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Research article

Estimating the causal impact of the Paris agreement on the ESG market: A Bayesian structural time-series approach

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ABSTRACT

This study uses a Bayesian structural time-series model to examine the causal impact of the Paris Agreement on Environmental, Social, and Governance (ESG) markets across 18 countries. The research addresses key gaps in understanding the long-term effects of international climate agreements on sustainable finance. By analyzing MSCI ESG Leaders indices from 2013 to 2022, the study reveals significant variations in the agreement's impact across different economies. Countries like China and Indonesia experienced substantial increases in their ESG indices (31.01 %), while others like the UK saw decreases (−2.63 %). A structural break analysis serves as a robustness test, confirming significant shifts in ESG indices coinciding with the Paris Agreement's adoption in 2015. The study also highlights subsequent structural breaks in 2017, 2019, and 2021, reflecting ongoing regulatory changes and global events affecting ESG markets. This research contributes to a more nuanced understanding of how international climate policies shape sustainable investment practices, offering valuable insights for policymakers and investors navigating the evolving landscape of climate finance.

1. Introduction

Stern (2008) suggests that we can avoid the worst impact of climate change on our economy if we act immediately. The sixth assessment report by IPCC (Intergovernmental Panel on Climate Change) suggests that global warming will exceed 1.5° or 2° by the mid-21st century unless we can significantly reduce greenhouse gases (GHGs) in the following decades. Climate change policies to reduce GHGs emerged in the 1990s around the world to tackle climate change by mainly market-based mechanisms, such as emission trading (Meckling and Allan, 2020). However, due to discrepancies in carbon pricing in the global landscape[1], global carbon pricing has not been successful in reducing emissions. Only 24 % of global GHG emissions are covered by carbon pricing, either through emissions trading schemes (ETSs) or carbon taxes (Cui et al., 2021).

To combat climate change impacts, world leaders reached an unprecedented commitment in the UN Climate Change Conference (COP 21), which is known as the historic Paris Agreement. The Paris Agreement, adopted in 2015, set long-term goals to guide all nations: i) to reduce greenhouse gas emissions to hold global temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the increase to 1.5°C (UNFCCC, 2015), ii) conducting periodic assessment of the collective progress to achieve long-term goals, iii) to provide financing to developing countries to mitigate, and better adapt climate change impacts. It is a legally binding international treaty[2], providing a framework for developed countries to assist developing countries in climate change mitigation efforts. Nationally determined contribution (NDC) is due from each signatory country every five years, detailing the roadmaps to reduce greenhouse gas emissions. Net-zero emissions are the Paris agreement's key ambition, emphasizing achieving the Sustainable Development Goals. The Paris agreement intends to achieve its targets by raising the attention of both firms and investors towards

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[1] "Achieving a universal carbon price faces challenges related to measurement, enforcement, political will, and economic disparities" Cui et al. (2021).

[2] This agreement represents a significant evolution from previous climate accords, such as the Kyoto Protocol of 1998, which imposed binding emission reduction targets primarily on developed countries, and the Copenhagen Accord of 2009, which relied on voluntary pledges without binding commitments (UNFCCC, 1996, 2009).

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sustainability.

The commitments reached in the Paris agreement fell short of target emissions largely (emission gap of 23 billion metric tonnes (Gt) carbon dioxide equivalent by 2030[3]). This has raised the argument towards the effectiveness of different climate-related policies, which Stechemesser et al. (2024) answered. They studied two decades of 1500 climate policies across 41 countries and six continents of developed and developing markets. They apply a difference-in-difference approach and find that "one size fits all" is not recommended across sectors and countries regarding climate-related policies. Policy effectiveness varies with economic development. For example, pricing tools have been more successful in emission controls in developed markets than in developing countries. The lack of liberalization in the market's price distortions could limit the pricing-based policy instruments.

Bolton and Kacperczyk (2023a) study firm-level commitments to reduce carbon emissions. They find a weak negative relationship between total emissions and the number of firms making commitments. However, this relationship is strongly negative in Europe, indicating that EU firms are highly serious about carbon emissions and maintaining their commitments. Carbon reduction commitments are less prevalent in firms located in countries where governments' national commitments exist.

There are two main types of climate-related risks: physical and transition risks. Climate physical risks include floods, cyclones, drought, temperature rise, and sea level rise. Transition risks involve policy changes and investor preferences to achieve a low-carbon economy. A stream of literature documents the impact of climate physical vis-à-vis climate transition risks on financial markets. Climate transition risks are high in the post-Paris agreement era, specifically in sustainable and conventional markets. In this paper, we examine how climate transition risks (policy changes, i.e., the Paris agreement) affect Environmental, Social, and Governance (ESG) markets (which are thriving due to a shift in investors' preferences to sustainability and social wellbeing).

Investors' increasing preferences for social benefit rather than financial performance of the portfolio have led to the rise of ESG-induced investment, implying that firms with improved ESG performance should rise in their value. ESG investing, which incorporates environmental, social, and governance factors into investment decisions alongside traditional financial metrics, has evolved from a niche approach focused on excluding specific industries to a comprehensive framework for assessing corporate sustainability and resilience (Eccles and Klimenko, 2019; Friede et al., 2015). This evolution has been driven by increasing awareness of climate change risks, changing consumer preferences, and growing regulatory pressures (Amel-Zadeh and Serafeim, 2018; Eccles et al., 2014).

Edmans (2023) described ESG as not a niche but rather as one of the mainstream topics in his paper "The End of ESG". The author suggested that ESG is critical for long-term value for the firm, making it extremely important. ESG is a set of value-relevant factors that are no better or worse than other long-term value drivers. His work was motivated by the Nobel laureate Richard Thaler's article on "The End of Behavioral Finance" (Larcker et al., 2022). studied seven myths of ESG investment. One of the myths is that the stock market is myopic and short-term focused and only rewards a boost in profits in the short term. However, ESG is a long-term value-increasing strategy. For example, if companies invest in a sustainable supply chain and reduce carbon emissions, that will boost profit in the long run and ensure wealth maximization. Regulators are being tough on the greenwashing - people who claim to be ESG compliant but in reality, they are not. That is why ESG is an important issue from a financial valuation perspective. Assets under management have increasingly skewed to sustainable investment because asset managers are considering environment, social, and governance (ESG) issues in their analysis more than ever. In 2022, globally sustainable investment constituted 37.9 % of total assets under management ([4]Sustainable Investment Review, 2022). According to the Sustainable Investment Review of 2022, 30.3 trillion dollars has been invested in sustainable assets globally following responsible investing criteria, a 28 % increase since 2016. The UN secretary general has convened the United Nations Principles for Responsible Investment (UNPRI) to build a global financial system that prioritize ESG issues keeping focus six principles of responsible investment, with 4,375 investors managing $121 trillion had signed the Principles for Responsible Investment ("PRI") in 2021, surpassing the 63 investors managing $6.5 trillion who found the PRI in 2006 (Edmans, 2023). Fig. 5 in the appendix shows the conceptual framework based on the above story on the Paris agreements and ESG markets.

ESG has implications for asset pricing and stock markets. For example, Kacperczyk et al. (2023) document a style factor that causes co-movements in ESG improvers and other high ESG stocks. This has been the result of investors' increased attention to ESG. On the contrary, it sets clear targets for reducing greenhouse gas emissions and emphasizes the need for climate-resilient development. The Paris Agreement has heightened awareness of climate-related financial risks and opportunities (Krueger et al., 2020). The convergence of these two phenomena – international climate policy exemplified by the Paris Agreement and the rise of ESG investing – has created a dynamic landscape in global financial markets. This has, in turn, catalyzed growth in the ESG market, with global ESG assets projected to exceed $53 trillion by 2025, representing more than a third of the $140.5 trillion in projected total assets under management (Bloomberg, 2021).

While the Paris Agreement's impact on national policies and global climate action has been widely studied, its specific effects on ESG markets remain poorly understood. Previous research often captures short-term market reactions to climate agreements, but little is known about their long-term, causal impacts on ESG indices. Moreover, variations between developed and developing economies remain largely unexplored, and the interaction between global agreements and local policy responses is understudied. Addressing these gaps is critical for understanding how international climate commitments shape sustainable finance. Addressing these interconnected challenges is crucial for developing a comprehensive understanding of how international climate agreements, particularly the Paris Agreement, impact ESG markets. The primary objective of this research is to quantify the causal impact of the Paris Agreement on ESG markets across 18 countries using a Bayesian structural time-series model. In addition, we examine and compare the differential effects of the Paris Agreement across developed and developing economies. Finally, we employ structural break analysis as a robustness check to identify significant changes in ESG market trends associated with the implementation of the Agreement and other major global events. Together, these objectives allow us to provide a comprehensive assessment of how international climate policy has shaped the evolution of ESG markets.

By examining the interaction between the Paris Agreement and local and national policies, our study contributes to understanding policy coherence and multi-level governance in climate finance. This addresses a significant gap in the literature on how global commitments translate into market impacts at various governmental levels.

By analysing MSCI ESG Leaders indices from 2013 to 2022, the study reveals significant variations in the agreement's impact across different economies. Countries like China and Indonesia experienced substantial increases in their ESG indices (31.01 %), while others like the UK saw decreases (−2.63 %). A complementary structural break analysis corroborates these findings, identifying significant shifts in ESG indices coinciding with the Paris Agreement's adoption in 2015. The study also highlights subsequent structural breaks in 2017, 2019, and 2021, reflecting ongoing regulatory changes and global events affecting ESG

[3] UN estimates.

[4] https://www.gsi-alliance.org/members-resources/gsir2022/.

markets.

From a theoretical viewpoint, this study contributes to institutional theory by showing how global institutional arrangements such as the Paris Agreement could lead to heterogeneous outcomes across various regions. Institutional theory suggests that global norms and policy signals are interpreted, adapted, or resisted within local institutional environments shaped by political, economic, and organizational factors (Kostova and Roth, 2002; Scott, 2013). Our findings extend this perspective to the domain of global environmental governance by showing that the Paris Agreement's market effects are dependent on the institutional structures of the related countries. Specifically, the divergence in ESG market responses reflects the link between global agreements and national-level institutional systems, including variations in governance structures and regulatory enforcement.

The remainder of this paper is structured as follows: Section 2 reviews related literature. Section 3 details the data and methodology employed in this research. Section 4 presents the empirical results of our causal impact analysis and robustness test. Section 5 discusses the implications of our findings and concludes the paper.

2. Review of related literature

2.1. Climate change risks, climate policy shocks, and financial markets

The impact of climate agreements on financial markets is multifaceted. Stock markets have generally responded positively to the announcement of climate agreements, with renewable energy companies experiencing increased stock prices due to anticipated demand for clean technologies, while fossil fuel-dependent companies often see declines (Bolton and Kacperczyk, 2021; Kölbel et al., 2024). The green bond market has seen significant growth post-Paris Agreement, with a surge in issuances yielding positive financial and environmental outcomes for issuing firms through greenium (Flammer, 2021). Greenium has a lower yield of green bonds than its conventional counterparts, which is generated by investors' green and environmental preferences (Zerbib, 2019). Moreover, investors increasingly demand higher returns from carbon-intensive firms, suggesting a growing awareness of carbon risk in the post-Paris Agreement era in the stock market (Bolton and Kacperczyk, 2021). Climate regulatory and policy shocks penalize brown assets or "carbon-intensive" firms through lower leverage and higher financial distress costs (Nguyen and Phan, 2020), and lowering bond credit ratings and increasing yield spreads (Seltzer et al., 2022). Climate policy announcements are followed by a decline in stock prices in carbon-intensive firms (Nguyen and Phan, 2020), a mild impact on stock market reaction (Monasterolo and De Angelis, 2020), and a rise in stock prices (Bolton and Kacperczyk, 2023a; Hsu et al., 2023). Monasterolo and De Angelis (2020) find that the correlation between carbon-intensive and low-carbon firms reduces after the Paris Agreement.[5] Investors are putting more attention to low-carbon portfolio management; however, high-carbon assets are not punished adequately. Bolton and Kacperczyk (2021) find that investors require carbon risk premiums in the US stock market, while Bolton and Kacperczyk (2023a) find carbon premiums across the globe. Bolton and Kacperczyk (2023b) find higher carbon premia for emission growth for firms located in countries with lower economic development, larger energy sectors, and less inclusive political systems. Meanwhile, carbon premiums for emission levels are higher in countries with stricter domestic climate policies. Where investors' attention is an important source. Zhang (2025) documents negative carbon returns in the US and insignificant returns globally. Developed markets with high climate concern shocks observe lower carbon returns, while countries with stringent climate policies experience higher carbon returns.

Apart from climate transition risks, some papers also focus on climate physical risks in asset markets. For example, Goldsmith-Pinkham et al. (2023) find that sea level rise is priced in municipal bonds. Choi et al. (2020) find that retail investors sell carbon-intensive firms' shares in unusually warm weather, thus underperforming low-carbon assets. The prior literature also shows that asset prices misprice climate-related risks (Alok et al., 2020; Hong et al., 2019; Stroebel and Wurgler, 2021).

Many papers have already documented the role of climate risks (both physical and transition risks) in financial markets (see, for example, Campiglio et al. (2023) for a detailed survey). Faccini et al. (2023) find that natural disasters, global warming, and international summits do not affect investors in US stock markets. However, U.S. climate policy factors are priced in the stock market in the post-2012 period, implying the role of government policies to control climate change is more than the climate change itself. Naseer et al. (2024) find that higher climate change risks lead to higher stock market volatility. However, firms with higher ESG scores observe lower stock market volatility. Kruse et al. (2024) conducted an even study on investors' reaction to firms with green revenues. They take the Paris agreement as a quasi-natural experiment. The Paris agreement was a global exogenous shock to all firms, which increased future cash flows from green activities by the firms by reducing policy uncertainty (Kruse et al., 2024). This should have a positive impact on firm values. Kruse et al. (2024) found that the top 30 % of firms with green revenues in 2013 observed a rise in stock prices post-Paris agreement period. Painter (2020) uses the Stern Review as a quasi-natural experiment and finds that climate risks are priced in the long-term municipal bonds after the Stern Review is released, which supports investor attention. For short-term climate risks, there are no risks to bond pricing.

2.2. Climate agreements and economic impacts

Climate policies such as carbon pricing and renewable energy subsidies significantly influence markets by internalizing the environmental costs of greenhouse gas emissions, thus driving economic behavior towards sustainability (Gillingham and Stock, 2018; Nordhaus, 2019). Carbon pricing, implemented through mechanisms like carbon taxes or cap-and-trade systems, incentivizes businesses to reduce emissions of greenhouse gases (Ellerman et al., 2010). For example, the European Union Emissions Trading System (EU ETS) efficiently allocates resources to meet emission targets at the lowest cost. In contrast, subsidies for renewable energy lower the cost of clean technologies, fostering investment and innovation in the energy sector (Borenstein et al., 2019). These market mechanisms also impact various sectors differently; the energy sector sees a shift from fossil fuels to renewables, while industries face higher production costs but opportunities for efficiency improvements (Martin et al., 2014). However, to ensure economic efficiency and equity, policymakers must address the disproportionate burdens on low-income households and vulnerable industries, potentially through revenue recycling (Carbone and Rivers, 2017; Metcalf, 2018). These policies reshape economic incentives, promoting sustainable practices and fostering long-term economic growth (Stern, 2008).

The market impacts and policy implementation of climate agreements vary significantly between developed and developing countries due to differences in economic capacity, technology, and development priorities. Developed countries, such as those participating in the European Union's Emissions Trading System (EU ETS), have successfully reduced emissions through robust market mechanisms like cap-and-trade, which incentivize emission reductions and drive investments in clean technologies (Ellerman et al., 2010). In contrast, developing countries often face limited financial resources and technological capabilities. However, the Clean Development Mechanism (CDM) facilitates sustainable development by allowing developed countries to invest in emission reduction projects in these regions (Olsen, 2007). Case studies illustrate these dynamics: the EU ETS has reduced emissions by

[5] They estimated performance, optimal weights of carbon and non-carbon stocks, and structural changes in market risks after Paris agreements.

21 % from 2005 to 2020 (EEA, 2022), while China is advancing its climate goals through significant investments in renewable energy and the establishment of a national carbon market (Stoerk et al., 2019). In the United States, state-level initiatives like California's Cap-and-Trade Program demonstrate effective climate action despite fluctuating federal policies, aiming to reduce emissions and promote clean technology innovation significantly.[6]

Climate agreements are crucial in promoting long-term economic growth and sustainability by driving investment in renewable energy, fostering technological innovation, and enhancing energy efficiency (Stern, 2008). These agreements encourage the development of green industries, leading to job creation and economic activity, as evidenced by the European Union's policies that have stimulated significant growth in the green sector (European Commission, 2019).[7] By setting ambitious emission reduction targets, climate agreements incentivize research and development in clean technologies, resulting in lower costs and increased competitiveness of renewables like solar and wind energy (IRENA, 2021). Additionally, improved energy efficiency standards reduce energy consumption and costs, contributing to economic savings and competitiveness (IEA, 2019).[8] Climate agreements also promote resilience and adaptation to climate change, ensuring economies can sustain growth despite environmental challenges (IPCC, 2014).[9] Furthermore, these agreements enhance global cooperation and policy coherence, enabling collective progress towards sustainability goals (UNFCCC, 2015). Climate agreements mitigate environmental risks while creating economic opportunities, paving the way for a sustainable future.

2.3. ESG markets and sustainable investing

The ESG market has emerged as a critical focus area for studying the implications of climate agreements, particularly the Paris Agreement, on financial markets. This sector's alignment with sustainability goals and its growing prominence in investment strategies make it an ideal lens to examine the broader economic impacts of climate policies.

ESG investing incorporates environmental, social, and governance factors into investment decisions and traditional financial metrics. The environmental aspect, which is most relevant to climate agreements, considers factors such as a company's carbon emissions, energy efficiency, and overall environmental impact (Eccles and Klimenko, 2019; Friede et al., 2015).

The concept of ESG investing has evolved significantly over the past few decades. What began as a niche approach focused primarily on excluding specific industries' "sin stocks" (e.g., tobacco, weapons) has transformed into a comprehensive framework for assessing corporate sustainability and resilience. This evolution has been driven by increasing awareness of climate change risks, changing consumer preferences, and regulatory pressures (Amel-Zadeh and Serafeim, 2018; Eccles et al., 2014).

The ESG market has experienced remarkable growth, particularly after international climate agreements. Global ESG assets are projected to exceed $53 trillion by 2025, representing over a third of the $140.5 trillion in projected total assets under management (Bloomberg, 2021). This growth is attributed to increased investor demand, policy support, and a growing recognition of the financial materiality of ESG factors (Boffo and Patalano, 2020).

Studies have shown that ESG-focused funds have demonstrated resilience during market downturns, including the COVID-19 pandemic. For instance, Demers et al. (2021) found that firms with higher ESG ratings experienced higher returns during the first quarter of 2020, suggesting that ESG performance may serve as a buffer during crises.

The Paris Agreement has been a significant catalyst for growth in the ESG market. By setting clear targets for greenhouse gas emissions reduction and emphasizing the need for climate-resilient development, the agreement has heightened awareness of climate-related financial risks and opportunities (Krueger et al., 2020; UNFCCC, 2015).

Eight central banks and supervisors established the Network of Central Banks and Supervisors for Greening the Financial System (NGFS), which calls for short-term and long-term stress testing and scenario analysis for climate-related risks for financial firms and systems. The long-term scenarios are more appropriate for structural changes in the financial markets. The Paris Agreement can drive the long-term structural shift in ESG markets due to a reduction in ESG uncertainty and positive shocks to the shift to a low-carbon economy.

Over the last decades, ESG investing has evolved from socially responsible investment (SRI), ethical investing, and corporate social responsibility (CSR) activities, where the primary concern is not financial motive but social well-being[10]. Riedl and Smeets (2017) studied why investors hold socially responsible mutual funds. They found that social preferences and signalling explain socially responsible investment (SRI) decisions.

Due to investors' positive outlook[11] on ESG investments and higher regulatory changes around sustainable investing, firms are often involved in misleading information on sustainability issues. This leads to greenwashing. This makes transitioning to a low-carbon economy difficult, undermines climate transition risks, and the credibility of ESG scores. Greenwashing increases agency problems. For example, Liang et al. (2022) find that hedge funds that signed the UN Principles of Responsible Investment underperform other non-signatory hedge funds by 2.45 % per annum. Low ESG exposure drives this underperformance, which supports greenwashing and agency theory-based explanation. However, performance and ESG exposure have improved after regulatory reforms.

Hedge funds experienced higher fund inflows when the fund managers are signatories of UN PRI (Kuang et al., 2023; Liang et al., 2022). Pastor et al. (2023) find that ESG-related investment tilts were 6 % of investment industry assets, while large institutions, UN PRI signatories, and EU institutions tilt towards green stocks, while banks and households tilt towards browner assets. Pástor and Vorsatz (2020) find that investors fund highly sustainability-rated firms during the crisis, revealing investors' sustainability preferences.

A recent theoretical underpinning in sustainable finance is that green assets are preferred over brown assets. There are at least two possible explanations for this green asset preference: i) first, green assets are a hedge against climate risks (Andersson et al., 2016; Bua et al., 2024; Cepni et al., 2022, 2023; Engle et al., 2020), ii) second, investors have a green taste for green assets (Ardia et al., 2023; Fama and French, 2007; Pástor et al., 2021, 2022). Pedersen et al. (2021) and Pástor et al. (2021) combined ESG criteria in the asset pricing framework by attaching pro-social preferences in portfolio choices. Thus, prior literature empirically shows that ESG and/or green investments are not a luxury, but rather a necessary one (Akhtaruzzaman et al., 2022, 2023; Ameur et al., 2024; Cepni et al., 2022, 2023; Guo et al., 2024; Yousaf et al., 2022). This stream of literature suggests that green assets reduce portfolio risks, help diversification, hedge physical and transition climate risks, and have important implications for cross-border risk spillovers.

[6] https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program/about.

[7] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en.

[8] https://www.iea.org/reports/energy-efficiency-2019.

[9] https://www.ipcc.ch/report/ar5/wg2/.

[10] See for example the survey of Kräussl et al. (2024).

[11] Bancel et al. (2023) find that investors are more likely to include ESG in their valuation than the insiders.

2.4. Gaps addressed

While the Paris Agreement's impact on national policies and global climate action has been widely studied, its specific effects on ESG markets remain less understood and quantified. This gap in understanding presents several interconnected challenges; first, despite observed correlations between the Paris Agreement and ESG market growth, establishing a clear causal relationship remains challenging. The complex interplay between international climate agreements and financial market behavior, particularly in sustainable investing, poses significant analytical difficulties. Previous studies, such as those by Ramelli et al. (2021) and Flammer (2021), have provided valuable insights into market reactions to climate agreements. However, they often focus on short-term effects or specific market segments, leaving largely unexplored the long-term, causal impacts on the broader ESG market. The long-term perspectives are important considering ESG being a long-term value-relevant factor, and the NGFS provided recommendations for long-term scenario analysis and stress testing with climate tail risks. Second, the market impacts and policy implementation of climate agreements vary significantly between developed and developing countries due to differences in economic capacity, technology, market liberalization, price distortions, and development priorities (Ellerman et al., 2010; Olsen, 2007; Stechemesser et al., 2024). However, a comprehensive cross-country analysis of how these variations manifest in ESG markets post-Paris Agreement is absent. This gap hinders our understanding of the agreement's global effectiveness and role in shaping sustainable finance across diverse economic contexts. Third, the evolution of ESG markets over time, particularly in response to the Paris Agreement, is poorly understood. While studies have shown initial positive market reactions to the agreement (Bolton and Kacperczyk, 2021; Kölbel et al., 2024; Kruse et al., 2024), the long-term trajectories of ESG indices and their relationship to ongoing policy implementation remain unclear.

How structural changes have taken place in financial markets can be revealed by long-term analysis. This lack of understanding impedes our ability to assess the sustained impact of international climate agreements on financial markets. Fifth, existing research often employs methodologies that struggle to fully account for the complex, nonlinear dynamics inherent in climate-finance interactions. While useful for short-term analysis, event studies are limited in their ability to capture long-term, evolving impacts (Mukanjari and Sterner, 2018; Ramelli et al., 2021). Similarly, panel data regression models and time series analyses often fail to establish robust causal links in this context (Alessi et al., 2019; In et al., 2017). Moreover, the interaction between global climate agreements and local or national policies remains understudied. While the (UNFCCC, 2015) provides a broad framework, research is needed to understand how these global commitments translate into coherent policy actions across different governmental levels and how they interact with existing local initiatives to influence ESG markets.

3. Method and data

3.1. Bayesian structural time series models (BSTS)

To infer the causal impact, it is necessary to have a control dataset that can measure the effect of a market event before and after the intervention. When real-world control data is unavailable, it becomes essential to synthesize it. By generating a control dataset based on pre-intervention information, we can estimate what would have occurred in the absence of the intervention. The difference between the synthesized and the observed data can then be used to quantify the effect of the intervention. Several methods exist for constructing this control dataset, with the Bayesian structural time series model being one of the most widely adopted approaches (Brodersen et al., 2015).

This Bayesian structural time series model considers the most general representation of a time series by decomposing it into an error term and four key components: a local level representing the series' local mean, a local linear trend capturing the trend dynamics, a seasonal component accounting for periodic patterns, and a regression component including any covariates that may influence the series. A simple form of the equation of this model can be written as:

$$y_t = \mu_t + \gamma_t + c_t + \epsilon_t \quad (1)$$

where μ_t is the local linear trend, γ_t is the seasonality, c_t is the regression component and $\epsilon_t \sim \mathcal{N}(0, \sigma^2)$ is an independent error term. Other equations define each component of this equation. For instance, the local linear component can be further specified as follows:

$$\mu_{t+1} = \mu_t + \delta_t + \eta_{\mu,t} \quad (2)$$

$$\delta_{t+1} = \delta_t + \eta_{\delta,t} \quad (3)$$

where $\eta_{\mu,t} \sim \mathcal{N}\left(0, \sigma_\mu^2\right)$ and $\eta_{\delta,t} \sim \mathcal{N}(0, \sigma_\delta^2)$. The μ_t component is the value of the trend at the time t. The δ_t component is the expected increase in μ between times t and $t+1$, so it can be thought of as the slope at the time t. In a more abstract form, the Bayesian structural time series model can be formulated by a pair of equations as:

$$y_t = Z_t^T \alpha_t + \epsilon_t \quad (4)$$

$$\alpha_{t+1} = T_t \alpha_t + R_t \eta_t \quad (5)$$

This equation, which is known as the observation equation, links the observed data y_t to a state vector α_t. Here $\epsilon_t \sim \mathcal{N}(0, \sigma^2)$ is an independent error term and Z_t^T is the output vector. Equation (5) is the state equation; it governs the evolution of the state vector α_t through time. In this equation, $\eta_t \sim \mathcal{N}(0, Q_t)$ is an independent error term, T_t is the transition matrix, and R_t is the control matrix.

After specifying the model to simulate the data, we employ Bayesian inference to estimate the parameters and their posterior distributions, thus generating the synthetic control data set. Bayesian inference is a statistical approach that updates the probability of a hypothesis based on new evidence using Bayes' theorem. Subsequently, we utilize the observed data set and compute the R-squared score to assess the goodness of fit:

$$R^2 = 1 - \frac{\sum_i (y_i - \hat{y}_i)^2}{\sum_i \left(y_i - \bar{y}\right)^2} \quad (6)$$

The R-squared score measures the proportion of the dependent variable's variance that is predictable from the independent variables in a regression model, ranging from 0 to 1, where 1 indicates a perfect fit and 0 indicates the model explains none of the variability. Here, y_i is the observed value, $\hat{y}_i$ is the predicted value and $\bar{y}$ is the mean of the observed values.

Finally, after calculating the difference between the observed and predicted values following the intervention, we conduct a one-sample student t-test to determine whether the difference between their sample means is statistically significant. We compute the t-statistic of the difference using the standard t-statistic formula as:

$$t = \frac{\bar{X}}{\sigma / \sqrt{n}} \quad (7)$$

where X Is the difference between observed and predicted values, σ is the standard deviation of X and n is the sample size. This value is then used to calculate the p-value which indicates the statistical significance of the difference in the data sets.

3.2. Structural break

To validate our causal impact findings and ensure robustness, we employ structural break analysis as a complementary test. This approach serves to confirm whether the timing of identified impacts aligns with the Paris Agreement implementation and other major policy events. We utilized the Bai and Perron approach for detecting multiple structural breaks (Bai and Perron, 2003). The Bai and Perron method is designed to identify multiple structural breaks within a linear regression model. This approach is particularly effective in detecting shifts in the model's mean. The method entails estimating the location of breakpoints, testing their statistical significance, and selecting the optimal number of breakpoints based on model selection criteria. In the absence of regressors, which is the case in this study, their technique identifies changes in the mean level of the series.

Consider a time series data y_t for $t = 1, 2, \ldots, T$. The objective is to identify m breakpoints, at the times $T_1, T_2, \ldots, T_m$, where the parameters of the linear regression model change. The model can be represented as follows:

$$y_t = \begin{cases} \beta_1 + \epsilon_t & \text{for } t = 1, \ldots, T_1 \\ \beta_2 + \epsilon_t & \text{for } t = T_1 + 1, \ldots, T_2 \\ \vdots & \vdots \\ \beta_{m+1} + \epsilon_t & \text{for } t = T_m + 1, \ldots, T \end{cases} \quad (8)$$

where β_i are the mean levels of y_t in each segment i. ϵ_t is the error term, assumed to be independently and identically distributed (i.i.d.) with mean zero and constant variance σ^2. The breakpoints are identified by iteratively estimating the model parameters for different segments and locating the points where the model fit improves significantly. To accomplish this, the residual sum of squares is utilized to quantify the discrepancy between the data and the estimated model. Considering m breakpoints, we have:

$$RSS(T_1, T_2, \cdots, T_m) = \sum_{i=0}^{m} \sum_{t=T_i+1}^{T_{i+1}} (y_t - \beta_{i+1})^2 \quad (9)$$

where y_t is the observed value and β_i is the mean of the values in the i^{th} interval. We then use the Bayesian Information Criterion (BIC) to determine the optimal number of breakpoints. The BIC is calculated as:

$$BIC = n \log\left(\frac{RSS}{n}\right) + K \log(n) \quad (10)$$

where n is the number of data points and K is the number of parameters estimated in the model (number of the breakpoints). The optimal number of breakpoints and their locations are then determined by minimizing the BIC function (Kim, 1997). In other words, the BIC function balances the goodness of fit of the model and its complexity, favoring fewer breakpoints to minimize the BIC.

3.3. Data

Our analysis is based on the MSCI ESG Leaders[12] indices and the corresponding MSCI country indices for 18 countries, covering the period from 12 July 2013 to 8 March 2022 (with Russia ending on 25 February 2022). The sample period was chosen to ensure sufficient pre-treatment observations before the 2015 Paris Agreement and capturing subsequent medium-to long-term market dynamics, while considering the data availability. The data is obtained from Datastream. The MSCI ESG Leaders indices are free-float market capitalization–weighted indices that select companies with the highest environmental, social, and governance (ESG) performance relative to their sector peers, while maintaining broad market representation. They are designed to serve as benchmarks for investors who wish to integrate ESG considerations while closely tracking the parent market performance. The corresponding MSCI country indices are used as control benchmarks. These represent the full investable equity market of each country. Using the ESG Leaders indices as the "treatment" and the MSCI country indices as the "control" allows us to estimate the causal effect of the Paris Agreement on sustainability-focused investments, while accounting for broader market dynamics. Summary statistics and cross-country correlations are reported in Section 4 to provide an overview of the data characteristics prior to the causal impact analysis.

4. Empirical results

4.1. Descriptive statistics and correlation

The descriptive statistics of the MSCI ESG Leaders and MSCI indices (Table 1) reveal significant variations across 18 countries. The ESG Leaders indices generally exhibit higher mean values with varying degrees of standard deviation, skewness, and kurtosis, indicating different risk-return profiles than the MSCI indices. For instance, countries like Australia, Canada, and the USA show positive skewness in their ESG indices, suggesting a higher frequency of returns above the mean. In contrast, the MSCI indices in these regions display different skewness characteristics. Countries like India and Taiwan have shown considerable variability and higher positive skewness in their ESG indices, reflecting potential for higher returns and increased volatility. Overall, the ESG indices often display different distributional properties compared to their MSCI counterparts, highlighting the distinctive performance and risk characteristics of sustainable investments across global markets.

The Correlation Plot shown in Fig. 1 highlights the highly correlated ESG indices in dark blue. The significance level is set at 0.01 to determine statistically significant correlations. Correlations with a p-value >0.01 are considered statistically insignificant and marked with a cross. The correlation heatmap of the MSCI ESG Leaders indices across countries reveal varying degrees of correlation among the indices. Generally, the indices show a high degree of positive correlation, especially among developed markets such as Canada, the USA, Japan, Taiwan, Hong Kong,

[12] The ESG market is closely aligned with the climate objectives of the Paris Agreement, which aims to combat climate change by reducing greenhouse gas emissions and promoting sustainability. Companies and investments that prioritize environmental sustainability are at the forefront of efforts to meet these targets (Bolton and Kacperczyk, 2021). The ESG market's comprehensive coverage across various industries allows for a holistic assessment of the Paris Agreement's impact on different economic sectors, essential for understanding the financial market's responses to climate policies (Flammer, 2021). Furthermore, ESG investments focus on mitigating climate-related risks and building resilient companies and economies, which is crucial for adapting to climate change impacts (Kölbel et al., 2024; UNFCCC, 2015). Thus, the ESG market not only aligns with the climate objectives of the Paris Agreement but also serves as a crucial indicator of how financial markets respond to and prioritize sustainability, climate risk management, and long-term resilience.

Table 1
The descriptive statistics of the MSCI ESG Leaders.

		Obs.	Mean	SD	Min.	Max.	Skewness	Kurtosis
Australia	Response	2258	971.07	80.89	725.66	1185.35	0.65	−0.16
	Control		811.73	89.86	467.91	1005.79	−0.31	−0.05
Brazil	Response	2258	1482.12	332.41	891.87	2167.64	0.26	−1.22
	Control		1832.89	370.89	859.87	2719.02	−0.27	−0.5
Canada	Response	2258	1394.26	220.87	991.01	2007.55	0.65	0.12
	Control		1717.01	230.6	1063.78	2351.42	0.71	0.81
China	Response	2258	1474.57	451.79	805.33	2828.41	0.62	−0.47
	Control		76.6	16.14	47.87	129.6	0.63	−0.21
Hong Kong	Response	2258	1332.96	198.33	944.3	1811.95	0.14	−0.87
	Control		10902.27	1267	8078.7	13715.3	0.11	−1.01
India	Response	2258	2679.63	858.98	1405.52	5035.3	1.03	0.36
	Control		548.13	114.28	316.42	890.62	1.04	0.91
Indonesia	Response	2258	1759.41	245.16	1142.45	2221.64	−0.28	−0.98
	Control		767.42	85.18	417.03	965.35	−0.68	0.3
Japan	Response	2258	957.69	147.98	664.9	1325.68	0.26	−0.48
	Control		3115.08	425.87	2311.28	4257.8	0.6	−0.6
Korea	Response	2258	1143.32	168.18	635.88	1620.56	0.91	0.38
	Control		467.5	95.5	292.41	746.77	1.04	0.43
Malaysia	Response	2258	1003.14	98.83	716.38	1171.1	−0.35	−0.79
	Control		370	67.51	233.88	525.36	0.89	−0.24
Russia	Response	2251	1824.92	669.95	898.22	3592.02	0.66	−0.69
	Control		2315.25	741.13	1237.43	4287.52	0.75	−0.29
South Africa	Response	2258	2667.91	363.28	1762.51	3424.72	−0.41	−0.47
	Control		483.29	64.93	245.54	656.16	−0.43	0.54
Sweden	Response	2258	2045.26	261.78	1550.35	2799.37	1.1	0.68
	Control		7858.37	1350.95	5094.42	11695.39	1.39	1.27
Switzerland	Response	2258	1419.11	235.43	1066.34	2170.35	1.32	1.2
	Control		5592.92	863.2	4343.78	8117.56	1.15	0.45
Taiwan	Response	2258	1844.08	724.82	1021.45	3802.28	1.3	0.51
	Control		393.81	135.3	235.07	772.47	1.46	0.9
Thailand	Response	2258	1617.85	183.92	1082.68	2069.29	0.16	−0.19
	Control		402.76	52.17	273.88	526.55	0.18	−0.5
UK	Response	2258	1039.97	50.53	776.49	1145.92	−0.94	1.59
	Control		1155.3	126.89	683.88	1447.31	−0.23	0.29
USA	Response	2258	150.56	44.75	94.01	273.29	1.11	0.33
	Control		2581.71	781.24	1559.69	4621.16	1.01	0.11

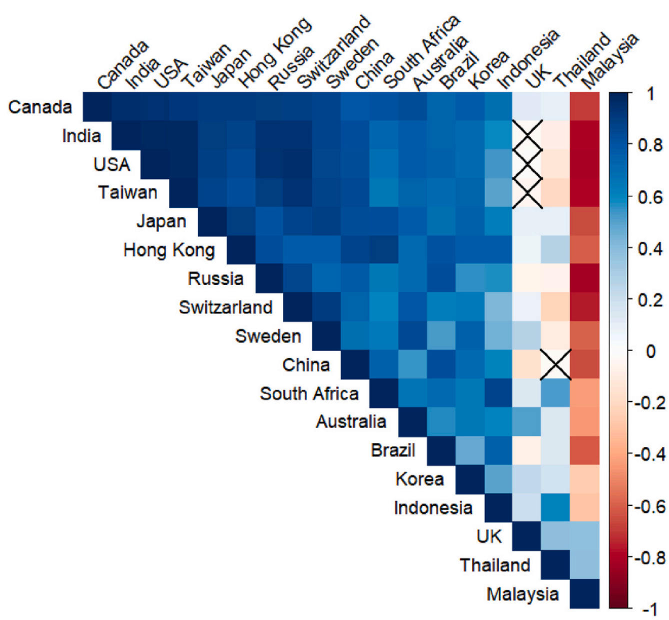


Fig. 1. The correlation matrix of ESG leaders.

Switzerland, and Sweden, indicating that these markets move together in response to global factors affecting ESG investments. Notably, the correlation is robust among Canada, the USA, and Japan, with values close to 1. Conversely, markets like Indonesia, the UK, Thailand, and Malaysia exhibit lower or negative correlations with other countries, suggesting diverse regional dynamics and less synchronization with global ESG trends. The heatmap also indicates certain regions with strong inter-regional correlations, such as between South Africa and other regions, emphasizing the interconnectedness within specific geographic or economic blocks. Overall, the high correlations among most developed markets and the varying correlations in emerging markets highlight the complex interplay of global and local factors in ESG investment performance.

4.2. Causal impact analysis

In this section, we report the results of causal impact analysis carried out in Python 3.12 using the “causal impact” and “stats models.” tsa. arima_process” libraries.

4.2.1. Top plot: observed vs. predicted values

The top plot of the causal impact analysis (Fig. 2) shows the observed values of the ESG leaders index (represented by the black line) against the predicted values (represented by the blue dashed line) that would have occurred had the Paris Agreement not taken place. We can categorize the countries into three distinct groups based on the patterns observed post-intervention. The first group is countries with a consistent positive impact, such as Australia, Brazil, Canada, China, Hong Kong, India, Indonesia, Japan, South Africa, Switzerland, and Taiwan. The observed values for these countries before the intervention (marked by the vertical dashed line) closely follow the predicted values, indicating that the model fits the data well. After the intervention, there is a noticeable divergence where the observed values consistently exceed the predicted values. This suggests a positive impact of the Paris Agreement on the ESG leaders index in these countries. The divergence indicates that the ESG leaders index performed better than expected in

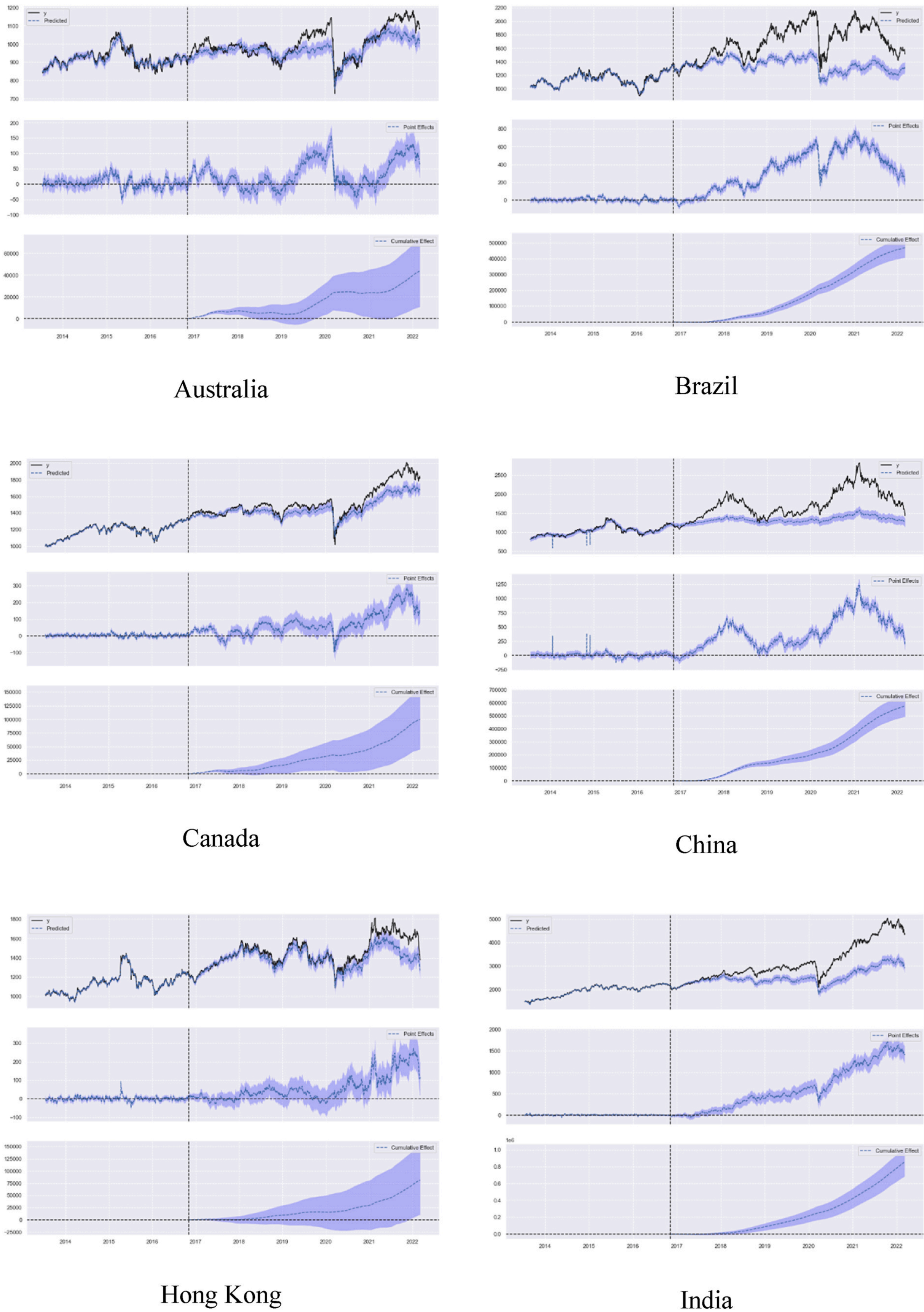
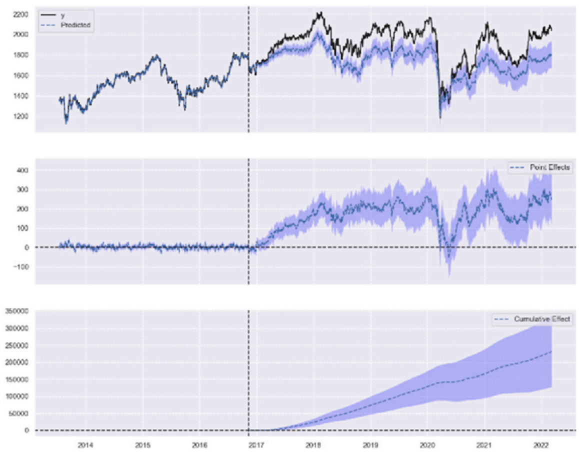
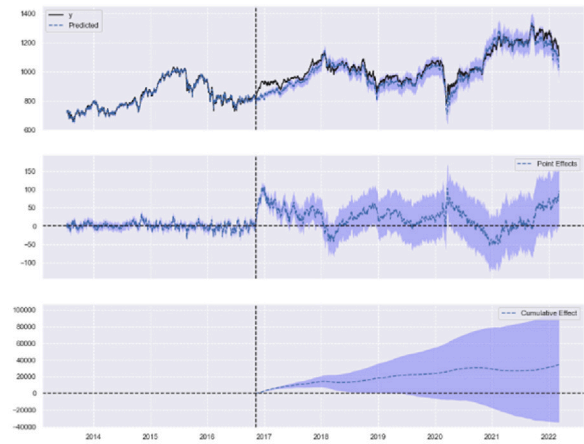


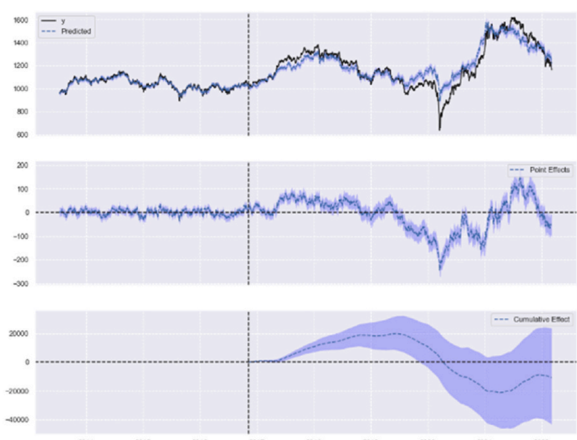
Fig. 2. The causal impact analysis.



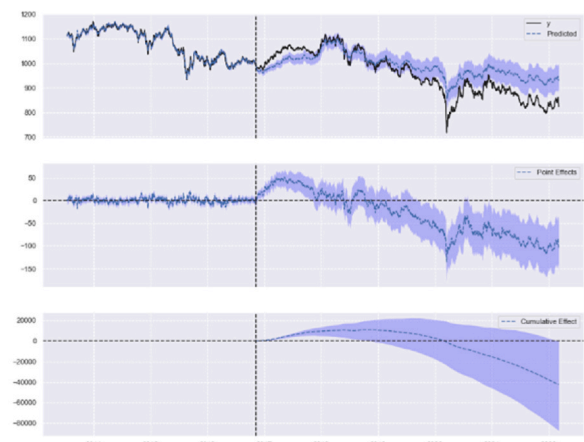
Indonesia



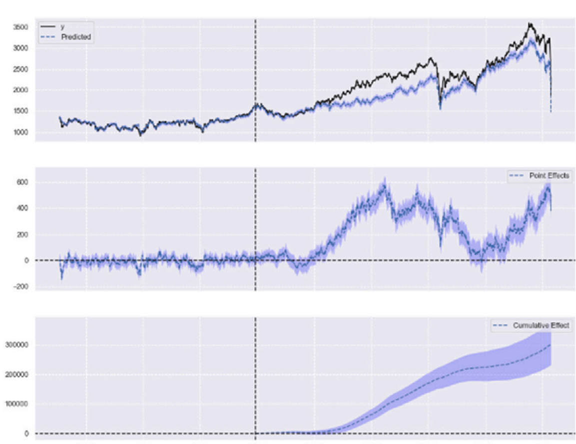
Japan



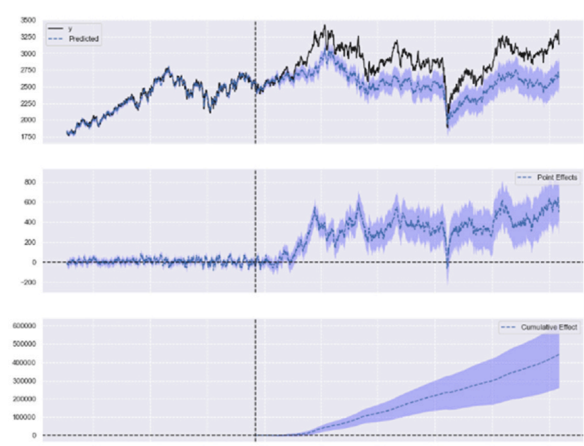
Korea



Malaysia

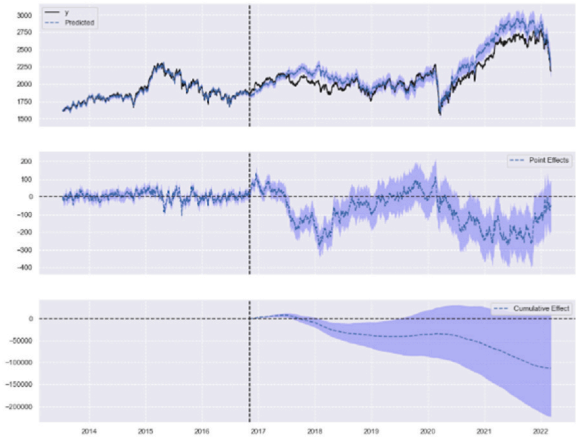


Russia



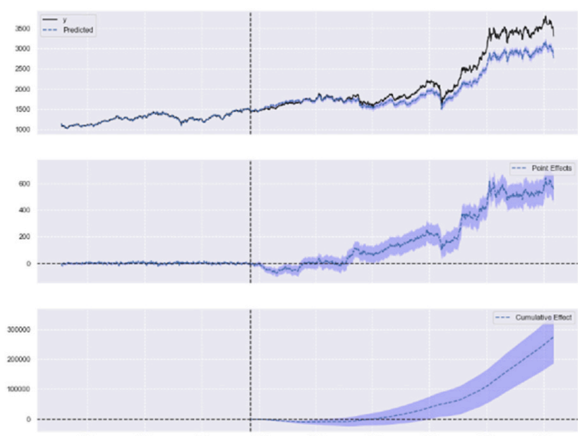
South Africa

Fig. 2. (*continued*).

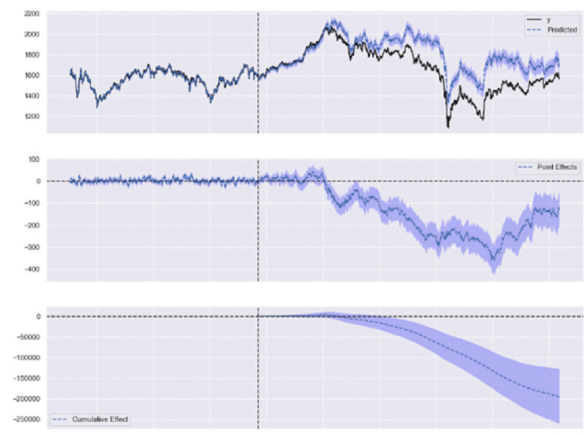


Sweden

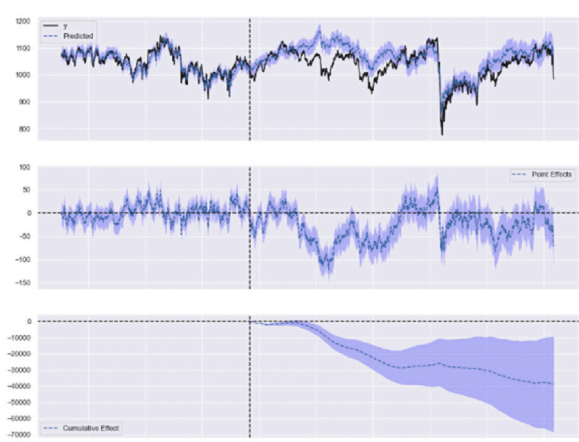
Switzerland



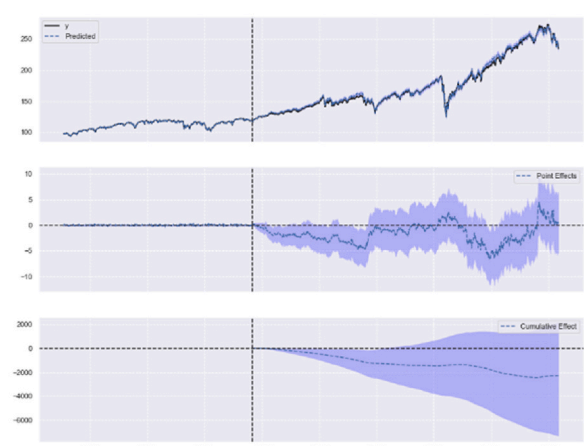
Taiwan



Thailand



UK



USA

Fig. 2. (*continued*).

the absence of the intervention, highlighting a beneficial influence of the Paris Agreement on sustainability practices within these countries. The second group is those countries that show an initial positive impact, followed by an adverse or diminishing effect, such as Malaysia, Sweden, Thailand, and the UK. For these countries, before the intervention, the observed values closely follow the predicted values, indicating a good model fit. After the intervention, the observed values rise above the predicted values, suggesting an initial positive impact of the Paris Agreement. However, this is followed by a decline where the observed values fall below the predicted values, indicating an adverse or diminishing effect over time. This pattern suggests that while the Paris Agreement initially spurred positive changes in the ESG leaders index, other factors or diminishing returns might have contributed to a longer-term performance decline. Moreover, the third group comprises countries with mixed impacts and no clear positive trend, including Korea and the USA. In Korea and the USA, the observed values closely follow the predicted values before the intervention, indicating a good model fit. Post-intervention, the observed values diverge from the predicted values but do not consistently exceed them. In Korea, the observed values initially rise above the predicted values, suggesting a positive impact, but later align more closely and even drop below the predicted values towards the end of the period. In the USA, the observed values remain relatively close to the predicted values with occasional deviations, and the cumulative effect indicates a sustained negative impact over the long term. This suggests that the Paris Agreement may not have had a clear or sustained positive impact on the ESG leaders index in these countries, and other factors could have contributed to the mixed results observed. Further investigation is needed to understand the reasons behind these patterns and to identify any external influences affecting the outcomes.

4.2.2. Middle plot: pointwise effects

The middle plot (Fig. 2) depicts the pointwise effects. The blue dashed line (point effects) shows the difference between the observed and predicted values, and the shaded area represents the confidence interval for these pointwise effects. Based on the pointwise effects, we can categorize the countries into three groups based on the post-intervention patterns. The first group, which shows positive impact with wide fluctuations, includes countries like Australia, Brazil, Canada, China, Hong Kong, India, Indonesia, Japan, South Africa, Switzerland, and Taiwan. Before the intervention, the point effects for these countries fluctuated around zero, indicating no significant difference between observed and predicted values. After the intervention, the point effects become positive and fluctuate more widely. This suggests that the intervention (the Paris Agreement) has significantly and positively affected the ESG leaders index in these countries. The positive point effects imply that the observed values were generally higher than the predicted values post-intervention, highlighting a beneficial influence of the Paris Agreement. The second group comprises countries with an initial positive impact, followed by an adverse or diminishing effect, such as Korea, Malaysia, Sweden, Thailand, and the UK. For these countries, the point effects fluctuate around zero before the intervention, indicating no significant difference between observed and predicted values. After the intervention, the point effects initially became positive, suggesting an initial positive impact of the Paris Agreement. However, this is followed by increased fluctuations and a trend towards negative values over time. This pattern suggests that while the Paris Agreement initially spurred positive changes, other factors or diminishing returns might have contributed to a decline or adverse impact on the ESG leaders index in the longer term. Moreover, the third group consists of only the USA, which has a mixed impact with an overall negative trend. In the USA, the point effects fluctuate around zero before the intervention, indicating no significant difference between observed and predicted values. After the intervention, the point effects show more variability and are slightly negative overall. This suggests the Paris Agreement may have hurt the ESG leaders index over time. The adverse point effects imply that the observed values were generally lower than predicted post-intervention. This indicates other factors' potential adverse effect or influence on the index performance.

4.2.3. Bottom plot: Cumulative effects

Bottom plot (Fig. 2) presents the cumulative effects where the blue dashed line (cumulative effect) shows the cumulative sum of the pointwise effects over time, and the shaded area indicates the confidence interval for the cumulative effects. Based on the cumulative effects of the causal impact analysis, we can categorize the countries into three groups based on the patterns observed post-intervention. The first group with substantial and sustained positive impact includes countries such as Australia, Brazil, Canada, China, Hong Kong, India, Indonesia, Japan, South Africa, Switzerland, and Taiwan. Before the intervention, the cumulative effect for these countries remains close to zero, as expected. After the intervention, the cumulative effect increases significantly and steadily over time, suggesting a substantial and sustained positive impact on the ESG leaders' index. This indicates that the Paris Agreement has had a long-lasting beneficial influence on the sustainability practices within these countries. The second group consists of countries with an initial positive impact followed by an adverse or diminishing effect, such as Korea, Malaysia, Sweden, Thailand, and the UK. For these countries, the cumulative effect remains close to zero before the intervention, as expected. After the intervention, the cumulative effect initially increases, indicating a positive cumulative impact. However, over time, the cumulative effect decreases significantly and turns negative, suggesting that the positive impact was not sustained and may have been reversed. This pattern implies that while the Paris Agreement initially spurred positive changes, other factors or diminishing returns might have contributed to a decline or adverse impact on the ESG leaders index in the longer term. Moreover, the last group, which includes the USA, showed a sustained negative impact. In the USA, the cumulative effect remains near zero before the intervention, as expected. After the intervention, the cumulative effect decreases steadily, suggesting a sustained negative impact on the ESG leaders' index over time. This indicates that the Paris Agreement may have hurt the index, or other factors could have contributed to the decline. The adverse cumulative effect implies that the overall performance of the ESG leaders index was lower than expected post-intervention.

The causal impact analysis results (see Fig. 3) indicate significant differences in the performance of the MSCI ESG Leaders indices post-intervention (post-Paris Agreement enforcement) compared to their expected performance without the intervention. Table 2 shows the summary of the results.

The causal impact analysis results indicate that the enforcement of the Paris Agreement had a generally positive impact on the MSCI ESG Leaders indices in several countries. Specifically, Australia saw a 3.25 % increase in average value, with an estimated causal effect of 31.51 (P-value: 0.0). Brazil exhibited a substantial relative increase of 24.87 %, with the average value rising by 336.95 (P-value: 0.0). Canada experienced a 4.96 % increase, with an estimated causal effect of 71.96 (P-value: 0.0). China had a significant relative increase of 31.01 %, with an average value increase of 412.41 (P-value: 0.0). Hong Kong showed a 4.2 % increase, with an estimated causal effect of 58.52 (P-value: 0.0). India experienced a substantial increase of 24.33 %, with the average value rising by 613.78 (P-value: 0.0). Indonesia saw a 31.01 % increase, similar to China, with an average value rise of 412.41 (P-value: 0.0). South Africa had a 12.46 % increase, with an estimated causal effect of 318.61 (P-value: 0.0). Switzerland saw a modest increase of 3.25 %, with an average value rise of 47.64 (P-value: 0.02). Taiwan experienced a relative increase of 9.84 %, with an average value rise of 197.47 (P-value: 0.0).

Conversely, some countries showed either negative impacts or no significant change. Japan had a slight increase of 2.43 % in average value, which was not statistically significant (P-value: 0.1838). Korea experienced a slight decrease of 0.64 %, which was also not statistically significant (P-value: 0.2907). Malaysia saw a decrease of 3.1 %, with an

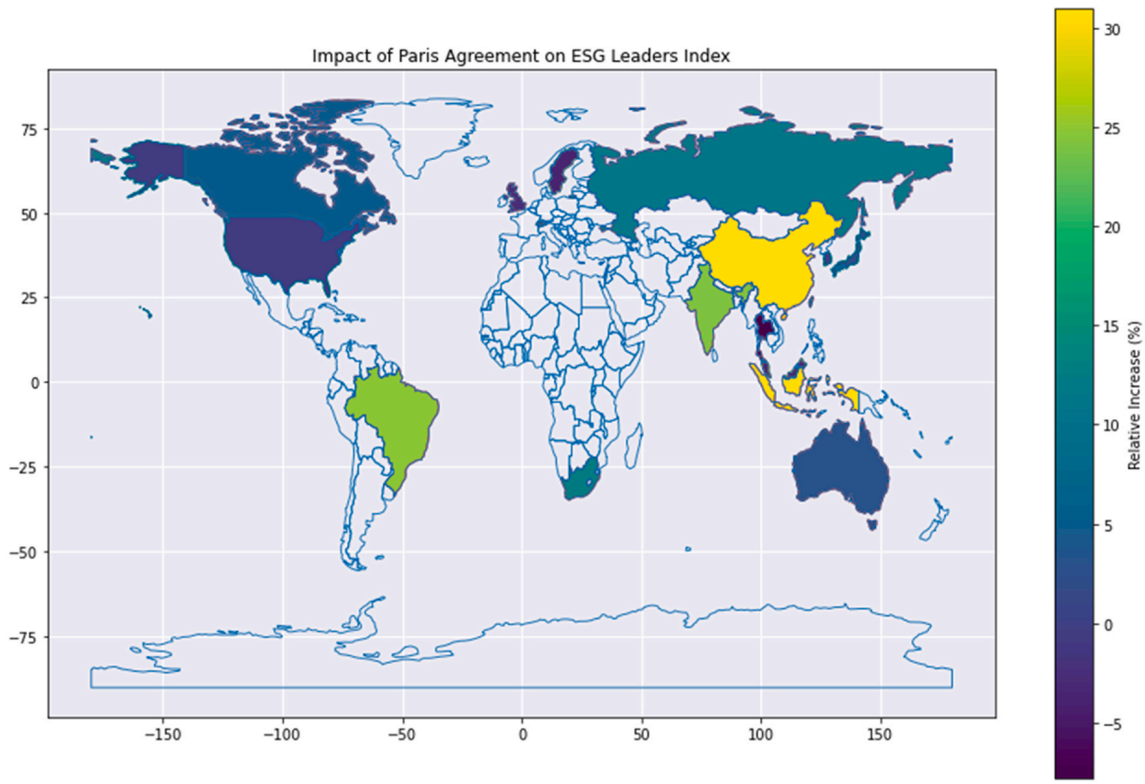


Fig. 3. The global impact of the Paris agreement on ESG Leader.

average causal effect of −30.58 (P-value: 0.03). Sweden experienced a decrease of 3.66 %, with an average causal effect of −81.41 (P-value: 0.04). Thailand saw a significant decrease of 7.8 %, with an average causal effect of −140.16 (P-value: 0.0). The UK experienced a decrease of 2.63 %, with an average causal effect of −28.01 (P-value: 0.01). Lastly, the USA showed a minor decrease of 0.93 %, which was not statistically significant (P-value: 0.1618).

4.3. Robustness test: structural break analysis

To test the robustness of our causal impact findings, we conducted structural break analysis[13] to validate whether significant changes in ESG indices occurred at theoretically expected times, particularly around the 2015 Paris Agreement adoption. In this section, we report the results of structural analysis conducted in R programming software using the "strucchange" package.

The structural break analysis of the ESG leaders index across 18 countries (Fig. 4 and Table 3) reveals notable global patterns of change, particularly concentrated in 2015, 2017, 2019, and 2021. In 2015, almost all countries experienced structural breaks, likely influenced by adopting the Paris Agreement, which marked a significant global commitment to combating climate change. This period also coincided with shifts in global market conditions as economies recovered from the 2008 financial crisis, driving changes in ESG practices and reporting standards.

In et al., 2017, numerous countries exhibited structural breaks, reflecting the introduction and tightening of environmental regulations and significant political changes influencing ESG policies worldwide. This year marked a period of heightened regulatory activity and shifts in governance that significantly impacted ESG indices.

The year 2019 saw substantial structural breaks, potentially due to increased global awareness and activism around climate change, driven by movements like Fridays for Future. This period also experienced economic adjustments and uncertainties stemming from global trade tensions, such as the US-China trade war, which likely impacted ESG investments and reporting practices.

The breaks observed in 2021 were nearly universal, highlighting the profound impact of the COVID-19 pandemic. The pandemic prompted significant economic recovery efforts and led to the implementation of green recovery initiatives by many governments, promoting sustainability and influencing ESG indices globally.

These frequent structural breaks underscore the dynamic nature of ESG factors, reflecting the growing integration of ESG considerations into business practices and investment decisions. The analysis highlights the significant influence of regulatory changes, shifts in investor behavior towards ESG-focused strategies, and the responsiveness of ESG indices to major global events and economic shifts. Understanding these patterns is crucial for stakeholders, including investors, policymakers, and corporate leaders, to make informed decisions regarding ESG investments, regulatory policies, and corporate governance strategies.

The structural break analysis, indicated by the Residual Sum of Squares (RSS) and Bayesian Information Criterion (BIC), provides robust support for identifying significant changes in the ESG leaders' indices across the 18 countries analyzed. The RSS values consistently decrease as more breakpoints are added, illustrating an improved model fit; for instance, Australia's RSS decreases from 8120011 with one breakpoint to 6506321 with five breakpoints, and China's RSS reduces from 74766550 with one breakpoint to 62126528 with four breakpoints. These decreasing RSS values signify that the model better captures variations in the data when more structural breaks are incorporated. Concurrently, the BIC values generally decrease with additional breakpoints, indicating a more optimal balance between model fit and

[13] Its primary role is to validate the timing of the intervention, specifically whether significant shifts in ESG indices coincide with the adoption of the Paris Agreement in 2015. Confirming this break strengthens the causal inference by showing that the observed divergence in ESG performance is not only statistically significant in the Bayesian model but also independently detected through structural break tests.

Table 2
The causal impact analysis results.

Country	Post Avg.	Pred. Avg.	95 % PI (Avg.)	Causal Eff.	95 % CI (Eff.)	Post Total	Pred. Total	95 % PI (Total)	Rel. Inc. (%)	95 % CI (Rel. Inc.)	P value
Australia	1001.98	970.47	[948.77, 994.27]	31.51	[7.71,53.21]	1.39E+06	1.34E+06	[1.31E+06, 1.38E+06]	3.25 %	[0.79 %,5.48 %]	0
Brazil	1691.8	1354.85	[1305.09, 1400.08]	336.95	[291.71, 386.71]	2.35E+06	1.88E+06	[1.82E+06, 1.95E+06]	24.87 %	[21.53 %, 28.54 %]	0
Canada	1523.55	1451.59	[1411.85, 1491.4]	71.96	[32.15, 111.71]	2.12E+06	2.02E+06	[1.96E+06, 2.07E+06]	4.96 %	[2.21 %, 7.7 %]	0
China	1742.33	1329.92	[1261.75, 1389.82]	412.41	[352.51, 480.58]	2.43E+06	1.85E+06	[1.76E+06, 1.94E+06]	31.01 %	[26.51 %, 36.14 %]	0
Hong Kong	1452.59	1394.07	[1341.78, 1445.38]	58.52	[7.21, 110.81]	2.02E+06	1.94E+06	[1.87E+06, 2.01E+06]	4.20 %	[0.52 %, 7.95 %]	0
India	3137.03	2523.25	[2401.97, 2645.67]	613.78	[491.36, 735.06]	4.36E+06	3.50E+06	[3.34E+06, 3.67E+06]	24.33 %	[19.47 %, 29.13 %]	0
Indonesia	1742.33	1329.92	[1261.75, 1389.82]	412.41	[352.51, 480.58]	2.43E+06	1.85E+06	[1.76E+06, 1.94E+06]	31.01 %	[26.51 %, 36.14 %]	0
Japan	1038.41	1013.79	[966.16, 1063.19]	24.62	[-24.78, 72.25]	1.44E+06	1.41E+06	[1.34E+06, 1.48E+06]	2.43 %	[-2.44 %, 7.13 %]	0.1838
Korea	1208.23	1215.96	[1191.1, 1239.4]	−7.73	[-31.17, 17.13]	1.68E+06	1.69E+06	[1.66E+06, 1.72E+06]	−0.64 %	[-2.56 %, 1.41 %]	0.2907
Malaysia	956.76	987.35	[956.72, 1019.67]	−30.58	[-62.91, 0.04]	1.33E+06	1.37E+06	[1.33E+06, 1.42E+06]	−3.10 %	[-6.37 %, 0.0 %]	0.03
Russia	2239.71	2009.38	[1950.03, 2062.62]	230.33	[177.09, 289.68]	2.92E+06	2.62E+06	[2.54E+06, 2.69E+06]	11.46 %	[8.81 %, 14.42 %]	0
South Africa	2875.37	2556.76	[2433.78, 2688.28]	318.61	[187.1, 441.59]	4.00E+06	3.55E+06	[3.38E+06, 3.74E+06]	12.46 %	[7.32 %, 17.27 %]	0
Sweden	2140.48	2221.89	[2131.28, 2301.21]	−81.41	[-160.73, 9.2]	2.98E+06	3.09E+06	[2.97E+06, 3.20E+06]	−3.66 %	[-7.23 %, 0.41 %]	0.04
Switzerland	1515.35	1467.71	[1421.78, 1513.88]	47.64	[1.47, 93.56]	2.11E+06	2.04E+06	[1.98E+06, 2.11E+06]	3.25 %	[0.1 %, 6.37 %]	0.02
Taiwan	2203.78	2006.32	[1950.26, 2069.25]	197.47	[134.54, 253.52]	3.06E+06	2.79E+06	[2.71E+06, 2.88E+06]	9.84 %	[6.71 %, 12.64 %]	0
Thailand	1656.98	1797.14	[1748.03, 1844.01]	−140.16	[-187.02, −91.05]	2.30E+06	2.50E+06	[2.43E+06, 2.57E+06]	−7.80 %	[-10.41 %, −5.07 %]	0
UK	1035.21	1063.22	[1041.85, 1084.68]	−28.01	[-49.47, −6.64]	1.44E+06	1.48E+06	[1.45E+06, 1.51E+06]	−2.63 %	[-4.65 %, −0.62 %]	0.01
USA	174.55	176.19	[173.01, 179.82]	−1.64	[-5.27, 1.54]	2.43E+05	2.45E+05	[2.41E+05, 2.50E+05]	−0.93 %	[-2.99 %, 0.87 %]	0.1618

Note. Post = post-intervention; Pred. = predicted (without intervention); Avg. = average; PI = prediction interval; CI = confidence interval; Eff. = effect; Rel. Inc. = relative increase.

complexity. For example, Australia's BIC drops from 24926 with one breakpoint to 24488 with five breakpoints, and Brazil's BIC decreases from 28834 with one breakpoint to 28406 with three breakpoints before slightly increasing to 28418 with four breakpoints, suggesting an optimal model around three breakpoints. This trend is consistent across other countries, such as Canada, where the RSS decreases from 45449767 to 13214038 and the BIC from 28815 to 26088 with four breakpoints, and Japan, where the RSS decreases from 23601925 to 6203954 and the BIC from 27336 to 24380 with five breakpoints. The alignment of decreasing RSS and optimal BIC values confirms that the identified structural breaks significantly enhance the model's explanatory power. This robustness test corroborates the causal impact analysis by validating the timing and significance of the changes around adopting the Paris Agreement, reinforcing the conclusion that the agreement had a measurable impact on global ESG practices.

5. Discussion and conclusions

The causal impact analysis revealed heterogeneous effects of the Paris Agreement across countries: some (e.g., China, India, Indonesia) exhibited sustained positive impacts, others (e.g., UK, Sweden, Thailand) showed diminishing or negative effects, and a few (e.g., USA, Korea) had largely adverse or mixed outcomes. These divergent patterns highlight that the Paris Agreement did not affect ESG markets uniformly.

The positive effect of Paris agreement observed for China is likely due to their rigorous ESG and sustainability related policies and regulatory enforcements.[14] This resulted in immense emphasis on green transformation and substantial improvements in ESG disclosure (e.g., an increase in ESG reporting from 25 % in 2018 to over 40 % in 2022 (Gao et al., 2025) among A-share listed energy firms driven by regulatory pressure). Altogether, these pro-ESG initiatives could have strengthened the investor confidence in ESG assets, leading to our reported positive response for this country.

On the other hand, the negative effect observed for the UK could be partially attributed to post-Brexit regulatory divergence and subsequent financial market uncertainty. After Brexit, UK moved away from EU sustainable finance framework (later on establishing their own sustainable disclosure requirement (SDR)) which could have adversely affected the investor expectations and compliance norms. In addition to this regulatory shift, over £900bn worth of financial assets and 440 firms in banking and finance were relocated from UK to EU, which also might have contributed to the investor perception and expectations in ESG market (Hamre and Wright, 2021). Meanwhile the political upheaval in the US and Trump's withdrawal from Paris agreement and also boarder

[14] For example Environmental Protection Law in 2015 which introduced unlimited daily fines for polluters who refuse to comply with rectification orders; development of Green Financial System guidelines by People's Bank of China (PBOC) and six other ministries in 2016 and later on establishing the Carbon Trading Scheme in 2021 just to name a few.

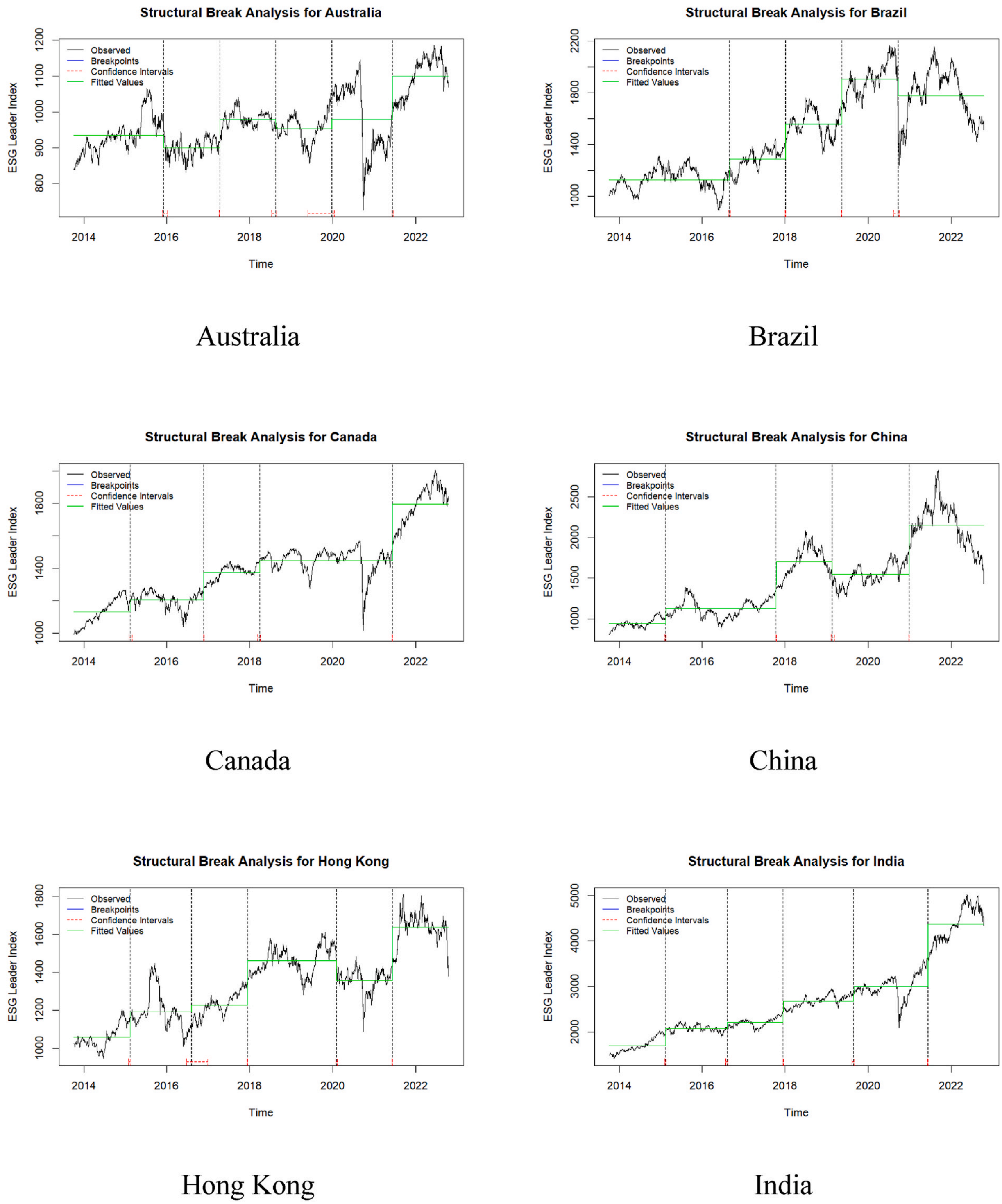


Fig. 4. The structural break analysis of the ESG leaders.

rollback of pro-ESG policies could be amongst the contributors to the US ESG market negative response (Boyapati, 2025).

The strong positive response in case of China, might also be a reflection of overall corporate leadership and governance structures influencing and facilitating the translation of government level mandates into organizational action. This notion is supported by recent research on "green transformational leadership" highlighting the fact that the leadership commitment level to environmental values is one of the main determinants of organizations' ability to innovate and implement ESG and sustainability strategies (Riva et al., 2021; Singh et al., 2020). In the context of China, with the dominance of state influence and hierarchical governance structures, corporate governance and leadership are key factors in effectively aligning corporate objectives with national agenda (possibly amplifying the Paris Agreement's institutional signal). On the other hand, in case of UK and US, the leadership response to climate policy may be more fragmented and based on managerial decisions and shareholder pressure. This varied governance structure and leadership models could offer possible

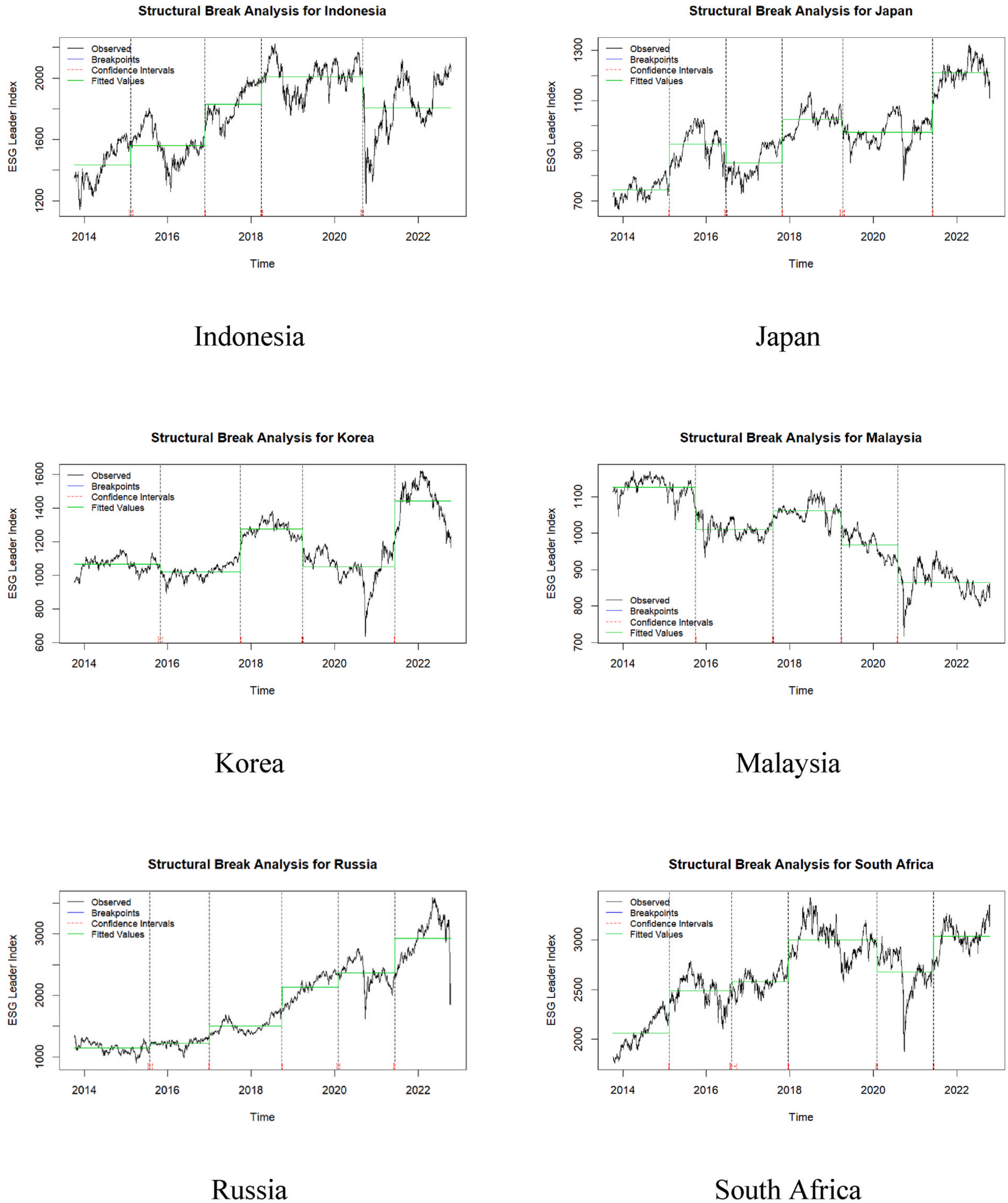


Fig. 4. (*continued*).

micro-level explanation for the heterogenous ESG impacts reported in this study.

Another critical factor which could be a plausible cause of the divergent ESG impact across countries is the degree of digital infrastructure maturity and its integration into environmental information systems. As highlighted in recent literature, digital transformation helps firm measure, manage and report sustainability data (Nguyen et al., 2023) which can in turn facilitate stronger market response to ESG policies. Therefore, countries with advanced digital ecosystem and state-supported environmental data platforms (such as China) can monitor and standardize ESG reporting leading to transparency and investor confidence, while market driven and decentralized digital adoption could lead to less coordinated ESG integration.

The structural break analysis supports the causal impact results by confirming significant shifts in ESG indices in 2015 for almost all countries, suggesting that the Paris Agreement likely catalyzes these changes. This alignment between the structural breaks and the timing of the Paris Agreement strengthens the validity of the causal impact analysis. Furthermore, the structural break analysis reveals key years such as 2017, 2019, and 2021, highlighting periods of heightened

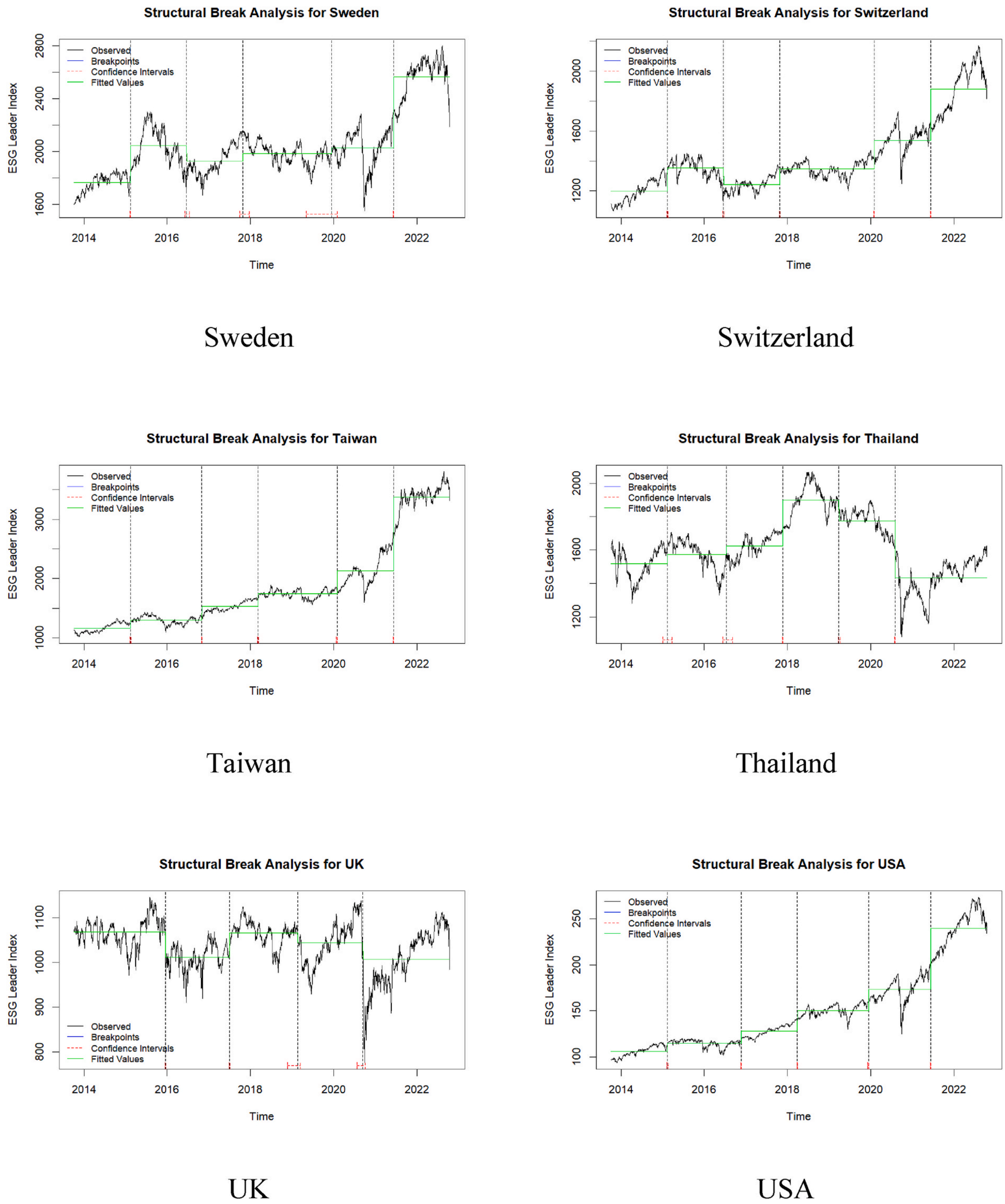


Fig. 4. (*continued*).

regulatory activity and global events that further impacted ESG indices. These periods coincide with increased environmental regulations, political changes, and the COVID-19 pandemic, which could have influenced ESG practices and reporting.

Theoretically, this study advances institutional perspectives on global environmental governance by showing that the Paris Agreement does not yield homogeneous influence across markets. Rather, its impact depends on the institutional context in which it operates. The evidence shows that countries with coherent institutional environments, characterized by strong regulatory coordination, state-driven sustainability initiatives, and centralized governance exhibit more positive ESG responses. In contrast, market-based or fragmented institutional systems reveal weaker or negative effects. These findings corroborate the argument that global institutional pressures are filtered through domestic institutional structures and governance models, shaping how sustainability norms are enacted within national financial systems.

Our findings have practical implications for both policymakers and investors. For policymakers, the evidence suggests that international agreements like the Paris Agreement can catalyze sustainable investment, but their effectiveness depends on domestic regulatory alignment

Table 3
The structural break analysis results.

		Break 1	Break 2	Break 3	Break 4	Break 5
Australia	Date	2015(231)	2017(69)	2018(157)	2019(245)	2021(111)
	RSS	8120011	6910388	6655891	6561973	6506321
	BIC	24926	24578	24508	24492	24488
Brazil	Date	2016(166)	2018(4)	2019(92)	2020(180)	
	RSS	45522911	40675018	37150922	37080893	
	BIC	28834	28596	28406	28418	
Canada	Date	2015(29)	2016(223)	2018(61)	2021(111)	
	RSS	45449767	15526251	14065391	13214038	
	BIC	28815	26406	26198	26088	
China	Date	2015(31)	2017(197)	2019(35)	2020(249)	
	RSS	74766550	67057540	62186944	62126528	
	BIC	29955	29724	29570	29583	
Hong Kong	Date	2015(29)	2016(149)	2017(237)	2020(23)	2021(111)
	RSS	30993189	18922456	14502241	12628345	12442272
	BIC	27951	26852	26267	25970	25952
India	Date	2015(29)	2016(151)	2017(239)	2019(164)	2021(111)
	RSS	4.93E+08	1.73E+08	1.26E+08	1.06E+08	1.03E+08
	BIC	3.42E+04	3.19E+04	3.12E+04	3.08E+04	3.07E+04
Indonesia	Date	2015(29)	2016(224)	2018(62)	2020(170)	
	RSS	49318407	42495245	40862364	40741533	
	BIC	29015	28694	28621	28630	
Japan	Date	2015(30)	2016(118)	2017(206)	2019(68)	2021(107)
	RSS	23601925	11821243	7690608	6737935	6203954
	BIC	27336	25790	24835	24551	24380
Korea	Date	2015(207)	2017(187)	2019(60)	2021(111)	
	RSS	23657734	12807381	12345276	12751706	
	BIC	27356	25986	25919	26007	
Malaysia	Date	2015(187)	2017(150)	2019(60)	2020(148)	
	RSS	3201695	2654489	2084448	2590138	
	BIC	22840	22433	21902	22408	
Russia	Date	2015(142)	2016(250)	2018(185)	2020(23)	2021(111)
	RSS	2.185e+08	1.244e+08	8.828e+07	8.596e+07	8.489e+07
	BIC	3.236e+04	3.110e+04	3.035e+04	3.030e+04	3.029e+04
South Africa	Date	2015(29)	2016(154)	2017(242)	2020(22)	2021(111)
	RSS	131478396	84911595	76599844	56836621	55445139
	BIC	31214	30242	30025	29366	29326
Sweden	Date	2015(29)	2016(117)	2017(205)	2019(239)	2021(111)
	RSS	47919280	33254673	32205228	30892393	30583758
	BIC	28935	28125	28068	27990	27983
Switzerland	Date	2015(29)	2016(117)	2017(205)	2020(23)	2021(111)
	RSS	39385539	23036688	19376074	18691822	16696658
	BIC	28492	27296	26921	26855	26616
Taiwan	Date	2015(29)	2016(208)	2018(46)	2020(23)	2021(111)
	RSS	2.23E+08	9.23E+07	5.75E+07	4.99E+07	4.65E+07
	BIC	3.24E+04	3.04E+04	2.94E+04	2.91E+04	2.89E+04
Thailand	Date	2015(29)	2016(134)	2017(222)	2019(60)	2020(148)
	RSS	51594417	22799272	20571803	19088954	18684771
	BIC	29102	27273	27056	26903	26870
UK	Date	2015(241)	2017(125)	2019(34)	2020(176)	
	RSS	4756161	4256026	4170747	4375537	
	BIC	23734	23499	23468	23592	
USA	Date	2015(29)	2016(222)	2018(60)	2019(239)	2021(111)
	RSS	1284333	438198	309318	268458	253854
	BIC	20762	18350	17579	17274	17163

and political stability. This highlights the importance of policy coherence. Global climate commitments must be complemented by consistent national frameworks to sustain investor confidence. For investors, the results emphasize the value of considering geopolitical and regulatory risks when allocating capital to ESG assets (since the Paris Agreement's effects varied substantially across countries). More broadly, the study contributes to the sustainable finance literature by demonstrating the utility of causal inference methods in assessing policy effectiveness in financial markets.

This study has limitations that should be acknowledged. It focuses exclusively on MSCI ESG Leaders indices, which, while comprehensive, may not capture the full spectrum of sustainable investment vehicles or reflect firm-level heterogeneity. In addition, although our methodology accounts for counterfactual trends, unobserved shocks unique to specific markets may still influence results.

Future research could extend this work in two directions. First, by incorporating alternative ESG measures, scholars could test whether findings are consistent across data sources. Second, comparative analyses of other international agreements (e.g., Kyoto Protocol, Glasgow Climate Pact) or sector-specific policies could provide a richer understanding of how climate governance shapes global financial markets over time. Beyond these extensions, an important next step is to examine whether the macro-level ESG market effects identified here translate into tangible firm-level financial outcomes. The findings that countries such as China, India, and Indonesia experienced substantial positive ESG response raise the question of whether firms within these markets also observed superior financial performance, market valuations, or capital cost advantages in the post-Paris Agreement period. Recent evidence suggests that enhanced ESG engagement can improve firm value and investor confidence by reducing information asymmetry and strengthening legitimacy (Buallay and Hamdan, 2023; Nguyen et al., 2025). Building on this literature, future research could bridge the macro–micro divide by integrating firm-level financial data with national ESG market trends. Such multi-level analysis would explain how global climate agreements shape not only market-level ESG trajectories but also the business case for sustainability at the firm level. This would advance the understanding of how institutional signals from international agreements cascade through markets to influence corporate finance outcomes, thereby linking global environmental governance with firm-level value creation.

CRediT authorship contribution statement

Babak Naysary: Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Javed Bin Kamal:** Writing – review & editing, Writing – original draft, Visualization, Validation, Investigation, Conceptualization. **Seyed Navid Mirpoorian:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis. **Keshab Shrestha:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis, Conceptualization.

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Declaration of competing interest

No conflict of interest exists.

Appendix

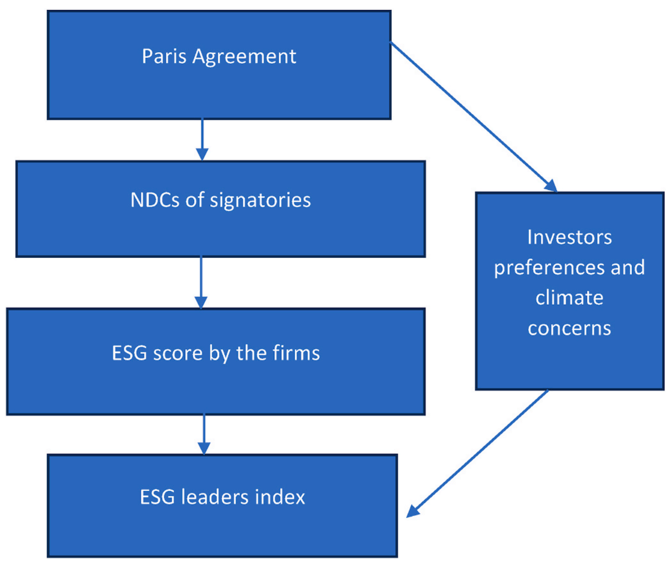

Fig. 5. Conceptual framework

Data availability

Data will be made available on request.

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