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Sustainability uncertainty and stock prices: Conditional effects across regulatory regimes

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ABSTRACT

This paper examines how stock markets price ESG-based sustainability uncertainty (ESGUI) as sustainability disclosure shifts from voluntary reporting to mandatory compliance. Using monthly data for 23 markets from 2002 to 2025, I estimate dynamic responses of real stock prices to country-specific and global ESGUI shocks. ESGUI is priced differently from traditional uncertainty measures such as economic policy uncertainty and geopolitical risk. During voluntary disclosure periods, country-specific ESGUI shocks raise developed-market stock prices, with a median 12-month response of 0.54 standard deviations, equivalent to about 11.88% in price terms. These positive responses survive innovation extraction and joint uncertainty controls. Global ESGUI shocks generate larger effects, consistent with systematic transition-related pricing. However, subperiod and country-specific timing tests show that ESGUI effects turn negative when mandatory disclosure becomes salient, especially in developed European markets. Environmental and social uncertainty drive positive responses, indicating transition opportunities. In contrast, governance uncertainty is priced negatively, consistent with agency risk, oversight quality, and disclosure credibility channels. Thus, sustainability uncertainty prices transition opportunities in some regimes and compliance/oversight risk in others.

1. Introduction

Over the past decade, sustainable investing has become a systemic feature of capital markets, while sustainability reporting has shifted from voluntary disclosure toward increasingly formalized and mandatory regimes. This transition matters for asset pricing because sustainability-related information can affect expected cash flows, discount rates, hedging demand, and investor preferences. In the equilibrium model of Pástor et al. (2021), green assets can earn lower expected returns because investors value sustainability, yet can outperform when sustainability preferences strengthen or climate concerns intensify. Pedersen et al. (2021) provide a complementary portfolio-choice perspective, showing how ESG scores, investor preferences, and ESG information shape the risk-return trade-off along the ESG-efficient frontier. Related empirical evidence shows that carbon risk and ESG rating uncertainty are also priced in equity markets (Avramov et al., 2022; Bolton & Kacperczyk, 2021).

Recent studies show that climate-policy and sustainability-related uncertainty affects financial markets, but the evidence remains fragmented across sectors, asset classes, and empirical settings. Bouri et al. (2022) show that climate-policy uncertainty affects the relative dynamics of green and brown energy stocks, indicating that transition uncertainty can have different implications across sustainability-exposed assets. Treepongkaruna et al. (2023) extend this evidence to the cross-section of stock returns, while Tedeschi et al. (2024) show that European financial-market responses to climate-policy uncertainty vary over time. Related

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evidence from Serafeim and Yoon (2023) suggests that disagreement about ESG ratings weakens the incorporation of ESG news into prices. Recent connectedness studies further document asymmetric and regime-sensitive transmission across renewable energy, non-renewable energy, carbon, artificial intelligence, and ESG-linked markets (Balcı, 2025; Özcan et al., 2023; Yildirim, 2025). However, existing work does not explain how a dedicated ESG-based sustainability uncertainty measure affects broad stock-market valuations across countries and disclosure regimes, or whether the same uncertainty shock is priced as opportunity-related information under voluntary disclosure but compliance-related risk under mandatory disclosure.

Accordingly, the research problem addressed in this paper is whether, and under what institutional conditions, shocks to ESG-based sustainability uncertainty (ESGUI) are priced in international stock markets. The main objective is to examine how country-specific and global ESGUI shocks affect real stock prices in 23 markets over 2002–2025, and whether the sign and magnitude of those effects vary across voluntary versus mandatory ESG disclosure regimes, across levels of market development, and across the environmental, social, and governance dimensions of uncertainty. By framing the analysis around regulatory-regime dependence, this paper contributes a conditional view of sustainability uncertainty transmission rather than treating ESG-related uncertainty as a uniformly negative shock.

More specifically, this study tests three related propositions. First, ESGUI should contain valuation information distinct from EPU and GPR. Second, its effect should depend on disclosure-regime structure. Voluntary regimes allow sustainability uncertainty to signal transition opportunities, whereas mandatory regimes make implementation costs, enforcement frictions, and compliance risk more salient. Third, effects should vary across market characteristics and ESG dimensions, implying that sustainability uncertainty is a context-dependent information shock rather than a homogeneous source of financial stress.

This study employs the smooth local projection framework of Barnichon and Brownlees (2019) to estimate stock price responses to country-specific and global ESGUI shocks. To isolate unexpected changes, I extract innovations in ESGUI following Brogaard and Detzel (2015). Benchmarking against traditional uncertainty measures, such as EPU and GPR, in joint specifications tests whether sustainability uncertainty operates through distinct channels and whether the effects persist after controlling EPU and GPR. Heterogeneity analysis examines transmission variation across market characteristics such as size, liquidity, value orientation, and inflation. Finally, component decomposition into environmental, social, and governance uncertainty, together with subperiod analysis, identifies which ESG dimensions and regulatory eras drive observed effects.

This study makes three contributions to understanding how uncertainty affects asset prices conditionally across institutional contexts. First, I document context-dependent asymmetry in sustainability uncertainty transmission. While economic policy uncertainty and geopolitical risk consistently depress valuations (Baker et al., 2016; Caldara & Iacoviello, 2022), sustainability uncertainty exhibits heterogeneous effects that depend critically on regulatory regime structure. During voluntary ESG disclosure periods (2002–2020), ESGUI shocks are associated with predominantly positive stock price responses in developed markets, consistent with uncertainty signaling investment opportunities and technological transitions. However, this relationship reverses once mandatory compliance frameworks take effect (2021–2025), particularly in developed European markets implementing comprehensive disclosure requirements. This regulatory lifecycle pattern provides international evidence that sustainability uncertainty operates through fundamentally different channels than traditional policy uncertainty, with economic interpretation shifting as institutional context evolves. Second, I show that global sustainability uncertainty shocks generate substantially stronger responses than country-specific shocks, particularly in larger and more liquid markets. This pattern is consistent with international transmission through financially integrated markets, although the analysis does not directly observe cross-border portfolio flows. Accordingly, the evidence should be interpreted as supporting a market-integration channel rather than directly identifying capital reallocation. Third, I provide novel international validation of the information content of ESGUI (Ongan et al., 2025) using two complementary analyses. Component decomposition establishes that environmental and social uncertainty components drive the observed positive associations, while governance uncertainty reflects institutional quality concerns and shows negative effects across most contexts. This confirms that different ESG dimensions embed fundamentally different information content. Subperiod analysis reveals that aggregate sustainability uncertainty effects follow a regulatory lifecycle, with the sign and magnitude of transmission varying with disclosure regime structure. Together, by isolating innovations orthogonal to trending salience and documenting sign reversals linked to regulatory transitions, these analyses establish that ESGUI captures economically meaningful uncertainty about sustainable transitions rather than merely trending attention to ESG topics.

The remainder of the paper proceeds as follows. Section 2 reviews the theoretical foundations linking uncertainty to asset prices. Section 3 describes the data and empirical methods. Section 4 presents the main empirical results and Section 5 concludes with implications for stakeholders and future research.

2. Theoretical background and related literature

This section develops the theoretical foundation for examining how sustainability uncertainty affects asset prices across institutional contexts. The framework integrates three strands of literature. The first strand links ESG characteristics to asset prices through investor preferences, hedging demand, expected cash-flow effects, and discount-rate channels. The second strand shows that climate-policy and sustainability-related uncertainty can affect financial markets asymmetrically across sectors, assets, and regimes. The third strand examines how mandatory sustainability disclosure changes firms' information environments and investors' interpretation of nonfinancial information. Combining these strands, I develop a conditional uncertainty framework in which the pricing effect of ESGUI depends on whether sustainability uncertainty is interpreted as opportunity-related information under voluntary disclosure regimes or as compliance-related risk under mandatory regimes.

2.1. Conditional uncertainty framework

Building on Segal et al. (2015), who distinguish between uncertainty types depending on whether resolution increases or decreases future growth opportunities, I develop a conditional framework in which the economic interpretation of sustainability uncertainty depends on the regulatory regime governing ESG disclosure. This distinction is important because sustainability uncertainty is not necessarily equivalent to traditional uncertainty. Whereas traditional uncertainty measures such as economic policy uncertainty and geopolitical risk typically increase discount rates, delay investment, and depress valuations (Baker et al., 2016; Bloom, 2009; Brogaard & Detzel, 2015; Caldara & Iacoviello, 2022), ESG-related uncertainty can contain both downside-risk and transition-opportunity components. Under voluntary disclosure regimes, firms can strategically reveal favorable ESG information, and investors may interpret sustainability uncertainty as a signal of future regulatory support, green innovation opportunities, or strengthening investor demand for sustainable assets. Under mandatory disclosure regimes, however, the same uncertainty is more likely to reflect implementation costs, enforcement heterogeneity, assurance requirements, and compliance risk.

Under voluntary ESG disclosure regimes, firms often self-select into reporting based on favorable performance or stronger ESG preparedness. This logic is consistent with Clarkson et al. (2008), who show that environmental disclosure is related to environmental performance, and with Grewal and Serafeim (2020), who emphasize the interaction between sustainability disclosure, firm incentives, and capital-market outcomes. Such self-selection creates informational asymmetries through which sustainability uncertainty can reveal strategic differentiation opportunities. In this context, uncertainty spikes may signal three positive channels. First, technological breakthroughs in green innovation create competitive advantages for early adopters (Chen et al., 2025). Second, shifting investor preferences toward sustainable assets generate reputational differentiation opportunities for ESG-prepared firms (Lins et al., 2017; Pástor et al., 2021). Third, regulatory support through subsidies, tax incentives, or favorable treatment creates structural growth opportunities. Each mechanism supports the real options value of waiting and adapting (Dixit & Pindyck, 1994), potentially raising current valuations even as uncertainty increases.

However, once regulatory frameworks transition toward mandatory compliance, sustainability uncertainty fundamentally changes its economic interpretation. Firms cannot avoid disclosure regardless of performance, transforming this uncertainty from opportunity-related uncertainty into compliance-related risk. Uncertainty now reflects implementation challenges, enforcement heterogeneity, and compliance cost variation across jurisdictions. Therefore, traditional uncertainty channels dominate i.e., higher risk premia, delayed investment due to real options effects under adverse resolution (Bloom, 2009), and reduced valuations through discount rate increases (Brogaard & Detzel, 2015). This regime shift generates the central testable prediction. *Sustainability uncertainty effects should reverse from positive under voluntary regimes to negative under mandatory compliance frameworks.* This conditional framework helps explain why sustainability-uncertainty effects may differ across periods, institutional settings, and market-development levels.

2.2. ESG pricing channels and transmission mechanisms

Understanding how sustainability uncertainty affects valuations requires specifying the transmission channels through which information flows into asset prices. Extensive research establishes that ESG performance correlates positively with financial outcomes on average (Atz et al., 2023; Friede et al., 2015), with high-ESG firms demonstrating superior returns during crisis periods when tail risk concerns intensify (Broadstock et al., 2021; Lins et al., 2017). The equilibrium model of Pástor et al. (2021) shows that green assets can have lower expected returns in steady states because investors derive non-pecuniary utility from holding them, yet temporarily outperform when positive ESG factor shocks occur through shifts in investor preferences or increased climate risk salience.

Three channels emerge from this literature for understanding sustainability uncertainty transmission. First, heightened uncertainty triggers portfolio rebalancing toward green assets as climate risk hedges, particularly when tail risk perceptions rise (Albuquerque et al., 2019; Pástor et al., 2021). Second, uncertainty amplifies competitive advantages of ESG-prepared firms through operational resilience, regulatory alignment, and stakeholder trust (Pedersen et al., 2021). Third, ESG characteristics provide downside protection when aggregate uncertainty rises, functioning as insurance against adverse scenarios (Albuquerque et al., 2019; Bouri et al., 2022).

These channels need not operate symmetrically across the environmental, social, and governance dimensions of ESG uncertainty. Environmental uncertainty may contain information about climate-policy trajectories, clean-technology investment, energy-transition opportunities, and future regulatory support (Bouri et al., 2022; Pástor et al., 2021). Social uncertainty may reflect changing stakeholder expectations, labor standards, consumer preferences, and reputational differentiation, which can be value-relevant when stakeholder trust provides insurance-like benefits during periods of uncertainty (Albuquerque et al., 2019; Lins et al., 2017). Governance uncertainty is different because it is more directly related to agency problems, board oversight, internal controls, disclosure credibility, shareholder protection, and enforcement risk. In the corporate-governance literature, agency conflicts arise when managers' incentives diverge from those of outside investors (Jensen & Meckling, 1976), while governance mechanisms shape whether investors can credibly expect managers to return capital and protect shareholder interests (Shleifer & Vishny, 1997). Empirically, weaker shareholder rights and weaker governance structures are associated with lower firm value, weaker performance, and less effective monitoring (Core et al., 1999; Gompers et al., 2003). Higher governance uncertainty may therefore raise perceived agency costs and discount rates if investors interpret it as a signal of weak monitoring, opaque reporting systems, or lower credibility of sustainability commitments. Accordingly, environmental and social uncertainty may generate positive valuation responses when markets interpret them as transition-related opportunities, whereas governance uncertainty is more likely to be priced as downside risk.

Critically, the relative importance of these channels depends on whether uncertainty primarily signals opportunities under voluntary regimes or risks under mandatory regimes. Under voluntary frameworks, the first two channels dominate as uncertainty resolution reveals which firms successfully navigate the transition. Under mandatory regimes, the third channel weakens as compliance becomes universal, while cost uncertainty and implementation risks intensify. This generates the second testable prediction. *Market development and financial integration should moderate transmission efficiency, with deeper and more liquid markets exhibiting stronger responses because sustainability-related information is incorporated more rapidly where trading capacity, investor participation, and market depth are greater.*

2.3. Innovation extraction and identification strategy

A key identification challenge is that text-based uncertainty indices may reflect slow-moving ESG salience rather than genuine uncertainty shocks. If ESGUI simply captures the rising prominence of ESG discourse, its correlation with stock prices could be spurious. Therefore, the analysis must isolate the unexpected component of ESGUI that is orthogonal to past uncertainty and market conditions. Following Brogaard and Detzel (2015), I treat ESGUI innovations as the unpredictable component of sustainability uncertainty after conditioning on lagged ESGUI and lagged stock-price changes. This procedure removes predictable ESG attention and mitigates reverse causality from market conditions to subsequent uncertainty coverage.

If the baseline results reflect genuine sustainability-uncertainty transmission, the positive valuation responses should persist when ESGUI innovations replace ESGUI levels. Conversely, insignificant or attenuated innovation responses would indicate that the baseline association is driven mainly by predictable trends. This logic generates the third testable prediction from the conditional framework. *If sustainability uncertainty genuinely transmits through the opportunity-related channels hypothesized under voluntary disclosure regimes, then positive valuation effects should remain statistically and economically significant when analyzing only unexpected ESGUI innovations, confirming that markets price true uncertainty shocks rather than predictable trends in ESG topic coverage.*

2.4. Recent empirical evidence on sustainability uncertainty

Recent research shows that sustainability-related uncertainty affects financial markets, but findings remain fragmented across contexts. Berestycki et al. (2022) show that climate-policy uncertainty rises around major negotiations and regulatory announcements, indicating that uncertainty is closely tied to the timing and credibility of sustainability transitions. In asset-market settings, Bouri et al. (2022) show that climate-policy uncertainty affects green and brown energy stocks differently, suggesting that transition uncertainty is priced through exposure-specific channels. Treepongkaruna et al. (2023) further show that climate-policy uncertainty is reflected in the cross-section of stock returns, while Tedeschi et al. (2024) provide European evidence that financial-market responses to climate-policy uncertainty are time-varying. These findings motivate examining ESGUI as a broader sustainability-uncertainty measure that captures not only climate-policy uncertainty but also social and governance-related uncertainty.

A related literature emphasizes asymmetric and regime-dependent transmission. Özcan et al. (2023) show that uncertainty shocks transmit differently across renewable and non-renewable energy markets. Balcı (2025) documents quantile-dependent connectedness between artificial intelligence stocks and carbon markets, while Yildirim (2025) shows dynamic interdependencies between artificial intelligence and ESG. Doğan and Zeren (2025) provide especially relevant evidence by examining the relationship between geopolitical risk and ESGUI in G7 economies. Using wavelet- and quantile-based methods, they show that GPR and ESGUI are positively related on average, but that the relationship is nonlinear, time-varying, quantile-dependent, and heterogeneous across countries. These studies support treating sustainability uncertainty as state-dependent rather than homogeneous and motivate the use of ESGUI alongside EPU and GPR to distinguish sustainability-specific pricing effects from broader uncertainty channels.

Disclosure-regulation studies provide another reason to expect regime dependence. Mandatory nonfinancial and sustainability reporting changes firms' information environments, reporting incentives, and market valuations (Christensen et al., 2021; Frankel et al., 2025; Grewal et al., 2019). This literature implies that ESGUI may be priced differently under voluntary disclosure incentives than under mandatory compliance obligations, especially for governance-related uncertainty, where reporting credibility, internal controls, assurance readiness, and oversight quality become more visible.

Regarding ESGUI, Zeren et al. (2025) find asymmetric positive effects in G7 markets, while Benammar et al. (2025) show that transmission strengthens at longer horizons. However, existing ESGUI studies do not provide broad international evidence across developed and emerging markets, benchmark ESGUI against EPU and GPR, or test whether ESGUI effects reverse across voluntary and mandatory disclosure regimes. I address these gaps using 23 markets, innovation extraction, traditional-uncertainty controls, ESG component decomposition, and regulatory-regime tests.

3. Data and methodology

This section details the empirical strategy for testing the hypotheses proposed in Section 2. I first define the sustainability uncertainty measure and describe the sample construction. Next, the local projections framework and the innovation extraction procedure used to identify unexpected ESGUI shocks are described. To examine heterogeneity in transmission mechanisms, I conduct state-dependent local projection analysis, component decomposition, subperiod analysis, country-specific regulatory-timing analysis, and robustness tests.

3.1. Sample and variable construction

The sample comprises 23 markets selected based on availability of monthly country-specific ESGUI data from Ongan et al. (2025) from November 2002 to June 2025 (272 observations). This limits the sample to markets covered by their systematic text analysis methodology. The sample balances broad international coverage with data reliability, yielding a sample spanning diverse development levels and regulatory environments. I classify markets as developed or emerging following the MSCI Market Classification Framework, which evaluates markets based on economic development (GDP per capita, investment environment), size and liquidity (market capitalization, trading volume), and market accessibility (foreign ownership openness, capital flow ease, operational efficiency). Developed markets include Australia, Belgium, Canada, France, Germany, Ireland, Italy, Japan, Netherlands, Singapore, Spain, Sweden, United Kingdom, and United States. Emerging markets include Brazil, Chile, China, Colombia, Greece, India, Mexico, Pakistan, and South Korea.[2]

Real stock prices are measured by country-specific stock price indices in U.S. dollars, deflated by the U.S. Consumer Price Index (CPI), following Yilmazkuday (2024).[3] Following Caldara et al. (2025), all stock price series are normalized to one standard deviation at the country level for estimation purposes, facilitating interpretation of cumulative impulse response coefficients.

I proxy the primary explanatory variable, sustainability uncertainty, by ESGUI index of Ongan et al. (2025).[4] For each country-month, they construct environmental, social, and governance sub-indices from ESG keyword frequencies in Economist Intelligence Unit country reports, and obtain an overall ESG index by averaging the three components. A separate uncertainty index (UI) is constructed from generic uncertainty terms. ESGUI is defined as the simple average of the ESG and UI indices, where both components are min–max normalized to $[0, 100]$ within countries. Constructed from ESG keyword frequencies in Economist Intelligence Unit country reports, ESGUI captures *policy salience*, intensified discourse regarding regulations and transitions, rather than pure second-moment uncertainty. This distinction is critical because while ESGUI spikes during major events like the Paris Agreement, it correlates only moderately with general World Uncertainty Index of Ahir et al. (2022), EPU of Baker et al. (2016) and GPR of Caldara and Iacoviello (2022). Consequently, ESGUI shocks may signal regulatory momentum that benefits ESG-aligned firms, distinct from the pure discount rate effect associated with broad uncertainty. ESGUI is also normalized to one standard deviation before entering regressions following Caldara et al. (2025).

To benchmark ESGUI, this study considers two established uncertainty measures. First, the economic policy uncertainty (EPU) index of Baker et al. (2016) which is constructed from newspaper coverage of policy-related uncertainty. Second, the geopolitical risk (GPR) index of Caldara and Iacoviello (2022) which is based on newspaper coverage of geopolitical tensions and threats. Both are widely used in studies of uncertainty and financial markets (Bouri et al., 2019; Brogaard & Detzel, 2015; Rafi & Ali, 2025; Yilmazkuday, 2024). For comparability, EPU and GPR series are also normalized to one standard deviation.

For global analyses, I use the GDP-weighted global ESGUI index of Ongan et al. (2025), with analogous global measures for EPU and GPR. Control variables include market size (log market capitalization), liquidity (log trading volume), value orientation (dividend yield), inflation (change in CPI), term spread (10-year minus 3-month Treasury yield), default spread (BAA minus AAA corporate bond yield), and industrial production growth. Stock price and firm characteristic data are obtained from LSEG Workspace and macroeconomic variables are downloaded from FRED database.[5]

The variable selection follows the theoretical channels in Section 2. Real stock prices capture valuation-level responses to sustainability uncertainty, while ESGUI is the main shock variable because it measures uncertainty linked to environmental, social, and governance discourse. EPU and GPR serve as benchmark uncertainty measures, allowing the analysis to test whether ESGUI contains pricing information beyond conventional policy and geopolitical uncertainty. Market size and liquidity capture market depth and trading capacity; dividend yield captures value orientation and mature-firm exposure; and inflation, term spread, default spread, and industrial production growth control for macro-financial conditions. These variables therefore map the empirical model to sustainability information, traditional uncertainty, market development, investment style, and business-cycle channels.

3.2. Descriptive statistics

Table 1 presents descriptive statistics for the uncertainty measures across 23 international markets. Panel A shows that ESGUI exhibits lower volatility relative to its mean. The coefficient of variation for developed market ESGUI is approximately 0.35, compared to 0.60 for EPU.[6] This suggests sustainability uncertainty evolves gradually through legislative cycles rather than discrete shocks like geopolitical crises. Excess kurtosis patterns confirm this. GPR shows kurtosis exceeding 13 (rare explosive events) while ESGUI exhibits moderate kurtosis around 3. Panel B reports that ESGUI contains information orthogonal to general economic or political distress. The within-country correlation between ESGUI and EPU are low ($\rho = 0.29$), and even lower with GPR ($\rho = 0.19$). This orthogonality is crucial for our identification strategy. The lower correlation of 0.52 between country-specific and Global ESGUI than for EPU or GPR implies significant idiosyncratic variation despite global coordination. This heterogeneity provides the necessary identification leverage to isolate country-specific transmission channels.

[2] This classification captures institutional differences in regulatory capacity, enforcement quality, and financial market integration that theory predicts should moderate sustainability uncertainty transmission. While regulatory adoption timing varies across countries within each group, a feature I address through subperiod analysis, the developed versus emerging distinction provides a first-order proxy for institutional capacity that conditions how sustainability uncertainty affects valuations.

[3] This approach ensures cross-country comparability by expressing all series in constant U.S. dollar purchasing power.

[4] Downloaded from https://www.policyuncertainty.com/sustainability_index.html.

[5] Obtained from https://fred.stlouisfed.org/release?rid=205 and https://fred.stlouisfed.org/tags/series.

[6] Coefficient of variation is calculated by dividing standard deviation by the mean.

Table 1
Descriptive statistics and diagnostic tests for stock returns and uncertainty measures.

Panel A: Descriptive statistics of uncertainty indices for developed and emerging countries					
Variable	Mean	SD	Skew.	Kurt.	AC1
ESG-based sustainability uncertainty index (ESGUI):					
Developed countries average	31.25	11.03	1.05	2.94	0.66
Emerging countries average	27.30	10.96	1.40	3.46	0.66
Global	28.28	7.76	2.56	10.96	0.79
Economic policy uncertainty index (EPU):					
Developed countries average	160.38	96.84	1.67	5.33	0.77
Emerging countries average	129.96	80.75	1.79	5.16	0.77
Global	160.51	85.09	1.54	4.09	0.89
Geopolitical risk index (GPR):					
Developed countries average	0.45	0.23	2.87	13.00	0.62
Emerging countries average	0.22	0.14	3.06	18.61	0.55
Global	105.43	36.71	2.84	12.87	0.74

Panel B: Correlation between uncertainty measure		
Measure pair	Correlation	Range
Correlation between global uncertainty measures:		
Global ESGUI - Global EPU	0.50	
Global ESGUI - Global GPR	0.45	
Global EPU - Global GPR	0.12	
Avg. corr. between country-specific & global uncertainty measures:		
ESGUI (country to global)	0.52	(0.38, 0.88)
EPU (country to global)	0.65	(−0.05, 0.99)
GPR (country to global)	0.60	(0.14, 0.98)
Within-country average correlation across measures:		
ESGUI - EPU	0.29	(−0.12, 0.78)
ESGUI - GPR	0.19	(−0.02, 0.47)
EPU - GPR	0.19	(−0.12, 0.64)

This table reports descriptive statistics and correlation for monthly uncertainty measures across 23 international markets from November 2002 to June 2025. Panel A presents statistics for country-specific and global uncertainty measures in index levels. ESGUI denotes the ESG-based sustainability uncertainty index, EPU denotes the economic policy uncertainty index, and GPR denotes the geopolitical risk index. Panel B reports correlations among uncertainty measures. Global uncertainty measure correlations shows the correlation among global ESGUI, EPU, and GPR, respectively. Country-to-global correlations show how country-specific measures correlate with their corresponding global indices. Within-country across-measure correlations show how different uncertainty measures correlate with each other within the same country. All correlations are computed using index levels for uncertainty measures.

Having documented the distinct properties of sustainability uncertainty, I next examine the behavior of dependent variable, real stock prices, to look at their cross-sectional variation. Fig. 1 presents time-series properties of real stock prices and documents synchronized declines of 1.5–2.5 standard deviations during the 2008–2009 crisis, followed by sharply divergent recovery paths. Emerging markets and core European economies (e.g., Sweden, Netherlands) rebounded rapidly, while peripheral economies (e.g., Greece, Italy) stagnated.

Fig. 2 aggregates these dynamics and plots the cross-sectional distribution of normalized prices. The dispersion between best and worst performers widens dramatically during global distress. It confirms that while systematic shocks drive correlations, substantial idiosyncratic variation remains. This time-varying heterogeneity allows us to test how market-specific traits such as liquidity and ESG preparedness condition the transmission of uncertainty shocks.

3.3. Empirical methodology

The empirical model follows the conditional uncertainty framework in Section 2. The baseline specification estimates dynamic responses of real stock prices to country-specific ESGUI shocks. I then extend the model to test the proposed mechanisms: global ESGUI shocks capture internationally coordinated sustainability uncertainty; ESGUI innovations isolate unexpected information; joint EPU–GPR specifications test whether ESGUI effects are distinct from traditional uncertainty; state-dependent models test market heterogeneity; and decomposition and regulatory-regime analyses test variation across ESG dimensions and disclosure regimes. The identifying assumption is that, conditional on lagged stock prices, lagged uncertainty measures, and relevant controls, ESGUI shocks capture sustainability-related information not already embedded in past market conditions.

3.3.1. Local projection framework

To estimate dynamic stock-price responses to sustainability uncertainty shocks, I employ the local projection method of Jordà (2005). Local projections are appropriate because the central prediction of the paper is dynamic rather than purely contemporaneous.

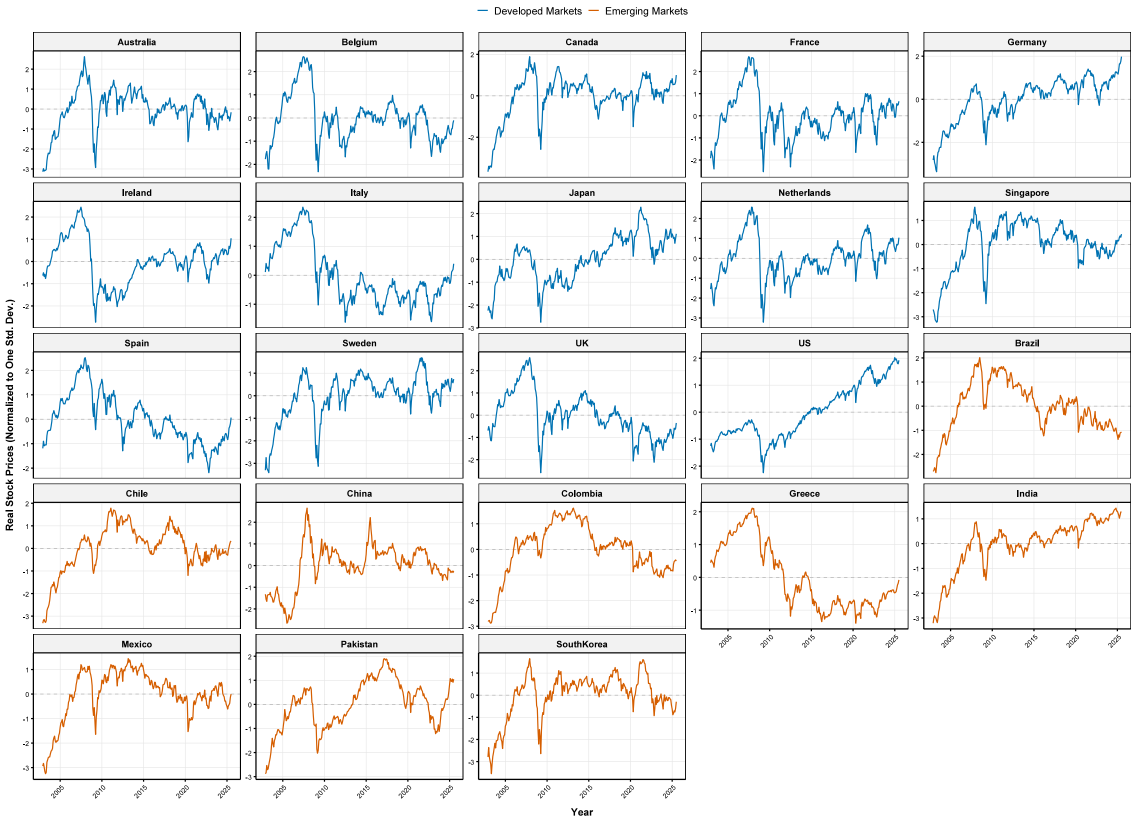

Fig. 1. Time-series evolution of real stock prices across country.
This figure plots monthly real stock prices for 23 countries from November 2002 to June 2025. Real prices are constructed by deflating nominal price indices by the US Consumer Price Index and normalizing to one standard deviation to facilitate cross-country comparisons. Countries are classified as developed markets (n = 14, blue lines) or emerging markets (n = 9, orange lines) following MSCI classification and sorted alphabetically within each group. Each panel uses independent y-axis scaling to highlight country-specific dynamics. The normalization implies that a value of 1.0 represents a one-standard-deviation increase above the country's mean real price level over the sample period.

Stock prices may respond gradually as investors revise expectations about sustainability regulation, transition opportunities, compliance costs, and discount rates. Unlike a tightly parameterized VAR, local projections estimate horizon-specific responses directly and do not require specifying the full dynamic system linking stock prices, uncertainty indices, and macro-financial variables. This flexibility is particularly useful in an international setting where markets differ in size, liquidity, institutional structure, and persistence of stock-price dynamics.

Following Caldara et al. (2025) and Yilmazkuday (2024), I estimate the following h-step-ahead predictive regression for each country i[7]:

$$s_{i,t+h} = \alpha_{i(h)} + \beta_{i(h)}\text{ESGUI}_{i,t} + \sum_{k=1}^{p} \phi_{k(h)} s_{i,t-k} + \sum_{k=1}^{p} \gamma_{k(h)}\text{ESGUI}_{i,t-k} + \varepsilon_{i(h),t+h}, \tag{1}$$

where $s_{i,t}$ and $\text{ESGUI}_{i,t}$ denote real stock prices and country-specific ESGUI, both normalized to one standard deviation, for country i, $\beta_{i(h)}$ measures the h-step-ahead cumulative response of stock prices to a one-standard-deviation ESGUI shock, the lagged values of $s_{i,t}$ and $\text{ESGUI}_{i,t}$ serve as control variables, with the lag order is set to $p = 12$, and $\varepsilon_{i(h),t+h}$ is a prediction error term. Standard errors are Newey–West adjusted with automatic lag selection. Estimation is conducted separately for each horizon $h = 6, 9, 12, \ldots, 24$

[7] Following established precedent in international uncertainty-transmission research (Caldara et al., 2025; Yilmazkuday, 2024), I analyze real stock-price levels rather than returns because the objective is to examine valuation effects over extended horizons rather than short-horizon return dynamics. Lag-augmented local projections are suitable for persistent financial series and do not require first-differencing that would change the interpretation from valuation effects to return effects (Montiel Olea & Plagborg-Møller, 2021).

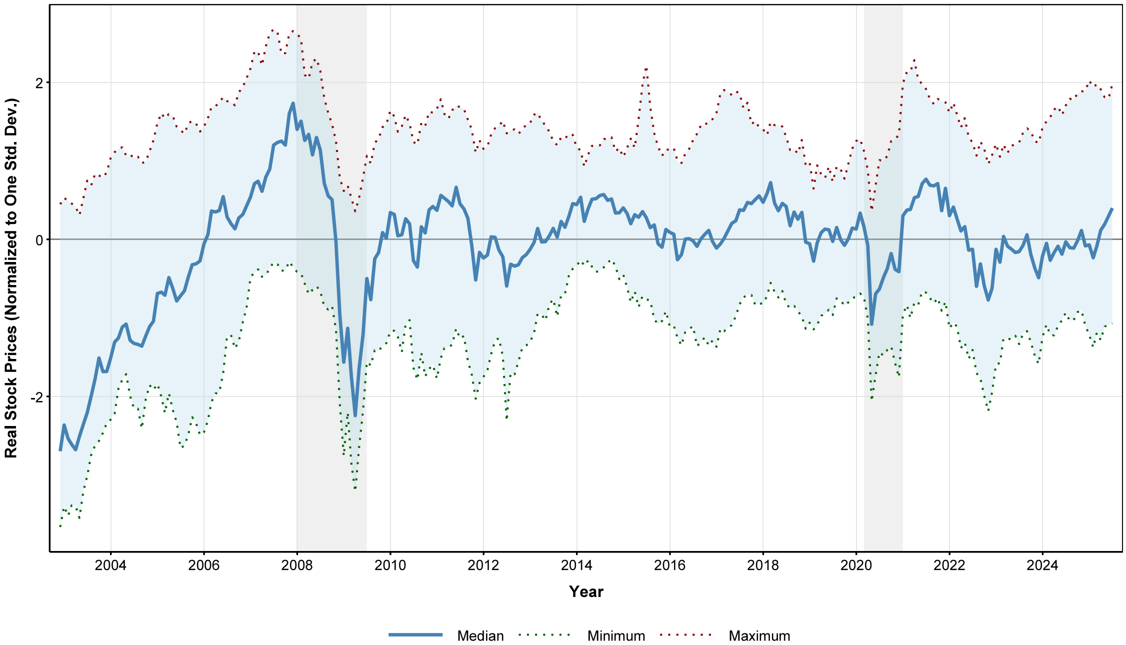

Fig. 2. Cross-sectional dispersion in real stock prices.
This figure illustrates the time-varying cross-sectional dispersion of real stock prices across all 23 sample countries from November 2002 to June 2025. At each monthly observation, the minimum, median, and maximum values of normalized real stock prices across countries are plotted. The solid blue line represents the median (50th percentile), while dotted lines bound the range between the minimum and maximum, with shading indicating the full cross-sectional distribution. Gray vertical bands mark periods of major financial stress: the Global Financial Crisis (January 2008-June 2009) and the COVID-19 pandemic (March 2020-December 2020). Widening dispersion during crisis periods reveals heterogeneous country-level resilience to global shocks, while convergence suggests synchronized market movements.

months, with primary results reported for $h = 12, 18, 24$. Following Yilmazkuday (2024), responses are systematic for a country group when over 50% of countries exhibit significance at the 10% level.[8]

I use the smooth local projection estimator of Barnichon and Brownlees (2019) as the baseline because monthly data and long response horizons can produce noisy impulse-response estimates when each horizon is estimated independently. Smoothing improves precision by imposing regularity across adjacent horizons, while standard local projections are retained as a robustness test to ensure that the results are not driven by the smoothing procedure. For global shocks, I replace $\text{ESGUI}_{i,t}$ with the GDP-weighted global ESGUI and estimate:

$$s_{i,t+h} = \mu_{i(h)} + \theta_{i(h)}\text{ESGUI}_t + \sum_{k=1}^{p} \varphi_{k(h)} s_{i,t-k} + \sum_{k=1}^{p} \psi_{k(h)}\text{ESGUI}_{t-k} + u_{i(h),t+h}, \tag{2}$$

where ESGUI_t denotes global ESGUI, normalized to one standard deviation, at time t, and $\theta_i(h)$ measures country i's cumulative response to a one-standard-deviation global sustainability uncertainty shock. Estimating country-specific and global ESGUI shocks separately allows the analysis to distinguish local sustainability-policy discourse from internationally coordinated sustainability uncertainty, such as global climate agreements, multinational disclosure standards, and cross-border regulatory developments. Analogous specifications are estimated for EPU and GPR to enable direct comparison across uncertainty types.

Because normalization makes the baseline coefficients comparable across countries but less directly interpretable in economic units, I also translate the standardized impulse-response estimates into percentage price changes. In Appendix, I report these economic magnitudes using the transformation $100 \times [\exp(\hat{\beta}_{i,h}\sigma_i) - 1]$, where $\hat{\beta}_{i,h}$ is the estimated standardized response and σ_i is the standard deviation of the corresponding unstandardized real log stock-price series.

[8] The lagged values of $s_{i,t}$ and $\text{ESGUI}_{i,t}$ control for persistence in valuation levels and sustainability uncertainty so that $\beta_{i(h)}$ captures the incremental predictive content of ESGUI beyond past market and uncertainty conditions.

3.3.2. ESGUI innovation analysis

Observed ESGUI levels may reflect predictable trends in ESG salience or slow-moving institutional developments rather than genuine shocks. This distinction is important because the empirical framework aims to estimate market responses to new sustainability-related information, not simply correlations between stock prices and the rising prominence of ESG discourse. To isolate the unpredictable component of ESGUI orthogonal to past information, I extract innovations for each country i following Brogaard and Detzel (2015):

$$\mathrm{ESGUI}_{i,t} = \omega_i + \sum_{k=1}^{p} \delta_{i,k} \mathrm{ESGUI}_{i,t-k} + \sum_{k=1}^{p} \eta_{i,k} \Delta s_{i,t-k} + v_{i,t},$$

where $\Delta s_{i,t-k} = s_{i,t-k} - s_{i,t-k-1}$ denotes lagged stock price changes, and the lag order p is selected by Bayesian information criterion (maximum 12 lags). The residuals $v_{i,t}$ represent innovations orthogonal to past ESGUI and stock market conditions. Including lagged price changes addresses potential reverse causality because past market movements may predict subsequent ESGUI coverage through feedback from financial-market conditions to policy or media attention.[9] I then re-estimate Eq. (1) with $v_{i,t}$ as the shock variable:

$$s_{i,t+h} = \tilde{\alpha}_{i(h)} + \tilde{\beta}_{i(h)} v_{i,t} + \sum_{k=1}^{p} \tilde{\phi}_{k(h)} s_{i,t-k} + \sum_{k=1}^{p} \tilde{\gamma}_{k(h)} v_{i,t-k} + e_{i(h),t+h}, \tag{3}$$

where $\tilde{\beta}_{i(h)}$ measures the response to an unexpected one-standard-deviation increase in sustainability uncertainty. Comparing $\tilde{\beta}_{i(h)}$ from Eq. (3) with $\beta_{i(h)}$ from Eq. (1) reveals whether positive effects persist after removing predictable patterns. Global ESGUI innovations are constructed analogously using an autoregression that includes lagged global stock market changes.

3.3.3. Controlling for traditional uncertainty measures

While benchmarking ESGUI against EPU and GPR separately establishes stylized facts, it does not rule out omitted variable bias. To test whether ESGUI effects reflect genuinely distinct transmission channels rather than correlation with traditional uncertainty, I estimate an augmented specification that includes country-specific EPU and GPR alongside ESGUI:

$$\begin{aligned} s_{i,t+h} = {} & \alpha_{i(h)} + \beta_{1(h)} \mathrm{ESGUI}_{i,t} + \beta_{2(h)} \mathrm{EPU}_{i,t} + \beta_{3(h)} \mathrm{GPR}_{i,t} \\ & + \sum_{k=1}^{p} \phi_{k(h)} s_{i,t-k} + \sum_{k=1}^{p} \delta_{k(h)} \mathbf{u}_{i,t-k} + \varepsilon_{i(h),t+h}, \end{aligned} \tag{4}$$

where $\mathbf{u}_{i,t-k} = [\mathrm{ESGUI}_{i,t-k}, \mathrm{EPU}_{i,t-k}, \mathrm{GPR}_{i,t-k}]'$ represents the vector of lagged uncertainty measures. The coefficient $\beta_{1(h)}$ now captures the marginal effect of sustainability uncertainty conditional on traditional uncertainty levels. If ESGUI simply proxies for general uncertainty that EPU and GPR partially capture, its coefficient should diminish or reverse sign in this specification. Conversely, if $\beta_{1(h)}$ remains positive and significant, this validates that sustainability uncertainty operates through channels distinct from EPU and GPR.

3.3.4. Endogeneity concerns and identification strategy

Three potential endogeneity concerns could bias the estimated responses and require explicit identification strategies. First, reverse causality may arise if stock market conditions influence ESGUI construction through media coverage responding to market movements. Second, omitted global shocks (e.g., financial crises, pandemic events) could drive both sustainability uncertainty and stock prices simultaneously, generating spurious correlation. Third, measurement error in text-based ESGUI could attenuate estimates or introduce bias if errors correlate with market conditions.

I address these concerns through four complementary identification approaches. First, the innovation extraction procedure following Brogaard and Detzel (2015) isolates the unexpected component of ESGUI orthogonal to past information and lagged market conditions. By conditioning on 12 lags of both ESGUI and stock price changes, this procedure removes predictable variation that might reflect market-driven media coverage, substantially mitigating reverse causality concerns. Second, the baseline local-projection specification includes 12 lags each of the dependent variable and shock variable, which controls for persistence in stock prices and sustainability uncertainty. In robustness tests, I further augment the specification with macro-financial controls, including the term spread, default spread, and industrial production growth, to verify that the results are not driven by business-cycle conditions or credit-market stress.

Third, I implement instrumental variables analysis in robustness tests using lagged global ESGUI as an instrument for country-specific ESGUI. Global sustainability policy developments influence domestic uncertainty through spillover effects while plausibly avoiding direct feedback from domestic market conditions. This approach provides an alternative identification strategy based on international transmission channels rather than time-series filtering alone. Fourth, I conduct Granger causality tests to examine the temporal ordering of ESGUI and stock price movements, testing whether sustainability uncertainty precedes valuation changes or vice versa. Combined with innovation extraction that conditions on lagged returns, this temporal precedence analysis provides additional evidence on the direction of causation.

While these approaches do not achieve full experimental identification, which would require exogenous variation in sustainability uncertainty independent of all economic conditions, they substantially mitigate the key endogeneity concerns identified above.

[9] Brogaard and Detzel (2015) include lagged returns in their EPU innovation extraction for the same reason that past market movements may predict future policy uncertainty coverage.

The robustness of findings across levels analysis, innovation extraction, joint uncertainty controls, and instrumental variables specifications will provide converging evidence on whether sustainability uncertainty transmission represents a genuine economic relationship. The conditional framework developed in Section 2, which predicts sign reversals linked to regulatory regime transitions, provides further testable implications by showing whether estimated responses align with theoretical predictions about how institutional context shapes transmission mechanisms.

3.3.5. Heterogeneity analysis

To test the heterogeneity hypotheses from Section 2, I employ state-dependent local projections following Ramey and Zubairy (2018). I posit that transmission strengthens in deeper and more liquid markets where information incorporation and portfolio adjustment are more efficient (Pástor et al., 2021), and weakens under macroeconomic instability when investors may place less weight on long-horizon sustainability considerations (Segal et al., 2015). Thus, I define a high-state indicator $I^H_{i,t} = \mathbf{1}(Z_{i,t} > \text{median}(Z))$, where $Z_{i,t}$ represents the conditioning variable (market size, liquidity, dividend yield, or inflation).[10] Then, I estimate the following model:

$$s_{i,t+h} = \alpha_{i(h)} + \beta^L_{i(h)}\text{ESGUI}_{i,t} \cdot (1 - I^H_{i,t}) + \beta^H_{i(h)}\text{ESGUI}_{i,t} \cdot I^H_{i,t} + \boldsymbol{\Phi}'_{(h)}\mathbf{C}_{i,t} + \varepsilon_{i(h),t+h}, \tag{5}$$

where $\beta^L_{i(h)}$ and $\beta^H_{i(h)}$ capture ESGUI effects when the conditioning variable is below its median (low state) and above its median (high state) respectively, $\mathbf{C}_{i,t}$ includes 12 lags each of stock prices and ESGUI, and $\boldsymbol{\Phi}'_{(h)}$ is the corresponding coefficient vector.[11] The difference $\beta^H_{i(h)} - \beta^L_{i(h)}$ indicates how transmission changes with the conditioning variable. For instance, if $\beta^H_{i(h)} > \beta^L_{i(h)}$ for market size, ESGUI effects strengthen in larger markets. This state-dependent specification follows directly from the theoretical prediction that sustainability uncertainty should be incorporated into prices more strongly in markets where depth, liquidity, and macroeconomic stability facilitate information processing and portfolio adjustment. I estimate Eq. (5) separately for each conditioning variable at the 12-month horizon.

To test whether market development affects sensitivity and how this relationship evolves, I construct a composite development index following Bekaert et al. (2005) by averaging standardized market size and liquidity and estimate panel regressions with development interaction where the specification includes a time trend interaction to capture the integration of ESG factors over the sample period[12]:

$$\begin{aligned} s_{i,t+h} = {} & \alpha_i + \beta_{(h)}\text{ESGUI}_{i,t} + \lambda_{1(h)}(\text{Dev}_i \times \text{ESGUI}_{i,t}) + \lambda_{2(h)}(\text{Trend}_t \times \text{ESGUI}_{i,t}) \\ & + \lambda_{3(h)}(\text{Dev}_i \times \text{Trend}_t \times \text{ESGUI}_{i,t}) + \boldsymbol{\Phi}'_{(h)}\mathbf{C}_{i,t} + \varepsilon_{i,t+h}, \end{aligned} \tag{6}$$

where α_i are country fixed effects, Dev_i is the time-invariant composite development index, and Trend_t represents a linear time trend. The coefficient $\lambda_{3(h)}$ captures the triple interaction, testing whether the influence of market development on transmission converges or diverges over time. A positive $\lambda_{(h)}$ indicates that more developed markets exhibit stronger responses to sustainability uncertainty. Standard errors are clustered at the country level to account for serial correlation.

3.3.6. Decomposition and subperiod analysis

To understand which dimensions of sustainability uncertainty drive the aggregate effects, I decompose ESGUI into environmental (E), social (S), and governance (G) components.[13] I estimate Eq. (1) separately for each component to allow direct comparison of their relative importance.

Beyond this decomposition, the relationship between sustainability uncertainty and stock prices may vary across different stages of ESG regulatory development. Following Yilmazkuday (2024), who examine how geopolitical risk effects vary across crisis periods, I partition the sample into four subperiods reflecting distinct ESG regulatory eras. The decomposition and subperiod analyses are designed to test whether ESGUI operates as a homogeneous uncertainty index or whether its pricing effects depend on the ESG dimension and regulatory regime through which uncertainty is transmitted. As illustrated in Fig. A.1, these divisions correspond to meaningful shifts in both sustainability uncertainty levels and regulatory intensity. Early ESG Era (November 2002-December 2010) covers initial voluntary frameworks and the financial crisis testing of ESG resilience. Pre-Paris Consolidation (January 2011-December 2015) marks increased institutional focus on pre-Paris Agreement. Paris-TCFD Implementation (January 2016-December 2020) encompasses the Paris Agreement (2015) and TCFD recommendations (2017). Finally, CSRD-ISSB Era (January 2021-June 2025) is characterized by mandatory disclosure regimes including the EU's Corporate Sustainability Reporting Directive (CSRD) and ISSB global standards. I estimate Eq. (1) separately for each subperiod to test whether positive ESGUI effects strengthen or weaken as ESG integration matures.

[10] For example, when examining market size, $I^H_{i,t} = 1$ identifies large markets (above median capitalization) and $I^H_{i,t} = 0$ identifies small markets (below median).

[11] The interaction structure ensures that when $I^H_{i,t} = 1$ (high state), the term $(1 - I^H_{i,t}) = 0$ turns off the low-state coefficient, activating only $\beta^{High}_{i(h)}$. Conversely, when $I^H_{i,t} = 0$ (low state), $(1 - I^H_{i,t}) = 1$ activates only $\beta^{Low}_{i(h)}$.

[12] The index captures market depth and activity. I exclude dividend yield and inflation, which proxy for investment style and macroeconomic stability, respectively, rather than financial sophistication.

[13] Each component is constructed analogously to the overall ESGUI but using only keywords specific to that dimension. For example, the environmental component (EUI) combines environmental keyword salience with the generic uncertainty index. For details, see Ongan et al. (2025).

Because the transition from voluntary to mandatory sustainability disclosure did not occur simultaneously across jurisdictions, I also conduct a country-specific regulatory-timing analysis. For this exercise, I construct monthly indicators for mandatory and anticipation regimes using country-level disclosure calendars. The mandatory-regime indicator equals one beginning from the first month of the first mandatory fiscal year applying to large listed firms or the dominant listed-company reporting cohort. The anticipation-regime indicator captures earlier announcement, adoption, roadmap, or effective-date events where these precede mandatory application. The quarterly timing information collected during the coding process is not used in the present monthly analysis. I report the voluntary-regime effect, the country-specific mandatory or anticipation-regime effect, and the interaction delta between them in Appendix.

3.3.7. Robustness tests

I conduct robustness tests to validate the main findings. First, I use standard local projections of Jordà (2005) to confirm findings are not artifacts of the smoothing procedure. Second, I examine alternative lag structures to ensure results are not sensitive to lag specification. Third, I augment Eq. (1) with macroeconomic controls (term spread, default spread, industrial production growth) to account for confounding economic conditions. Fourth, I exclude high volatility periods (defined as months when VIX exceeds its 90th percentile) to confirm effects operate during normal market conditions rather than extreme market stress. Fifth, I estimate specifications using equal-weighted rather than GDP-weighted global ESGUI of Ongan et al. (2025) to verify global shock findings.

4. Empirical results

4.1. Preliminary evidence

Before estimating the dynamic stock-price responses to sustainability uncertainty, I verify that ESGUI captures information distinct from general economic or political distress. Fig. 3 plots global ESGUI alongside global EPU and GPR indices respectively over 2002–2025. The indices display divergent trajectories. ESGUI exhibits distinct spikes around regulatory milestones, most visibly during the 2015 Paris Climate Agreement and 2021 EU CSRD announcement, while EPU and GPR remain relatively stable. Conversely, GPR is dominated by explosive, short-lived shocks (e.g., 2003 Iraq War, 2022 Ukraine invasion) that do not translate into sustainability uncertainty spikes. This orthogonality, consistent with the low correlations observed in Panel B of Table 1 (ESGUI-EPU: 0.29; ESGUI-GPR: 0.19), confirms that ESGUI captures distinct information about the resolution of sustainability transition uncertainty rather than general institutional or military risks.

Fig. 4 illustrates the cross-sectional heterogeneity exploited in subsequent tests. Fig. 4a shows bilateral correlations by market group. The average (median) correlation is 0.63 (0.66) across country pairs, with developed markets highly integrated ($\rho = 0.79$) but emerging markets retaining substantial idiosyncratic dynamics ($\rho = 0.46$).[14] Fig. 4b documents that correlations spike during global crises (e.g.,2008–2009 and 2020) but recede during normal periods. This confirms that global shocks are not absorbed uniformly and allows identification of how market characteristics condition sustainability uncertainty transmission.

4.2. ESGUI effects on stock prices

Having established ESGUI's distinctness from traditional uncertainty measures, I now test the central prediction from the conditional framework developed in Section 2 i.e., sustainability uncertainty effects should vary across institutional contexts. Fig. 5 displays cumulative impulse responses of stock prices to country-specific ESGUI shocks for each country, with coefficients reported in Table 2 at horizons of 12, 18, and 24 months.

The results reveal substantial cross-country heterogeneity in how stock markets respond to sustainability uncertainty shocks. Among developed markets, countries with mature ESG ecosystems show strong positive associations. A one-standard-deviation country-specific ESGUI shock is associated with stock price increases of 1.98 standard deviations in the Netherlands, 1.53 in Sweden, and 1.22 in Belgium at the 12-month horizon. These magnitudes persist and strengthen over longer horizons, reaching 2.73, 1.88, and 2.18 standard deviations respectively at 24 months.

Conversely, distinct clusters exhibit negative or insignificant associations. Southern European markets show negative coefficients. A one-standard-deviation country-specific ESGUI shock is associated with stock price declines of 0.39 standard deviations in Italy and 0.52 in Greece at 12 months. These patterns may reflect structural characteristics including carbon intensity of production, capital market depth, and institutional capacity differences across markets. Japan displays muted insignificant responses despite high disclosure rates, potentially reflecting institutional frictions where ESG practices emphasize nominal compliance over value-creating integration. Emerging markets show generally weaker and mixed responses with wide variation across countries reflecting differences in ESG integration levels, market development, and investor sophistication.

When median responses are considered across market groups, developed markets exhibit stronger positive associations than emerging markets. In standardized terms, the developed-market median response equals 0.54 standard deviations at 12 months and increases to 1.22 standard deviations by 24 months, whereas the corresponding emerging-market responses are close to zero at 12 months and more modest at longer horizons. As shown in Fig. 5, cumulative responses at 24 months are markedly stronger

[14] This bilateral correlation ranges between 0.12 (between China and Pakistan) and 0.94 (between France and Germany).

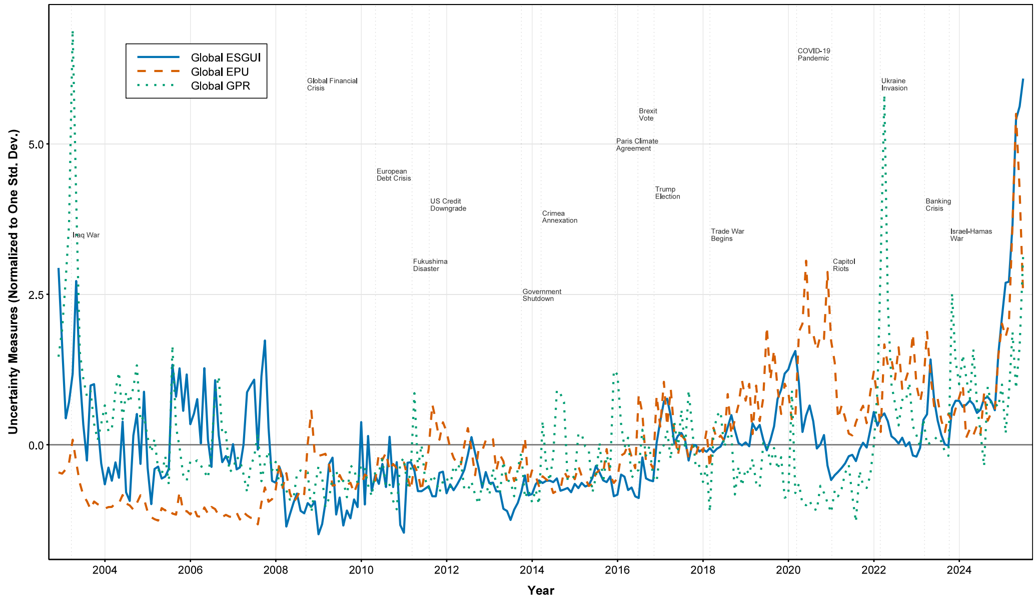

Fig. 3. Global uncertainty measures and major economic events.
This figure displays three global uncertainty indices from November 2002 to June 2025, each normalized to one standard deviation. The indices are: ESG-based sustainability uncertainty index (ESGUI, solid blue line), Economic policy uncertainty index (EPU, dashed orange line), and Geopolitical risk index (GPR, dotted green line). Vertical dotted lines mark major events generating uncertainty spikes including geopolitical crises (Iraq War 2003, Crimea 2014, Ukraine 2022, Israel-Hamas 2023), financial crises (Global Financial Crisis 2008, European Debt Crisis 2010, Banking Crisis 2023), policy uncertainty events (US government shutdown 2013, Brexit 2016, Trump election 2016, Trade War 2018), and sustainability milestones (Paris Agreement 2015). Co-movements and divergences across indices reveal distinct uncertainty dimensions and their varying sensitivities to different event types.

in developed markets (1.22) than in emerging markets (0.26), suggesting that ESGUI effects persist and strengthen over longer horizons.

To make these standardized responses economically interpretable, Table A.1 translates the impulse-response estimates into percentage price changes. The developed-market median effect corresponds to an estimated price increase of approximately 11.88% at 12 months, 23.12% at 18 months, and 28.44% at 24 months. For emerging markets, the corresponding median effects are smaller, amounting to approximately 0.38%, 7.39%, and 16.36%, respectively. These magnitudes indicate that ESGUI shocks are not only statistically relevant but also economically meaningful, particularly in developed markets where ESG-related information is more rapidly incorporated into asset prices.

After examining country-specific ESGUI shocks, I next investigate the effects of global ESGUI shocks on stock prices. While country-specific ESGUI captures domestic sustainability-policy discourse, global ESGUI reflects internationally coordinated sustainability developments, including climate agreements, multinational disclosure standards, and global transition-related policy attention. Fig. 6 visualizes these country-level responses, while Table 3 reports coefficients at horizons of 12, 18, and 24 months. Global ESGUI shocks generate substantially stronger and more pervasive associations than country-specific shocks. The median 12-month coefficient for developed markets is 1.92 standard deviations, approximately 3.5 times larger than country-specific effects. Notably, markets responding negatively to local shocks often respond positively to global shocks. Italy shows associations of 1.63 standard deviations following global ESGUI shocks compared to −0.39 following local shocks. Similar patterns occur in Spain and Brazil.

This pattern, visualized in Fig. 6, suggests that global sustainability uncertainty operates as a systematic transition-related factor that can dominate idiosyncratic local policy frictions. Because the analysis does not directly observe cross-border portfolio flows, this evidence should be interpreted as consistent with international market-integration and information-transmission channels rather than as direct evidence of capital reallocation.

A potential concern is that ESGUI levels may proxy for trending ESG salience rather than genuine uncertainty shocks. To address this, I extract innovations in ESGUI orthogonal to past information following Brogaard and Detzel (2015). Fig. 7 displays cumulative responses of stock prices to innovations in country-specific ESGUI, with coefficients presented in Table 4. The results confirm that associations remain significant after removing predictable components, though magnitudes decline as expected when isolating pure innovations. This indicates that markets respond to unexpected sustainability uncertainty rather than merely trending attention to ESG topics. Negative associations in Southern European markets (Greece, Italy, Spain) preserve their sign when using innovations.

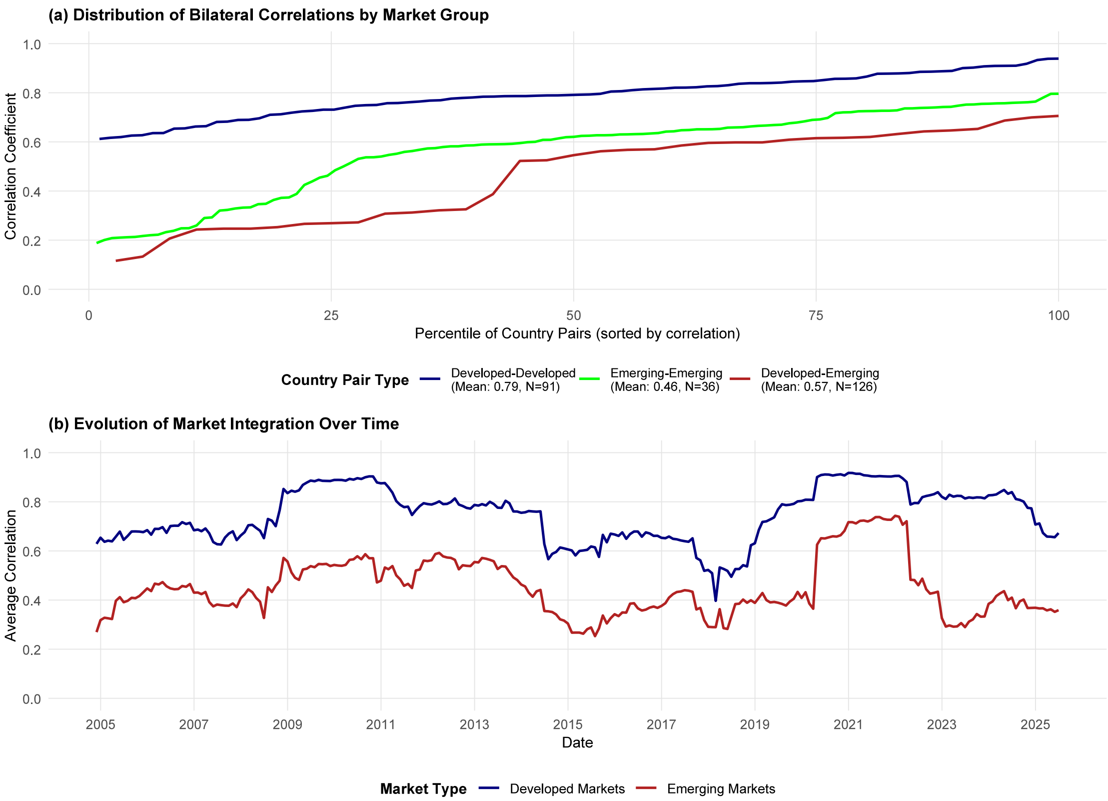

Fig. 4. Bilateral correlations across market development groups.
This figure examines bilateral correlations of monthly stock returns across 23 countries from November 2002 to June 2025. (a) displays the distribution of bilateral correlations separately for three types of country pairs: developed-developed (91 pairs), emerging-emerging (36 pairs), and developed-emerging (126 pairs). Within each group, country pairs are sorted from lowest to highest correlation along the horizontal axis (expressed as percentiles), with the vertical axis showing the correlation coefficient. The position of each line indicates the average level of integration for that group, while the slope indicates variability within the group. (b) displays the evolution of average pairwise correlations over time using 24-month rolling windows, calculated separately for developed and emerging market pairs. Correlations are calculated using monthly stock returns, defined as first differences of log real stock prices. Real stock prices are constructed by deflating nominal stock price indices with the US Consumer Price Index and expressing values in US dollar terms. Developed markets follow MSCI classification and include Australia, Belgium, Canada, France, Germany, Ireland, Italy, Japan, Netherlands, Singapore, Spain, Sweden, United Kingdom, and United States. Emerging markets include Brazil, Chile, China, Colombia, Greece, India, Mexico, Pakistan, and South Korea.

For emerging markets, the modest positive median response (0.01 standard deviations) using ESGUI levels in Table 2 becomes negative (−0.03) when using innovations. This suggests differential sensitivity to predictable versus unexpected components of sustainability uncertainty across market development levels. Fig. 7 visualizes these innovation-based responses. The results confirm that the main patterns hold when focusing on unexpected shocks and reinforce that unexpected local regulatory tightening is consistently viewed as friction in these jurisdictions.

4.3. Comparison with EPU and GPR

The empirical evidence so far demonstrates that sustainability uncertainty shocks are associated with positive stock price responses across most developed markets. To verify that positive valuation effects are specific to ESGUI rather than a general property of uncertainty, I replicate the analysis using EPU and GPR (see Table 5), while Figs. A.2 and A.3 visualize the cumulative responses of country-specific EPU and GPR respectively for each horizon and for each country. A stark asymmetry emerges from the results. While a positive unit shock to country-specific EPU (GPR) reduces median stock prices in the developed market by 1.51 (0.54) at

Table 2
Cumulative impulse responses of stock prices to country-specific ESG-based sustainability uncertainty shocks.

Country	12 months			18 months			24 months		
	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound
Australia	**0.52***	0.05	0.99	**0.60***	0.03	1.16	**1.11***	0.46	1.76
Belgium	**1.22***	0.83	1.61	**2.12***	1.56	2.68	**2.65***	1.92	3.38
Brazil	**−0.04**	−0.27	0.18	**0.15**	−0.15	0.44	**0.83***	0.46	1.20
Canada	**0.32**	−0.14	0.78	**0.62***	0.04	1.19	**0.96***	0.29	1.63
Chile	**−0.16**	−0.66	0.33	**−0.19**	−0.89	0.51	**−0.69**	−1.57	0.19
China	**0.51***	0.08	0.93	**0.70***	0.14	1.26	**1.10***	0.41	1.78
Colombia	**0.29**	−0.02	0.60	**0.35**	−0.04	0.74	**0.26**	−0.17	0.69
France	**0.52***	0.04	1.00	**0.81***	0.19	1.42	**0.47**	−0.26	1.20
Germany	**0.75***	0.52	0.98	**1.31***	1.02	1.61	**1.56***	1.19	1.92
Greece	**−0.52***	−0.75	−0.30	**−0.77***	−1.05	−0.48	**−0.87***	−1.20	−0.55
India	**0.01**	−0.20	0.22	**0.15**	−0.09	0.40	**0.14**	−0.16	0.44
Ireland	**0.99***	0.57	1.40	**1.66***	1.09	2.23	**2.05***	1.24	2.85
Italy	**−0.39***	−0.64	−0.13	**−0.29**	−0.60	0.02	**−0.29**	−0.64	0.06
Japan	**−0.04**	−0.48	0.40	**0.12**	−0.43	0.68	**0.06**	−0.61	0.72
Mexico	**−0.18**	−0.43	0.08	**−0.29**	−0.66	0.08	**−0.09**	−0.52	0.33
Netherlands	**1.98***	1.59	2.37	**3.59***	3.03	4.14	**4.26***	3.55	4.98
Pakistan	**0.94***	0.64	1.24	**0.99***	0.52	1.46	**0.83***	0.23	1.44
Singapore	**0.55***	0.13	0.97	**1.74***	1.18	2.29	**2.37***	1.76	2.97
South Korea	**0.53***	0.04	1.03	**0.93***	0.36	1.51	**0.99***	0.36	1.62
Spain	**−0.12**	−0.46	0.23	**0.20**	−0.20	0.61	**0.51***	0.05	0.96
Sweden	**1.53***	1.13	1.93	**2.80***	2.31	3.29	**2.93***	2.28	3.57
UK	**0.57***	0.17	0.97	**1.07***	0.51	1.62	**1.34***	0.70	1.98
US	**0.31***	0.13	0.48	**0.62***	0.37	0.87	**0.75***	0.40	1.10
Developed countries	**0.54***	0.23	0.81	**0.94***	0.47	1.84	**1.22***	0.57	2.29
Emerging countries	**0.01**	−0.16	0.31	**0.15**	−0.19	0.35	**0.26***	−0.09	0.83

This table reports cumulative impulse responses of real stock prices to a one-standard-deviation shock in country-specific ESG-based sustainability uncertainty index (ESGUI) at horizons of 12, 18, and 24 months. Individual country results are estimated using smooth local projections following Barnichon and Brownlees (2019) with 12 lags of the dependent variable and shock variable. The dependent variable is real stock prices normalized to one standard deviation. The independent variable is country-specific ESGUI (normalized to one standard deviation). For individual countries, estimated coefficients represent the cumulative impulse of stock prices to a unit shock in country-specific ESGUI. For country-specific results, * represents significance of the estimates, whereas the upper and lower bounds represent the confidence intervals based on the 90 percent significance level. For country groups (developed and emerging countries), estimates represent the median across the corresponding constituent countries, whereas upper and lower bounds represent the interquartile range across the corresponding countries. Statistical significance (*) denotes that more than 50% of countries in the group show significant responses at the 10% level, following Yilmazkuday (2024). Sample period is from November 2002 to June 2025.

12 months, ESGUI shock raises stock prices by 0.54 for the same horizon. This is consistent with standard downside risk pricing observed by Yilmazkuday (2024), who finds that GPR shocks reduce stock prices.[15]

This divergence supports the conditional theoretical framework that sustainability uncertainty operates through distinct transmission mechanisms compared to traditional uncertainty, with economic interpretation depending on regulatory regime structure. Whereas EPU and GPR consistently depress investment through real options and credit channels (Bloom, 2009; Caldara & Iacoviello, 2022), ESGUI transmission shows positive associations that are consistent with sustainability uncertainty signaling regulatory support, technological transitions, and competitive opportunities for ESG-prepared firms during periods when disclosure operates under voluntary frameworks (Pástor et al., 2021).

While Table 5 establishes that ESGUI, EPU, and GPR generate distinct effects when estimated separately, ensuring ESGUI does not merely proxy for omitted dimensions of traditional policy risk requires joint estimation. Table 6 presents results from specifications including all three uncertainty measures simultaneously. The findings support the hypothesis that sustainability uncertainty operates through channels distinct from traditional uncertainty during the sample period. In the joint specification, the median 12-month ESGUI coefficient for developed markets increases to 0.73 (compared to 0.54 in baseline), indicating that EPU and GPR act as suppressors. Since ESGUI exhibits positive correlation with these typically value-reducing uncertainties, controlling for them isolates the component of sustainability uncertainty associated with transition opportunities and regulatory momentum. EPU (−1.45) and GPR (−0.42) coefficients remain stable and negative, confirming minimal multicollinearity and supporting the interpretation that these uncertainty types transmit through fundamentally different channels.

[15] Notably, the negative EPU effect (−1.51) exceeds the positive ESGUI effect (0.54) in magnitude, suggesting that while sustainability uncertainty signals opportunity, traditional policy uncertainty remains a more powerful source of downside risk.

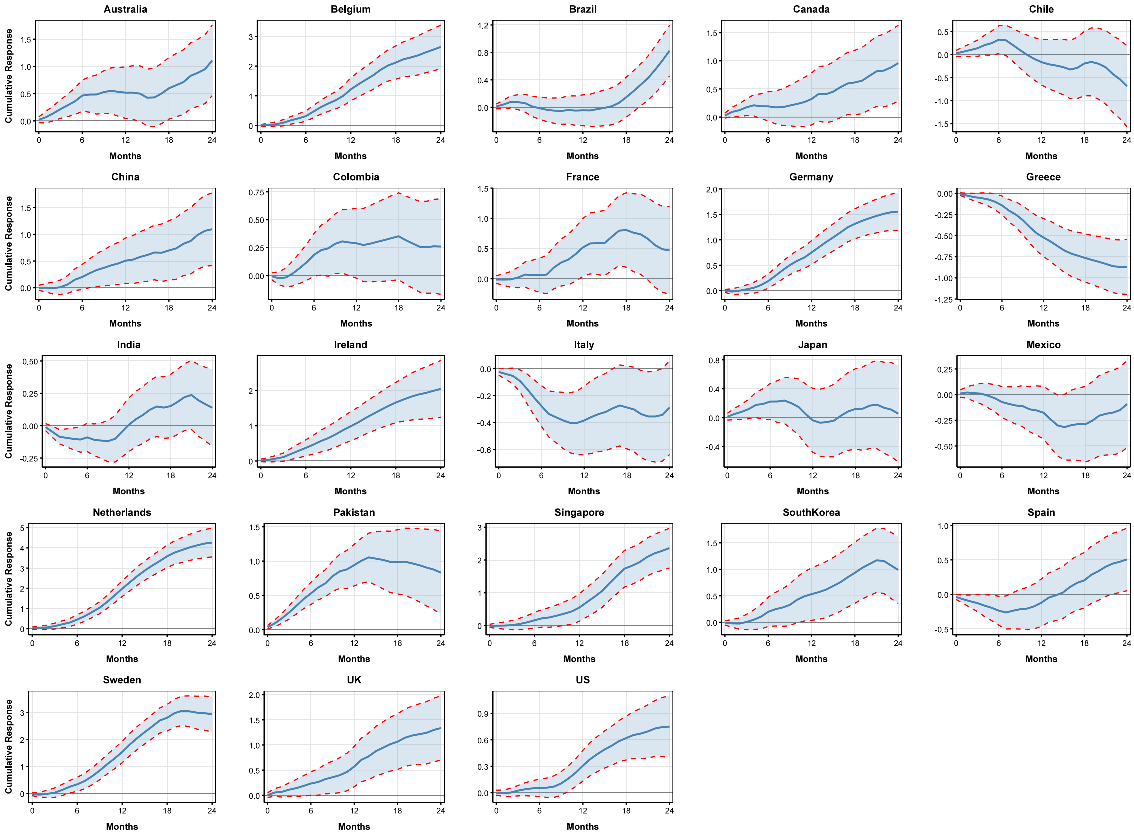

Fig. 5. Cumulative impulse responses of stock prices to country-specific ESGUI.
This figure displays cumulative impulse responses of real stock prices to a one-standard-deviation shock in country-specific ESG-based sustainability uncertainty index (ESGUI) using smooth local projections following Barnichon and Brownlees (2019). Each panel represents a different country, arranged alphabetically. Solid blue lines show point estimates of the cumulative response, and dashed red lines show 90% confidence intervals based on Newey–West standard errors with optimal lag selection. The x-axis measures months after the shock (0 to 24), and the y-axis measures the cumulative response in standard deviations with free scales across countries. The smooth local projection method estimates separate regressions at each horizon with 12 lags of the dependent variable and the shock variable as controls. Sample period is from November 2002 to June 2025.

Cross-sectional heterogeneity also persists; markets with mature ESG ecosystems, such as the Netherlands and Sweden, continue to exhibit the strongest positive responses (2.18 and 1.45). However, transition-vulnerable economies like Greece and Italy show muted effects. This evidence supports that sustainability uncertainty operates as a unique pricing factor by signaling opportunity that is distinct from the investment impediments associated with general policy or geopolitical risks.

4.4. Result from decomposition analysis

The contrast between ESGUI and traditional uncertainty measures raises a natural follow-up question: which dimensions of sustainability uncertainty drive the positive stock price responses? To identify which dimensions drive the positive ESGUI effects, I utilize the decomposed ESGUI index (environmental: EUI, social: SUI, and governance: GUI) of Ongan et al. (2025).[16] Table 7 reports the 12-month response to each component separately.

This decomposition empirically identifies which dimensions drive the observed aggregate patterns. Environmental and social components predominantly generate positive associations, particularly in developed markets. Environmental uncertainty produces

[16] Component decomposition analysis extends through September 2024, using disaggregated ESGUI series graciously provided by Dr. Ismet Gocer (co-author of Ongan et al. (2025)). These component series are not yet publicly available.

Table 3
Cumulative impulse responses of stock prices to GDP-weighted global ESG-based sustainability uncertainty shocks.

Country	12 months			18 months			24 months		
	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound
Australia	**2.12***	1.42	2.82	**3.28***	2.40	4.16	**3.17***	1.97	4.37
Belgium	**2.95***	2.33	3.57	**5.01***	4.18	5.84	**5.97***	4.89	7.06
Brazil	**1.77***	1.35	2.18	**2.57***	2.05	3.09	**2.59***	1.96	3.21
Canada	**1.73***	1.13	2.34	**2.63***	1.85	3.41	**2.44***	1.38	3.51
Chile	**0.43***	0.01	0.84	**0.46**	−0.05	0.97	**−0.48**	−1.09	0.13
China	**0.79***	0.19	1.40	**1.19***	0.47	1.91	**1.79***	0.94	2.65
Colombia	**0.44***	0.16	0.72	**0.28**	−0.06	0.61	**−0.51***	−0.91	−0.10
France	**2.58***	1.89	3.27	**4.61***	3.76	5.46	**5.63***	4.54	6.73
Germany	**1.55***	1.14	1.95	**2.59***	2.10	3.08	**2.99***	2.35	3.62
Greece	**0.98***	0.68	1.27	**1.61***	1.24	1.98	**2.03***	1.59	2.47
India	**1.38***	0.98	1.78	**1.92***	1.45	2.39	**1.82***	1.24	2.41
Ireland	**2.18***	1.62	2.73	**3.81***	2.99	4.64	**4.50***	3.40	5.60
Italy	**1.63***	1.24	2.03	**2.77***	2.28	3.26	**3.28***	2.65	3.90
Japan	**1.70***	1.20	2.19	**3.60***	2.89	4.30	**4.70***	3.81	5.59
Mexico	**0.76***	0.31	1.22	**1.02***	0.45	1.58	**0.35**	−0.37	1.07
Netherlands	**3.14***	2.43	3.85	**5.74***	4.84	6.65	**6.90***	5.69	8.12
Pakistan	**1.51***	1.07	1.94	**2.18***	1.54	2.83	**2.31***	1.48	3.14
Singapore	**1.15***	0.57	1.72	**1.69***	0.98	2.40	**1.06***	0.14	1.98
South Korea	**2.10***	1.55	2.65	**3.37***	2.68	4.05	**3.63***	2.71	4.54
Spain	**1.41***	0.92	1.90	**2.17***	1.57	2.76	**2.37***	1.67	3.08
Sweden	**1.49***	0.99	1.99	**2.42***	1.74	3.10	**2.44***	1.47	3.41
UK	**2.17***	1.50	2.84	**3.41***	2.55	4.27	**3.41***	2.32	4.50
US	**0.70***	0.46	0.94	**1.38***	1.03	1.73	**1.69***	1.20	2.19
Developed countries	**1.92***	1.57	2.18	**3.33***	2.60	4.41	**3.35***	2.58	4.65
Emerging countries	**0.79***	0.70	1.38	**1.38***	1.02	1.92	**1.79***	0.35	2.03

This table reports cumulative impulse responses of real stock prices to a one-standard-deviation shock in GDP-weighted global ESG-based sustainability uncertainty index (ESGUI) of Ongan et al. (2025) at horizons of 12, 18, and 24 months. Individual country results are estimated using smooth local projections following Barnichon and Brownlees (2019) with 12 lags of the dependent variable and shock variable. The dependent variable is real stock prices normalized to one standard deviation. The independent variable is GDP-weighted global ESGUI (normalized to one standard deviation). For individual countries, estimated coefficients represent the cumulative impulse of stock prices to a unit shock in global ESGUI. For country-specific results, * represents significance of the estimates, whereas the upper and lower bounds represent the confidence intervals based on the 90 percent significance level. For country groups (developed and emerging countries), estimates represent the median across the corresponding constituent countries, whereas upper and lower bounds represent the interquartile range across the corresponding countries. Statistical significance (*) denotes that more than 50% of countries in the group show significant responses at the 10% level, following Yilmazkuday (2024). Sample period is from November 2002 to June 2025.

positive responses in Belgium (1.16), the Netherlands (1.43), and Sweden (0.86), consistent with these markets pricing climate-policy developments as opportunities for green technology leadership, transition investment, and clean-energy adjustment. Social uncertainty shows positive associations in 17 countries, suggesting that uncertainty related to stakeholder relations, labor practices, social responsibility, and reputational positioning can contain opportunity-related information when firms voluntarily engage with social issues. Governance uncertainty, however, generates negative effects across most contexts, indicating that the governance dimension contains a different type of information from the environmental and social dimensions.

The negative governance response is consistent with the agency-cost and oversight channels developed in Section 2. Governance uncertainty is more directly related to managerial credibility, board oversight, internal controls, disclosure quality, shareholder protection, and enforcement risk. Investors may therefore price governance uncertainty as downside risk because it raises doubts about whether firms can allocate sustainability investments efficiently, disclose ESG information credibly, and comply with new reporting obligations.

The heterogeneity in environmental uncertainty component (EUI) responses, positive for developed markets (0.17) but negative for emerging markets (−0.14), supports the conditional framework developed in Section 2. In developed economies with institutional capacity and technological infrastructure, environmental uncertainty signals innovation opportunities in climate adaptation and clean technology. In emerging markets with carbon-intensive production structures and limited institutional capacity, the same uncertainty transmits primarily through compliance cost and transition risk channels. Figs. A.4 to A.6 provide country-by-country visual evidence of how environmental, social, and governance uncertainties affect stock prices differently across contexts. These component-level results imply that investors and policymakers should not treat ESG uncertainty as homogeneous. Environmental and social uncertainty are more closely tied to transition opportunities, while governance uncertainty is more closely tied to agency risk, oversight quality, and disclosure credibility.

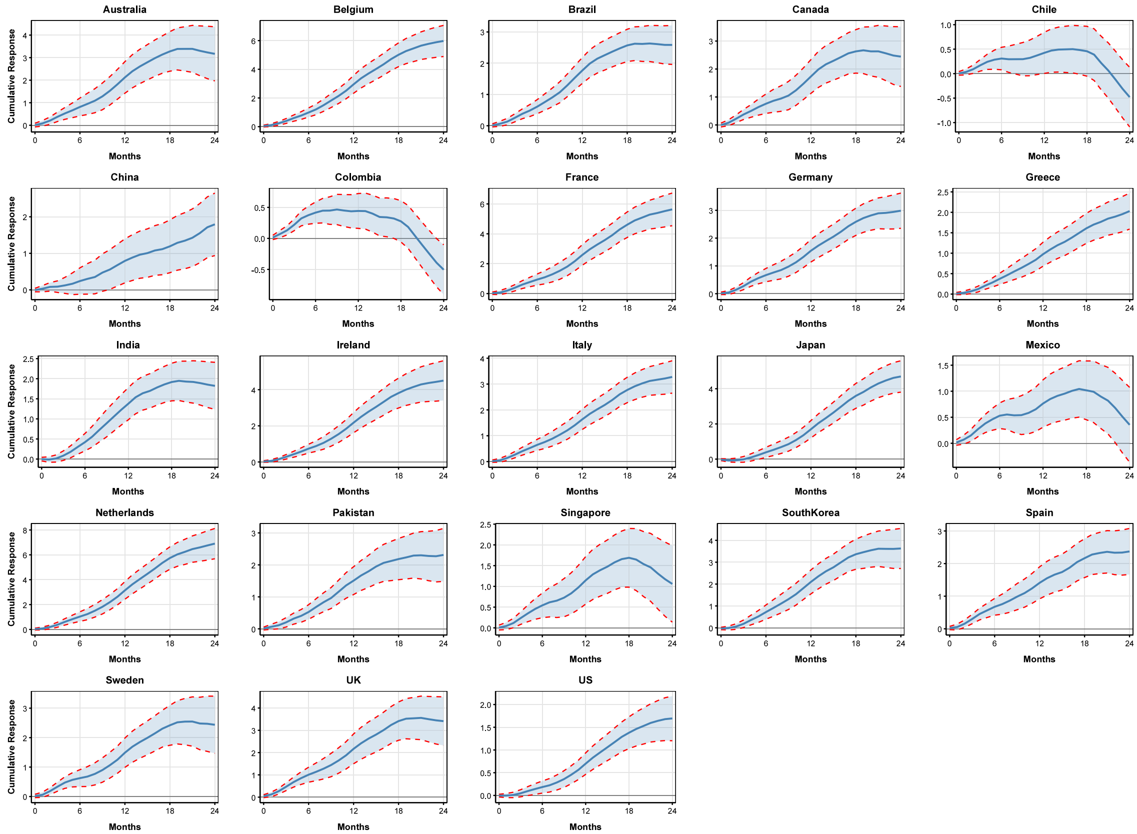

Fig. 6. Cumulative impulse responses of stock prices to global ESGUI.
This figure displays cumulative impulse responses of real stock prices to a one-standard-deviation shock in global ESG-based sustainability uncertainty index (ESGUI) using smooth local projections following Barnichon and Brownlees (2019). Unlike country-specific ESGUI where each country faces idiosyncratic ESGUI shocks, here all countries experience the same global uncertainty innovation simultaneously. It allows direct comparison of response magnitudes. Each panel represents a different country's response to the common global shock, with countries arranged alphabetically. Solid blue lines show point estimates, and dashed red lines show 90% confidence intervals based on Newey–West standard errors with optimal lag selection. The x-axis measures months after the shock (0 to 24), and the *y*-axis measures the cumulative response in standard deviations with free scales across countries. The global ESGUI shock is common across all countries, allowing comparison of heterogeneous responses to a shared uncertainty event. Sample period is from November 2002 to June 2025.

This decomposition analysis motivates examination of whether ESGUI effects vary across regulatory periods. Table 8 presents subperiod analysis dividing the sample into four periods capturing the evolving landscape of sustainability regulation (see Fig. A.1).[17] The results reveal a clear regulatory lifecycle pattern consistent with the conditional theoretical framework. During the *Early ESG* era (2002–2010), ESGUI is associated with positive effects in developed markets (median stock price increase of 0.45 standard deviations), consistent with uncertainty signaling first-mover advantages and downside protection value within voluntary frameworks (Lins et al., 2017).

The *Pre-Paris Consolidation* era (2011–2015) shows diminished but positive associations (median coefficient of 0.06 in developed markets), consistent with regulatory ambiguity generating "wait-and-see" behavior. With the Paris Agreement not yet negotiated, sustainability uncertainty during this period contained significant existence uncertainty about whether comprehensive climate action would materialize. This ambiguity reduced the clarity of transition signals without yet imposing compliance costs, dampening the first-mover advantages observed in the earlier period.

Associations strengthen significantly during the *Paris-TCFD Implementation* era (2016–2020). The 2015 Paris Climate Agreement and 2017 Task Force on Climate-related Financial Disclosures (TCFD) recommendations resolved existence uncertainty, validating

[17] While subperiod lengths vary due to regulatory milestone timing, sensitivity tests with equal-length windows confirm that observed regime shifts are not artifacts of differential sample sizes (unreported, available upon request).

Table 4
Cumulative impulse responses of stock prices to innovation in country-specific ESG-based sustainability uncertainty shocks.

Country	12 months			18 months			24 months		
	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound
Australia	**0.00**	−0.35	0.35	**−0.39**	−0.80	0.03	**−0.31**	−0.79	0.16
Belgium	**0.38***	0.10	0.67	**0.58***	0.18	0.99	**0.60***	0.09	1.11
Brazil	**−0.23***	−0.40	−0.07	**−0.25***	−0.47	−0.03	**0.15**	−0.11	0.41
Canada	**0.15**	−0.24	0.53	**0.26**	−0.22	0.75	**0.36**	−0.20	0.93
Chile	**0.06**	−0.12	0.25	**0.11**	−0.15	0.36	**0.04**	−0.28	0.36
China	**−0.03**	−0.27	0.20	**−0.07**	−0.37	0.24	**0.07**	−0.27	0.41
Colombia	**0.24***	0.07	0.42	**0.18**	−0.05	0.40	**0.12**	−0.14	0.37
France	**−0.15**	−0.46	0.15	**−0.36**	−0.76	0.04	**−0.75***	−1.21	−0.29
Germany	**0.46***	0.26	0.66	**0.87***	0.61	1.13	**1.01***	0.67	1.34
Greece	**−0.31***	−0.48	−0.15	**−0.41***	−0.61	−0.21	**−0.39***	−0.61	−0.17
India	**−0.21***	−0.41	−0.01	**−0.17**	−0.41	0.07	**−0.27**	−0.55	0.01
Ireland	**0.33***	0.05	0.60	**0.63***	0.26	0.99	**0.96***	0.47	1.46
Italy	**−0.26***	−0.49	−0.04	**−0.13**	−0.40	0.14	**−0.04**	−0.35	0.27
Japan	**−0.03**	−0.27	0.22	**0.19**	−0.14	0.53	**0.56***	0.16	0.95
Mexico	**−0.14**	−0.31	0.03	**−0.27***	−0.50	−0.04	**−0.16**	−0.42	0.11
Netherlands	**0.93***	0.68	1.19	**1.82***	1.47	2.18	**2.12***	1.67	2.58
Pakistan	**0.38***	0.18	0.58	**0.32***	0.02	0.62	**0.20**	−0.19	0.58
Singapore	**−0.04**	−0.28	0.20	**0.60***	0.26	0.95	**0.97***	0.58	1.35
South Korea	**0.87***	0.57	1.17	**1.44***	1.08	1.81	**1.74***	1.31	2.17
Spain	**−0.31***	−0.50	−0.12	**−0.17**	−0.41	0.06	**0.03**	−0.25	0.31
Sweden	**0.97***	0.73	1.21	**1.83***	1.53	2.13	**1.91***	1.51	2.32
UK	**0.44***	0.20	0.67	**0.78***	0.46	1.11	**0.96***	0.58	1.34
US	**0.17***	0.06	0.29	**0.33***	0.18	0.48	**0.41***	0.20	0.62
Developed countries	**0.24***	−0.04	0.46	**0.59***	−0.05	1.30	**0.78***	0.11	1.00
Emerging countries	**−0.03***	−0.21	0.17	**−0.07***	−0.25	0.18	**0.07**	−0.16	0.15

This table reports cumulative impulse responses of real stock prices to a one-standard-deviation shock in innovation in country-specific ESG-based sustainability uncertainty index (ESGUI) at horizons of 12, 18, and 24 months. Innovations are extracted using AR(p) processes following Brogaard and Detzel (2015), where the lag length p is selected via Bayesian information criterion (BIC: maximum 12 lags) for each country. This approach isolates unexpected components of ESGUI by controlling for lagged ESGUI and lagged real stock price changes. Individual country results are estimated using smooth local projections following Barnichon and Brownlees (2019) with 12 lags of the dependent variable and shock variable. The dependent variable is real stock prices normalized to one standard deviation. The independent variable is innovation in country-specific ESGUI (normalized to one standard deviation). For individual countries, estimated coefficients represent the cumulative impulse of stock prices to a unit shock in innovation in ESGUI. For country-specific results, * represents significance of the estimates, whereas the upper and lower bounds represent the confidence intervals based on the 90 percent significance level. For country groups (developed and emerging countries), estimates represent the median across the corresponding constituent countries, whereas upper and lower bounds represent the interquartile range across the corresponding countries. Statistical significance (*) denotes that more than 50% of countries in the group show significant responses at the 10% level, following Yilmazkuday (2024). Sample period is from November 2002 to June 2025.

that the sustainability transition would proceed while disclosure requirements remained largely voluntary. During this period, heightened ESGUI is associated with strong positive responses as markets priced sustainability uncertainty as confirmation of structural transition momentum benefiting ESG-prepared firms through competitive positioning advantages.

However, the *CSRD-ISSB* era (2021–2025) marks a systematic reversal as the median coefficient turns negative (−1.13) in developed markets. This sign reversal is consistent with the conditional framework's central prediction i.e., once regulatory frameworks transition toward mandatory compliance, sustainability uncertainty transforms from opportunity-related to risk-related.[18]

Strikingly, emerging markets exhibit the opposite pattern during the CSRD–ISSB era. After showing modest negative or insignificant associations in earlier periods, emerging-market coefficients become strongly positive during 2021–2025.[19] This divergence is consistent with differential regulatory exposure across market groups. Developed markets, particularly in Europe, face more immediate and binding sustainability-disclosure obligations, making ESGUI shocks more likely to be interpreted as compliance-related risk. In many emerging markets, where mandatory disclosure requirements are less comprehensive, later in implementation,

[18] The European Union's Corporate Sustainability Reporting Directive (CSRD) affects approximately 50,000 companies with mandatory, audited disclosure requirements. The International Sustainability Standards Board's (ISSB) global framework similarly imposes comprehensive reporting obligations. Under these mandatory compliance regimes, heightened sustainability uncertainty no longer signals voluntary differentiation opportunities but rather reflects implementation costs, enforcement heterogeneity, and compliance risk uncertainty.

[19] The reversal in the CSRD-ISSB period is robust to excluding high-volatility months and controlling for concurrent global shocks (unreported results available upon request), suggesting genuine regime-dependent pricing rather than confounding events.

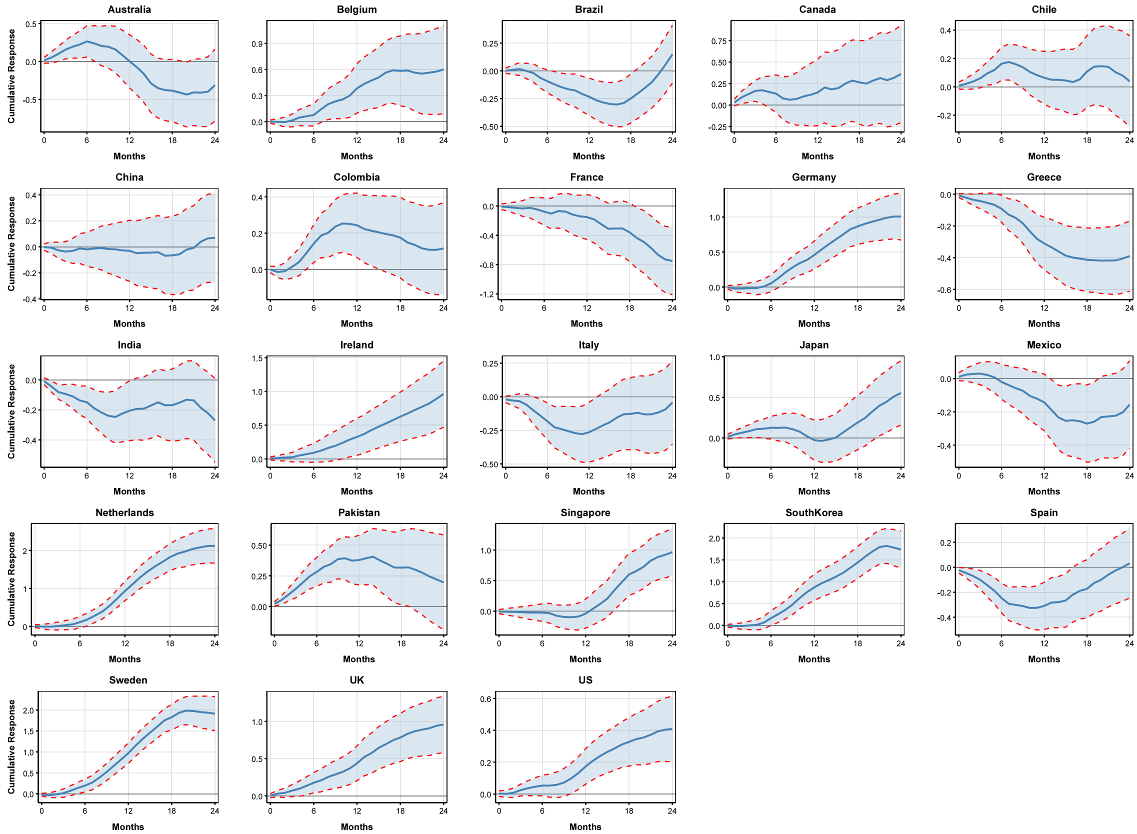

Fig. 7. Cumulative impulse responses of stock prices to innovation in country-specific ESGUI.
This figure displays cumulative impulse responses of real stock prices to a one-standard-deviation in innovation in country-specific ESG-based sustainability uncertainty index (ESGUI) using smooth local projections following Barnichon and Brownlees (2019). Innovations represent the unexpected component of ESG uncertainty and are extracted using AR(p) processes following Brogaard and Detzel (2015), where the lag length p is selected via Bayesian information criterion (BIC: maximum 12 lags) for each country. This approach isolates unexpected components of ESG uncertainty by controlling for lagged ESGUI and lagged real stock returns. Each panel represents a different country, arranged alphabetically. Solid blue lines show point estimates using smooth local projections, and dashed red lines show 90% confidence intervals based on Newey–West standard errors with optimal lag selection. The x-axis measures months after the shock (0 to 24), and the y-axis measures the cumulative response in standard deviations with free scales. Sample period is from November 2002 to June 2025.

or less strictly enforced, global sustainability uncertainty may still be interpreted as transition-related opportunity. The developed–emerging divergence therefore supports the view that institutional capacity, enforcement intensity, and regulatory timing condition sustainability-uncertainty transmission. Global ESGUI shocks show similar patterns in Table A.2.

Because Table 8 uses common global regulatory eras, Table A.3 replaces the common 2021 breakpoint with country-specific monthly mandatory- and anticipation-regime indicators. The results confirm the regulatory-lifecycle interpretation. Voluntary-regime effects remain positive, while mandatory- and anticipation-regime effects become negative at longer horizons, with negative and statistically significant interaction deltas at 18 and 24 months. Thus, the regime-switching result is not an artifact of imposing a uniform transition date across countries.

The reversal from positive associations in voluntary regimes to negative associations in mandatory regimes suggests that disclosure mandates change the economic content of sustainability uncertainty. Under voluntary frameworks, firms can self-select into disclosure and use ESG preparedness as a differentiation signal. Once disclosure becomes mandatory and externally verified, this signaling channel weakens because all firms must report regardless of ESG quality. ESGUI then reflects implementation costs, assurance requirements, enforcement heterogeneity, and compliance risk, consistent with the disclosure-regulation literature (Christensen et al., 2021).

This regulatory-lifecycle pattern also helps reconcile mixed evidence on climate-policy uncertainty. Studies finding that uncertainty discourages innovation emphasize financing constraints and implementation frictions, while studies finding positive effects emphasize strategic positioning and green investment incentives. The results here suggest that both mechanisms can operate. Sustainability uncertainty is more likely to signal opportunity under voluntary regimes but risk under mandatory compliance regimes. For policymakers, this implies that mandatory disclosure should be accompanied by clear implementation guidance, credible phase-in schedules, proportionate assurance requirements, and cross-country comparability.

Table 5
Cumulative impulse responses of stock prices to country-specific ESGUI, EPU, and GPR shocks.

Country	Shock: ESGUI			Shock: EPU			Shock: GPR		
	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound
Australia	**0.52***	0.05	0.99	**−1.37***	−1.79	−0.94	**−0.09**	−0.31	0.12
Belgium	**1.22***	0.83	1.61	**−2.10***	−2.54	−1.67	**−0.44***	−0.70	−0.18
Brazil	**−0.04**	−0.27	0.18	**−0.58***	−0.83	−0.33	**0.33***	0.18	0.47
Canada	**0.32**	−0.14	0.78	**−1.61***	−2.29	−0.93	**−0.68***	−0.90	−0.46
Chile	**−0.16**	−0.66	0.33	**−2.31***	−2.70	−1.91	**−0.10**	−0.36	0.16
China	**0.51***	0.08	0.93	**−0.26**	−0.59	0.07	**−0.79***	−1.09	−0.49
Colombia	**0.29**	−0.02	0.60	**−0.93***	−1.13	−0.73	**0.06**	−0.07	0.19
France	**0.52***	0.04	1.00	**−1.90***	−2.34	−1.46	**−1.05***	−1.32	−0.78
Germany	**0.75***	0.52	0.98	**−1.87***	−2.39	−1.34	**−0.84***	−1.02	−0.66
Greece	**−0.52***	−0.75	−0.30	**−0.96***	−1.12	−0.80	**−0.91***	−1.04	−0.78
India	**0.01**	−0.20	0.22	**−1.16***	−1.32	−1.00	**0.10**	−0.08	0.27
Ireland	**0.99***	0.57	1.40	**−0.52***	−0.84	−0.20	**−0.34**	−0.73	0.05
Italy	**−0.39***	−0.64	−0.13	**−0.98***	−1.19	−0.77	**−0.98***	−1.16	−0.80
Japan	**−0.04**	−0.48	0.40	**−1.48***	−1.82	−1.15	**0.24**	−0.02	0.49
Mexico	**−0.18**	−0.43	0.08	**−1.76***	−2.20	−1.33	**0.18**	−0.02	0.38
Netherlands	**1.98***	1.59	2.37	**−2.41***	−3.02	−1.80	**−0.64***	−0.89	−0.39
Pakistan	**0.94***	0.64	1.24	**−1.55***	−1.84	−1.26	**−0.66***	−0.83	−0.50
Singapore	**0.55***	0.13	0.97	**−1.53***	−1.95	−1.11	**0.34***	0.12	0.56
South Korea	**0.53***	0.04	1.03	**−1.65***	−2.02	−1.27	**0.32***	0.11	0.52
Spain	**−0.12**	−0.46	0.23	**−1.57***	−1.80	−1.33	**−0.92***	−1.09	−0.76
Sweden	**1.53***	1.13	1.93	**−0.72***	−1.00	−0.44	**−0.78***	−0.98	−0.57
UK	**0.57***	0.17	0.97	**−0.72***	−1.09	−0.34	**0.13**	−0.28	0.53
US	**0.31***	0.13	0.48	**−0.74***	−0.94	−0.54	**−0.31***	−0.50	−0.12
Developed countries	**0.54***	0.23	0.81	**−1.55***	−1.82	−1.08	**−0.54***	−0.83	0.08
Emerging countries	**0.01**	−0.16	0.31	**−0.96***	−1.55	−0.74	**−0.10***	−0.66	0.10

This table contrasts the transmission mechanisms of three distinct uncertainty measures by estimating cumulative impulse responses from Eq. (1) separately for country-specific ESG-based sustainability uncertainty index (ESGUI) of Ongan et al. (2025), Economic policy uncertainty index (EPU) of Baker et al. (2016), and Geopolitical risk index (GPR) of Caldara and Iacoviello (2022) at horizons of 12 months. Individual results for all specifications are estimated using smooth local projections following Barnichon and Brownlees (2019) with 12 lags of the dependent variable and shock variable. The dependent variable is real stock prices normalized to one standard deviation. The independent variable is country-specific ESGUI, EPU and GPR (normalized to one standard deviation), respectively. For individual countries, estimated coefficients represent the cumulative impulse of stock prices to a unit shock in country-specific ESGUI, EPU and GPR, respectively. For country-specific results, * represents significance of the estimates, whereas the upper and lower bounds represent the confidence intervals based on the 90 percent significance level. For country groups (developed and emerging countries), estimates represent the median across the corresponding constituent countries, whereas upper and lower bounds represent the interquartile range across the corresponding countries. Statistical significance (*) denotes that more than 50% of countries in the group show significant responses at the 10% level, following Yilmazkuday (2024). Sample period is from November 2002 to June 2025.

4.5. Transmission mechanisms

Having established that observed associations depend on regulatory regime, I next examine how market-specific characteristics moderate these effects within regimes. Table 9 reports state-dependent local projections following Ramey and Zubairy (2018), conditioning on market characteristics at the 12-month horizon. Results show that response magnitudes increase with market size (statistically significant differences in 15 countries) and liquidity (20 countries), indicating that larger and more liquid markets incorporate sustainability-related uncertainty more strongly. This pattern is consistent with financial integration facilitating information transmission and portfolio adjustment, but it should not be interpreted as direct evidence of cross-border capital flows because the analysis does not include portfolio-flow or FDI data.

The value orientation channel reveals that high dividend yield markets (typically featuring value stocks and mature industries) also amplify responses, suggesting that mature firms with established cash flows leverage ESG positioning for reputational advantages (Albuquerque et al., 2019). Conversely, high inflation environments dampen transmission, with ESGUI shocks producing weaker effects when macroeconomic instability dominates investor attention and reduces the relative salience of sustainability considerations.

The interaction effects reveal economically important heterogeneity. Australia's negative direct effect (−1.25) but large positive size interaction (+2.67) suggests that ESGUI effects are more favorable in larger market segments, where firms may have greater resources, disclosure capacity, and investor visibility to respond to sustainability-related uncertainty. Negative inflation interactions across most countries indicate macro instability dominates sustainability considerations during economic stress. To formalize whether these individual characteristics reflect a broader development channel, I construct a composite development index,

Table 6
Cumulative impulse responses of stock prices to country-specific ESGUI shocks controlling for EPU and GPR.

Country	12 months			18 months			24 months		
	ESGUI	EPU	GPR	ESGUI	EPU	GPR	ESGUI	EPU	GPR
Australia	0.37	−1.44*	0.02	0.26	−1.21*	−0.31*	0.62	−0.32	−0.73*
Belgium	0.97*	−2.39*	0.01	1.46*	−2.36*	0.28*	1.37*	−3.08*	0.55*
Brazil	−0.29*	−0.27*	0.42*	−0.40*	−0.10	0.64*	0.16	0.11	0.88*
Canada	0.79*	−1.66*	−0.64*	1.19*	−1.08*	−0.86*	1.77*	0.42	−1.23*
Chile	0.65*	−2.79*	0.07	0.40	−3.72*	0.18	−0.82	−3.97*	0.62*
China	0.83*	0.24	−0.85*	1.13*	0.80*	−1.02*	1.65*	1.21*	−1.16*
Colombia	0.64*	−0.99*	0.38*	1.12*	−0.90*	0.50*	1.59*	−0.47*	0.67*
France	0.97*	−2.25*	−1.04*	1.37*	−2.68*	−1.17*	1.31*	−3.56*	−0.52*
Germany	0.79*	−1.80*	−1.04*	1.43*	−1.60*	−0.94*	1.63*	−1.33*	−0.67*
Greece	−0.26*	−0.80*	−0.78*	−0.49*	−0.95*	−1.02*	−0.55*	−1.39*	−1.18*
India	0.39*	−0.97*	0.12	0.66*	−1.04*	0.26*	0.77*	−0.98*	0.54*
Ireland	0.96*	−0.73*	−0.50*	1.43*	−1.13*	−0.04	1.50*	−1.96*	0.41
Italy	0.00	−0.87*	−0.77*	0.13	−0.71*	−0.93*	0.15	−0.97*	−0.82*
Japan	0.35	−1.53*	0.10	0.63*	−2.00*	0.53*	0.62	−1.96*	1.09*
Mexico	−0.14	−1.29*	0.39*	−0.10	−1.32*	0.39*	0.14	−1.00*	0.27
Netherlands	2.18*	−1.56*	−0.35*	3.86*	−1.62*	−0.42*	4.41*	−1.49*	−0.54*
Pakistan	1.40*	−0.74*	−1.34*	1.63*	−1.59*	−2.34*	1.78*	−2.43*	−2.77*
Singapore	0.10	−1.23*	0.48*	1.06*	−1.61*	0.81*	1.55*	−1.88*	1.14*
South Korea	0.56*	−1.47*	0.24*	0.94*	−0.87*	0.25	0.97*	−0.01	0.09
Spain	−0.04	−1.46*	−0.75*	0.34	−1.78*	−1.32*	0.67*	−1.66*	−1.74*
Sweden	1.45*	−1.04*	−1.13*	2.59*	−0.56*	−1.37*	2.90*	−0.13	−1.44*
UK	0.68*	−1.36*	−0.07	1.13*	−1.77*	0.59*	1.14*	−1.51*	1.14*
US	0.66*	−0.89*	−0.19*	1.02*	−0.85*	−0.12	1.09*	−0.69*	0.10
Developed countries	0.73*	−1.45*	−0.42*	1.16*	−1.61*	−0.37*	1.34*	−1.50*	−0.53*
Emerging countries	0.56*	−0.97*	0.12*	0.66*	−0.95*	0.25*	0.77*	−0.98*	0.27*

This table reports cumulative impulse responses of real stock prices to uncertainty shocks using smooth local projections with all three uncertainty measures (ESGUI, EPU, GPR) included simultaneously. The dependent variable is real stock prices normalized to one standard deviation. Independent variables include country-specific ESGUI (ESG-based sustainability uncertainty), EPU (economic policy uncertainty), and GPR (geopolitical risk), all normalized to one standard deviation and estimated jointly in the same regression. Coefficients represent cumulative stock price responses at 12, 18, and 24-month horizons to a one-standard-deviation shock in each respective uncertainty measure. The specification includes 12 lags of the dependent variable and all three shock variables following Barnichon and Brownlees (2019). This specification tests whether ESGUI effects persist after explicitly controlling for traditional uncertainty channels. Significance is based on Newey–West heteroskedasticity and autocorrelation consistent standard errors. For country-specific results, * represents significance of the estimates, whereas the upper and lower bounds represent the confidence intervals based on the 90 percent significance level. For country groups (developed and emerging countries), estimates represent the median across the corresponding constituent countries. Statistical significance (*) denotes that more than 50% of countries in the group show significant responses at the 10% level, following Yilmazkuday (2024). Sample period is from November 2002 to June 2025.

combining standardized market size and liquidity, following Bekaert et al. (2005) and estimate panel interactions. Table 10 presents panel regressions examining whether market development affects ESGUI sensitivity.

The baseline ESGUI effect is positive and statistically significant, with market development amplifying effects at short horizons (1–6 months). However, the negative horizon-development interaction indicates convergence over time. Differential sensitivity across development levels narrows as ESG integration deepens globally, with development effects becoming insignificant by 24 months. The negative triple interaction confirms that initial developed-market advantages dissipate at longer horizons. This suggests that while developed markets lead initially due to deeper ESG ecosystems, emerging markets gradually catch up as global standards diffuse and sustainability-related information becomes more widely incorporated into market pricing.

4.6. Robustness analyses

I conduct a battery of robustness tests to validate the main findings. Results are stable using standard local projections of Jordà (2005) (Table A.4). The median 24-month coefficient is 1.31 vs. 1.22 in baseline. This confirms that results are not artifacts of the smoothing procedure. Alternative lag structures (p = 6, 18) show similar effect (Tables A.5 and A.6). The median 24-month effect at p = 6 is 1.21 whereas at p = 18 it is 1.08, with qualitative patterns (positive in developed markets, negative in Southern Europe) preserved. Then, controlling for macroeconomic conditions (term spread, default spread, industrial production) in Table A.7 reduces magnitudes but maintains significance (0.33 in a year following the shock compared to 0.54 shown in Table 2). This confirms ESGUI captures ESG-specific information distinct from business cycles. Further, excluding crisis periods (VIX > 90th percentile) yields

Table 7
Cumulative impulse responses of stock prices to country-specific E-, S-, and G-based sustainability uncertainty shocks.

Country	Shock: EUI			Shock: SUI			Shock: GUI		
	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound
Australia	**−0.15**	−0.63	0.34	**0.85***	0.45	1.25	**−0.39**	−0.84	0.06
Belgium	**1.16***	0.70	1.63	**1.51***	1.15	1.88	**0.69***	0.27	1.10
Brazil	**−0.43***	−0.70	−0.15	**0.17**	−0.09	0.42	**0.02***	0.01	0.25
Canada	**0.00**	−0.40	0.40	**0.67***	0.24	1.10	**−0.18**	−0.57	0.11
Chile	**−0.65***	−1.19	−0.10	**0.14**	−0.20	0.49	**−0.53***	−0.88	−0.17
China	**0.38**	0.00	0.75	**1.00***	0.71	1.29	**−0.41**	−0.88	0.06
Colombia	**−0.14**	−0.39	0.11	**0.39***	0.08	0.69	**−0.35***	−0.62	−0.08
France	**0.28**	−0.20	0.76	**0.66***	0.22	1.10	**−0.03**	−0.41	0.35
Germany	**0.31***	0.03	0.59	**0.76***	0.53	0.99	**−0.58***	−0.81	−0.14
Greece	**−0.61***	−0.87	−0.36	**−0.14**	−0.29	0.00	**−0.61***	−0.81	−0.41
India	**−1.03***	−1.29	−0.78	**0.51***	0.32	0.70	**−0.10**	−0.31	0.11
Ireland	**0.06**	−0.28	0.40	**−0.23**	−0.48	0.02	**−0.20**	−0.45	0.07
Italy	**−0.62***	−0.85	−0.40	**0.41***	0.17	0.65	**−0.29***	−0.55	−0.04
Japan	**−0.51***	−0.95	−0.08	**0.55***	0.26	0.83	**−0.38***	−0.70	−0.06
Mexico	**−0.01**	−0.36	0.33	**−0.19**	−0.42	0.05	**−0.41***	−0.71	−0.10
Netherlands	**1.43***	0.88	1.98	**1.51***	1.15	1.86	**2.18***	1.83	2.54
Pakistan	**0.89***	0.67	1.12	**1.02***	0.79	1.26	**−0.14**	−0.42	0.13
Singapore	**−0.26**	−0.62	0.10	**1.21***	0.90	1.51	**−0.18**	−0.52	0.16
South Korea	**0.58***	0.16	1.01	**0.65***	0.26	1.05	**0.02**	−0.38	0.43
Spain	**−0.61***	−0.96	−0.27	**−0.28***	−0.56	−0.01	**−0.53***	−0.81	−0.25
Sweden	**0.86***	0.32	1.40	**1.58***	1.18	1.99	**0.78***	0.45	1.12
UK	**0.30**	−0.14	0.74	**0.71***	0.31	1.11	**0.46***	0.15	0.78
US	**0.35***	0.21	0.48	**0.24***	0.10	0.38	**0.29***	0.14	0.44
Developed countries	**0.17***	−0.23	0.51	**0.69***	0.58	1.12	**−0.18***	−0.36	0.42
Emerging countries	**−0.14***	−0.61	0.35	**0.24***	0.14	0.51	**−0.35***	−0.41	−0.10

This table reports cumulative impulse responses of real stock prices to a one-standard-deviation shock in country-specific E-, S-, and G-based sustainability uncertainty index (EUI, SUI, and GUI) at horizons of 12 months. Individual country results are estimated using smooth local projections following Barnichon and Brownlees (2019) with 12 lags of the dependent variable and shock variable. The dependent variable is real stock prices normalized to one standard deviation. The independent variable is country-specific EUI, SUI, and GUI (normalized to one standard deviation), respectively. For individual countries, estimated coefficients represent the cumulative impulse of stock prices to a unit shock in country-specific EUI, SUI, and GUI, respectively. For country-specific results, * represents significance of the estimates, whereas the upper and lower bounds represent the confidence intervals based on the 90 percent significance level. For country groups (developed and emerging countries), estimates represent the median across the corresponding constituent countries, whereas upper and lower bounds represent the interquartile range across the corresponding countries. Statistical significance (*) denotes that more than 50% of countries in the group show significant responses at the 10% level, following Yilmazkuday (2024). Sample period is from November 2002 to September 2024.

positive effects shown in Table A.8. The median coefficient of 0.90 indicates that the observed associations during voluntary periods persist beyond crisis episodes. Table A.9 shows that equal-weighted global ESGUI, instead of GDP-weighted global ESGUI, produces qualitatively identical results with smaller magnitudes (median developed market coefficient of 1.44 vs. 1.92 GDP-weighted shown in Table 3). This confirms that large economies drive transmission.

Finally, I address potential endogeneity in Table A.10. Granger causality tests in Panel A show minimal bidirectional predictability. Stock prices predict ESGUI in only 4.3% of countries, while ESGUI predicts prices in 8.7%. This is consistent with market efficiency where prices respond to new information rather than stale trends.[20] Panel B presents instrumental variable (IV) estimations using lagged global ESGUI. The instruments are robust, with first-stage F-statistics exceeding threshold value of 10 in all cases. Crucially, the IV coefficients closely track the baseline estimates in magnitude and significance across developed markets. Together, the robustness tests show that the main findings are not driven by smoothing choices, lag length, macroeconomic controls, crisis periods, global-index weighting, reverse causality, or predictable ESGUI variation. Table A.1 further shows that the standardized responses are economically meaningful, while Table A.3 confirms that the regulatory-lifecycle pattern is not an artifact of imposing a uniform 2021 transition date.

[20] The significant impulse responses documented in our baseline analysis confirm that markets respond dynamically to new sustainability shocks. This distinction supports the validity of our identification strategy, as it suggests the observed valuation effects are driven by genuine innovations rather than feedback loops.

Table 8
Cumulative impulse responses of stock prices to country-specific ESGUI shocks for different sample periods.

Country	Early ESG			Pre-Paris Cons.			Paris TCFD			CSRD ISSB		
	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound
Australia	**−1.70***	−2.15	−1.26	**1.36***	0.59	2.13	**1.72***	0.05	3.39	**−1.11***	−2.20	−0.02
Belgium	**0.87***	0.54	1.20	**0.11**	−0.07	0.29	**0.27**	0.08	0.46	**2.27**	0.00	4.54
Brazil	**−0.73***	−0.92	−0.53	**0.69***	0.44	0.94	**−0.03**	−0.59	0.53	**−1.24***	−2.33	−0.15
Canada	**1.43***	1.16	1.70	**0.76**	−0.04	1.56	**0.34***	−0.48	1.16	**−1.35**	−3.05	0.35
Chile	**−0.03**	−0.34	0.28	**0.99***	0.32	1.66	**−0.94***	−1.48	−0.39	**2.01***	0.44	3.59
China	**0.97***	0.62	1.33	**−0.20**	−0.46	0.06	**−6.47***	−7.80	−5.14	**1.60***	0.81	2.40
Colombia	**1.45***	1.17	1.72	**0.24**	−0.12	0.60	**−0.83**	−1.99	0.34	**1.78***	0.44	3.12
France	**0.35**	−0.10	0.80	**0.66***	0.07	1.25	**0.72***	−0.09	1.53	**−1.24***	−2.28	−0.20
Germany	**0.72***	0.47	0.97	**1.26***	0.37	2.15	**1.37***	0.46	2.28	**−0.48***	−1.37	0.42
Greece	**−0.08**	−0.37	0.21	**−1.21***	−1.56	−0.87	**0.64**	−0.56	1.84	**1.43***	0.82	2.04
India	**0.67***	0.38	0.96	**1.70***	1.03	2.38	**0.16***	−0.58	0.91	**1.49**	−0.90	3.88
Ireland	**0.13**	−0.15	0.42	**0.06**	−0.16	0.28	**−3.08***	−4.60	−1.57	**−1.16**	−3.98	1.67
Italy	**0.16**	−0.08	0.40	**−0.43***	−0.81	−0.06	**−0.44***	−1.48	0.60	**−0.41***	−1.16	0.35
Japan	**0.15**	−0.26	0.56	**−0.78***	−1.18	−0.39	**−4.38***	−5.87	−2.89	**−5.85***	−9.42	−2.29
Mexico	**−0.04**	−0.28	0.21	**−1.21***	−2.12	−0.30	**0.06**	−0.70	0.82	**3.03***	0.86	5.20
Netherlands	**1.15***	0.80	1.50	**0.66***	0.06	1.26	**0.86***	0.18	1.54	**−0.33**	−1.68	1.03
Pakistan	**−0.21***	−0.51	0.09	**−0.15**	−0.36	0.06	**1.22***	0.86	1.58	**1.86***	0.98	2.73
Singapore	**−0.43***	−0.84	−0.03	**2.65***	1.64	3.67	**3.18***	2.15	4.20	**−1.20**	−2.53	0.13
South Korea	**1.89***	1.50	2.28	**−0.83**	−1.70	0.03	**−1.47***	−2.45	−0.50	**−0.28**	−1.36	0.79
Spain	**0.54***	0.23	0.86	**−1.22***	−1.85	−0.58	**−0.95**	−2.12	0.22	**−0.44**	−1.04	0.16
Sweden	**1.14***	0.56	1.72	**−0.09**	−0.30	0.12	**3.77***	1.81	5.73	**−2.52***	−3.60	−1.45
UK	**1.08***	0.79	1.38	**−0.72**	−1.68	0.24	**0.68***	0.46	0.90	**1.22**	−0.14	2.59
US	**0.21**	−0.22	0.64	**−0.27***	−0.53	−0.01	**−0.11**	−0.71	0.49	**−2.94***	−3.95	−1.93
Developed coun.	**0.45***	0.14	1.11	**0.06***	−0.58	1.01	**0.51***	−0.70	1.55	**−1.13***	−1.33	−0.41
Emerging coun.	**−0.21***	−0.04	0.67	**−0.15***	−0.83	0.24	**−0.03***	−0.94	0.16	**1.60***	1.43	1.86

This table reports cumulative impulse responses of real stock prices to a one-standard-deviation shock in country-specific ESG-based sustainability uncertainty index (ESGUI) for different sample periods at horizons of 12 months. The full sample is divided into four distinct periods that capture the changing landscape of sustainability regulation: (1) Early ESG Era (November 2002–December 2010), which covers the initial emergence of voluntary ESG frameworks and the 2008 financial crisis testing ESG resilience; (2) Pre-Paris Consolidation (January 2011–December 2015), marking increased institutional focus on ESG but prior to binding international agreements; (3) Paris Agreement & TCFD Implementation (January 2016–December 2020), characterized by the landmark Paris Climate Agreement in 2015 and the introduction of the Task Force on Climate-related Financial Disclosures (TCFD) recommendations in 2017; and (4) CSRD & ISSB Era (January 2021–June 2025), encompassing the European Union's Corporate Sustainability Reporting Directive (CSRD) affecting 50,000 companies and the International Sustainability Standards Board's (ISSB) global disclosure framework. Local projections are estimated separately for each sample period. Individual country results are estimated using smooth local projections following Barnichon and Brownlees (2019) with 12 lags of the dependent variable and shock variable. The dependent variable is real stock prices normalized to one standard deviation. The independent variable is country-specific ESGUI (normalized to one standard deviation). For individual countries, estimated coefficients represent the cumulative impulse of stock prices to a unit shock in country-specific ESGUI. For country-specific results, * represents significance of the estimates, whereas the upper and lower bounds represent the confidence intervals based on the 90 percent significance level. For country groups (developed and emerging countries), estimates represent the median across the corresponding constituent countries, whereas upper and lower bounds represent the interquartile range across the corresponding countries. Statistical significance (*) denotes that more than 50% of countries in the group show significant responses at the 10% level, following Yilmazkuday (2024). Sample period is from November 2002 to June 2025.

5. Conclusion

5.1. Discussion of the findings

This paper examines whether ESG-based sustainability uncertainty (ESGUI) is priced in international stock markets and whether its pricing effect depends on disclosure regime structure. Using monthly ESGUI data for 23 markets over 2002–2025, this paper shows that ESGUI behaves differently from traditional uncertainty. Whereas EPU and GPR generally depress valuations (Baker et al., 2016; Caldara & Iacoviello, 2022), ESGUI has regime-dependent effects. It is associated with positive stock price responses during voluntary disclosure periods but negative responses once mandatory compliance regimes become more relevant, especially in developed European markets.

The first finding is that ESGUI contains pricing information distinct from conventional uncertainty measures. The negative responses to EPU and GPR are consistent with the standard uncertainty-pricing channel, where policy and geopolitical uncertainty raise discount rates, delay investment, and reduce asset prices (Bloom, 2009; Brogaard & Detzel, 2015). By contrast, the positive ESGUI response during voluntary disclosure regimes is closer to the ESG asset-pricing literature, where sustainability preferences, climate concerns, and ESG information can affect expected returns, investor demand, and the risk-return trade-off (Pástor et al., 2021; Pedersen et al., 2021). The contrast is that these studies primarily examine ESG characteristics, preferences, or ratings, whereas this paper shows that uncertainty about sustainability itself can be positively priced when it signals transition opportunities, regulatory momentum, and strategic differentiation.

Table 9
Transmission channels of ESG-based sustainability uncertainty effects on stock prices.

Country	Size		Liquidity		Value orientation		Inflation	
	Direct	Interact.	Direct	Interact.	Direct	Interact.	Direct	Interact.
Australia	−1.25***	2.67***	2.64***	3.53***	−0.28	0.68*	2.49***	−3.46***
Belgium	0.16	0.41	1.63***	1.14**	0.52	0.75*	0.22	1.96***
Brazil	−0.44***	0.47*	0.86***	1.54***	−0.60***	1.24***	−0.03	0.13
Canada	−0.04	−0.14	−1.28***	3.50***	1.27***	3.54***	0.08	0.54*
Chile	1.67***	6.04***	−1.63***	2.22***	−2.01***	3.73***	−1.33***	1.92***
China	1.14***	2.91***	1.29***	3.02***	0.53**	−0.18	0.22	0.58***
Colombia	0.51***	0.04	0.43***	0.51*	0.74***	1.95***	0.70***	−0.81***
France	1.13***	0.90**	−0.49	1.64***	1.45***	1.06***	0.92***	−0.80***
Germany	0.73***	−0.31	0.18	0.91***	1.09***	0.64***	0.82***	−0.26
Greece	−2.41***	2.21***	−0.25**	0.34**	−0.63***	0.57***	−0.85***	0.44***
India	−0.96***	2.76***	0.38***	1.99***	0.43***	−0.65***	−0.77***	0.94***
Ireland	3.24***	4.85***	1.33***	0.27	−2.57***	4.91***	2.40***	−2.66***
Italy	−1.90***	2.39***	−0.41**	0.09	−1.33***	2.28***	−0.21	−0.34*
Japan	0.68***	3.59***	−0.61**	1.53***	0.53***	4.84***	1.53***	−2.48***
Mexico	−0.32***	−0.25	0.24*	2.63***	0.55***	3.21***	−0.21*	0.20
Netherlands	2.83***	3.37***	−1.38***	4.27***	0.98***	1.28***	1.46***	1.40***
Pakistan	1.09***	−0.43	−0.87***	1.80***	0.96***	0.06	1.63***	−0.77***
Singapore	0.56***	−0.58	2.23***	3.39***	−2.54***	5.04***	−0.04	0.88***
South Korea	0.41*	1.28**	1.09***	2.22***	0.94***	−0.35	−0.05	0.60
Spain	−0.54***	0.69**	0.78***	1.97***	1.35***	3.65***	−0.63***	0.82***
Sweden	1.51***	0.97***	1.19***	0.42	1.60***	0.16	0.62***	1.82***
UK	0.73***	0.97***	−3.20***	5.53***	0.85***	0.25	0.04	1.11***
US	0.08	0.32	−0.33***	1.19***	−0.20*	1.24***	−0.07	0.68***

This table reports channel analysis results examining through which mechanisms ESGUI affects stock prices at the 12-month horizon state-dependent local projections following Ramey and Zubairy (2018). This approach extends the baseline local projections method by allowing impulse responses to vary across different states of the economy. State-dependent impulse responses are estimated where the state is defined by whether a channel variable exceeds its median value. The indicator function creates a median split and classifies observations into high versus low channel states based on whether market size, liquidity, value orientation, or inflation expectations exceed their respective median values. The direct and interaction effect (Interact.) of ESGUI on real stock prices are reported. Direct Effect shows the baseline ESG uncertainty impact. Interaction effect shows the additional impact when the channel variable is above its median (high size, high liquidity, high valuation, high inflation expectations). Size is measured by log market capitalization, liquidity by log trading volume, valuation by dividend yield, and inflation by change in consumer price index. Coefficients are based on Newey–West standard errors with automatic lag selection. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 10
Market development heterogeneity in ESG-based sustainability uncertainty effects.

Panel A: Continuous development interactions

Effect	1 month		6 months		12 months		24 months	
	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat
Baseline ESG	0.003***	3.90	0.009***	6.14	0.011***	5.72	0.004	1.40
Development Int.	0.001	1.56	0.004**	2.49	0.004*	1.70	−0.005*	−1.75
Time Interaction	−0.003**	−2.50	−0.011***	−4.86	−0.009***	−3.10	−0.006	−1.59
Triple Interaction	−0.001	−1.06	−0.005**	−2.30	−0.007**	−2.10	0.001	0.25

Panel B: Development tercile interactions

Effect	1 month		6 months		12 months		24 months	
	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat
High development	0.001	0.49	0.001	0.23	−0.003	−0.54	−0.016**	−2.17
Medium development	0.000	0.25	0.004	1.11	0.001	0.14	−0.015**	−2.23

This table shows whether ESG uncertainty sensitivity varies with financial market development using pooled panel estimation with country fixed effects. Following standard practice in international finance (e.g., Bekaert et al. (2005)), a composite market development index combining market size (log market capitalization) and liquidity (log trading volume) is constructed to measure financial market integration. Panel A shows continuous development interactions where Development Int. captures how ESG uncertainty sensitivity varies with the continuous market development index. Time Interaction shows how ESG sensitivity has evolved over the sample period. Triple Interaction captures whether development effects have changed over time. Panel B compares High and Medium development countries to Low development countries (omitted reference category). All regressions include country fixed effects and 6 lags of dependent variable and ESG uncertainty. Standard errors are heteroskedasticity-robust. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. Sample period is from November 2002 to June 2025.

The second finding is that the sign of ESGUI effects depends on the disclosure regime. This result complements climate-policy uncertainty studies showing that sustainability-related uncertainty affects green and brown energy stocks, stock-return cross sections, and European financial markets (Bouri et al., 2022; Tedeschi et al., 2024; Treepongkaruna et al., 2023). The similarity is that both literatures show that sustainability-related uncertainty is financially relevant. The difference is that the present evidence shows a sign reversal. ESGUI is positively priced under voluntary disclosure but negatively priced when mandatory compliance becomes salient. This regime dependence helps reconcile mixed findings by showing that sustainability uncertainty can signal transition opportunities in one institutional setting but compliance costs, assurance requirements, financing constraints, and implementation risk in another.

The third finding is that ESGUI transmission is nonlinear and state-dependent. This is consistent with recent evidence that uncertainty shocks transmit asymmetrically across renewable and non-renewable energy markets (Özcan et al., 2023), that carbon and artificial-intelligence-related markets exhibit quantile-dependent connectedness (Balcı, 2025), and that artificial intelligence and ESG are dynamically interdependent (Yildirim, 2025). It is also consistent with Doğan and Zeren (2025), who show that GPR and ESGUI are connected in a nonlinear, quantile-dependent, and country-specific manner in G7 economies. The difference is that these studies focus on connectedness or determinants of ESG-related uncertainty, while this paper examines how ESGUI shocks are priced in stock markets across disclosure regimes, ESG dimensions, and market-development levels.

The fourth finding is that ESG uncertainty is not homogeneous across components. Environmental and social uncertainty are more often priced as transition-related opportunity, consistent with the view that sustainability preferences, stakeholder trust, and climate-transition opportunities can have valuation effects (Lins et al., 2017; Pástor et al., 2021; Pedersen et al., 2021). Governance uncertainty, in contrast, is priced negatively. This is consistent with corporate-governance research showing that agency conflicts, weak monitoring, and weaker shareholder rights are associated with lower firm value and weaker performance (Core et al., 1999; Gompers et al., 2003; Jensen & Meckling, 1976; Shleifer & Vishny, 1997). The contribution is to show that these governance mechanisms also matter for ESGUI. When uncertainty concerns governance quality, disclosure credibility, or oversight capacity, markets treat it as downside risk rather than transition opportunity.

5.2. Policy implications

The findings have practical implications for sustainability-disclosure policy. Mandatory reporting can improve transparency and comparability, but it may also change the pricing content of sustainability uncertainty. Under voluntary regimes, ESGUI shocks appear to contain information about transition opportunities and strategic differentiation. Under mandatory regimes, the same shocks increasingly reflect implementation risk, assurance costs, enforcement uncertainty, and governance capacity. Policymakers should therefore complement mandatory disclosure rules with clear implementation guidance, credible phase-in schedules, proportionate assurance requirements, and internationally comparable reporting standards.

The economic magnitudes reinforce the practical relevance of these results. Table A.1 shows that the developed-market median response corresponds to estimated price increases of 11.88%, 23.12%, and 28.44% at 12, 18, and 24 months, respectively, following a country-specific ESGUI shock. These magnitudes suggest that sustainability uncertainty is not merely a statistical feature of ESG discourse but a valuation-relevant market signal. For investors, ESGUI shocks should therefore be interpreted jointly with the regulatory regime and the ESG dimension. For firms, the results imply that voluntary ESG preparedness can create strategic value before disclosure becomes mandatory, while the mandatory phase places greater emphasis on credible reporting systems, internal controls, board oversight, and assurance readiness.

The country-specific regulatory-timing results also imply that policy design should account for institutional capacity and implementation timing. Table A.3 shows that the regulatory-lifecycle pattern is not an artifact of imposing a common 2021 breakpoint. Voluntary-regime effects remain positive, while mandatory- and anticipation-regime effects become negative at longer horizons. This suggests that the transition from voluntary reporting to mandatory compliance should be managed carefully, especially where reporting infrastructure, assurance capacity, and enforcement mechanisms are still developing.

5.3. Limitations and future research

Several limitations suggest directions for future research. First, although the country-specific regulatory-timing analysis improves on a uniform breakpoint, regulatory exposure may still vary within countries by firm size, sector, listing status, assurance requirements, and enforcement intensity. Future research could construct firm-level regulatory exposure measures to identify more precisely how mandatory disclosure affects the pricing of sustainability uncertainty.

Second, this study uses aggregate stock market indices. This design enables international market-level comparison, but it cannot fully distinguish whether ESGUI affects valuations through expected cash flows, discount rates, financing costs, investor clientele, or sectoral composition. Firm-level or sector-level analyses could decompose these channels and examine whether ESG-prepared firms benefit more during voluntary regimes and whether firms with weaker governance systems are penalized more during mandatory regimes.

Third, the analysis does not directly observe portfolio flows, FDI, or institutional ownership. The stronger responses to global ESGUI shocks are therefore interpreted as consistent with international market integration and information transmission rather than direct evidence of cross-border capital reallocation. Future research could combine ESGUI shocks with fund-flow, ownership, or portfolio-holding data to test this channel more directly. Finally, as CSRD, ISSB-based standards, and national disclosure frameworks mature, future work could examine whether the negative pricing effects observed during the mandatory-compliance phase weaken as firms, auditors, regulators, and investors learn to process the new reporting requirements.

CRediT authorship contribution statement

Md Khaled Hossain Rafi: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization.

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Declaration of competing interest

The author declare that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix. Tables and figures

See Figs. A.1–A.6 and Tables A.1–A.10

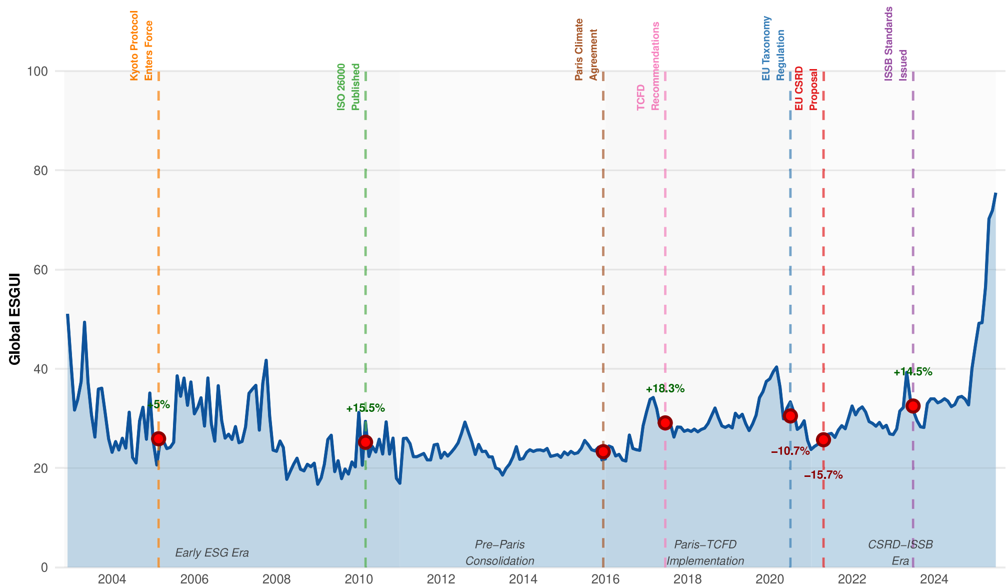

Fig. A.1. Global sustainability uncertainty (ESGUI) and ESG regulatory milestones.
This figure displays the global ESGUI from November 2002 to June 2025 with vertical dashed lines marking major ESG regulatory milestones. Shaded regions indicate the four analytical subperiods: Early ESG Era (2002–2010), Pre-Paris Consolidation (2011–2015), Paris-TCFD Implementation (2016–2020), and CSRD-ISSB Era (2021–2025). Red points show ESGUI levels at event dates, with percentage labels indicating changes relative to the six-month prior baseline.

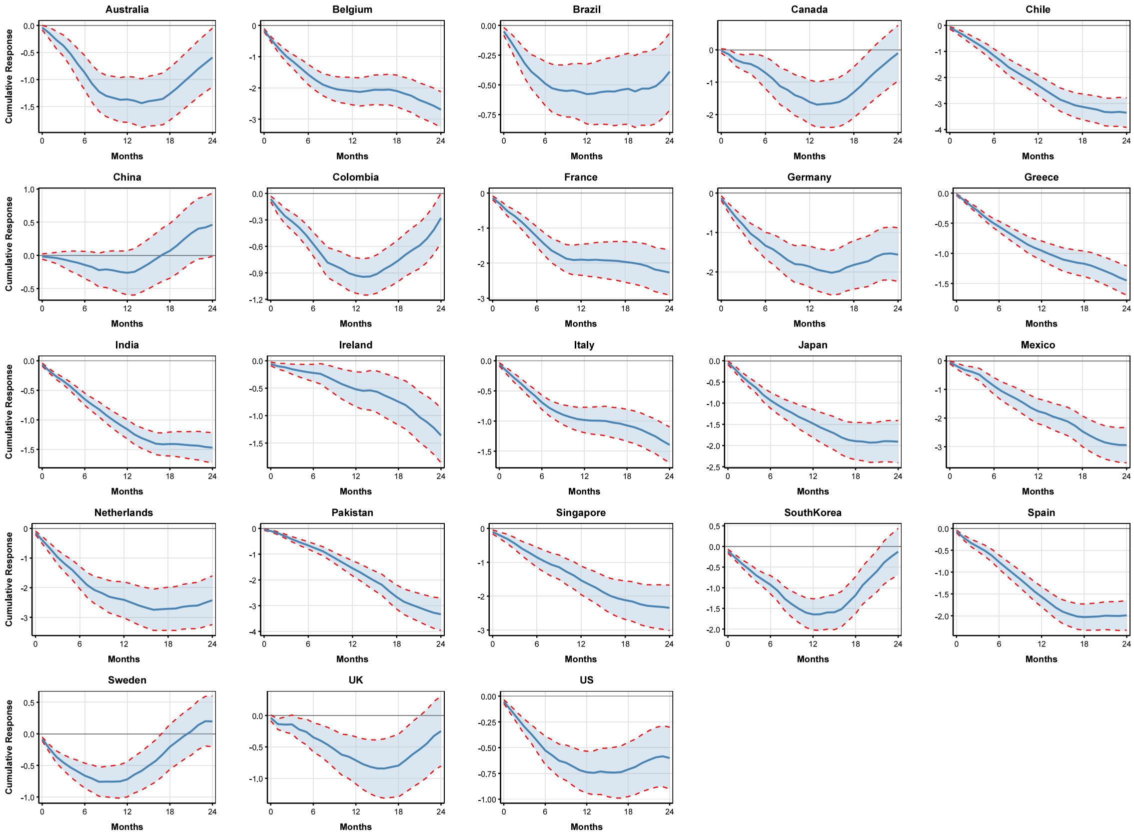

Fig. A.2. Cumulative impulse responses of stock prices to country-specific EPU.
This figure displays cumulative impulse responses of real stock prices to a one-standard-deviation shock in country-specific Economic Policy Uncertainty index (EPU) using smooth local projections following Barnichon and Brownlees (2019). Each panel represents a different country, arranged alphabetically. Solid blue lines show point estimates of the cumulative response, and dashed red lines show 90% confidence intervals based on Newey–West standard errors with optimal lag selection. The x-axis measures months after the shock (0 to 24), and the y-axis measures the cumulative response in standard deviations with free scales across countries. The smooth local projection method estimates separate regressions at each horizon with 12 lags of the dependent variable and the shock variable as controls. Sample period is from November 2002 to June 2025.

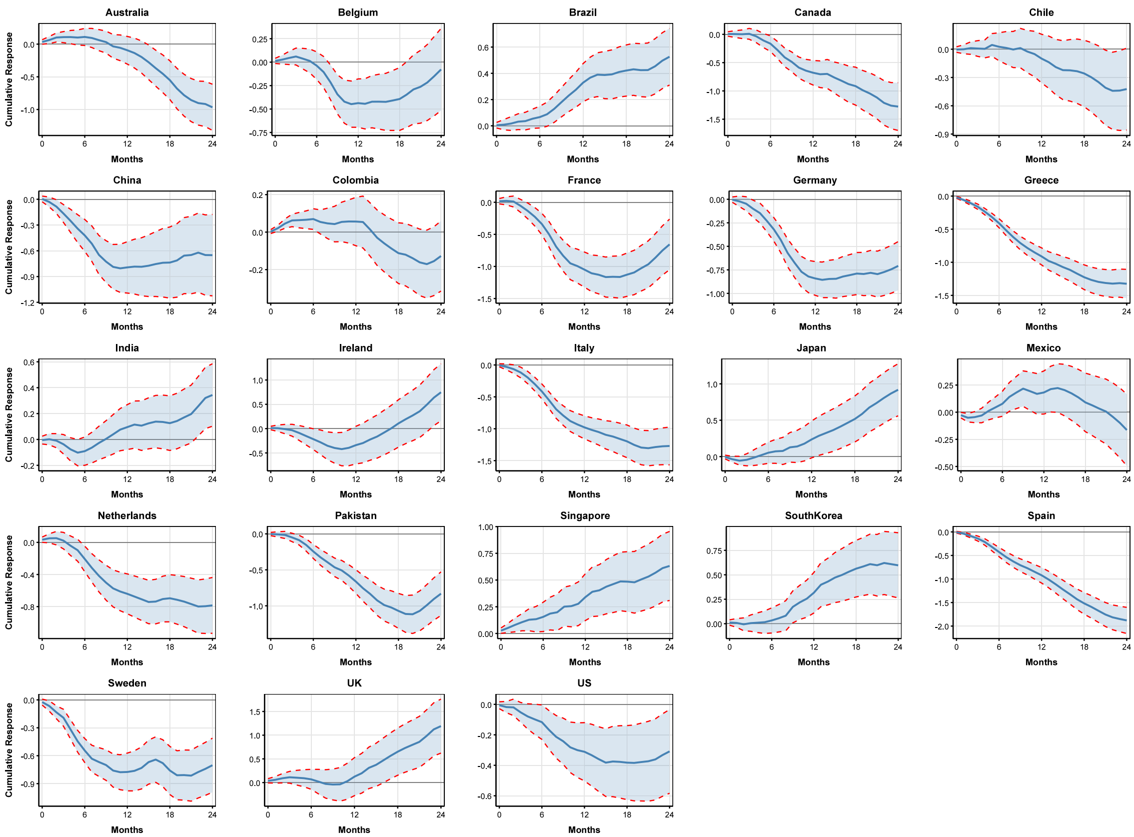

Fig. A.3. Cumulative impulse responses of stock prices to country-specific GPR.
This figure displays cumulative impulse responses of real stock prices to a one-standard-deviation shock in country-specific Geopolitical Risk index (GPR) using smooth local projections following Barnichon and Brownlees (2019). Each panel represents a different country, arranged alphabetically. Solid blue lines show point estimates of the cumulative response, and dashed red lines show 90% confidence intervals based on Newey–West standard errors with optimal lag selection. The x-axis measures months after the shock (0 to 24), and the y-axis measures the cumulative response in standard deviations with free scales across countries. The smooth local projection method estimates separate regressions at each horizon with 12 lags of the dependent variable and the shock variable as controls. Sample period is from November 2002 to June 2025.

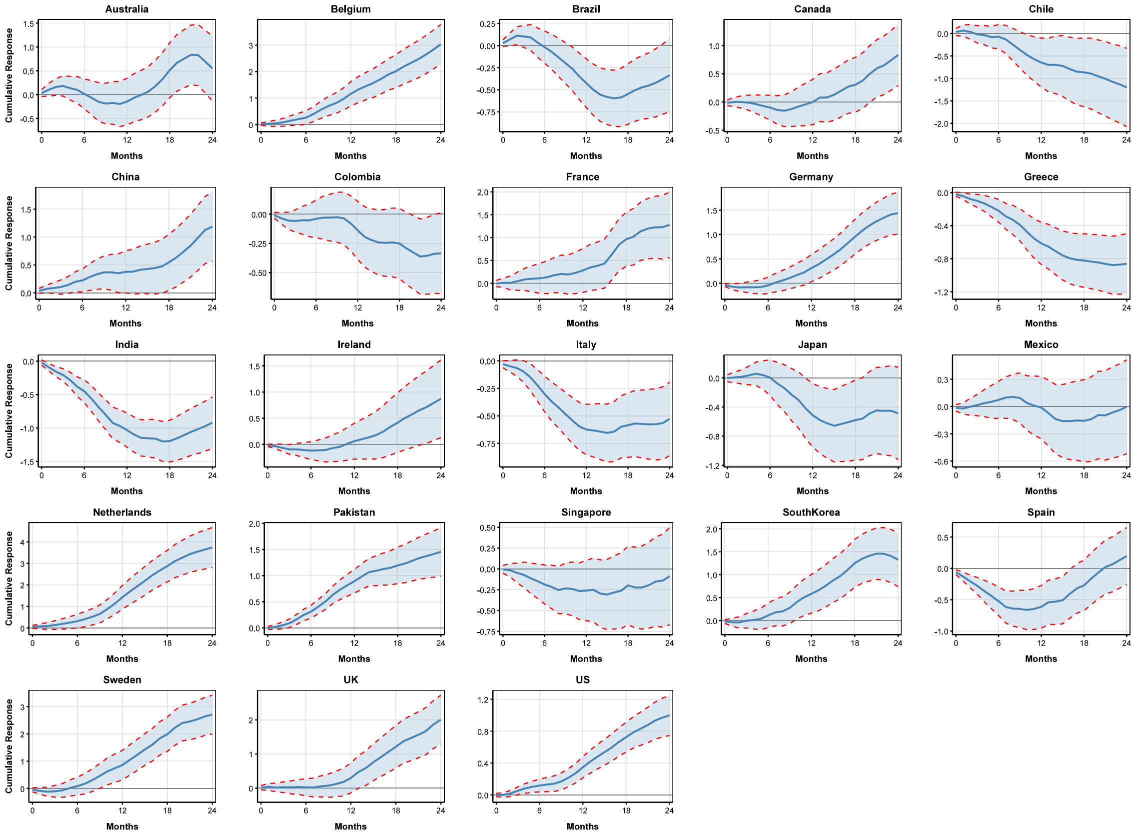

Fig. A.4. Cumulative impulse responses of stock prices to country-specific EUI.
This figure displays cumulative impulse responses of real stock prices to a one-standard-deviation shock in country-specific Environment-related sustainability uncertainty index (EUI) using smooth local projections following Barnichon and Brownlees (2019). Each panel represents a different country, arranged alphabetically. Solid blue lines show point estimates of the cumulative response, and dashed red lines show 90% confidence intervals based on Newey–West standard errors with optimal lag selection. The x-axis measures months after the shock (0 to 24), and the y-axis measures the cumulative response in standard deviations with free scales across countries. The smooth local projection method estimates separate regressions at each horizon with 12 lags of the dependent variable and the shock variable as controls. Sample period is from November 2002 to September 2024.

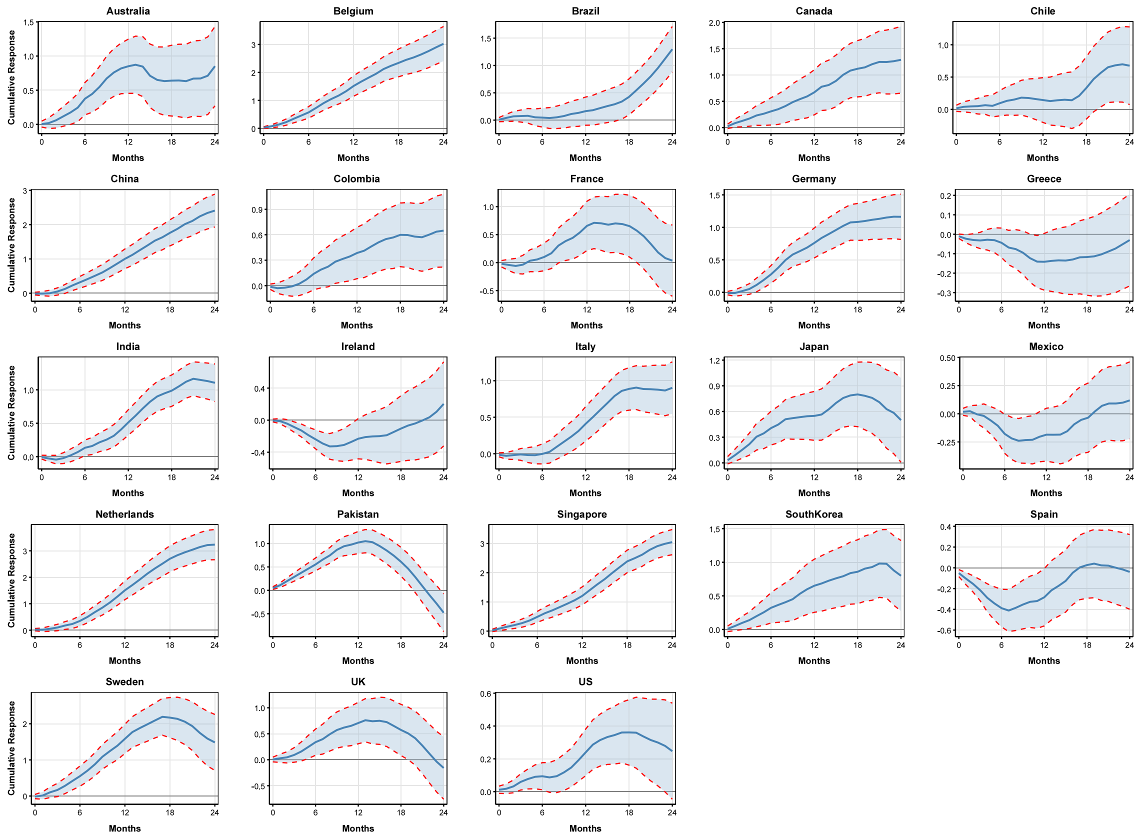

Fig. A.5. Cumulative impulse responses of stock prices to country-specific SUI.
This figure displays cumulative impulse responses of real stock prices to a one-standard-deviation shock in country-specific Social-related sustainability uncertainty index (SUI) using smooth local projections following Barnichon and Brownlees (2019). Each panel represents a different country, arranged alphabetically. Solid blue lines show point estimates of the cumulative response, and dashed red lines show 90% confidence intervals based on Newey–West standard errors with optimal lag selection. The x-axis measures months after the shock (0 to 24), and the y-axis measures the cumulative response in standard deviations with free scales across countries. The smooth local projection method estimates separate regressions at each horizon with 12 lags of the dependent variable and the shock variable as controls. Sample period is from November 2002 to September 2024.

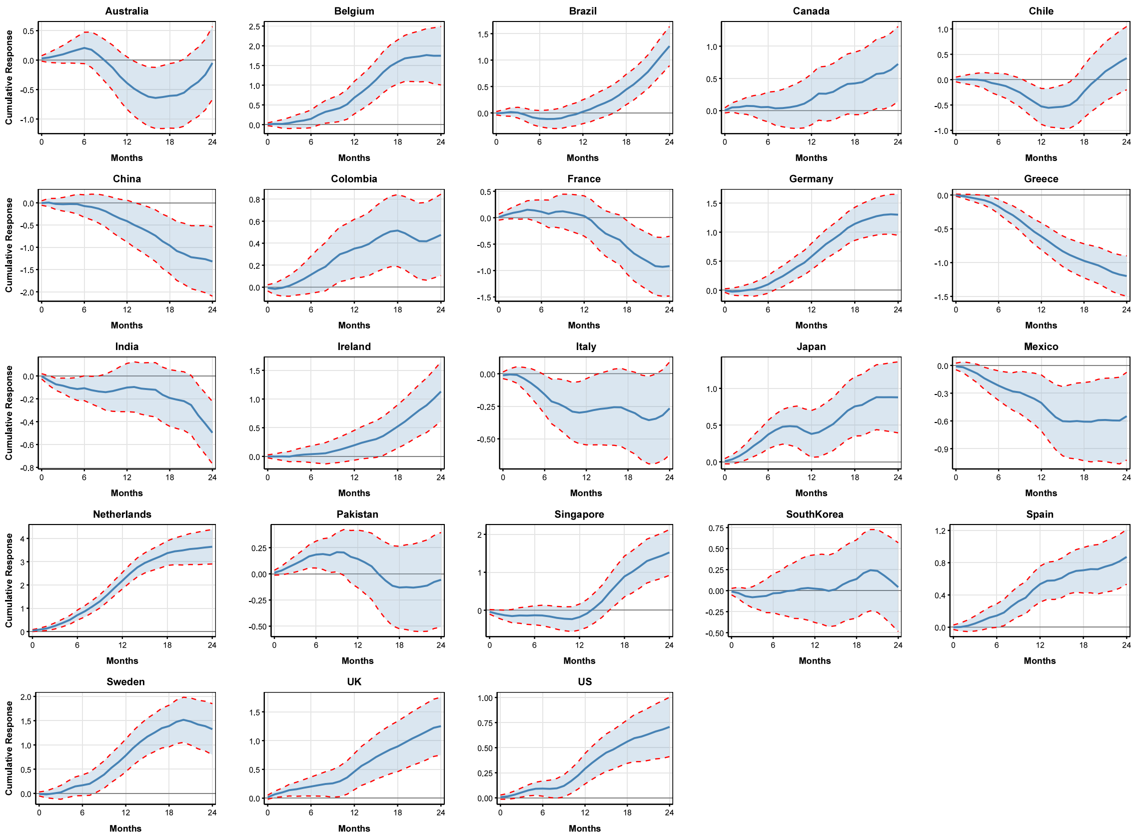

Fig. A.6. Cumulative impulse responses of stock prices to country-specific GUI.
This figure displays cumulative impulse responses of real stock prices to a one-standard-deviation shock in country-specific Governance-related sustainability uncertainty index (GUI) using smooth local projections following Barnichon and Brownlees (2019). Each panel represents a different country, arranged alphabetically. Solid blue lines show point estimates of the cumulative response, and dashed red lines show 90% confidence intervals based on Newey–West standard errors with optimal lag selection. The *x*-axis measures months after the shock (0 to 24), and the *y*-axis measures the cumulative response in standard deviations with free scales across countries. The smooth local projection method estimates separate regressions at each horizon with 12 lags of the dependent variable and the shock variable as controls. Sample period is from November 2002 to September 2024.

Table A.1
Economic interpretation of cumulative impulse responses of stock prices to country-specific ESG-based sustainability uncertainty shocks.

Country	12 Months			18 Months			24 Months		
	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound
Australia	**10.53***	0.92	20.14	**12.15***	0.66	23.64	**22.55***	9.40	35.70
Belgium	**28.40***	19.37	37.44	**49.43***	36.35	62.50	**61.73***	44.66	78.80
Brazil	**−2.18**	−13.46	9.10	**7.39**	−7.27	22.06	**41.55***	22.90	60.20
Canada	**6.77**	−2.94	16.49	**12.97***	0.92	25.02	**20.21***	6.01	34.41
Chile	**−5.86**	−23.67	11.95	**−6.94**	−32.03	18.14	**−24.63**	−56.15	6.89
China	**16.86***	2.74	30.97	**23.20***	4.67	41.73	**36.44***	13.76	59.11
Colombia	**18.23**	−1.49	37.95	**22.18**	−2.36	46.73	**16.36**	−10.65	43.37
France	**9.52***	0.71	18.33	**14.81***	3.51	26.11	**8.60**	−4.75	21.95
Germany	**24.80***	17.11	32.50	**43.40***	33.66	53.14	**51.35***	39.17	63.53
Greece	**−41.19***	−58.82	−23.55	**−60.19***	−82.57	−37.81	**−68.48***	−94.02	−42.94
India	**0.38**	−9.65	10.41	**7.32**	−4.54	19.19	**6.68**	−7.68	21.04
Ireland	**32.41***	18.84	45.98	**54.47***	35.69	73.26	**67.21***	40.79	93.64
Italy	**−13.83***	−22.97	−4.68	**−10.36**	−21.40	0.69	**−10.37**	−22.91	2.18
Japan	**−0.80**	−10.40	8.80	**2.65**	−9.45	14.75	**1.21**	−13.34	15.75
Mexico	**−6.30**	−15.47	2.86	**−10.30**	−23.41	2.80	**−3.26**	−18.37	11.85
Netherlands	**37.10***	29.84	44.35	**67.14***	56.81	77.46	**79.84***	66.51	93.18
Pakistan	**43.32***	29.38	57.26	**45.50***	24.00	67.01	**38.26***	10.37	66.16
Singapore	**13.49***	3.28	23.70	**42.40***	28.78	56.02	**57.79***	42.98	72.59
South Korea	**15.66***	1.09	30.24	**27.53***	10.54	44.52	**29.14***	10.45	47.83
Spain	**−3.80**	−14.74	7.15	**6.45**	−6.38	19.28	**16.11***	1.72	30.50
Sweden	**36.98***	27.34	46.62	**67.62***	55.75	79.49	**70.62***	54.94	86.29
UK	**11.09***	3.29	18.89	**20.68***	9.92	31.44	**25.94***	13.51	38.36
US	**12.67***	5.46	19.89	**25.57***	15.34	35.79	**30.95***	16.58	45.32
Developed countries	**11.88***	7.46	27.50	**23.12***	12.36	47.92	**28.44***	17.13	60.74
Emerging countries	**0.38**	−5.86	16.86	**7.39**	−6.94	23.20	**16.36***	−3.26	36.44

This table translates the cumulative impulse-response estimates reported in Table 2 into economically interpretable percentage price changes. Because the dependent variable in the local-projection models is the standardized real stock-price index, the percentage effect for country i at horizon h is calculated as $100 \times \left[\exp(\hat{\beta}_{i,h}\sigma_i) - 1\right]$, where $\hat{\beta}_{i,h}$ is the estimated cumulative response in standardized units and σ_i is the standard deviation of the corresponding unstandardized real log stock-price series. This transformation expresses the estimated response as an approximate market-price impact in percentage terms. For country-specific results, * represents significance of the estimates, whereas the upper and lower bounds represent the confidence intervals based on the 90 percent significance level. For developed and emerging country groups, the reported estimate is the median across countries, while the lower and upper bounds refer to the interquartile range across the countries in each group rather than confidence intervals. Statistical significance (*) follows the same rule as in the main tables where an asterisk indicates that more than 50% of countries in the group show significant responses at the 10% level, following Yilmazkuday (2024). Sample period is from November 2002 to June 2025.

Table A.2
Cumulative impulse responses of stock prices to global ESGUI shocks for different sample periods.

Country	Early ESG			Pre-Paris Cons.			Paris TCFD			CSRD ISSB		
	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound
Australia	**1.07***	0.61	1.53	**0.54**	0.42	0.66	**1.38**	−1.14	3.90	**2.91***	0.39	5.43
Belgium	**1.27***	0.87	1.68	**0.40**	0.04	0.76	**1.41***	−0.18	3.00	**−0.55**	−5.44	4.34
Brazil	**0.78***	0.52	1.05	**−0.39***	−0.68	−0.11	**2.58***	1.14	4.02	**−0.50**	−2.30	1.29
Canada	**1.35***	0.96	1.75	**−0.98***	−1.34	−0.63	**0.07***	1.87	2.01	**2.66***	0.80	4.52
Chile	**0.44***	0.15	0.73	**0.98***	0.75	1.20	**−0.04**	−0.79	0.70	**2.27**	−3.47	8.01
China	**0.25**	−0.24	0.73	**3.01***	2.35	3.67	**0.26**	−1.20	1.71	**1.79***	0.46	3.11
Colombia	**1.27***	1.04	1.51	**−0.20**	−0.44	0.04	**0.68**	−0.45	1.81	**0.99**	−1.17	3.14
France	**1.28***	0.83	1.73	**0.35***	0.13	0.57	**2.47***	1.26	3.68	**−1.40**	−4.13	1.33
Germany	**0.88***	0.51	1.26	**0.45***	0.29	0.61	**1.57***	0.21	2.93	**1.12**	−1.10	3.33
Greece	**1.26***	0.87	1.65	**−0.48**	−0.96	0.00	**−1.53***	−2.87	−0.18	**2.64***	1.38	3.91
India	**1.25***	0.91	1.59	**−0.99***	−1.40	−0.57	**−1.31***	−2.35	−0.27	**−2.95**	−5.87	−0.02
Ireland	**1.03***	0.69	1.36	**−0.50***	−0.75	−0.25	**1.44***	−0.28	3.16	**−1.88***	−3.58	−0.18
Italy	**1.18***	0.75	1.61	**−0.74***	−1.35	−0.14	**−0.85***	−2.93	1.23	**−3.27***	−4.60	−1.94
Japan	**1.87***	1.45	2.30	**−0.07**	−0.41	0.27	**0.14**	−0.90	1.19	**0.25**	−1.17	1.68
Mexico	**0.96***	0.69	1.23	**0.44**	−0.06	0.94	**−2.02***	−3.22	−0.81	**8.05***	4.34	11.75
Netherlands	**1.61***	1.09	2.14	**0.41***	−0.05	0.87	**1.40***	0.04	2.76	**−5.58***	−7.34	−3.82
Pakistan	**1.70***	1.32	2.07	**−0.17***	−0.37	0.03	**1.68***	1.09	2.27	**−0.59**	−1.61	0.43
Singapore	**0.77***	0.38	1.16	**−0.79**	−1.83	0.25	**0.29**	−0.64	1.23	**5.82***	3.07	8.58
South Korea	**1.77***	1.34	2.19	**0.05**	−0.57	0.67	**−0.14**	−1.25	0.97	**5.20***	3.22	7.19
Spain	**0.93***	0.50	1.36	**−0.10***	−0.69	0.49	**−1.63***	−2.78	−0.49	**9.03***	6.18	11.89
Sweden	**0.83***	0.41	1.26	**0.34***	−0.17	0.85	**0.06***	1.53	1.65	**−5.12***	−7.34	−2.90
UK	**1.43***	0.92	1.93	**0.51**	0.06	0.96	**1.48***	0.07	2.89	**−3.64***	−5.67	−1.61
US	**0.86***	0.37	1.35	**−0.33***	−0.61	−0.05	**0.76**	0.36	1.16	**−0.34**	−1.73	1.05
Developed coun.	**1.12***	0.90	1.33	**0.24***	−0.62	0.43	**1.07**	0.07	1.46	**−0.45***	−2.93	2.27
Emerging coun.	**1.25***	0.78	1.27	**−0.17***	−0.39	0.44	**−0.04***	−1.31	0.68	**1.79***	−0.50	2.64

This table reports cumulative impulse responses of real stock prices to a one-standard-deviation shock in global ESG-based sustainability uncertainty index (ESGUI) for different sample periods at horizons of 12 months. The full sample is divided into four distinct periods that capture the changing landscape of sustainability regulation: (1) Early ESG Era (November 2002–December 2010), which covers the initial emergence of ESG considerations in mainstream finance and includes the 2008 financial crisis; (2) Pre-Paris Consolidation (January 2011–December 2015), marking increased institutional focus on ESG but prior to binding international agreements; (3) Paris Agreement & TCFD Implementation (January 2016–December 2020), characterized by the landmark Paris Climate Agreement in 2015 and the introduction of the Task Force on Climate-related Financial Disclosures (TCFD) recommendations in 2017; and (4) CSRD & ISSB Era (January 2021–June 2025), encompassing the European Union's Corporate Sustainability Reporting Directive (CSRD) affecting 50,000 companies and the International Sustainability Standards Board's (ISSB) global disclosure framework. Local projections are estimated separately for each subperiod. Individual country results are estimated using smooth local projections following Barnichon and Brownlees (2019) with 12 lags of the dependent variable and shock variable. The dependent variable is real stock prices normalized to one standard deviation. The independent variable is global ESGUI (normalized to one standard deviation). For individual countries, estimated coefficients represent the cumulative impulse of stock prices to a unit shock in global ESGUI. For country-specific results, * represents significance of the estimates, whereas the upper and lower bounds represent the confidence intervals based on the 90 percent significance level. For country groups (developed and emerging countries), estimates represent the median across the corresponding constituent countries, whereas upper and lower bounds represent the interquartile range across the corresponding countries. Statistical significance (*) denotes that more than 50% of countries in the group show significant responses at the 10% level, following Yilmazkuday (2024). Sample period is from November 2002 to June 2025.

Table A.3
Country-specific regulatory-timing robustness of ESGUI effects on stock prices.

Specification	12 Months			18 Months			24 Months		
	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound
Panel A. Country-specific mandatory timing									
Voluntary-regime effect	**0.52**	−0.14	1.19	**1.23***	0.43	2.03	**1.26***	0.27	2.26
Mandatory-regime effect	**−2.53**	−5.97	0.91	**−4.57**	−9.23	0.09	**−5.66***	−10.74	−0.57
Interaction delta	**−3.06**	−6.45	0.33	**−5.80***	−10.64	−0.96	**−6.92***	−12.26	−1.58
Panel B. Country-specific anticipation timing									
Voluntary-regime effect	**0.56**	−0.17	1.28	**1.29***	0.41	2.17	**1.33***	0.27	2.39
Anticipation-regime effect	**−4.70**	−11.13	1.73	**−7.71***	−13.43	−1.99	**−9.28***	−15.93	−2.62
Interaction delta	**−5.25**	−12.09	1.58	**−9.00***	−15.38	−2.61	**−10.61***	−18.02	−3.20

This table reports cumulative impulse responses of real stock prices to a one-standard-deviation shock in country-specific ESG-based sustainability uncertainty (ESGUI) when regulatory timing is modeled using country-specific disclosure calendars rather than a common 2021 breakpoint. Panel A uses the country-specific mandatory-regime indicator, while Panel B uses the anticipation-regime indicator. The mandatory-regime dummy equals one beginning from the first month of the first mandatory fiscal year applying to large listed firms or the dominant listed-company reporting cohort in each country. For phased regimes, the first affected large-listed-firm cohort is used because stock-market indices are dominated by listed firms. For EU countries, the baseline timing follows the CSRD wave-1 fiscal-year start for large public-interest/listed entities, while national transposition dates are recorded separately where available. For jurisdictions in which sustainability standards were adopted, proposed, stayed, voluntary, or not yet mandatory within the sample period, the main mandatory dummy remains zero until the first binding fiscal-year start. The anticipation-regime indicator captures earlier announcement, adoption, roadmap, or effective-date events where these precede mandatory application. Country-specific timing was hand-collected from official regulatory and legal sources, including national securities regulators, government gazettes, legislation portals, stock-exchange disclosure rules, IFRS jurisdiction profiles, and CSRD/national transposition materials. Estimates are reported for the voluntary-regime effect, the country-specific mandatory or anticipation-regime effect, and the interaction delta, defined as the difference between the regime-specific effect and the voluntary-regime effect. Lower and upper bounds are 90% confidence intervals based on robust standard errors. Statistical significance (*) denotes significance at the 10% level. Sample period is from November 2002 to June 2025.

Table A.4
Cumulative impulse responses of stock prices to country-specific ESGUI shocks using standard local projection.

Country	12 Months			18 Months			24 Months		
	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound
Australia	**−0.14**	−0.59	0.31	**−0.47**	−1.03	0.09	**−0.25**	−0.89	0.39
Belgium	**0.24**	−0.25	0.73	**0.31**	−0.41	1.02	**−0.12**	−1.03	0.79
Brazil	**0.29**	−0.01	0.59	**0.84***	0.43	1.26	**1.86***	1.31	2.41
Canada	**0.28**	−0.20	0.77	**0.47**	−0.12	1.06	**0.65**	−0.03	1.32
Chile	**−0.31**	−0.81	0.20	**−0.52**	−1.23	0.20	**−1.31***	−2.20	−0.43
China	**−0.09**	−0.59	0.42	**−0.33**	−1.03	0.36	**−0.31**	−1.12	0.49
Colombia	**−0.06**	−0.47	0.35	**−0.18**	−0.75	0.39	**−0.50**	−1.17	0.16
France	**1.12***	0.62	1.62	**1.79***	1.11	2.47	**1.94***	1.09	2.80
Germany	**0.85***	0.60	1.11	**1.51***	1.16	1.86	**1.86***	1.41	2.32
Greece	**−0.28***	−0.49	−0.06	**−0.30***	−0.59	−0.01	**−0.14**	−0.50	0.22
India	**0.44***	0.18	0.69	**0.98***	0.63	1.33	**1.40***	0.98	1.81
Ireland	**0.83***	0.25	1.42	**1.41***	0.64	2.19	**2.10***	1.13	3.06
Italy	**0.18**	−0.12	0.47	**0.78***	0.36	1.20	**1.28***	0.79	1.78
Japan	**0.52***	0.08	0.96	**1.07***	0.50	1.65	**1.20***	0.46	1.93
Mexico	**−0.15**	−0.44	0.13	**−0.22**	−0.64	0.21	**−0.02**	−0.53	0.49
Netherlands	**1.94***	1.51	2.36	**3.59***	2.98	4.19	**4.36***	3.58	5.13
Pakistan	**1.13***	0.80	1.46	**1.46***	0.95	1.96	**1.46***	0.77	2.14
Singapore	**0.09**	−0.33	0.52	**0.97***	0.37	1.58	**1.34***	0.67	2.02
South Korea	**−0.09**	−0.57	0.38	**−0.06**	−0.63	0.50	**−0.31**	−0.95	0.33
Spain	**−0.57***	−0.96	−0.17	**−0.59***	−1.09	−0.09	**−0.64***	−1.24	−0.04
Sweden	**1.44***	0.93	1.96	**2.67***	2.01	3.34	**2.78***	1.94	3.63
UK	**0.66***	0.18	1.13	**1.20***	0.53	1.88	**1.48***	0.70	2.26
US	**0.43***	0.21	0.65	**0.83***	0.49	1.17	**1.00***	0.52	1.49
Developed countries	**0.47***	0.19	0.85	**1.02***	0.55	1.49	**1.31***	0.74	1.92
Emerging countries	**−0.09**	−0.15	0.29	**−0.18**	−0.30	0.84	**−0.14**	−0.31	1.40

This table reports cumulative impulse responses of real stock prices to a one-standard-deviation shock in country-specific ESG-based sustainability uncertainty index (ESGUI) at horizons of 12, 18, and 24 months. Individual country results are estimated using standard local projections following Jordà (2005). The dependent variable is real stock prices normalized to one standard deviation. The independent variable is country-specific ESGUI (normalized to one standard deviation). For country-specific results, * represents significance at the 10% level or better. For country groups, estimates represent the median across constituent countries. Sample period is from November 2002 to June 2025.

Table A.5
Cumulative impulse responses of stock prices to country-specific ESGUI shocks using 6 lags.

Country	12 Months			18 Months			24 Months		
	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound
Australia	**0.27**	−0.09	0.63	**−0.06**	−0.51	0.40	**0.10**	−0.42	0.62
Belgium	**1.17***	0.79	1.56	**1.91***	1.35	2.48	**2.36***	1.60	3.12
Brazil	**−0.20**	−0.44	0.05	**−0.10**	−0.42	0.21	**0.61***	0.23	1.00
Canada	**0.10**	−0.29	0.48	**0.19**	−0.29	0.66	**0.32**	−0.24	0.89
Chile	**0.24**	−0.14	0.63	**0.08**	−0.43	0.60	**−0.22**	−0.84	0.40
China	**0.39***	0.06	0.72	**0.76***	0.32	1.20	**1.41***	0.84	1.98
Colombia	**0.37***	0.08	0.66	**0.35**	−0.02	0.73	**0.24**	−0.18	0.65
France	**1.27***	0.78	1.77	**2.08***	1.43	2.73	**2.53***	1.73	3.33
Germany	**0.60***	0.40	0.80	**1.07***	0.82	1.33	**1.28***	0.96	1.60
Greece	**−0.46***	−0.67	−0.25	**−0.66***	−0.93	−0.38	**−0.77***	−1.10	−0.44
India	**−0.06**	−0.27	0.15	**0.08**	−0.19	0.35	**0.10**	−0.23	0.42
Ireland	**0.71***	0.30	1.13	**1.17***	0.60	1.74	**1.66***	0.87	2.45
Italy	**−0.35***	−0.60	−0.11	**−0.19**	−0.50	0.12	**−0.21**	−0.55	0.14
Japan	**0.00**	−0.45	0.46	**0.21**	−0.35	0.78	**0.19**	−0.49	0.87
Mexico	**−0.05**	−0.30	0.20	**−0.05**	−0.43	0.32	**0.23**	−0.21	0.67
Netherlands	**1.81***	1.46	2.17	**3.32***	2.80	3.84	**3.89***	3.21	4.57
Pakistan	**0.62***	0.36	0.88	**0.79***	0.40	1.18	**0.93***	0.42	1.43
Singapore	**0.26**	−0.01	0.54	**0.93***	0.50	1.36	**1.25***	0.76	1.75
South Korea	**0.48***	0.04	0.92	**0.69***	0.16	1.23	**0.60***	0.02	1.19
Spain	**−0.33***	−0.66	0.00	**−0.21**	−0.61	0.18	**−0.13**	−0.59	0.33
Sweden	**0.99***	0.57	1.41	**1.97***	1.45	2.49	**1.97***	1.31	2.62
UK	**0.52***	0.12	0.92	**0.99***	0.42	1.55	**1.16***	0.51	1.81
US	**0.29***	0.12	0.46	**0.58***	0.35	0.82	**0.69***	0.36	1.03
Developed countries	**0.41***	0.14	0.92	**0.96***	0.20	1.73	**1.21***	0.22	1.89
Emerging countries	**0.24***	−0.06	0.39	**0.08**	−0.05	0.69	**0.24***	0.10	0.61

This table reports cumulative impulse responses of real stock prices to a one-standard-deviation shock in country-specific ESG-based sustainability uncertainty index (ESGUI) at horizons of 12, 18, and 24 months using 6 lags. Individual country results are estimated using smooth local projections following Barnichon and Brownlees (2019) with 6 lags of the dependent variable and shock variable. The dependent variable is real stock prices normalized to one standard deviation. The independent variable is country-specific ESGUI (normalized to one standard deviation). For individual countries, estimated coefficients represent the cumulative impulse of stock prices to a unit shock in country-specific ESGUI. For country-specific results, * represents significance of the estimates, whereas the upper and lower bounds represent the confidence intervals based on the 90 percent significance level. For country groups (developed and emerging countries), estimates represent the median across the corresponding constituent countries, whereas upper and lower bounds represent the interquartile range across the corresponding countries. Statistical significance (*) denotes that more than 50% of countries in the group show significant responses at the 10% level, following Yilmazkuday (2024). Sample period is from November 2002 to June 2025.

Table A.6
Cumulative impulse responses of stock prices to country-specific ESGUI shocks using 18 lags.

Country	12 Months			18 Months			24 Months		
	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound
Australia	**0.11**	−0.35	0.57	**−0.14**	−0.69	0.41	**0.15**	−0.48	0.79
Belgium	**1.32***	0.94	1.70	**2.19***	1.65	2.73	**2.41***	1.68	3.13
Brazil	**0.14**	−0.12	0.39	**0.43***	0.09	0.76	**1.25***	0.85	1.66
Canada	**0.03**	−0.44	0.51	**0.34**	−0.23	0.90	**0.69***	0.03	1.35
Chile	**0.22**	−0.35	0.78	**0.40**	−0.41	1.21	**−0.10**	−1.10	0.90
China	**0.43***	0.02	0.84	**0.68***	0.13	1.22	**1.00***	0.33	1.68
Colombia	**0.36***	0.00	0.72	**0.39**	−0.06	0.84	**0.33**	−0.17	0.83
France	**0.52**	0.00	1.04	**0.70***	0.05	1.36	**0.17**	−0.58	0.93
Germany	**0.72***	0.50	0.95	**1.33***	1.05	1.62	**1.53***	1.18	1.88
Greece	**−0.33***	−0.53	−0.13	**−0.43***	−0.69	−0.17	**−0.38***	−0.67	−0.08
India	**−0.02**	−0.25	0.21	**0.08**	−0.19	0.34	**−0.01**	−0.31	0.29
Ireland	**0.88***	0.44	1.32	**1.15***	0.56	1.75	**1.08***	0.28	1.89
Italy	**−0.73***	−0.98	−0.47	**−0.73***	−1.03	−0.43	**−0.73***	−1.07	−0.38
Japan	**−0.45***	−0.87	−0.02	**−0.49**	−1.05	0.08	**−0.53**	−1.22	0.16
Mexico	**−0.28***	−0.55	−0.01	**−0.61***	−1.01	−0.21	**−0.53***	−0.98	−0.07
Netherlands	**1.66***	1.26	2.05	**3.12***	2.57	3.67	**3.64***	2.95	4.33
Pakistan	**0.66***	0.37	0.95	**0.39**	−0.06	0.84	**−0.03**	−0.61	0.56
Singapore	**−0.05**	−0.44	0.34	**0.97***	0.45	1.49	**1.49***	0.92	2.06
South Korea	**0.93***	0.52	1.34	**1.56***	1.08	2.05	**1.77***	1.21	2.33
Spain	**−0.38***	−0.74	−0.03	**−0.44***	−0.84	−0.04	**−0.56***	−1.00	−0.12
Sweden	**1.62***	1.19	2.06	**2.93***	2.41	3.45	**3.02***	2.33	3.71
UK	**1.11***	0.67	1.56	**2.04***	1.44	2.65	**2.76***	2.08	3.44
US	**0.41***	0.20	0.61	**0.77***	0.49	1.05	**1.08***	0.70	1.45
Developed countries	**0.46***	−0.03	1.06	**0.87***	−0.02	1.87	**1.08***	0.16	2.19
Emerging countries	**0.22***	−0.02	0.43	**0.39***	0.08	0.43	**−0.01***	−0.10	1.00

This table reports cumulative impulse responses of real stock prices to a one-standard-deviation shock in country-specific ESG-based sustainability uncertainty index (ESGUI) at horizons of 12, 18, and 24 months using 18 lags. Individual country results are estimated using smooth local projections following Barnichon and Brownlees (2019) with 18 lags of the dependent variable and shock variable. The dependent variable is real stock prices normalized to one standard deviation. The independent variable is country-specific ESGUI (normalized to one standard deviation). For individual countries, estimated coefficients represent the cumulative impulse of stock prices to a unit shock in country-specific ESGUI. For country-specific results, * represents significance of the estimates, whereas the upper and lower bounds represent the confidence intervals based on the 90 percent significance level. For country groups (developed and emerging countries), estimates represent the median across the corresponding constituent countries, whereas upper and lower bounds represent the interquartile range across the corresponding countries. Statistical significance (*) denotes that more than 50% of countries in the group show significant responses at the 10% level, following Yilmazkuday (2024). Sample period is from November 2002 to June 2025.

Table A.7
Cumulative impulse responses of stock prices to country-specific ESGUI shocks including macroeconomic variables.

Country	12 Months			18 Months			24 Months		
	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound
Australia	**0.80***	0.37	1.22	**1.04***	0.53	1.54	**1.63***	1.05	2.21
Belgium	**0.27**	−0.04	0.58	**0.47**	−0.05	0.99	**0.63**	−0.07	1.32
Brazil	**−0.05**	−0.27	0.17	**0.09**	−0.20	0.37	**0.69***	0.34	1.04
Canada	**0.18**	−0.27	0.63	**0.52**	−0.04	1.07	**1.11***	0.47	1.74
Chile	**0.11**	−0.37	0.59	**0.25**	−0.36	0.87	**0.03**	−0.67	0.73
China	**0.50***	0.13	0.88	**0.86***	0.38	1.34	**1.52***	0.92	2.13
Colombia	**0.39***	0.07	0.71	**0.52***	0.12	0.92	**0.50***	0.07	0.93
France	**0.56***	0.15	0.96	**0.83***	0.28	1.39	**0.46**	−0.23	1.14
Germany	**0.47***	0.27	0.67	**0.80***	0.53	1.07	**0.85***	0.50	1.20
Greece	**−0.46***	−0.61	−0.31	**−0.68***	−0.87	−0.49	**−0.78***	−1.02	−0.55
India	**0.26***	0.07	0.44	**0.51***	0.29	0.72	**0.63***	0.36	0.90
Ireland	**0.39***	0.01	0.77	**0.57***	0.03	1.10	**0.50**	−0.21	1.22
Italy	**−0.55***	−0.76	−0.34	**−0.49***	−0.76	−0.23	**−0.41***	−0.72	−0.11
Japan	**−1.30***	−1.66	−0.94	**−1.85***	−2.35	−1.36	**−2.44***	−3.04	−1.83
Mexico	**−0.37***	−0.61	−0.13	**−0.30**	−0.63	0.03	**0.15**	−0.23	0.53
Netherlands	**1.29***	0.96	1.62	**2.31***	1.83	2.79	**2.52***	1.92	3.12
Pakistan	**0.38***	0.08	0.68	**−0.04**	−0.48	0.41	**−0.45**	−1.01	0.11
Singapore	**0.89***	0.47	1.32	**2.40***	1.82	2.98	**3.29***	2.67	3.91
South Korea	**0.38**	0.00	0.75	**0.34**	−0.09	0.78	**0.15**	−0.37	0.66
Spain	**−0.79***	−1.13	−0.45	**−1.04***	−1.43	−0.64	**−1.15***	−1.58	−0.72
Sweden	**1.24***	0.85	1.63	**2.20***	1.71	2.70	**2.11***	1.50	2.72
UK	**−0.24**	−0.56	0.09	**−0.28**	−0.70	0.15	**−0.37**	−0.87	0.13
US	**0.04**	−0.14	0.22	**0.23**	−0.02	0.47	**0.35***	0.04	0.66
Developed countries	**0.33***	−0.17	0.74	**0.54***	−0.15	0.98	**0.57***	−0.19	1.50
Emerging countries	**0.26***	−0.05	0.38	**0.25**	−0.04	0.51	**0.15***	0.03	0.63

This table reports cumulative impulse responses of real stock prices to a one-standard-deviation shock in country-specific ESG-based sustainability uncertainty index (ESGUI) at horizons of 12, 18, and 24 months including macroeconomic variables (term spread, default spread, change in industrial production) as controls. Individual country results are estimated using smooth local projections following Barnichon and Brownlees (2019) with 12 lags of the dependent variable, shock variable and the above-mentioned one-month lagged macroeconomic variables as controls. The dependent variable is real stock prices normalized to one standard deviation. The independent variable is country-specific ESGUI (normalized to one standard deviation). For individual countries, estimated coefficients represent the cumulative impulse of stock prices to a unit shock in country-specific ESGUI. For country-specific results, * represents significance of the estimates, whereas the upper and lower bounds represent the confidence intervals based on the 90 percent significance level. For country groups (developed and emerging countries), estimates represent the median across the corresponding constituent countries, whereas upper and lower bounds represent the interquartile range across the corresponding countries. Statistical significance (*) denotes that more than 50% of countries in the group show significant responses at the 10% level, following Yilmazkuday (2024). Sample period is from November 2002 to June 2025.

Table A.8
Cumulative impulse responses of stock prices to country-specific ESGUI shocks excluding crisis periods.

Country	12 Months			18 Months			24 Months		
	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound
Australia	**−0.03**	−0.46	0.40	**−0.52***	−1.02	−0.01	**−0.65***	−1.23	−0.07
Belgium	**1.30***	0.96	1.63	**2.01***	1.55	2.46	**2.71***	2.16	3.26
Brazil	**−0.13**	−0.35	0.09	**0.19**	−0.10	0.47	**0.64***	0.31	0.98
Canada	**0.03**	−0.33	0.40	**0.41**	−0.07	0.90	**0.78***	0.21	1.35
Chile	**−0.18**	−0.72	0.37	**−0.56**	−1.28	0.17	**−1.40***	−2.26	−0.53
China	**0.50***	0.12	0.88	**0.95***	0.45	1.45	**1.52***	0.90	2.14
Colombia	**−0.16**	−0.46	0.14	**−0.50***	−0.86	−0.14	**−0.79***	−1.19	−0.38
France	**0.58***	0.13	1.03	**0.82***	0.26	1.39	**0.27**	−0.38	0.93
Germany	**0.86***	0.61	1.11	**1.37***	1.07	1.66	**1.77***	1.42	2.13
Greece	**−0.13**	−0.33	0.07	**−0.15**	−0.43	0.13	**−0.06**	−0.39	0.27
India	**0.16**	−0.02	0.33	**0.28***	0.08	0.48	**0.15**	−0.09	0.39
Ireland	**1.11***	0.79	1.44	**1.62***	1.11	2.13	**1.88***	1.18	2.58
Italy	**−0.23**	−0.48	0.02	**0.05**	−0.23	0.34	**0.47***	0.16	0.78
Japan	**0.12**	−0.29	0.53	**0.10**	−0.43	0.63	**0.24**	−0.39	0.87
Mexico	**0.05**	−0.15	0.24	**0.17**	−0.09	0.43	**0.64***	0.35	0.94
Netherlands	**2.39***	2.00	2.77	**3.75***	3.21	4.30	**4.54***	3.88	5.20
Pakistan	**0.75***	0.41	1.08	**0.71***	0.25	1.18	**0.37**	−0.22	0.96
Singapore	**−0.18**	−0.50	0.14	**0.00**	−0.39	0.39	**0.00**	−0.45	0.45
South Korea	**1.01***	0.62	1.41	**1.54***	1.10	1.98	**1.13***	0.66	1.61
Spain	**−0.02**	−0.29	0.25	**0.39***	0.08	0.71	**0.74***	0.37	1.12
Sweden	**0.47***	0.15	0.79	**1.13***	0.71	1.55	**1.36***	0.84	1.88
UK	**0.64***	0.28	1.01	**1.09***	0.62	1.56	**1.59***	1.04	2.13
US	**0.40***	0.25	0.56	**0.62***	0.38	0.86	**1.01***	0.72	1.31
Developed countries	**0.44***	−0.01	0.81	**0.72***	0.17	1.31	**0.90***	0.32	1.73
Emerging countries	**0.05**	−0.13	0.50	**0.19***	−0.15	0.71	**0.37***	−0.06	0.64

This table reports cumulative impulse responses of real stock prices to a one-standard-deviation shock in country-specific ESG-based sustainability uncertainty index (ESGUI) at horizons of 12, 18, and 24 months excluding crisis periods. Individual country results are estimated using smooth local projections following Barnichon and Brownlees (2019) with 12 lags of the dependent variable and shock variable. The dependent variable is real stock prices normalized to one standard deviation. The independent variable is country-specific ESGUI (normalized to one standard deviation). The crisis period is defined as months when VIX exceeds 90th percentile. Then, this crisis period is excluded from the sample and then the local projection is estimated. For individual countries, estimated coefficients represent the cumulative impulse of stock prices to a unit shock in country-specific ESGUI. For country-specific results, * represents significance of the estimates, whereas the upper and lower bounds represent the confidence intervals based on the 90 percent significance level. For country groups (developed and emerging countries), estimates represent the median across the corresponding constituent countries, whereas upper and lower bounds represent the interquartile range across the corresponding countries. Statistical significance (*) denotes that more than 50% of countries in the group show significant responses at the 10% level, following Yilmazkuday (2024). Sample period is from November 2002 to June 2025.

Table A.9
Cumulative impulse responses of stock prices to equal-weighted global ESGUI shocks.

Country	12 Months			18 Months			24 Months		
	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound	Estimate Coeff.	Lower bound	Upper bound
Australia	**1.67***	0.91	2.43	**3.16***	2.04	4.27	**3.43***	2.09	4.76
Belgium	**2.32***	1.66	2.98	**4.79***	3.75	5.82	**6.78***	5.48	8.08
Brazil	**0.84***	0.36	1.31	**1.30***	0.66	1.94	**0.88***	0.14	1.63
Canada	**1.38***	0.69	2.07	**2.47***	1.42	3.51	**2.22***	1.02	3.43
Chile	**0.53***	0.05	1.02	**0.69***	0.03	1.34	**−0.08**	−0.83	0.68
China	**−0.28**	−1.07	0.52	**−0.90**	−1.86	0.05	**−1.16***	−2.30	−0.02
Colombia	**0.67***	0.33	1.01	**0.52***	0.07	0.98	**−0.26**	−0.78	0.26
France	**1.43***	0.71	2.15	**3.52***	2.48	4.57	**5.39***	4.10	6.68
Germany	**0.91***	0.47	1.35	**1.93***	1.34	2.51	**2.84***	2.11	3.56
Greece	**0.48***	0.18	0.79	**1.08***	0.66	1.50	**1.71***	1.19	2.24
India	**0.82***	0.33	1.31	**1.27***	0.65	1.90	**0.99***	0.26	1.73
Ireland	**2.65***	2.05	3.26	**5.73***	4.71	6.75	**8.52***	7.26	9.78
Italy	**0.82***	0.38	1.27	**1.87***	1.23	2.51	**2.83***	2.04	3.63
Japan	**0.86***	0.15	1.58	**2.97***	2.01	3.92	**4.79***	3.70	5.88
Mexico	**1.31***	0.81	1.80	**2.56***	1.80	3.31	**3.02***	2.15	3.88
Netherlands	**1.68***	0.89	2.47	**4.21***	3.07	5.36	**6.02***	4.60	7.45
Pakistan	**1.92***	1.39	2.45	**3.62***	2.76	4.48	**5.49***	4.45	6.54
Singapore	**1.46***	0.85	2.07	**2.53***	1.63	3.43	**2.48***	1.42	3.54
South Korea	**1.80***	1.18	2.42	**3.25***	2.41	4.08	**3.78***	2.79	4.77
Spain	**0.77***	0.23	1.30	**1.40***	0.67	2.12	**1.99***	1.11	2.87
Sweden	**1.58***	0.98	2.18	**3.31***	2.40	4.21	**4.43***	3.33	5.53
UK	**2.66***	2.08	3.24	**5.08***	4.17	5.99	**6.60***	5.48	7.72
US	**0.76***	0.45	1.07	**1.92***	1.41	2.42	**2.84***	2.24	3.45
Developed countries	**1.44***	0.88	1.68	**3.06***	2.06	4.04	**3.93***	2.83	5.86
Emerging countries	**0.82***	0.53	1.31	**1.27***	0.69	2.56	**0.99***	−0.08	3.02

This table reports cumulative impulse responses of real stock prices to a one-standard-deviation shock in global ESG-based sustainability uncertainty index (ESGUI) at horizons of 12, 18, and 24 months. Instead of utilizing GDP-weighted global ESGUI, I utilize the equal-weighted global ESGUI of Ongan et al. (2025) as a robustness test. Individual country results are estimated using smooth local projections following Barnichon and Brownlees (2019) with 12 lags of the dependent variable and shock variable. The dependent variable is real stock prices normalized to one standard deviation. The independent variable is global ESGUI (normalized to one standard deviation). For individual countries, estimated coefficients represent the cumulative impulse of stock prices to a unit shock in global ESGUI. For country-specific results, * represents significance of the estimates, whereas the upper and lower bounds represent the confidence intervals based on the 90 percent significance level. For country groups (developed and emerging countries), estimates represent the median across the corresponding constituent countries, whereas upper and lower bounds represent the interquartile range across the corresponding countries. Statistical significance (*) denotes that more than 50% of countries in the group show significant responses at the 10% level, following Yilmazkuday (2024). The global ESGUI shock is common across all countries, revealing heterogeneity in sensitivity to shared uncertainty events. Sample period is from November 2002 to June 2025.

Table A.10
Identification and exogeneity robustness tests.

Country	Panel A: Granger causality tests		Panel B: Instrumental variables robustness			
	ESGUI→ Stock F-stat	Stock→ ESGUI F-stat	First-Stage F-Stat	IV coefficient	IV p-value	Baseline coefficient
Developed markets						
Australia	0.44	0.16	20.65	0.45*	0.11	0.52*
Belgium	0.32	0.04	50.62	1.13*	0.07	1.22*
Canada	0.93	0.54	111.25	0.28	0.03	0.32
France	0.65	0.47	58.53	0.51*	0.15	0.52*
Germany	0.87	0.28	36.54	0.68*	0.03	0.75*
Ireland	0.33	1.55	38.44	0.93*	0.05	0.99*
Italy	1.05	1.05	29.75	−0.33*	0.07	−0.39*
Japan	0.88	2.48*	126.78	−0.04	0.32	−0.04
Netherlands	1.83*	0.20	41.52	1.95*	0.15	1.98*
Singapore	0.53	0.94	30.56	0.49*	0.24	0.55*
Spain	0.10	0.78	91.56	−0.14	0.02	−0.12
Sweden	0.74	0.37	20.90	1.52*	0.22	1.53*
UK	0.61	0.97	16.58	0.53*	0.10	0.57*
US	0.83	0.45	140.33	0.29*	0.41	0.31*
Emerging markets						
Brazil	0.25	1.64	39.12	−0.02	0.10	−0.04
Chile	0.36	0.12	43.33	−0.18	0.14	−0.16
China	0.23	0.70	42.77	0.49*	0.23	0.51*
Colombia	0.37	0.30	39.47	0.25	0.33	0.29
Greece	0.21	1.45	26.84	0.47*	0.02	−0.52*
India	1.75*	0.85	22.51	0.03	0.10	0.01
Mexico	0.08	0.97	32.12	−0.19	0.10	−0.18
Pakistan	0.70	1.04	39.93	0.86*	0.08	0.94*
South Korea	0.12	1.43	26.19	0.48*	0.09	0.53*

This table reports two complementary tests of identification validity. Panel A presents Granger causality tests following Granger (1969) with optimal lag length selected by AIC. F-statistics test whether ESGUI Granger-causes stock prices (column 2) or vice versa (column 3). Panel B presents instrumental variables robustness using 1- and 2-month lags of global ESGUI as instruments for country-specific ESGUI. First-stage F-statistics test instrument strength following Staiger and Stock (1997) where values above 10 indicate strong instruments. Second-stage IV coefficients estimate the effect of instrumented ESGUI on 12-month ahead stock returns. The baseline coefficient (column 7) reports the corresponding 12-month local projection coefficient from Table 2 for comparison. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Sample is from November 2002 to June 2025.

Data availability

The ESGUI data used in this study are publicly available from the Policy Uncertainty website (https://www.policyuncertainty.com/sustainability_index.html). Stock price data and macroeconomic variables were obtained from LSEG Workspace and the Federal Reserve Economic Data (FRED) database. Component-level ESGUI data (EUI, SUI, GUI) were graciously provided by Dr. Ismet Gocer. The author does not have permission to share the data.

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