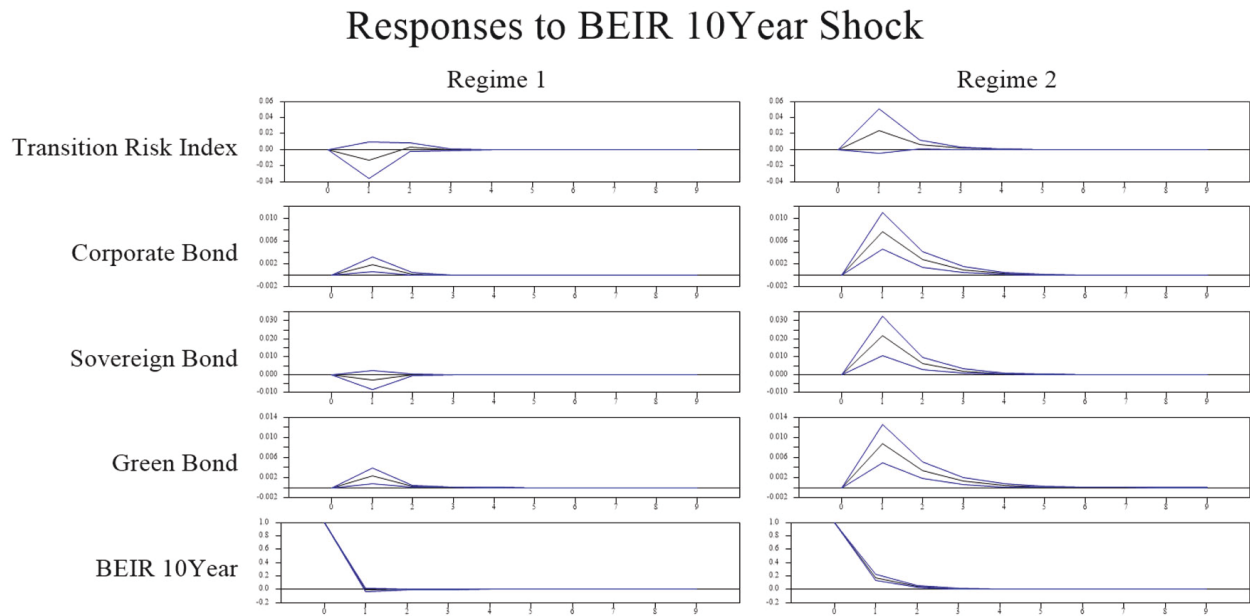


Figure 8. GIRFs showing the transmission dynamics of a ten-year BEIR shock on TRI and bond markets. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

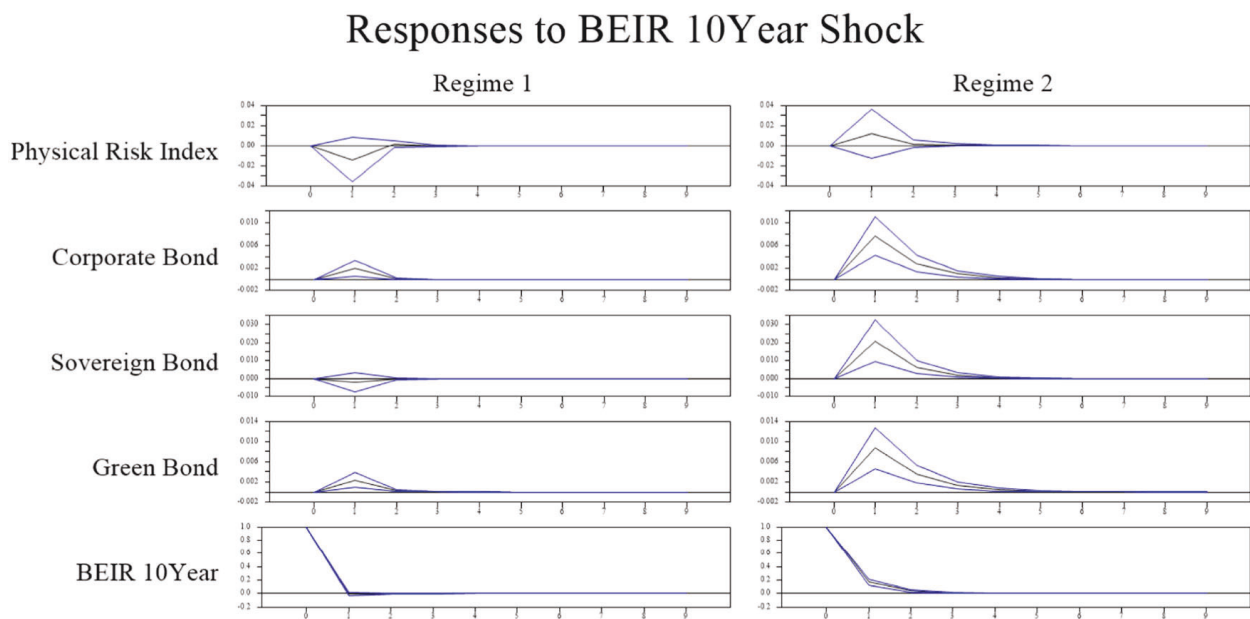


Figure 9. GIRFs showing the transmission dynamics of a ten-year BEIR shock on PRI and bond markets. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

Song 2017). For portfolio managers, this sensitivity underscores the importance of actively managing interest rate risk and inflation hedging strategies during periods of market stress. Understanding the effects of inflation expectations on bonds requires acknowledging that expected real interest rates depend on anticipated monetary policy decisions. In light of the provided example, the ECB initially interpreted the shock as transitory and hesitated to tighten its monetary policy. Moreover, in the other high volatility clusters outlined in Section 2, market circumstances constrained the ECB from adopting a hawkish stance.¹¹ In this context, the declining real value of bond payments further eroded investor confidence, reinforcing bond market instability.

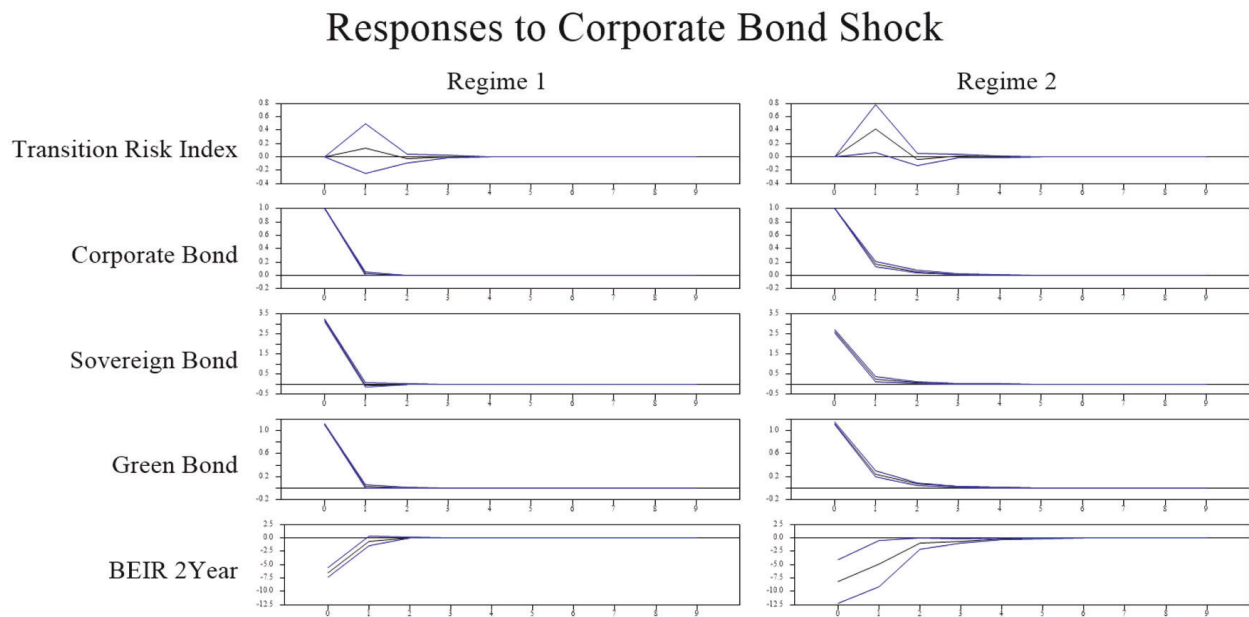


Figure 10. GIRFs illustrating the response of two-year BEIR, the TRI, and bond markets to a corporate bond shock under different volatility regimes. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

The findings on the effects of shocks to ten-year horizon inflation expectations are similarly robust (see Figures A12 and A13) with the exception of effects on bond classes in the low volatility regime. In contrast, the high volatility regime generates robust positive responses across all bond classes. While higher long-term inflation expectations may coincide with stronger economic prospects in specific contexts, they can also signal heightened inflation risks, prompting concerns about future monetary tightening (Diegel and Nautz 2021; Jarociński and Karadi 2020). In this vein, Chen, Chiang, and Lin (2023) show that in times of uncertainty and inflation-induced market volatility, investors seek a safe haven in fixed income, having a positive impact on bond returns and partially offsetting the negative effects of inflation on bond prices. Overall, the results of both inflation expectation horizons indicate stronger reactions to their own shocks in high volatility periods, broadly in line with Grishchenko, Mouabbi, and Renne (2017), Corsello, Neri, and Tagliabracci (2021), and Istrefi and PiloIU (2014).

4.4. Shock transmissions among bond classes

Finally, we examine the mutual effects of shocks across bond classes. To provide context, we introduce examples of such shocks. For corporate bonds, a positive shock can result from fiscal stimulus targeting the broader economy, as seen by the Next Generation EU program, a €750 billion recovery instrument aimed at supporting post-pandemic economic recovery (Havlik et al. 2021). For green bonds, a relevant positive shock stems from fiscal stimulus directed at the green economy, such as the European Green Deal Investment Plan, which aims to mobilise at least €1 trillion over the next decade to accelerate the transition to climate neutrality (European Environment Agency 2024b). For sovereign bonds, a positive shock can arise from flight-to-safety dynamics, as observed during the onset of COVID-19 in early 2020, when investors sought refuge in sovereign debt amid heightened economic uncertainty (ESMA 2021).

Figures 10, 11, 12 and 13 illustrate the system's response to a positive shock from the corporate bond variable.

In the low volatility regime (Regime 1), corporate bonds exhibit a quick convergence. Green bonds respond with equal strength and converge directly. Sovereign bonds also react positively but with more than three times the magnitude of the corporate bond shock. The two-year BEIR and the ten-year BEIR respond negatively at the time of the shock, with shock amplification reaching approximately six times the corporate bond shock. The TRI remains insignificant, while the PRI exhibits brief oscillatory behaviour.

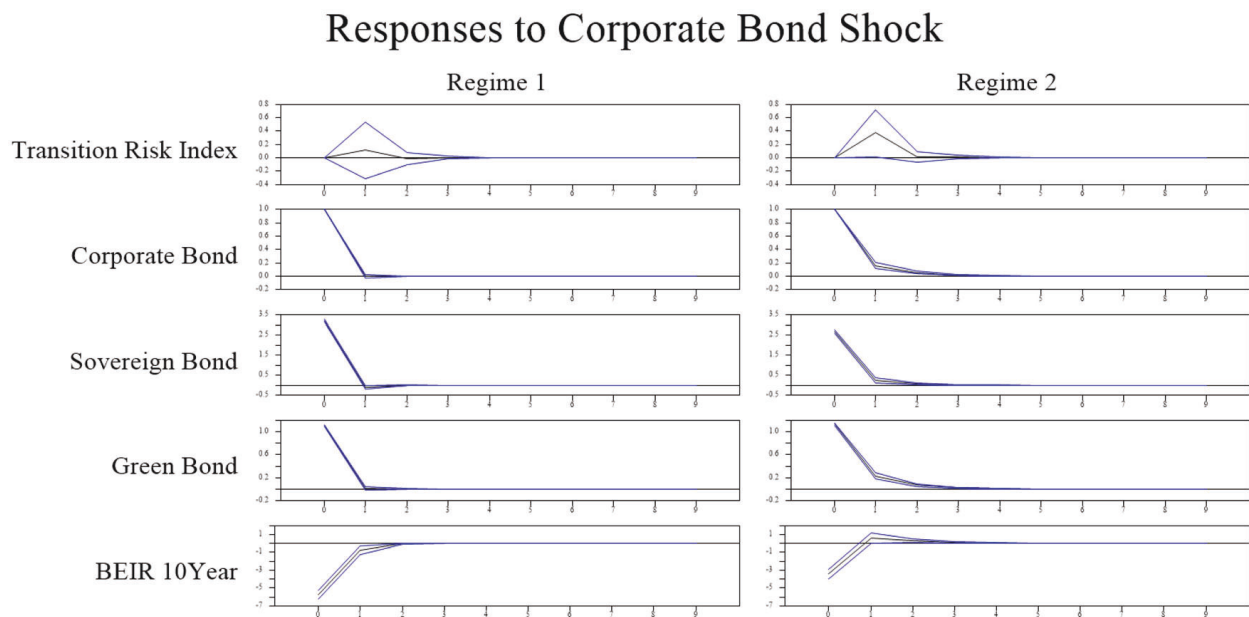


Figure 11. GIRFs illustrating the response of ten-year BEIR, the TRI, and bond markets to a corporate bond shock under different volatility regimes. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

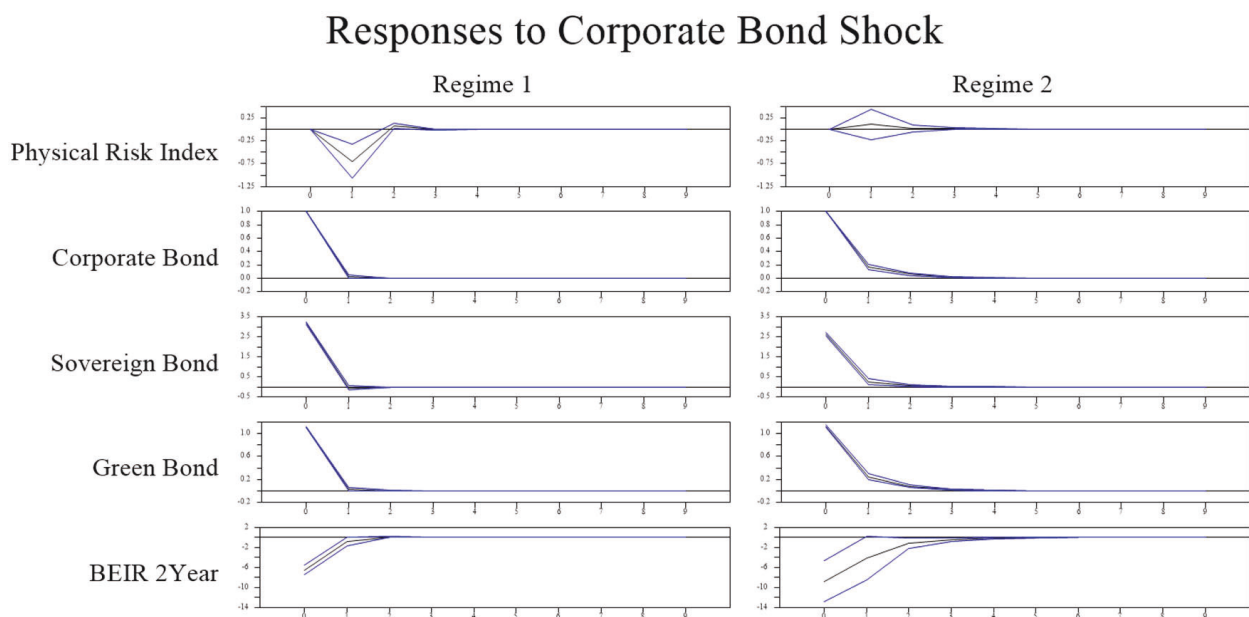


Figure 12. GIRFs illustrating the response of two-year BEIR, the PRI, and bond markets to a corporate bond shock under different volatility regimes. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

In the high volatility regime (Regime 2), corporate bonds exhibit monotonic convergence until period three following the shock. Green bonds and sovereign bonds respond similarly positively, yet with longer convergence, both indicating contagion patterns. The two-year BEIR also exhibits a significant negative reaction at period one, stabilising by period three, while the ten-year BEIR reacts negatively at the time of the shock and converges by period three. The TRI response varies across specifications, for example in Figure 10, it exhibits a slight increase with heightened uncertainty, whereas in Figure 11, it remains insignificant. Similarly, the PRI does not exhibit a significant effect.

Figures 14, 15, 16 and 17 illustrate the response following a shock to the green bond index.

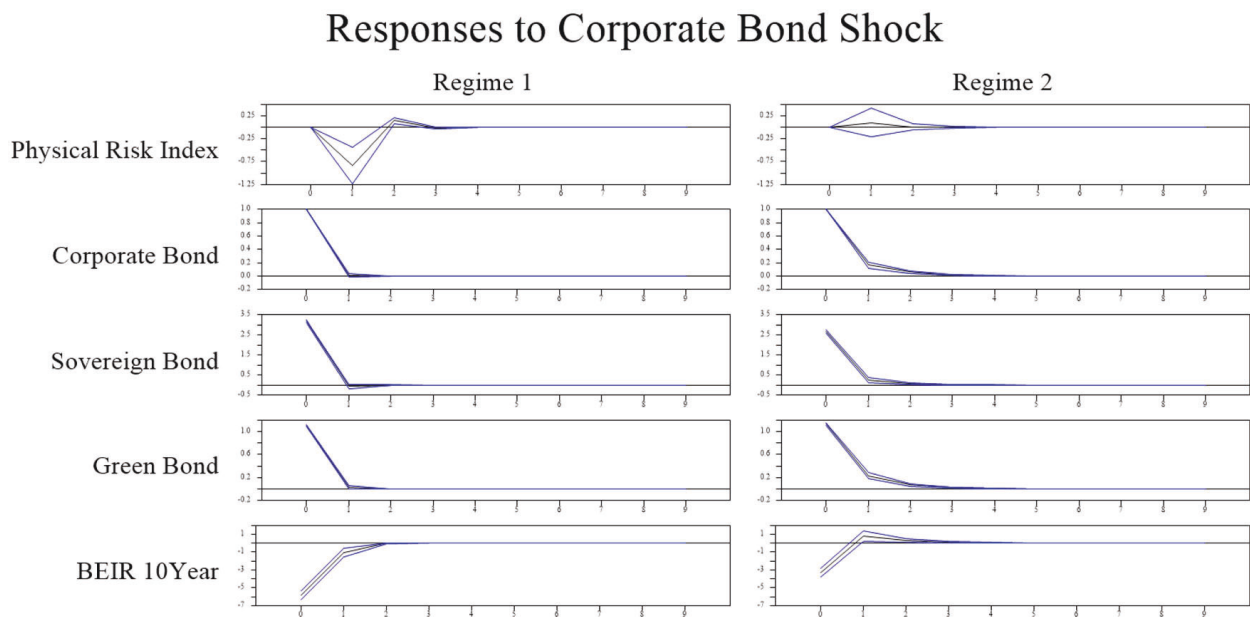


Figure 13. GIRFs illustrating the response of ten-year BEIR, the PRI, and bond markets to a corporate bond shock under different volatility regimes. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

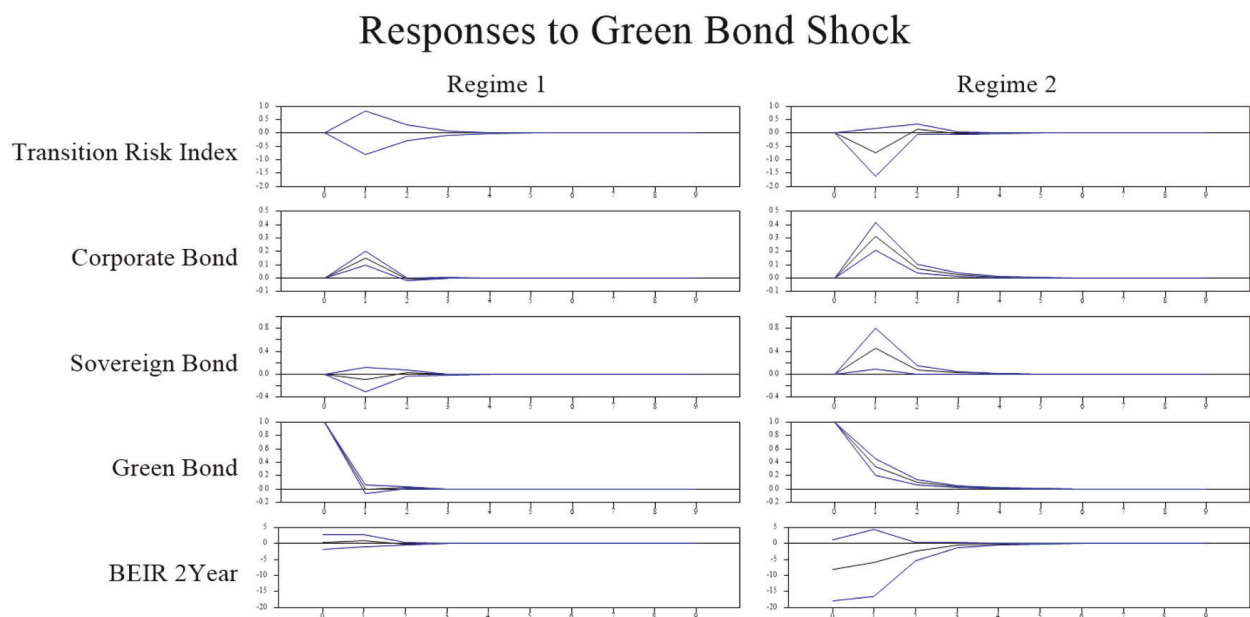


Figure 14. GIRFs showing the impact of an exogenous shock to Green Bonds on two-year BEIR, the TRI, and bond markets. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

In the low volatility regime (Regime 1), green bonds exhibit monotonic convergence at period one. Corporate bonds respond positively at period one. Sovereign bonds show no significant reaction. The two-year BEIR initially rises at the time of the shock, undergoing a negative adjustment at period one. The ten-year BEIR remains unresponsive. Similarly, the TRI shows no reaction, while the PRI responds with short-lived fluctuations.

In the high volatility regime (Regime 2), green bonds mirror their behaviour in the low volatility regime. Corporate bonds and sovereign bonds exhibit a positive effect at period one, with extended adjustments, indicating stronger shock transmission and, thus, contagion. In contrast, the two-year BEIR remains unchanged across all periods. Finally, the ten-year BEIR, the TRI and the PRI show no meaningful responses.

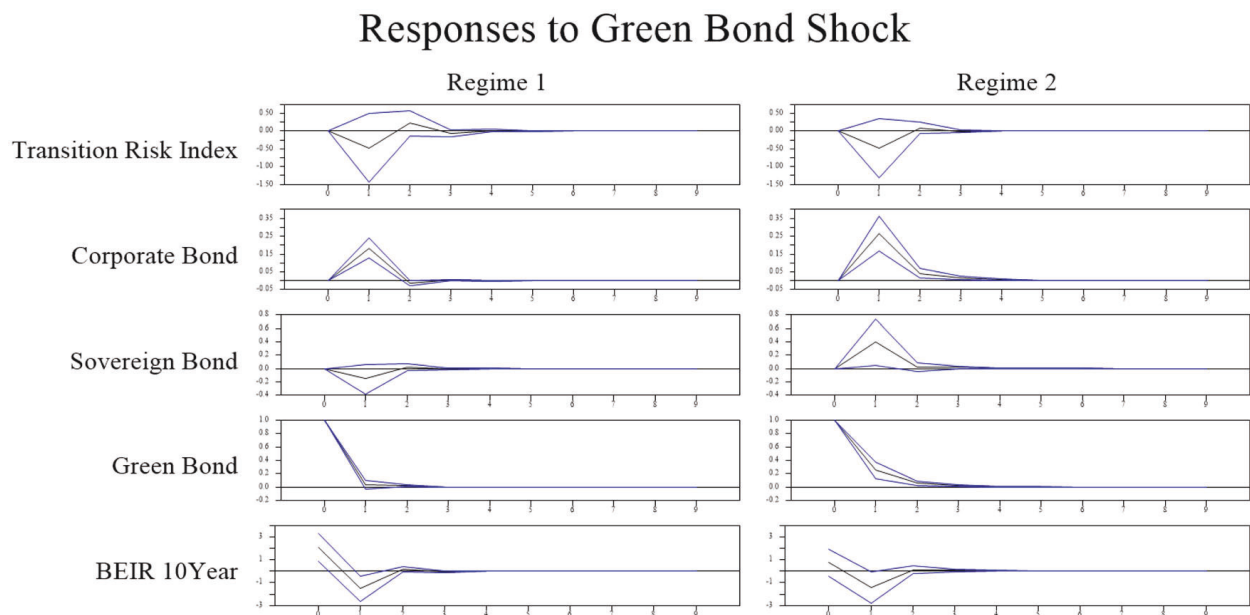


Figure 15. GIRFs showing the impact of an exogenous shock to Green Bonds on ten-year BEIR, the TRI, and bond markets. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

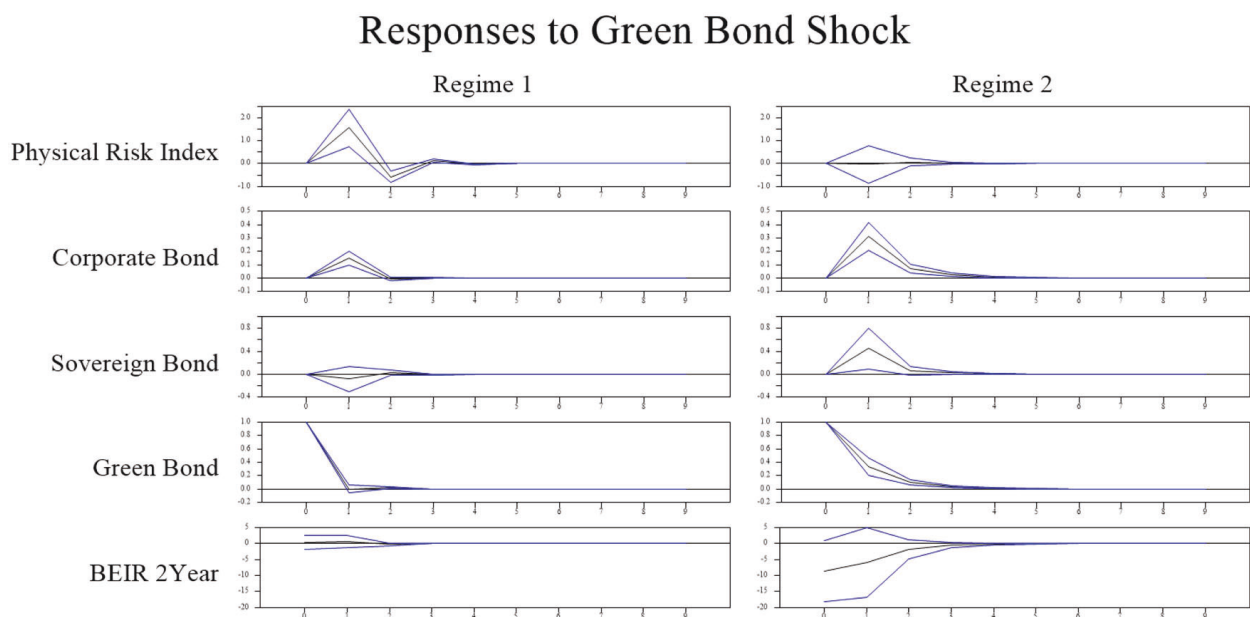


Figure 16. GIRFs showing the impact of an exogenous shock to Green Bonds on two-year BEIR, the PRI, and bond markets. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

Figures 18, 19, 20 and 21 capture the system's dynamic response to a shock to sovereign bonds.

In the low volatility regime (Regime 1) sovereign bonds exhibit monotonic convergence at period one. Green bonds respond positively at the time of the shock, followed by a negative reaction before fully converging at period two. Corporate bonds display a negative response at period one. The two- and ten-year BEIR experience a significant negative reaction at the time of the shock with nuanced shock amplification. The TRI and PRI remain insignificant.

In the high volatility regime (Regime 2), sovereign bonds behave as in the low volatility regime. Green bonds exhibit a positive reaction at the time of the shock, followed by a negative response at period one. However, they

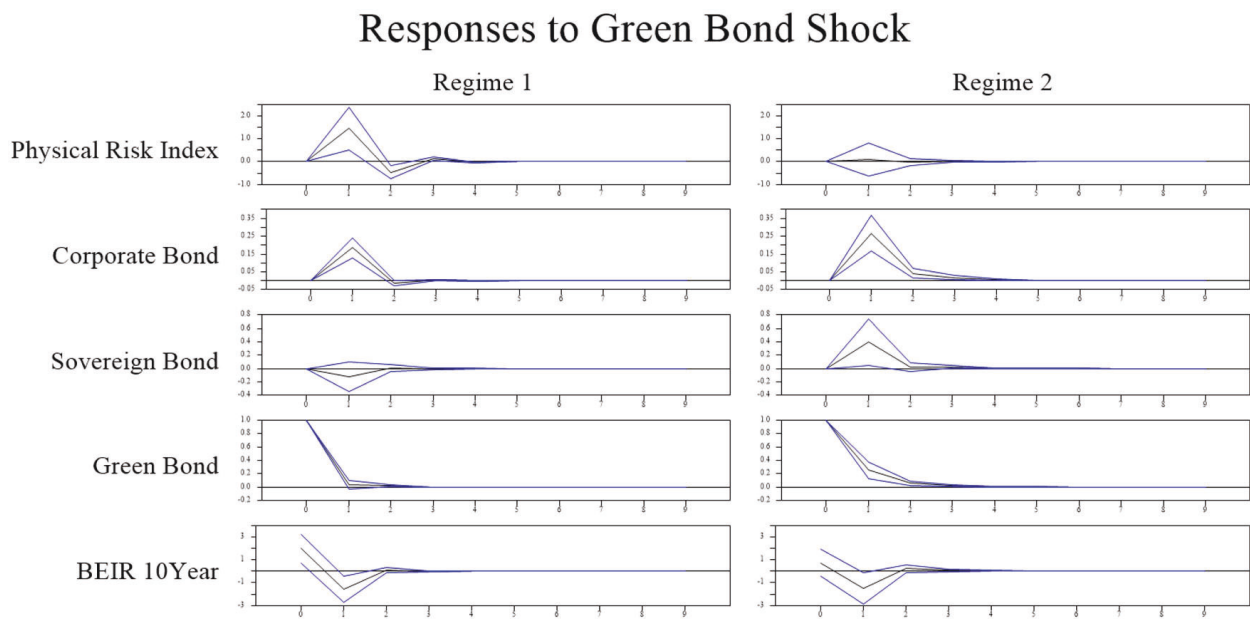


Figure 17. GIRFs showing the impact of an exogenous shock to Green Bonds on ten-year BEIR, the PRI, and bond markets. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

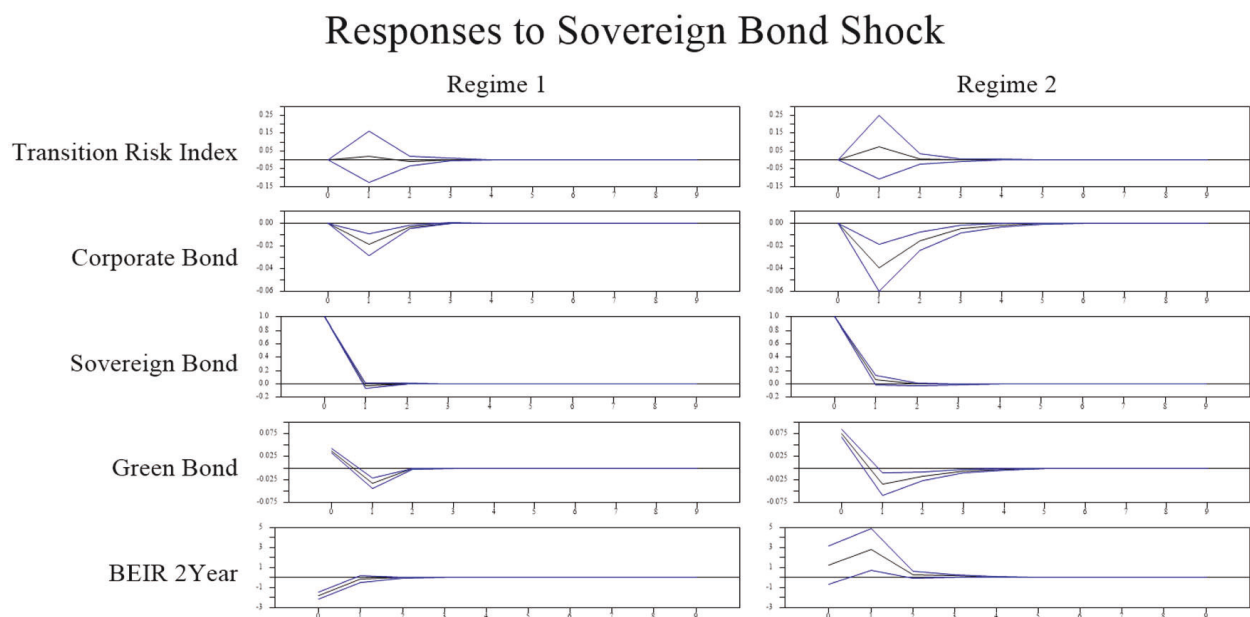


Figure 18. GIRFs displaying the effects of a Sovereign Bond shock on two-year BEIR, the TRI, and bond markets under different volatility regimes. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

undergo a more prolonged adjustment, with monotonic convergence extending until period four, indicating contagion. Corporate bonds again show a negative response at period one, with a more extended adjustment process, also suggesting contagion. The ten-year BEIR exhibits a significant negative reaction at period one, again showing nuanced shock amplification. In contrast, the two-year BEIR turns significantly positive at period one. The TRI and PRI remain insignificant.

The robustness checks in Figures A14 to A25 support the findings, while the evidence for green bonds is weaker and less stable.¹² However, the robust results confirm that green bonds and corporate bonds exhibit the strongest interrelationships, responding similarly to corporate shocks and showing amplified transmission

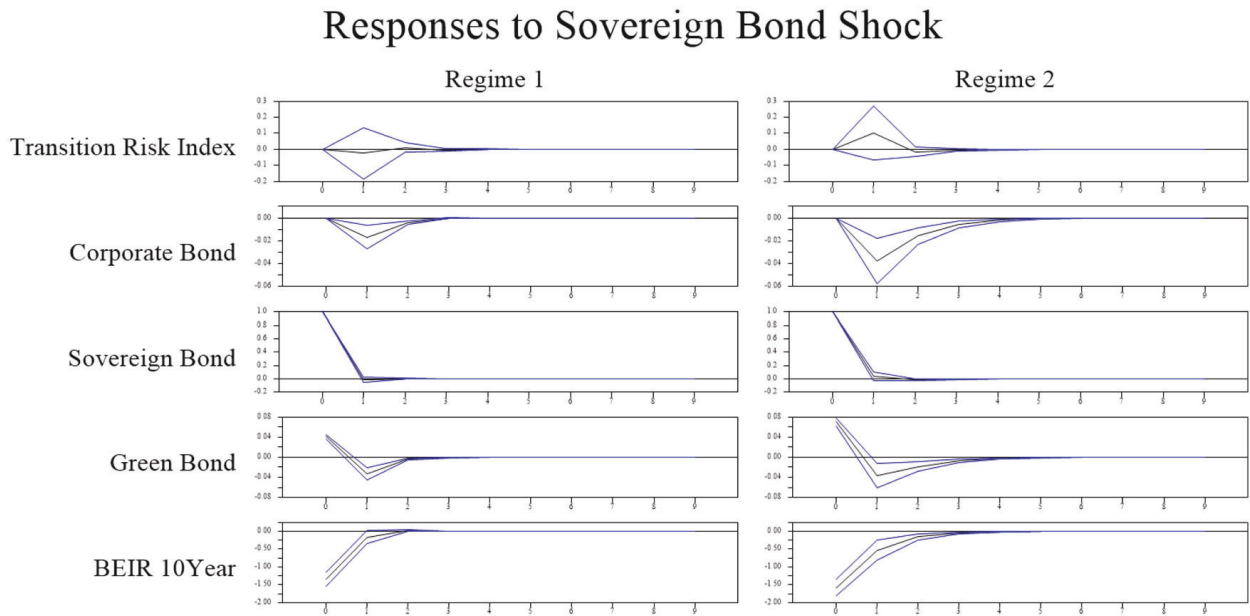


Figure 19. GIRFs displaying the effects of a Sovereign Bond shock on ten-year BEIR, the TRI, and bond markets under different volatility regimes. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

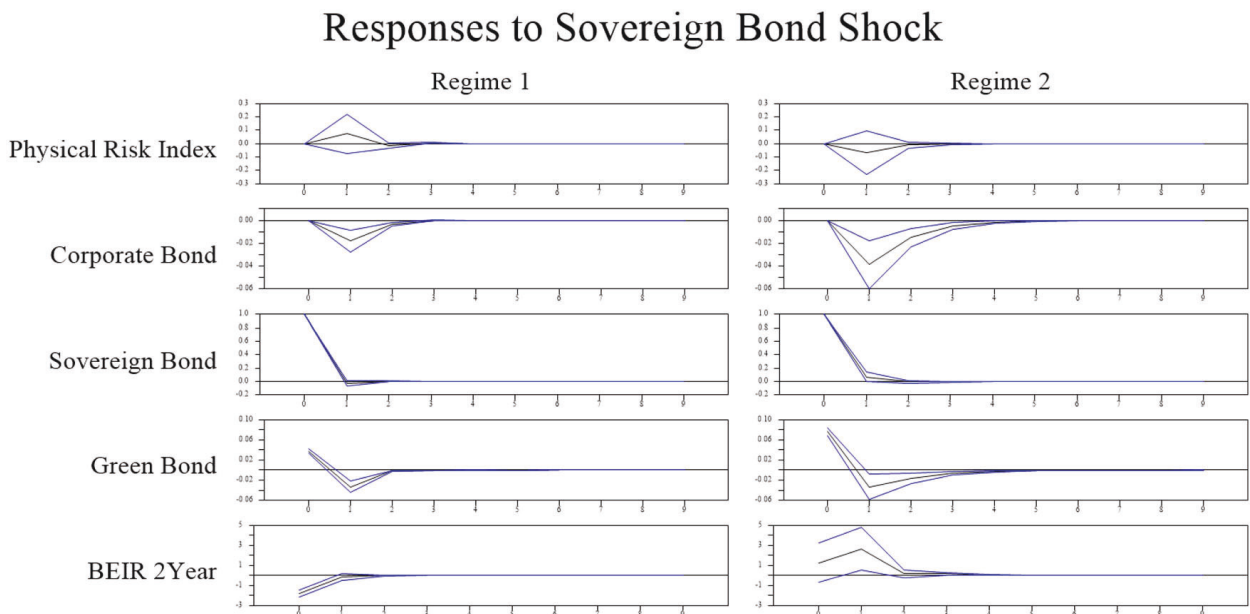


Figure 20. GIRFs displaying the effects of a Sovereign Bond shock on two-year BEIR, the PRI, and bond markets under different volatility regimes. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

patterns during periods of increased volatility. Our findings indicate that sovereign bonds and corporate bonds exhibit limited interconnectedness, as evidenced by their asymmetric responses to mutual shocks. While an increase in sovereign bonds leads to a decline in corporate bonds across both regimes, a more pronounced high volatility regime, an increase in corporate bonds, in contrast, elicits a positive response in sovereign bonds, with the crucial distinction that corporate bonds lack safe-haven characteristics.

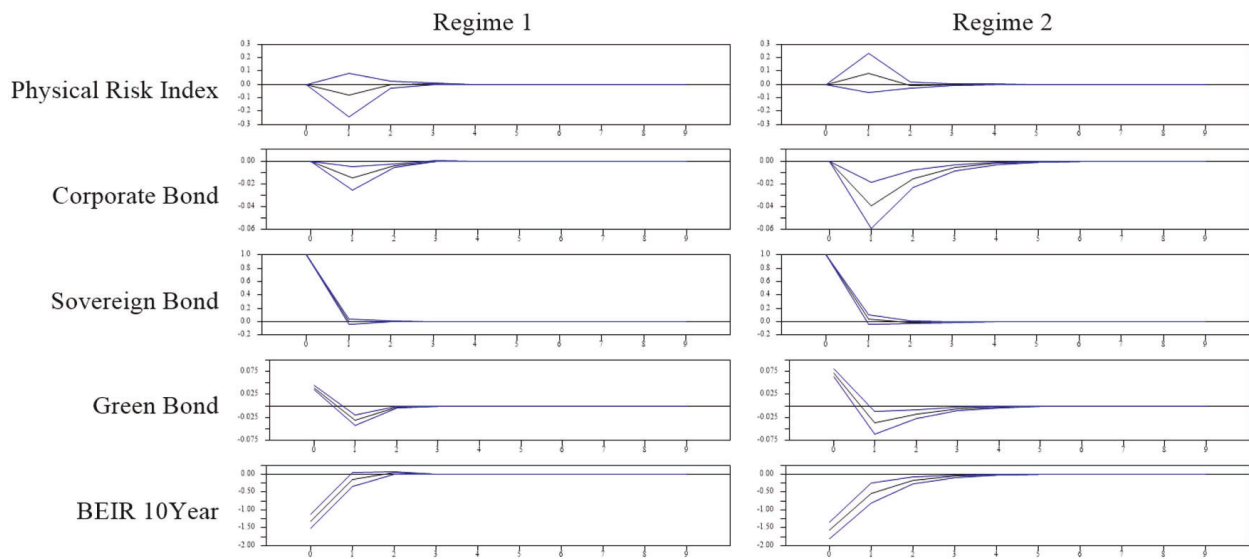


Figure 21. GIRFs displaying the effects of a Sovereign Bond shock on ten-year BEIR, the PRI, and bond markets under different volatility regimes. Solid black lines indicate the estimated responses, while blue bands represent 95% confidence intervals.

4.5. Regime-dependent reduced-form coefficients

To complement our GIRF analysis, we examine the MS-VAR's regime-dependent reduced-form coefficients, which offer a parametric view of the system's predictive dynamics. This section reconciles these lagged relationships with the contemporaneous shock responses from the GIRFs. Full coefficient magnitudes and significance levels for the four specifications, pairing (i) TRI or PRI with (ii) either the two-year or ten-year BEIR, are reported in Tables A2, A5 and discussed in Appendix 2.

The comparison between the MS-VAR coefficients and the GIRFs confirms the conclusion of state dependence: stronger bond–inflation comovement in high volatility regimes (contagion) and weaker, often insignificant, direct climate-to-BEIR loadings (interdependence or decoupling). Methodologically, the coefficients capture predictive relationships of lagged variables ($y_{t-1} \rightarrow y_t$), whereas GIRFs illustrate contemporaneous co-movement under generalised shocks. This distinction explains why coefficient signs sometimes diverge from shock responses.

For example, the lagged corporate coefficient in the government equation is negative and significant across regimes (e.g. -0.024^{**} / -0.061^{***} in Spec. 1), reflecting partial mean reversion in sovereign yields and a substitution channel when credit spreads widen. In contrast, a positive corporate bond shock in the GIRFs elicits a positive response in sovereign bonds, indicating contemporaneous contagion. A similar dynamic holds for inflation expectations in that lagged corporate conditions predict higher future BEIRs in high volatility states (e.g. corporate \rightarrow 10Y BEIR: 0.260^{**} in Spec. 2), yet an immediate corporate bond shock lowers BEIRs on impact.

These sign divergences, when interpreted through the difference between predictive linkages and shock-based co-movements, show how an immediate, shock-driven contagion can coexist with a predictable, opposing tendency in the subsequent period.

4.6. Implications of findings

We find that climate-related risks have only minor impacts on European bond markets. This likely reflects the relatively small scale of climate-related losses compared to the size of the EU economy, where damages remain limited as a share of GDP despite their large absolute value (European Environment Agency 2024a).¹³ By contrast, countries with higher exposure, such as small island developing states, experience far larger losses relative to output, implying stronger macro-financial transmission channels from physical risk to sovereign risk (International Monetary Fund 2016; IPCC 2022). This heterogeneity helps reconcile our muted European results with

evidence of stronger effects elsewhere. While we observe little divergence between green and conventional bonds facing TRI shocks, the possibility of a ‘too late, too sudden’ transition cannot be ruled out (Batten, Sowerbutts, and Tanaka 2016; European Systemic Risk Board 2016). The stronger impact of climate-related risks on short-term rather than long-term inflation expectations suggests that markets either trust the ECB’s capacity to contain medium-term inflation or do not yet view climate-risk related shocks as structural drivers of persistent inflation.

However, this aggregate finding masks a crucial state-dependency: financial markets price transition risk almost exclusively during periods of low volatility. This state-dependency has an important policy implication related to investor inattention during crises. During low volatility periods, the market functions as an efficient signal processor where market-based policies effectively reprice risk, triggering potentially a carbon divestment effect. In sharp contrast, during high volatility periods, dominant systemic risk signals saturate the market’s attention; consequently, the signal from the same climate policy is overshadowed by the salience of systemic risk and fails to be incorporated into asset prices. This might imply that policies are less effective when the system is stressed. While a full normative analysis is beyond the scope of this paper, our results support a non-delaying, proactive transition policy strategy to avoid policy efficacy losses by dealing with multiple problems in society all at once.

While we cannot directly identify the underlying causes of exogenous shocks to inflation expectations, insights from the literature, the characteristics of high volatility regimes, and the observed effect directions allow us to infer that the short-term BEIR shocks are rather supply-driven and long-term inflation expectation shocks are likely to be demand-driven. Against this backdrop, long-term inflation shocks driven by climate-related risks are likely to have a negative impact on bond markets. This scenario has not unfolded yet, but it warrants careful and ongoing scrutiny particularly, as in high volatility regimes markets tend to overreact to shocks, a pattern also reflected in our findings. As climate-related risks become more persistent, the challenge for central banks in balancing the credibility of their long-term inflation target with financial stability considerations becomes increasingly complex. Our findings, particularly the observed dynamics in high volatility regimes, highlight that such a scenario could necessitate a carefully considered policy stance. This inherent trade-off, where monetary authorities might need to adopt a cautiously hawkish approach while mitigating financial market destabilisation, is well-documented in the literature (Bandera et al. 2023; Boissay et al. 2023; Chavleishvili, Kremer, and Lund-Thomsen 2023). The robustness of our findings is reinforced by their consistency across model specifications with different datasets. However, for effective risk governance it is essential to recognise that backward-looking statistical approaches may fail to fully capture evolving risk drivers (Charpentier 2008). And as climate-related risks increase, continuous monitoring of emerging developments is and will be crucial.

While our current statistical framework identifies regime-dependent responses, it does not directly model central bank reaction functions or specific monetary policy instruments. However, even without explicit reaction functions or direct modelling of policy instruments, our regime-switching analysis provides crucial insights into how climate-related risks can amplify financial linkages and affect inflation expectations under different market conditions, thereby remaining highly relevant for central banks’ ongoing monitoring of financial stability under climate-related shocks. Future research could extend this analysis by explicitly incorporating short-term interest rates, policy rates, or indicators derived from central bank communication (for example ECB announcements) to empirically test their interaction with climate-related risks and inflation expectations within an extended model specification; this could build on frameworks that model central bank reactions to inflation shocks (for example the seminal work on policy rules by Taylor 1993) and on recent approaches considering the specific challenges of ‘greenflation’ and ‘climateflation’ for monetary policy (for example Lane 2022; Schnabel 2022a, 2022b). We also acknowledge that our MS-VAR framework is not designed to explicitly estimate credit spreads, duration risk (or specific maturity risk controls), or model risk premia; standard methodologies used for these estimates (e.g. term structure models) either do not inherently support the regime-dependent dynamics central to our findings, or integrating them would constitute a separate, substantial methodological contribution beyond the scope of this paper. For more direct insights into underlying causal mechanisms, future research could investigate specific transmission channels of climate-related risks, such as the explicit role of yield-curve shifts or credit-risk repricing, by applying structural identification or advanced causality-based approaches (for example using structural VAR models or alternative causality tests) as a complement to our statistical framework. Extending the analysis

to granular bond-level data would also allow explicit control of individual security liquidity, specific maturities, and issuer characteristics (for example firm-specific climate risk exposures, credit ratings), thereby refining insights into how climate risk impacts different bond segments. As the green bond market matures and liquidity improves, we expect these structural transmission channels to become clearer. From a policy perspective, this suggests that conventional markets currently provide more reliable signals for monitoring climate-related risk, while the role of green bonds as an indicator will strengthen over time as the market develops; in this vein, Malovaná and Frait (2017) emphasise the importance of close cooperation and coordination between monetary and macroprudential policymakers.

5. Concluding remarks

This study provides novel empirical evidence on how climate-related risks affect inflation expectations and bond markets in Europe through regime-dependent transmission mechanisms. Using an MS-VAR with European news-based transition and physical risk indices and GIRFs, our findings highlight the role of climate-related risk in shaping market linkages and stability.

Transition risks exert only limited effects, modestly dampening short-term inflation expectations in calm markets without materially impacting bond prices. Physical risks, however, depress bond returns and raise short-term inflation expectations under stress, suggesting that extreme events can amplify volatility and place temporary upward pressure on expectations. Long-term inflation expectations remain stable, indicating continued credibility of the ECB's target. We also find that shocks to short-term expectations and to corporate bonds propagate more strongly across bond classes in high volatility states, while green and conventional bonds do not materially diverge under stress, implying little evidence of abrupt capital reallocation.

These results suggest potential importance for both monetary and financial stability assessments to consider climate-related risk shocks and regime-dependent volatility when evaluating inflation dynamics, expected risk premia (via BEIRs), and systemic risk. For investors, the evidence points to the growing relevance of climate-aware asset allocation and stress testing, as climate-related shocks can alter correlations and increase systemic exposure during turbulent periods.

Findings are robust across alternative specifications and identification checks (see Appendix), though limitations remain regarding the measurement precision of news-based climate risk indices and regime classification. Future research could extend this analysis by examining cross-market spillovers, interactions with regulatory disclosure frameworks, and the evolving role of climate risk in shaping European capital market integration.

Overall, our results indicate that climate-related risks are transmitted through the inflation channel and interact with bond market dynamics in regime-dependent ways. This finding suggests avenues for potentially more active integration of climate-related risk considerations into macroprudential frameworks, monetary policy analyses, and portfolio risk management strategies, thereby informing future discussions on financial stability in European markets.

Notes

1. See, e.g. Boissay et al. (2023); Chavleishvili, Kremer, and Lund-Thomsen (2023) for detailed mechanisms.
2. Stranded assets are assets that experience unexpected or early reductions in value, write-offs, or are converted into financial liabilities.
3. For related evidence, see also Agliardi and Agliardi (2021), Antoniuk and Leirvik (2021), and Seltzer, Starks, and Zhu (2022).
4. The European Commission's Omnibus Simplification Package (February 2025) is a legislative initiative ostensibly designed to reduce administrative burden on firms. It has been widely criticised as a regulatory rollback (Merler 2025), particularly for amendments to the Corporate Sustainability Reporting Directive and the Corporate Sustainability Due Diligence Directive. Supervisory authorities, including the ECB, have warned that drastically raising reporting thresholds and eliminating data points will diminish the availability and reliability of standardised sustainability data, potentially leading to 'systematic and unquantifiable bias' in financial risk management (ECB 2025).
5. Formally, we compute the log-difference of BEIRs, $r_t = \log(\pi_{t+1}) - \log(\pi_t)$, to maintain parsimony.
6. All results available upon request.

7. The results are visualised in a multi-panel figure, where rows represent different asset classes and columns indicate the respective volatility regimes, allowing for a structured comparison of shock transmission patterns of a representative one-standard-deviation shock. Each panel displays the GIRF for the specified asset and regime, along with its 95% confidence intervals. The black lines represent the estimated effects, while the blue lines denote the confidence intervals. The scale remains consistent across regimes (columns) but varies between asset classes (rows).
8. Note: Given the model's symmetry, these shocks can be viewed as either positive or negative.
9. Our approach identifies regime-dependent co-movement patterns without imposing structural causal assumptions, which would require strong priors on variable ordering and shock identification.
10. Moving forward, it is important to note that since all model variables are treated as dependent, the TRI and PRI are not driven by bond markets, though correlations may arise from shared macroeconomic influences or reverse causality.
11. Following the sovereign debt crisis, exemplified by the cluster around 2015 and the COVID-19 pandemic, inflation remained low, even implying deflationary risks. As a result, the ECB prioritised supporting investment and economic growth (Benigno et al. 2022; Riet 2017).
12. This refers to the reaction to green bond shocks and the sovereign and green bond relationship. It is not to be interpreted as a methodological limitation of the MS-VAR model, but rather as a consequence of specific data characteristics. These include the shorter sample period of the control group, evolving index construction standards in the market's early stages, and the subsequent limited availability of consistent time series of adequate length. Furthermore, the lower liquidity and depth of the green bond market also contribute to the difficulty in identifying risk transmission within this segment. We therefore focus our discussion on the results that remain robust across specifications.
13. For EU-wide events in 2025, short-run losses are estimated at about 0.26% of GDP (Usman, Parker, and Vallat 2025), whereas SIDS commonly register annual damages near 2% of GDP on average and occasionally above 30% in single events (International Monetary Fund 2016; IPCC 2022). Recent UNDP estimates further suggest that SIDS experience disaster losses around seven times higher than other countries as a share of GDP (United Nations Development Programme 2024).

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Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

The authors report that the datasets analysed during the current study are proprietary to LSEG and cannot be made publicly available due to licensing restrictions. Access to these data can be obtained via LSEG subject to their terms and conditions.

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Appendices

Appendix 1. Data details and descriptive statistics

Table A1 provides the descriptive statistics for all financial and risk indices used in the analysis, including measures of central tendency, dispersion, and distributional characteristics.

Figure A1 presents the time series dynamics of the six key variables. The plot illustrates the response of financial market variables to major external shocks, such as the COVID-19 pandemic (2020) and the period of heightened geopolitical risk (since 2022), which are particularly evident in the two-year BEIR and bond markets. The longer-term BEIR shows the expected greater resilience. Spikes in the climate-related risk indices coincide with unexpected high-impact news discussions concerning these risks.

Appendix 2. Regime-dependent reduced-form coefficients

This appendix documents the regime-dependent MS-VAR coefficients and the associated regularities discussed in Section 4.

Overall, three regularities emerge. First, corporate bonds exhibit a materially negative loading on climate risk: the TRI–corporate coefficient is significantly negative in the low volatility regime (-0.187^{***} in Spec. 1; -0.199^{***} in Spec. 2), while under PRI the corporate exposure is significantly negative in both regimes (-0.126^{***} , -0.116^{**} in Spec. 3 and -0.132^{***} , -0.113^{**} in Spec. 4). This pattern suggests that physical risk is priced even in turbulent states, whereas transition risk is priced mainly in calm states. Second, we find a stable cross-asset spillover from corporate to sovereign bonds: the lagged corporate coefficient in the government equation is negative and significant in both regimes (e.g. $-0.024^{**}/-0.061^{***}$ in Spec. 1, $-0.021^{*}/-0.044^{**}$ in Spec. 2), consistent with partial mean reversion in sovereign yields (negative own-lag) and a substitution channel when credit spreads widen. Third, linkages to inflation expectations are state dependent: BEIR responds positively to corporate conditions—strongly so in high volatility states and when using the 10-year horizon (e.g. corporate \rightarrow 10Y BEIR: 0.260^{***} in Spec. 2; green \rightarrow 10Y BEIR: 3.332^{**} in Spec. 2 and 3.534^{**} in Spec. 4), and the government \rightarrow 2Y BEIR coefficient is positive in high volatility regimes (e.g. 0.322^{**} in Spec. 1; 0.324^{**} in Spec. 3; 0.248^{**} in Spec. 4). In contrast, the TRI and PRI coefficients in the BEIR equations are generally small and imprecise, indicating that climate risk affects inflation expectations primarily indirectly—through its impact on bond market conditions—rather than through a direct reduced-form channel.

Table A1. Descriptive statistics for the key financial indices.

Data	Mean	Median	Std. Dev.	Min	Max	Skewness	Kurtosis
TRI	-0.0029	-0.0047	0.0216	-0.0815	0.1380	0.6214	2.3682
PRI	-0.0017	-0.0040	0.0207	-0.0631	0.1225	0.8045	1.9147
Corporate Bonds	0.0000	0.0001	0.0019	-0.0196	0.0129	-0.4743	10.4251
Green Bonds	0.0000	0.0002	0.0067	-0.0358	0.0376	0.0123	3.0600
Sovereign Bonds	0.0001	0.0001	0.0023	-0.0242	0.0144	-0.8010	9.9208
Two-year BEIR	-0.0059	0.0010	0.1626	-0.7631	0.7358	-0.3723	11.5122
Ten-year BEIR	0.0002	0.0010	0.0290	-0.0800	0.0800	-0.0795	0.6782

Notes: TRI = Transition Risk Index, PRI = Physical Risk Index, BEIR = Breakeven Inflation Rate. Std. Dev. = Standard Deviation, Min = Minimum, Max = Maximum. The sample period spans from October 20, 2014, to June 24, 2024.

Table A2. MS-VAR(1) coefficients by regime (Specification 1 = TRI + 2-year BEIR).

Regressor	Regime 1: Low volatility	Regime 2: High volatility
Panel A: Dependent variable = Corporate bond		
Transition risk	-0.187*** (0.023)	-0.075 (0.047)
Corporate bond	-0.000 (0.001)	-0.003 (0.005)
Green bond	-0.001 (0.006)	-0.012 (0.018)
Government bond	0.000 (0.002)	-0.004 (0.007)
2-year BEIR	0.057 (0.052)	0.641 (0.533)
Panel B: Dependent variable = Green bond		
Transition risk	0.069 (0.982)	0.948 (1.036)
Corporate bond	-0.061 (0.066)	-0.020 (0.122)
Green bond	0.126 (0.274)	-0.330 (0.415)
Government bond	0.142* (0.078)	0.030 (0.148)
2-year BEIR	-1.028 (2.345)	-7.375 (12.098)
Panel C: Dependent variable = Government bond		
Transition risk	0.039 (0.150)	0.117 (0.190)
Corporate bond	-0.024** (0.010)	-0.061*** (0.022)
Green bond	-0.023 (0.039)	0.033 (0.076)
Government bond	-0.032*** (0.011)	-0.058** (0.027)
2-year BEIR	-0.251 (0.353)	3.586 (2.229)
Panel D: Dependent variable = 2-year BEIR		
Transition risk	0.007 (0.824)	-0.708 (0.909)
Corporate bond	0.150*** (0.052)	0.307*** (0.106)
Green bond	-0.089 (0.215)	0.423 (0.359)
Government bond	-0.005 (0.063)	0.322** (0.130)
2-year BEIR	0.954 (1.919)	-7.440 (10.493)

Notes: Coefficient estimates from a Markov-switching VAR(1) estimated on a five-dimensional system comprising TRI, corporate bonds, sovereign bonds, green bonds, and the 2-year BEIR. Lag order was chosen by the Hannan–Quinn Information Criterion (HQIC); only the first lag is reported. Reported values are regime-dependent coefficients with standard errors in parentheses. Regime 1 corresponds to the low volatility state; Regime 2 to the high volatility state. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

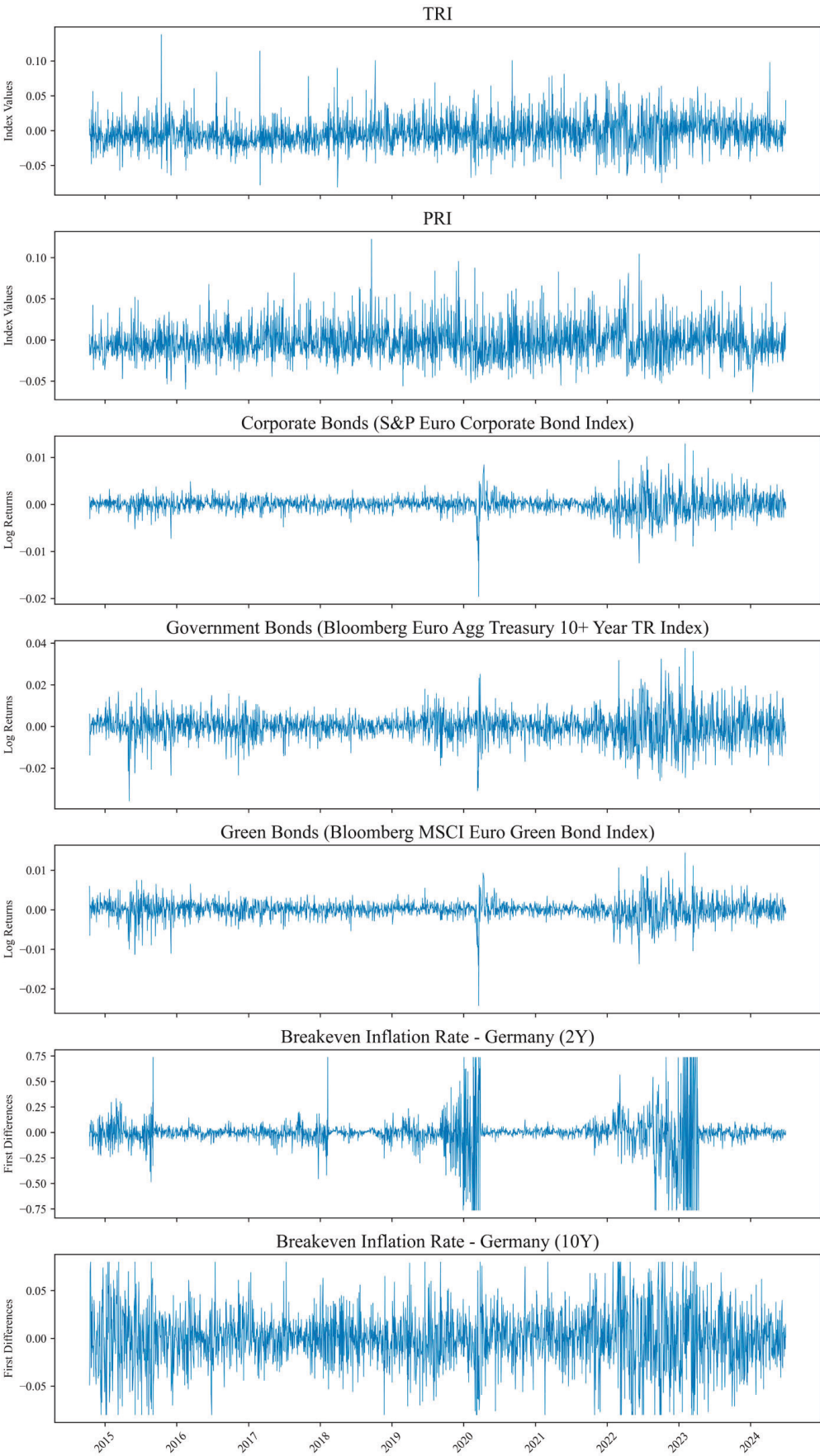


Figure A1. Time series of climate-related risks, bond returns, and breakeven inflation rates.
Notes: This figure displays TRI, PRI, corporate bond returns (S&P Euro Corporate Bond Index), government bond returns (Bloomberg Euro Agg Treasury 10+ Year TR Index), green bond returns (Bloomberg MSCI Euro Green Bond Index), and first differences of the German breakeven inflation rates (2Y and 10Y). Data are adjusted using 99% winsorisation to control for extreme outliers.

Table A3. MS-VAR(1) coefficients by regime (Specification 2: TRI + 10-year BEIR).

Regressor	Regime 1: Low volatility	Regime 2: High volatility
	Panel A: Dependent variable = Corporate bond	
Transition risk	−0.199*** (0.024)	−0.062 (0.046)
Corporate bond	−0.000 (0.001)	−0.002 (0.005)
Green bond	−0.111* (0.067)	0.014 (0.115)
Government bond	−0.021* (0.011)	−0.044** (0.021)
10-year BEIR	0.177*** (0.056)	0.260*** (0.099)
	Panel B: Dependent variable = Green bond	
Transition risk	0.589 (1.121)	0.534 (0.973)
Corporate bond	−0.111* (0.067)	0.014 (0.115)
Green bond	0.074(0.273)	−0.234 (0.398)
Government bond	0.098(0.080)	0.087 (0.140)
10-year BEIR	−0.150(0.225)	0.380 (0.339)
	Panel C: Dependent variable = Government bond	
Transition risk	−0.023 (0.173)	0.171 (0.185)
Corporate bond	−0.021* (0.011)	−0.044** (0.021)
Green bond	0.098 (0.080)	0.087 (0.140)
Government bond	−0.031** (0.013)	−0.040 (0.026)
10-year BEIR	0.027 (0.067)	0.246** (0.121)
	Panel D: Dependent variable = 10-year BEIR	
Transition risk	−0.429 (0.949)	−0.484 (0.825)
Corporate bond	−0.014 (0.027)	0.113 (0.074)
Green bond	1.175 (1.334)	3.332** (1.576)
Government bond	−0.117 (0.202)	−0.137 (0.300)
10-year BEIR	−1.472 (1.129)	−1.561 (1.361)

Notes: Coefficient estimates from a Markov-switching VAR(1) estimated on a five-dimensional system comprising TRI, corporate bonds, sovereign bonds, green bonds, and the 10-year BEIR. Lag order was chosen by the Hannan–Quinn Information Criterion (HQIC); only the first lag is reported. Reported values are regime-dependent coefficients with standard errors in parentheses. Regime 1 corresponds to the low volatility state; Regime 2 to the high volatility state. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table A4. MS-VAR(1) coefficients by regime (Specification 3: PRI + 2-year BEIR).

Regressor	Regime 1: Low volatility	Regime 2: High volatility
	Panel A: Dependent variable = Corporate bond	
Physical risk	−0.126*** (0.024)	−0.116** (0.046)
Corporate bond	0.002 (0.002)	0.003 (0.006)
Green bond	−0.067 (0.065)	−0.022 (0.122)
Government bond	−0.023** (0.010)	−0.061*** (0.022)
2-year BEIR	0.154*** (0.052)	0.309*** (0.105)
	Panel B: Dependent variable = Green bond	
Physical risk	−2.478** (0.980)	0.330 (0.937)
Corporate bond	−0.067 (0.065)	−0.022 (0.122)
Green bond	0.110 (0.271)	−0.332 (0.416)
Government bond	0.136* (0.077)	0.025 (0.149)
2-year BEIR	−0.076 (0.217)	0.425 (0.359)
	Panel C: Dependent variable = Government bond	
Physical risk	0.009 (0.155)	−0.057 (0.177)
Corporate bond	−0.023** (0.010)	−0.061*** (0.022)
Green bond	0.136* (0.077)	0.025 (0.149)
Government bond	−0.032*** (0.011)	−0.057** (0.027)
2-year BEIR	0.001 (0.064)	0.324** (0.130)
	Panel D: Dependent variable = 2-year BEIR	
Physical risk	1.548* (0.793)	−0.063 (0.821)
Corporate bond	−0.051 (0.056)	1.215** (0.571)
Green bond	−1.086 (2.294)	−6.372 (12.260)
Government bond	−0.204 (0.355)	3.428 (2.268)
2-year BEIR	0.596 (1.903)	−7.356 (10.695)

Notes: Coefficient estimates from a Markov-switching VAR(1) estimated on a five-dimensional system comprising PRI, corporate bonds, sovereign bonds, green bonds, and the 2-year BEIR. Lag order was chosen by the Hannan–Quinn Information Criterion (HQIC); only the first lag is reported. Reported values are regime-dependent coefficients with standard errors in parentheses. Regime 1 corresponds to the low volatility state; Regime 2 to the high volatility state. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

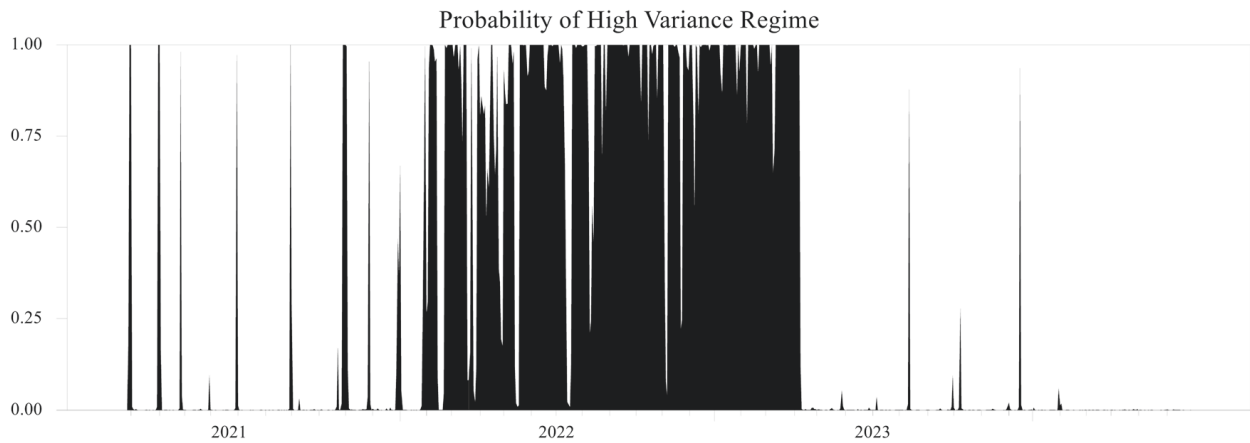


Figure A2. Specification 5, PRI, BEIR 2Y. Overview plot for the specification.

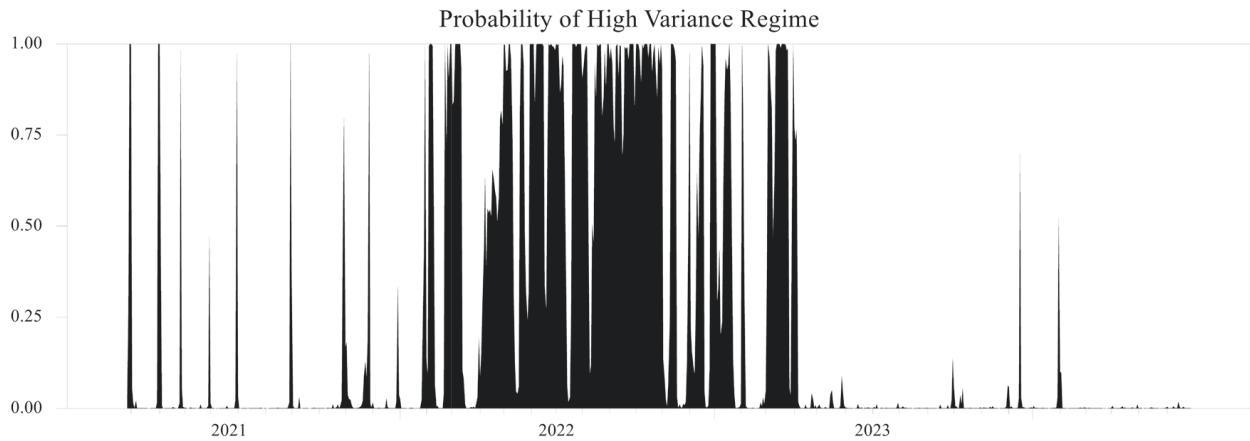


Figure A3. Specification 6, PRI, BEIR 10Y. Overview plot for the specification.

Appendix 3. Robustness checks: alternative dataset

This appendix reports robustness checks using a second dataset covering the period from 2021-02-23 to 2024-06-28. The main estimation is replicated for the identical sample. Both the regime classification and most estimated relations among the time series remain stable. The dataset includes the following variables: climate-related risks (TRI and PRI), Corporate Bonds (Bloomberg Euro Corporate Bond Index), Green Bonds (Bloomberg MSCI EUR Corporate and Agency Green Bond Index), Government Bonds (ICE BofA Euro Government Index), and BEIRs (Germany 2Y and 10Y). As in the main analysis, the robustness checks are conducted by alternating between the risk indices TRI and PRI and between the breakeven inflation rates of 2 and 10 years, resulting in the corresponding specifications.

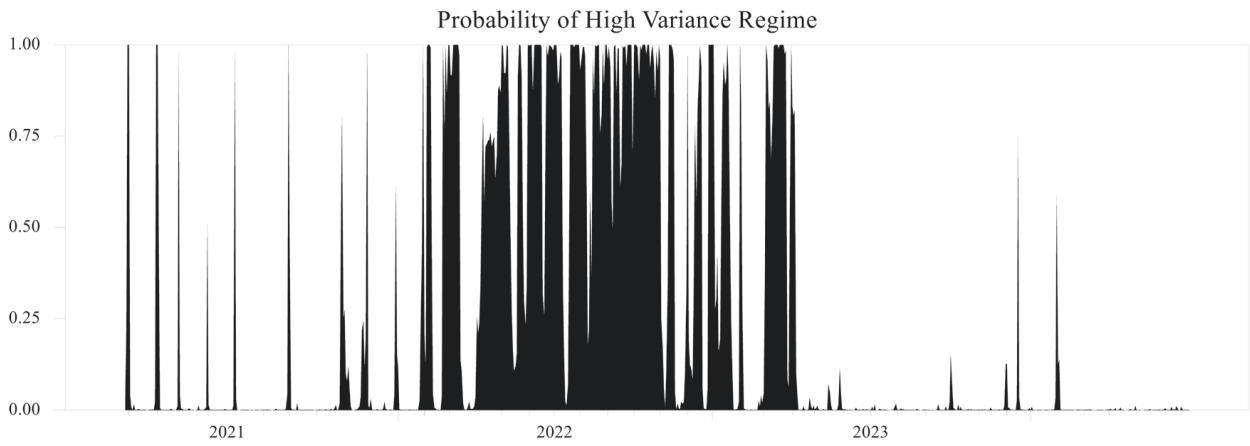


Figure A4. Specification 7, TRI, BEIR 10Y. Overview plot for the specification.

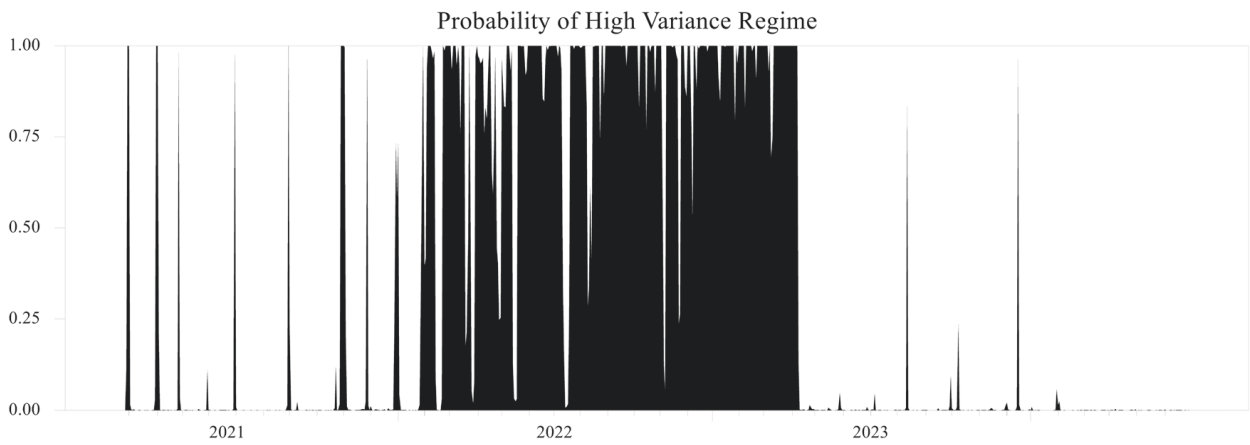


Figure A5. Specification 8, TRI, BEIR 2Y. Overview plot for the specification.

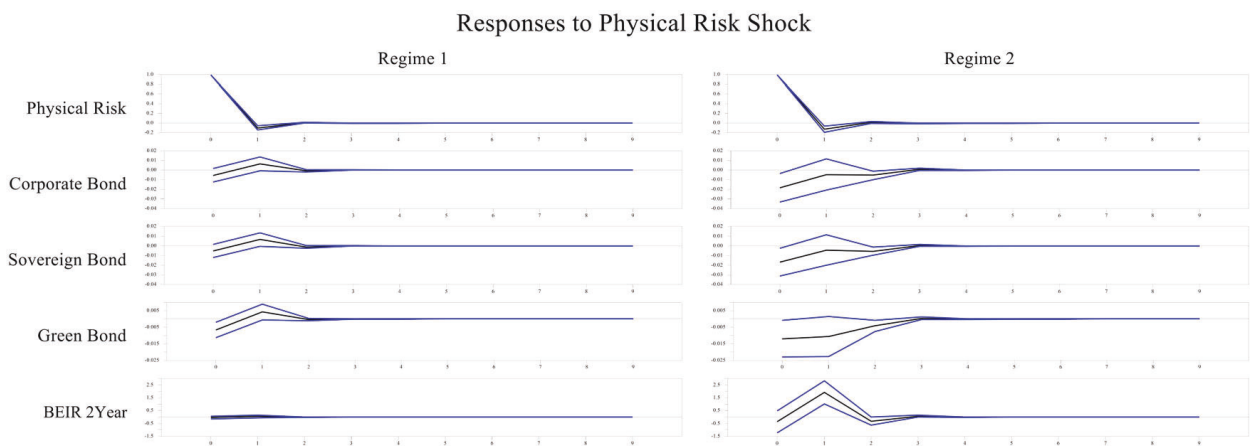


Figure A6. Specification 5, PRI, BEIR 2Y. Responses to a climate-risk shock.

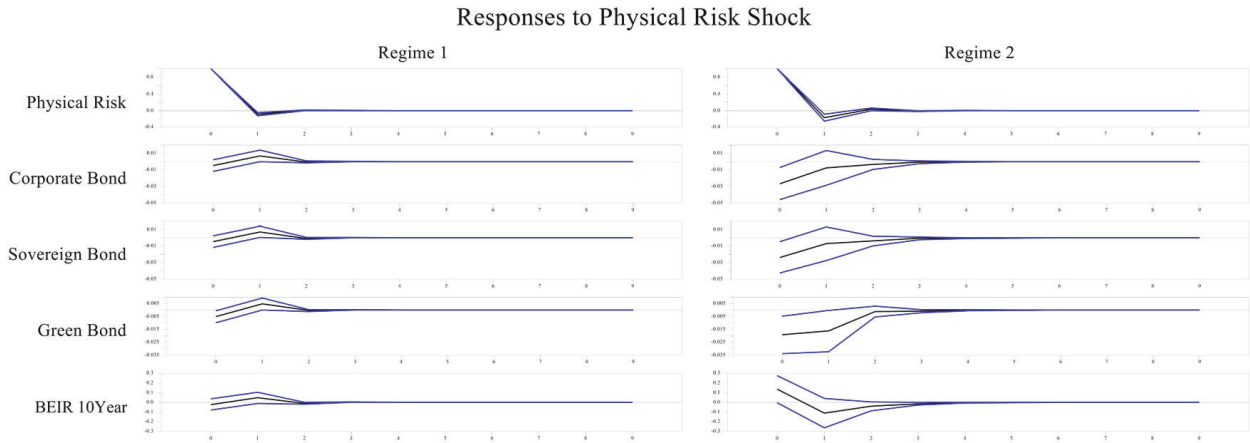


Figure A7. Specification 6, PRI, BEIR 10Y. Responses to a climate-risk shock.

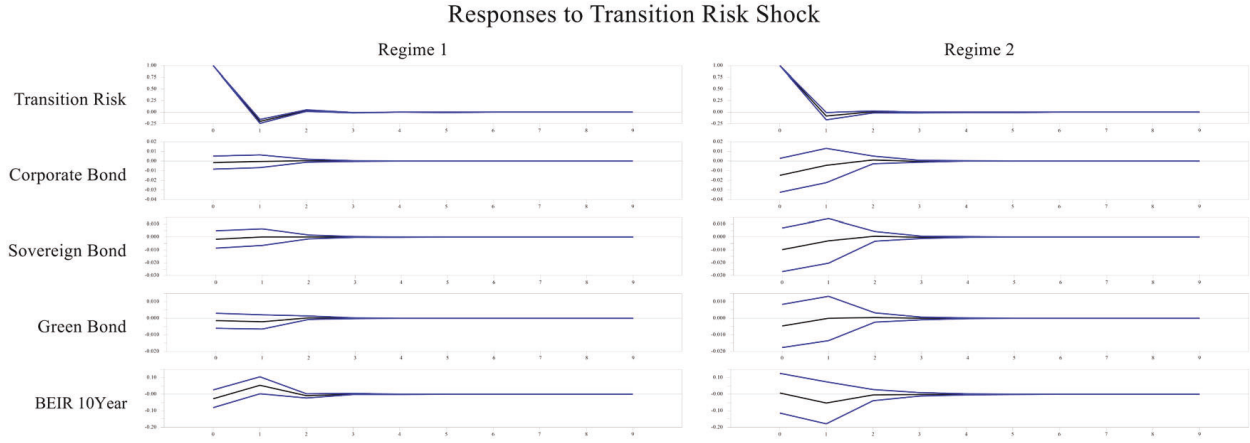


Figure A8. Specification 7, TRI, BEIR 10Y. Responses to a climate-risk shock.



Figure A9. Specification 8, TRI, BEIR 2Y. Responses to a climate-risk shock.

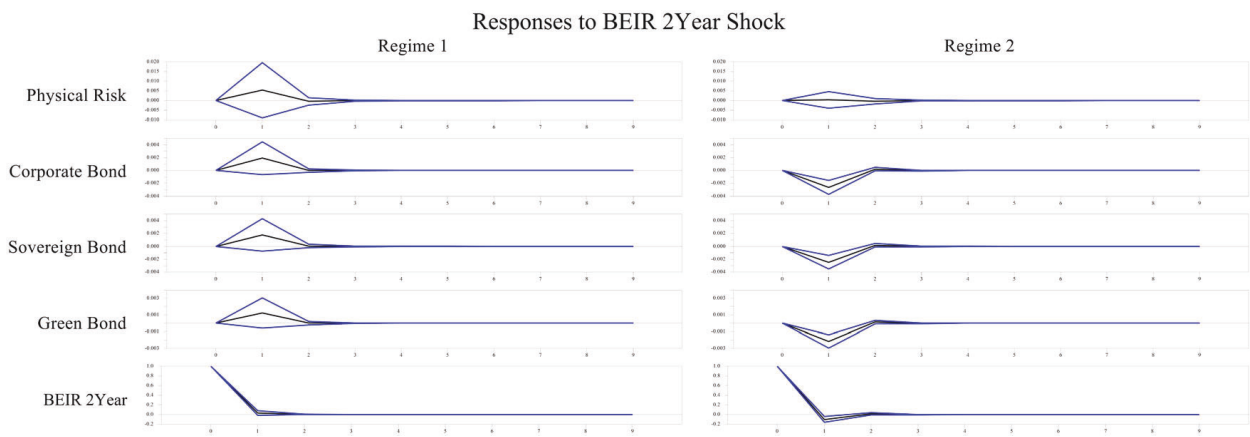


Figure A10. Specification 5, PRI, BEIR 2Y. Responses to a breakeven-inflation shock.

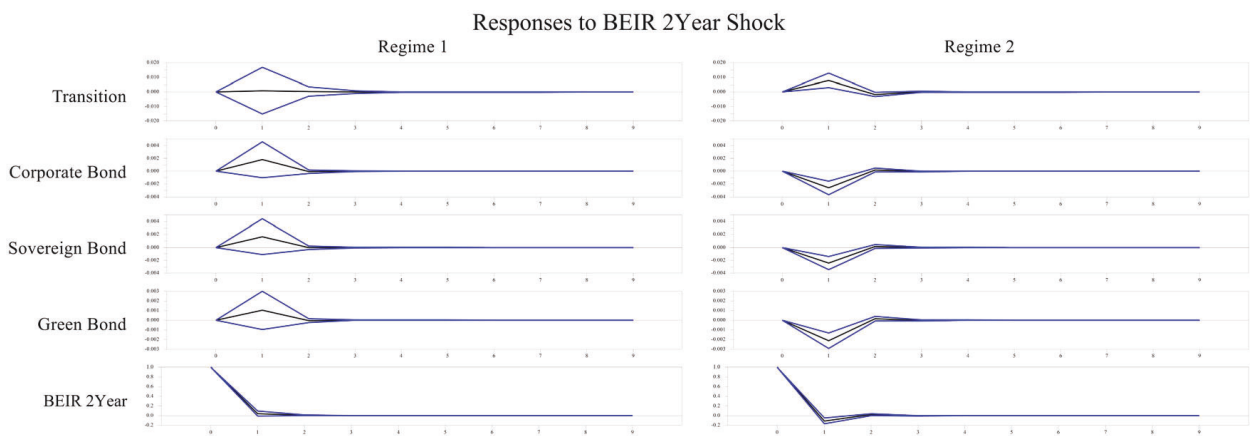


Figure A11. Specification 8, TRI, BEIR 2Y. Responses to a breakeven-inflation shock.

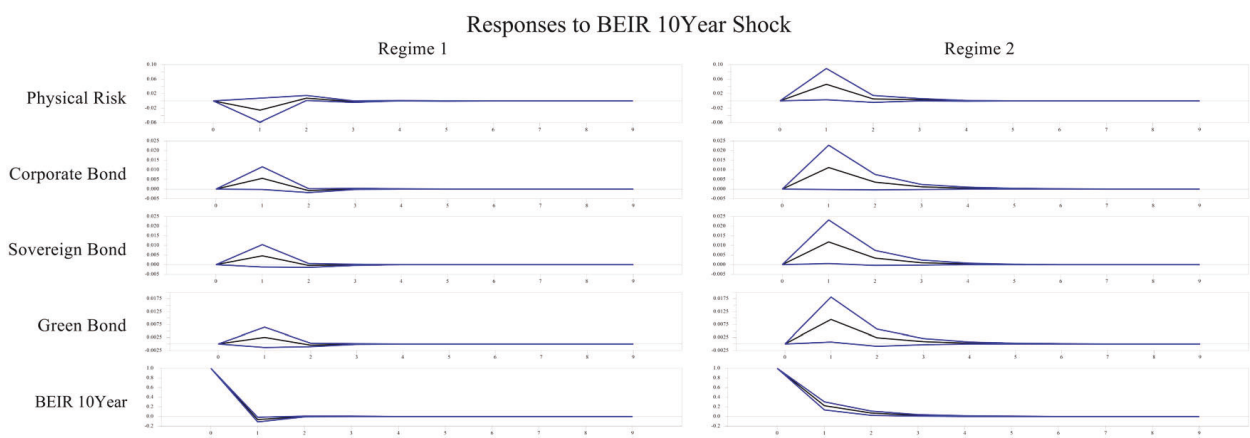


Figure A12. Specification 6, PRI, BEIR 10Y. Responses to a breakeven-inflation shock.

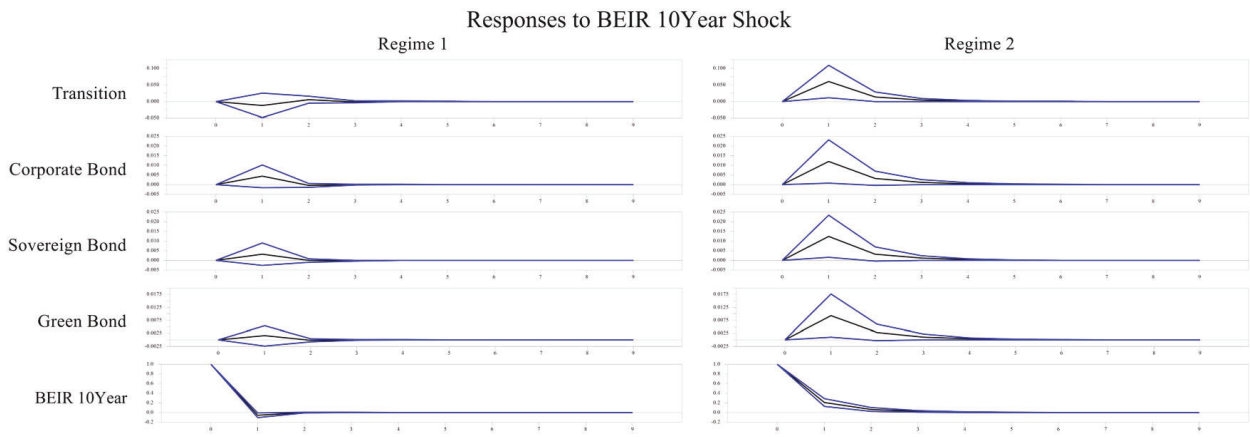


Figure A13. Specification 7, TRI, BEIR 10Y. Responses to a breakeven-inflation shock.

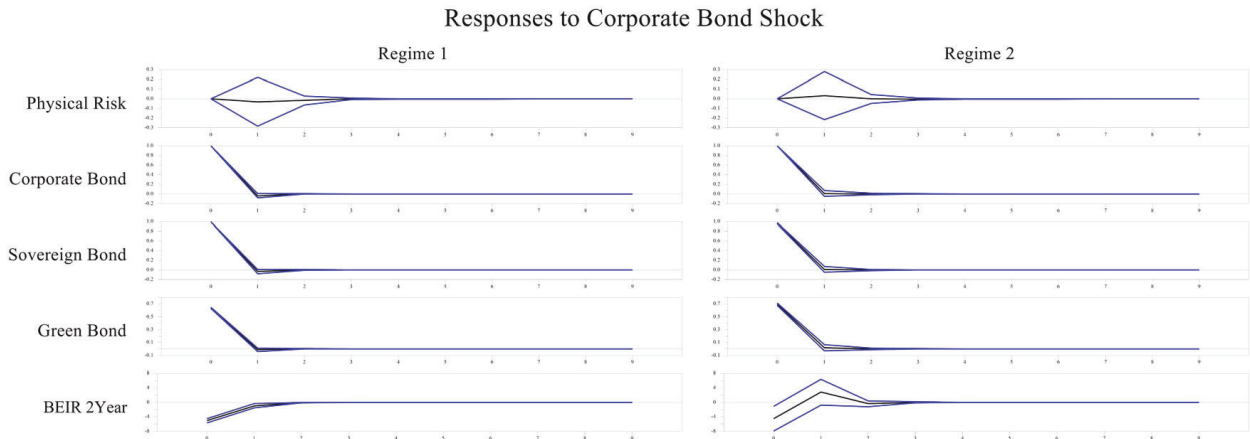


Figure A14. Specification 5, PRI, BEIR 2Y. Responses to a corporate-bond shock.

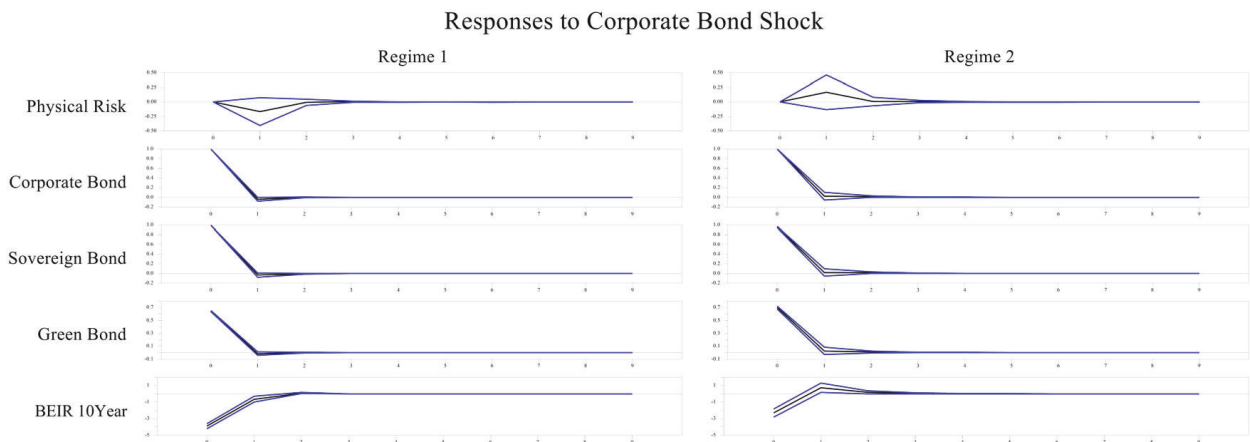


Figure A15. Specification 6, PRI, BEIR 10Y. Responses to a corporate-bond shock.

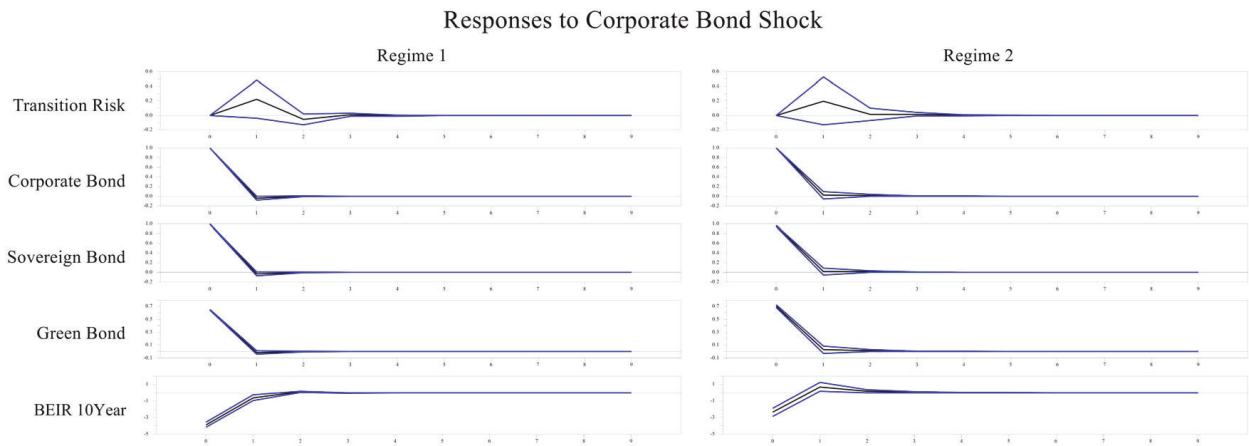


Figure A16. Specification 7, TRI, BEIR 10Y. Responses to a corporate-bond shock.

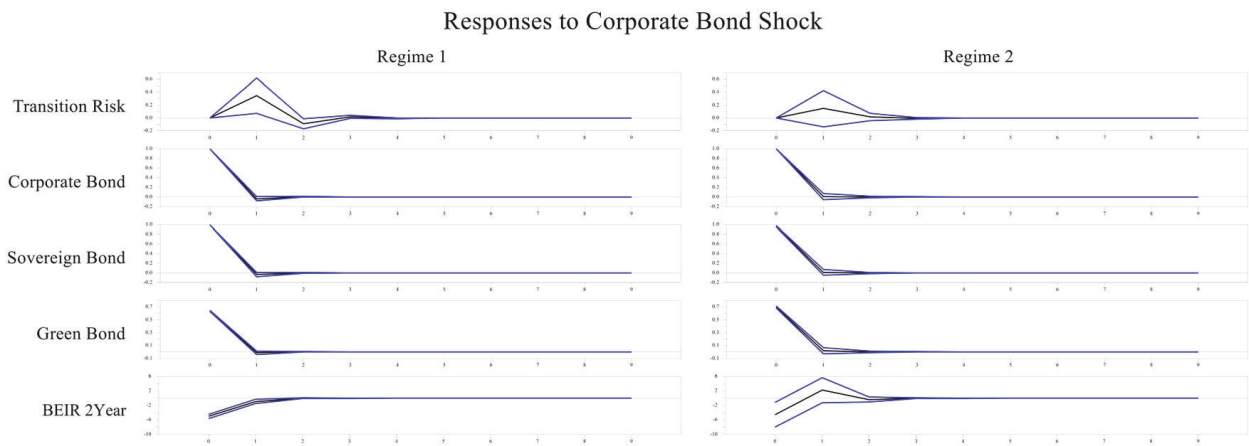


Figure A17. Specification 8, TRI, BEIR 2Y. Responses to a corporate-bond shock.

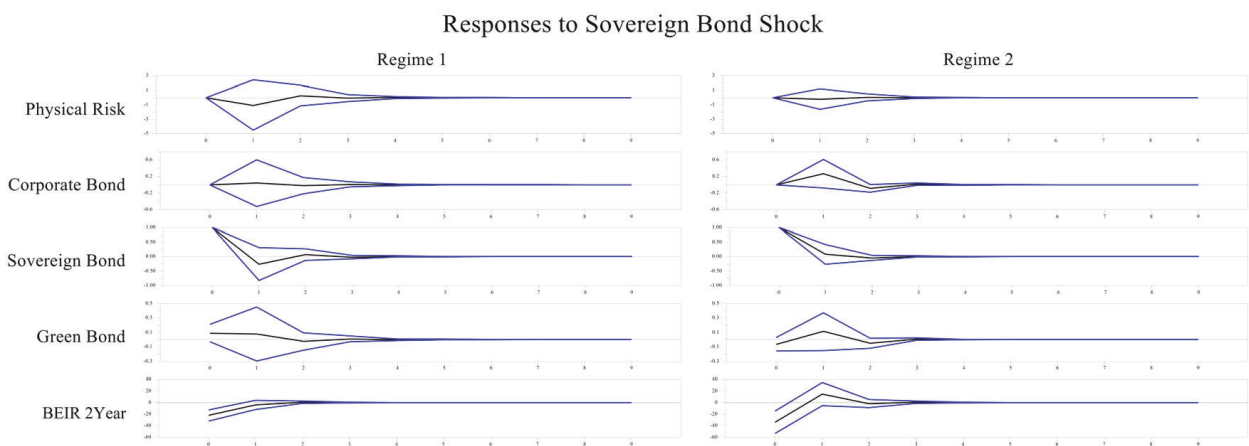


Figure A18. Specification 5, PRI, BEIR 2Y. Responses to a sovereign-bond shock.

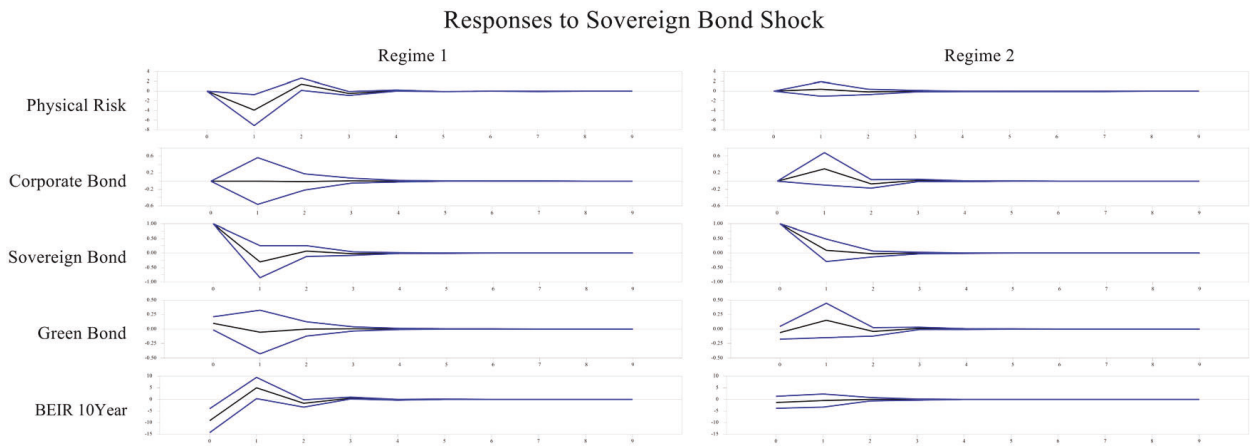


Figure A19. Specification 6, PRI, BEIR 10Y. Responses to a sovereign-bond shock.

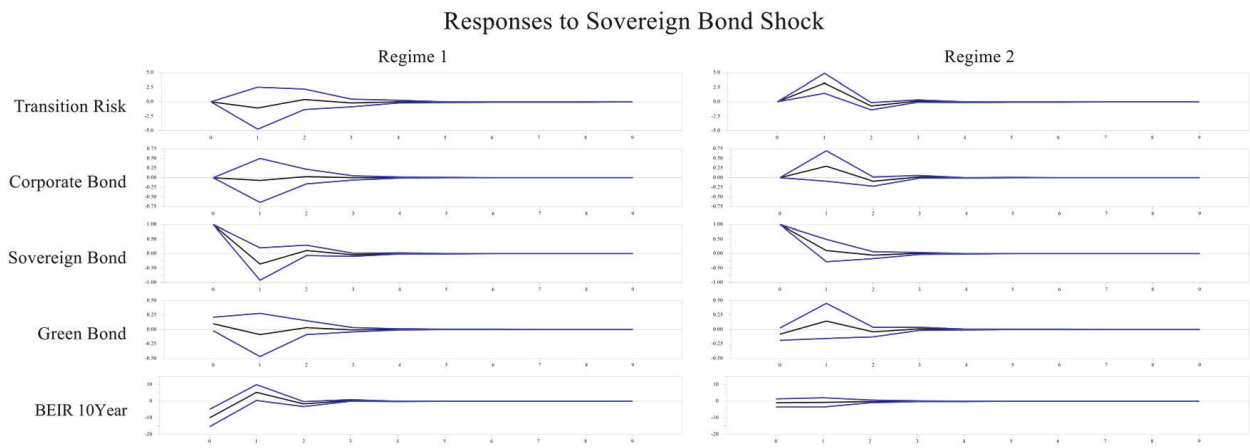


Figure A20. Specification 7, TRI, BEIR 10Y. Responses to a sovereign-bond shock.

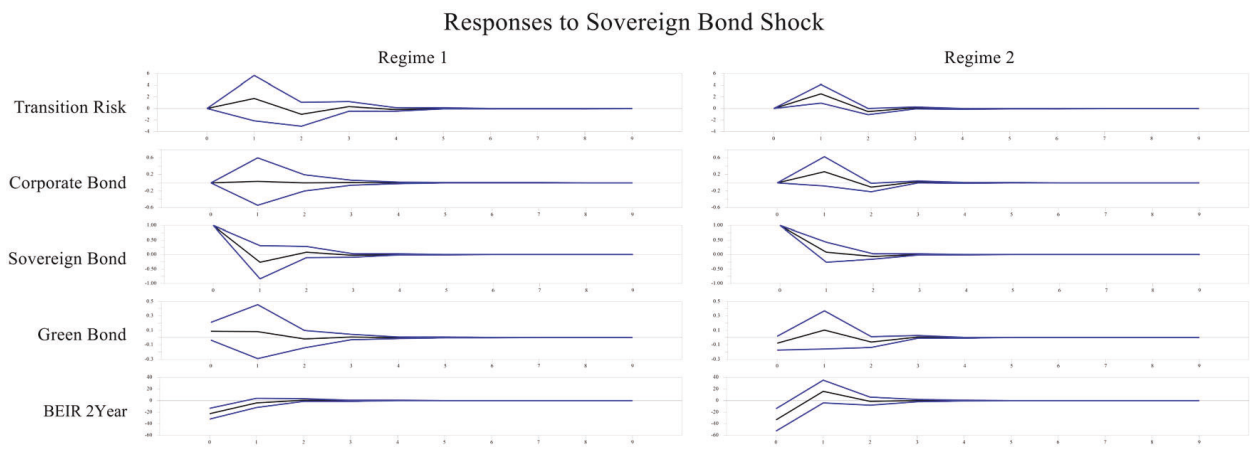


Figure A21. Specification 8, TRI, BEIR 2Y. Responses to a sovereign-bond shock.

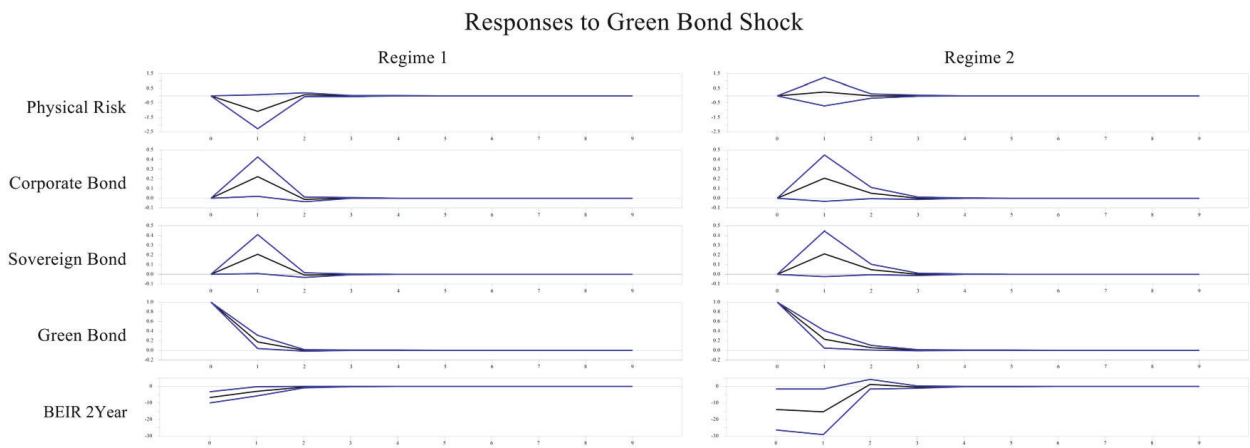


Figure A22. Specification 5, PRI, BEIR 2Y. Responses to a green-bond shock.

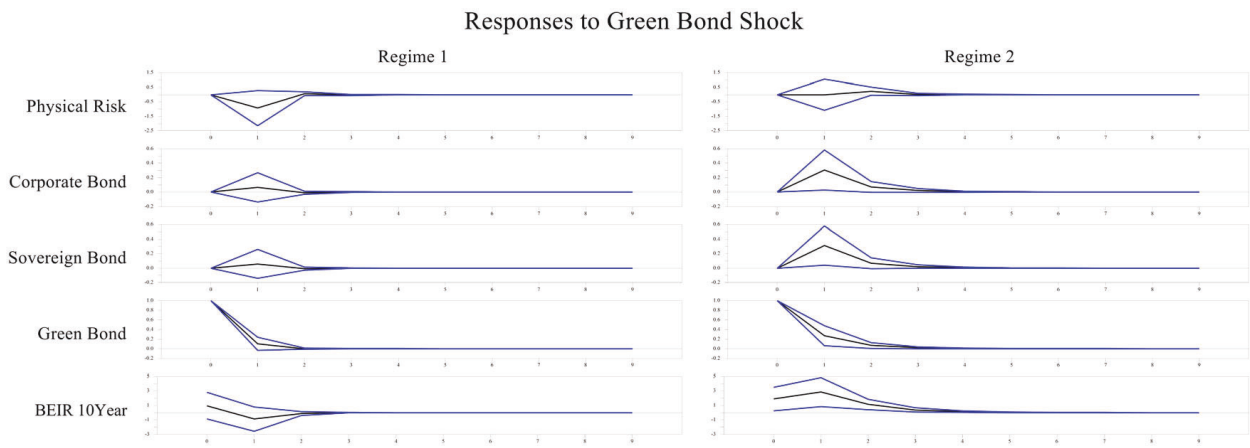


Figure A23. Specification 6, PRI, BEIR 10Y. Responses to a green-bond shock.

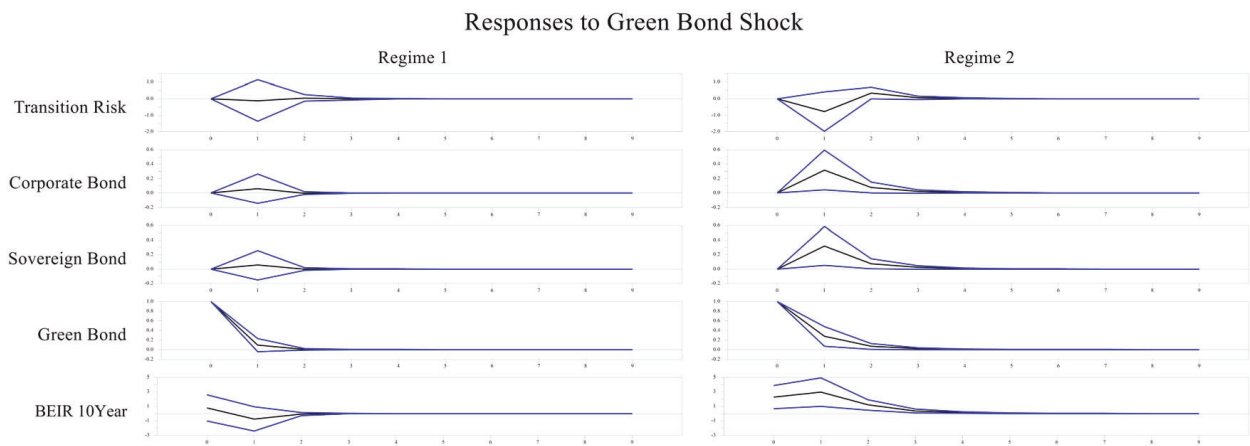


Figure A24. Specification 7, TRI, BEIR 10Y. Responses to a green-bond shock.

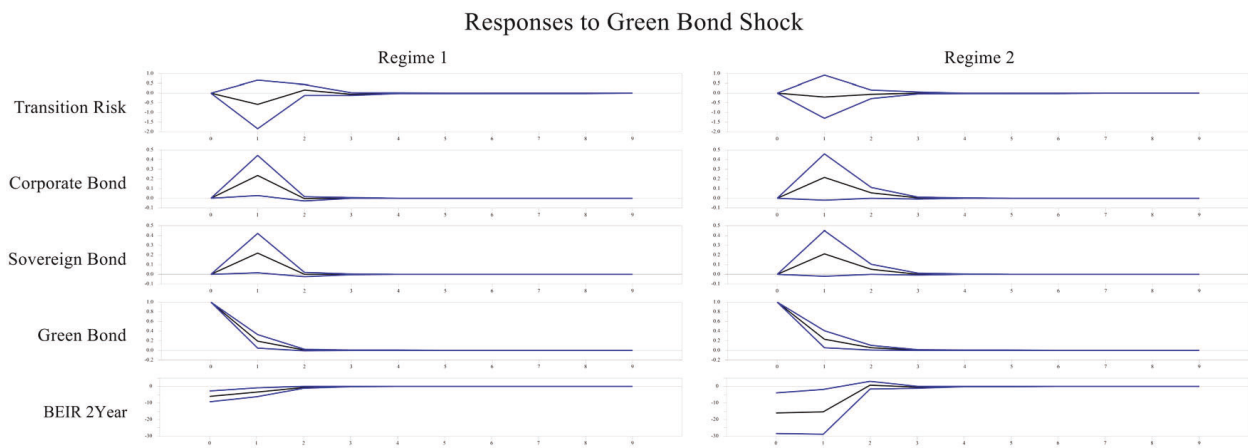


Figure A25. Specification 8, TRI, BEIR 2Y. Responses to a green-bond shock.

Table A5. MS-VAR(1) coefficients by regime (Specification 4: PRI + 10-year BEIR).

Regressor	Regime 1: Low volatility	Regime 2: High volatility
Panel A: Dependent variable = Corporate bond		
Physical risk	-0.132*** (0.025)	-0.113** (0.045)
Corporate bond	0.001 (0.001)	0.005 (0.006)
Green bond	-0.111* (0.067)	0.017 (0.116)
Government bond	-0.020* (0.011)	-0.046** (0.022)
10-year BEIR	0.179*** (0.055)	0.263*** (0.100)
Panel B: Dependent variable = Green bond		
Physical risk	-2.042* (1.107)	-0.205 (0.837)
Corporate bond	-0.111* (0.067)	0.017 (0.116)
Green bond	0.061 (0.270)	-0.214 (0.400)
Government bond	-0.001 (0.043)	0.092 (0.142)
10-year BEIR	-0.128 (0.221)	0.380 (0.345)
Panel C: Dependent variable = Government bond		
Physical risk	-0.166 (0.174)	0.103 (0.160)
Corporate bond	-0.020* (0.011)	-0.046** (0.022)
Green bond	0.097 (0.079)	0.092 (0.142)
Government bond	-0.029** (0.012)	-0.041 (0.027)
10-year BEIR	0.032 (0.066)	0.248** (0.123)
Panel D: Dependent variable = 10-year BEIR		
Physical risk	1.484 (0.928)	0.064 (0.724)
Corporate bond	-0.026 (0.028)	0.031 (0.082)
Green bond	0.971 (1.326)	3.534** (1.591)
Government bond	-0.094 (0.207)	-0.142 (0.303)
10-year BEIR	-1.575 (1.115)	-1.595 (1.361)

Notes: Coefficient estimates from a Markov-switching VAR(1) estimated on a five-dimensional system comprising PRI, corporate bonds, sovereign bonds, green bonds, and the 10-year BEIR. Lag order was chosen by the Hannan–Quinn Information Criterion (HQIC); only the first lag is reported. Reported values are regime-dependent coefficients with standard errors in parentheses. Regime 1 corresponds to the low volatility state; Regime 2 to the high volatility state. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.