# Central banks sowing the seeds for a green financial system? NGFS membership and market reactions[#]

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Central banks around the world have joined the Network for Greening the Financial System (NGFS), an initiative that seeks to mobilize mainstream finance to support the transition toward a sustainable economy. We document the development of this initiative and show that independent central banks from advanced economies are more likely to join—particularly after achieving their primary mandates. We further argue that announcements of NGFS membership can be interpreted as *green monetary policy surprises*, providing a novel setting to examine market reactions to a "greening" of central bank attitudes. In high-frequency event studies using daily price data, we find that such announcements trigger significant capital reallocation toward green stocks. In complementary difference-in-differences analyses based on annual data, we show that green bond issuance increases in countries after their central bank joins the NGFS.

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# 1 Introduction

Should central banks mobilize mainstream finance to support the transition toward a sustainable economy? In January 2025, Jerome Powell—in his role as Chair of the Board of Governors of the Federal Reserve System (the Fed)—answered this question unequivocally, arguing that such endeavors are "just way beyond any plausible mandate that you could attribute to the Fed [...] it's not right for the Fed."[1] At the same time, however, more than 80 central banks worldwide have subscribed to the Network for Greening the Financial System (NGFS). Founded in 2017 during the Paris One Planet Summit, the NGFS describes itself as "a coalition of the willing […] whose purpose is to share best practices, contribute to the development of climate- and environment-related risk management in the financial sector and mobilize mainstream finance to support the transition toward a sustainable economy".

This contrast raises two follow-up questions that we examine in this paper. First, which central banks join the NGFS with its explicit objective of mobilizing capital for the green transition? Given the challenge posed by climate change (Allen et al., 2022) and the critical role that capital markets are expected to play in enabling the transition to a low-carbon economy (e.g., European Commission, 2021; OECD, 2021; UNCTAD, 2014),[2] the debate among policymakers and scholars on whether, and how, central banks should engage in climate action is gaining momentum (e.g., Green Central Banking, 2023).

Several arguments have been advanced to justify public pressure on central banks to incorporate environmental considerations. These include links to core economic and financial objectives such as price stability, growth, and financial stability (e.g., Brunnermeier & Landau, 2020; Gonzalez, 2021), as well as ethical concerns (e.g., Honohan, 2020). Yet, calls to broaden central bank mandates have also been criticized, among others due to concerns that this may compromise their primary objectives of price stability (e.g., Binder, 2021) and economic growth (e.g., American Enterprise Institute Roundtable, 2023). Despite such opposing views, central bankers have adopted remarkably clear positions in this debate. For example, Mark Carney, then Governor of the Bank of

[1] Fed press conference from January 29, 2025. Available at www.federalreserve.gov/mediacenter/files/FOMCpresconf20250129.pdf (accessed: Feb 2, 2025). The quote refers to the answer to a question about the Fed's withdrawal from the Network for Greening the Financial System (NGFS) earlier the month, on January 17, 2025,

[2] In 2014 the UNCTAD estimated the investment need for achieving the 17 Sustainable Development Goals (SDGs) and concluded that (international) private capital is needed to close the investment need in excess of domestic public capital (UNCTAD, 2014). Acknowledging the same issue, the European Commission has defined a "EU Sustainable Finance Strategy" in 2021 which represents an integral component of the European Green Deal (European Commission, 2021).

England, emphasized in a speech on September 29, 2015, that central banks have *"a clear interest in ensuring the financial system is resilient to any transition [...] and that it can finance the transition efficiently"* (Carney, 2015). Similarly, on July 8, 2021, the European Central Bank (ECB) announced that it would *"incorporating climate change considerations into its monetary policy framework"*.[3]

*Second*, does joining the NGFS have any effect—particularly on capital markets? While a growing literature examines legal and institutional constraints on green monetary policy, relatively little is known about how financial and capital markets respond to changes in central banks' climate objectives. A key challenge lies in identification: climate-related policy actions and announcements are often endogenous to the wider macroeconomic environment and frequently anticipated by financial markets.[4]

To address this challenge, we make use of central banks' announcements to join the NGFS, as documented by their press statements. While we do document systematic patterns in the propensity to join, we also show that these decisions cannot be predicted based on prior central bank speeches—and the announcements are not accompanied by additional communication, which might provide novel information to the market.[5] Furthermore, given the name and self-description of the NGFS, as well as the above comment by Jerome Powell—all suggesting that the network is about climate change and green finance, we interpret NGFS membership announcements as *green monetary policy surprises*—unexpected policy actions that signal shift in a central bank's commitment to environmental objectives.

We develop three empirical settings to study our two research questions. First, using a country-level panel dataset, we analyze central banks' propensity to join the NGFS. We find that the likelihood of membership is associated with a country's level of economic development (notably GDP per capita and energy consumption), demographic structure (median age of the population), institutional factors (central bank independence), and

[3] ECB Press release from July 8, 2021 with title "ECB presents action plan to include climate change considerations in its monetary policy strategy". Available at www.ecb.europa.eu/press/pr/date/2021/html/ecb.pr210708_1~f104919225.en.html (accessed: Feb 2, 2025).

[4] Take the announcement of the European Central Bank (ECB) to include climate change considerations into its monetary policy framework on July 8, 2021. This policy shift was largely expected, partly due to remarks made by Jens Weidmann about a month earlier at the Green Swan 2021 Global Virtual Conference, where he suggested that the ECB "should only purchase securities [...] if their issuers meet certain climate-related reporting obligations". Given Weidmann's prior reputation to oppose such measures, his statement was picked up by several news sources, such as the Financial Times (Arnold, 2021) and Reuters (Canepa, 2021), as interpreted as a credible signal that the ECB would adopt a stronger stance on climate change in its upcoming strategy review.

[5] See the discussion in Section 3.

the fulfilment of primary mandates (price stability and economic growth). These results suggest that policymakers view greening the financial sector as subordinate to their primary mandates.

Second, we collect daily price data for (i) exchange-traded funds investing in clean energy and fossil fuel ("brown energy") stocks and (ii) U.S.-listed firms, and examine the short-run consequences for financial markets using an event-study design. We document that a positive green monetary policy surprise significantly increases the valuation of clean energy stocks. In economic terms, assuming a scenario in which the U.S. Federal Reserve joins the NGFS, our results suggest that a long–short portfolio (long clean energy, short fossil fuel) would earn an abnormal return of 11.9 percent over the following three days—roughly one and a half times the abnormal return of clean energy stocks following the announcement of the Paris Agreement. We substantiate these results with a firm-level event study for the FED announcement, which shows that stocks of "greener" firms experienced higher returns.

Third, we collect country-level data on green bond issuance to study the medium- to long-term consequences of green monetary policy surprises. Using a Difference-in-Differences design, we document a significant increase in green bond issuance in countries after a green monetary policy surprise, suggesting that green monetary policy can influence not only immediate market valuations but also longer-term capital allocation.

Our paper makes three main contributions. *First*, we are the first to systematically examine both the development and the consequences of the NGFS. Although the initiative has been described as a "*landmark in the international green finance framework*" (D'Orazio, 2023, p. 154), little is known about its evolution, the characteristics of the central banks that joined, and, in particular, its implications for capital markets. *Second*, we contribute to the literature on the role of central banks in shaping financial markets and the financial system (Giavazzi & Giovannini, 2011). Motivated by the growing interest in central banks' role in the transition to low-carbon economies (Diluiso et al., 2021), we study the impact of NGFS membership on both stock and bond markets. Moreover, we contribute to the identification challenge in empirical central bank research by introducing and operationalizing the concept of *green monetary policy surprises*, extending the notion of *monetary policy surprises* developed by Bauer & Swanson (2023). *Third*, we add to the growing literature on sustainable finance (Edmans & Kacperczyk, 2022) by documenting how central banks may influence the channeling of private capital

toward green projects. Our evidence highlights an institutional dimension of sustainable finance that has so far received little systematic attention.

The remainder of this paper is structured as follows: The next section provides some background information about the NGFS, briefly reviews the literature on green monetary policy, and introduces the concept of green monetary policy surprises. Section 3 describes and examines the development of the network. Section 4 and 5 examines the short-run consequences in stock markets and the mid- to long-term consequences in bond markets, respectively. Section 6 provides some additional discussions, before Section 7 concludes.

## 2 NGFS and green monetary policy

### 2.1 Network for Greening the Financial Sector

In December 2017, during the One Planet Summit in Paris, a group of central banks and supervisory authorities announced the foundation of the Network for Greening the Financial Sector. These founding members are listed in Table A1. Over time, the network became increasingly popular, not only in central bank communication, but also in internet searches (see Figure 1).

**[Table A1 goes about here]**

**[Figure 1 goes about here]**

One of the founding members, the Deutsche Bundesbank, describes the NGFS as "a global network of central banks and supervisory authorities advocating a more sustainable financial system. Its aims to analyse the consequences of climate change for the financial system and to redirect global financial flows in order to enable low-carbon economic growth".[6]

Since its beginning, the network worked "as a consensus-based forum"[7] and welcomed new members. The governance of the network is formalized in its charter, which also describes the different steps an institution interested in joining the network has to follow to become a member of the network.[8] Until 04/2023 an additional 76 central banks have

[6] See https://www.bundesbank.de/en/bundesbank/green-finance/-/network-for-greening-the-financial-system-808978 (accessed on September 1, 2023).

[7] See https://www.ngfs.net/en/about-us/origin-and-purpose (accessed on October 1, 2025).

[8] According to the NGFS, an institution interested in joining first contacts the NGFS Secretariat at the Banque de France. After an introductory call outlining the network's history, structure, and application process, the institution prepares an official application letter detailing its motivation for joining, examples of prior commitments consistent with the NGFS Charter, and areas of intended contribution. The Secretariat then circulates the application for approval by consensus

joined the network.[9] At the same time, the NGFS has been productive in up to five workstreams, one of them named "Scaling up green finance".[10] More recently, it has also established a number of task forces and expert networks.[11]

In this paper, we use announcements of central banks to join the NGFS as a signal that reveals a "greening" of central banks' attitudes towards climate change and the need to channel capital towards green projects. Thereby, we refer to the Joint Statement of the Founding Members stating that "[t]he Network […] is a group of authorities willing, on a voluntary basis, […] to mobilize mainstream finance to support the transition toward a sustainable economy" from 2017, and to the 2021 Glasgow Declaration "Committed to Action" arguing that "[l]ooking ahead, and in light of the urgency and seriousness of climate change and environmental issues, we will expand and strengthen our collective efforts to improve the resilience of the financial system to climate-related and environmental risks, and encourage the scaling up of the financing flows needed to support the transition towards a sustainable economy."[12]

## 2.2 Green monetary policy

The existing literature on green monetary policy primarily focuses on three main dimensions: de jure factors, which encompass legal constraints; de facto constraints, which involve practical implementation; and central bank signaling, conveyed through central bank communication, as to whether monetary policymakers are willing to implement green monetary policy tools.

First, research has highlighted the existing legal constraints within central bank mandates to address climate-related concerns. According to Skinner (2021), these constraints limit policymakers to a reactive stance rather than allowing them to adopt a proactive role. Opposing voices such as Schnabel (2021) and Bartholomew & Diggle (2021) argue either that climate action may already fall within established mandates or that such action

among existing members. Once approved, the institution receives an acceptance letter and is invited to nominate representatives to the NGFS Plenary and relevant working groups. See www.ngfs.net/en/about-us/join-us (accessed on October 1, 2025).

[9] See Section 3 for more details.

[10] See https://sustainableinsuranceforum.org/wp-content/uploads/2020/11/Network-for-Greening-the-Financial-System-NGFS.pdf (accessed on October 1, 2025).

[11] See https://www.ngfs.net/en/what-we-do (accessed on October 1, 2025)

[12] See https://www.ngfs.net/en/publications-and-statistics/publications/ngfs-glasgow-declaration-committed-action (accessed on October 1, 2025).

doesn't deviate substantially from the existing mandates, especially when compared to unconventional monetary policy tools.

Second, scholars have examined the methods by which such interventions can be implemented. Much of the literature in this area emphasizes the reorientation of asset purchases toward "green" securities (e.g., Brunnermeier & Landau, 2020; Ferrari, Nispi & Landi, 2020; Ilzetzki & Jia, 2021; Papoutsi et al., 2022, Schoenmaker, 2021). This literature argues that brown industries benefit disproportionately from the current market-neutral asset purchases, primarily due to their capital-intensive nature. As a result, accommodative monetary policy may actively impede the transition to a more sustainable economy. A separate strand of the literature addresses potential constraints on the conduct of monetary policy arising from climate change. Mongelli et al. (2022) and Dietrich et al. (2021) examine channels through which climate change lowers the natural rate of interest, which, in turn, would limit the policy space available to future monetary policymakers to employ accommodative measures.

Finally, a strand of literature has abstracted from the question of implementation and focused on the question whether policymakers are willing in the first place to intervene. That is, they assess the prevailing stance of policymakers on this subject, often achieved by analyzing central bankers' communications regarding the transition to a more sustainable future. Arseneau et al. (2022) have observed an upsurge in climate-related discourse among central bankers, with much of their language revolving around speculative projections regarding the green transition. Campiglio et al. (2024) further show that the focal points within this debate have shifted and evolved over time.

Our paper builds on and extends this literature by introducing the concept of *green monetary policy surprises*—unexpected policy actions that signal a shift in a central bank's commitment to environmental objectives. This concept extends the notion of *monetary policy surprises* developed by Bauer and Swanson (2023) to the context of environmental objectives. Below, we operationalize this concept using central banks' announcements to join the NGFS. These announcements provide a distinct empirical advantage for identifying the effects of central banks "going green," as we document that they are unanticipated and do not coincide with the release of other information related to conventional monetary policy objectives, such as price stability. We then exploit this identification strategy to study market reactions to green monetary policy surprises,

combining high-frequency event studies with country-level difference-in-differences analyses.

## 3 Development of the NGFS

Our first research question asks which central banks join the Network for Greening the Financial System with its explicit objective of mobilizing capital for the green transition? To shed light on this, we analyze the development of the NGFS, exploring both cross-sectional and time-varying determinants of central bank participation at the country level.

### 3.1 Sample construction

In 2023, we received a dataset maintained by the Deutsche Bundesbank, which lists the member institutions of the NGFS (as of end of April 2023). It also reports the internal joining date for each member institution. Interested in the role of central banks for greening the financial system, we exclude non-central bank financial supervisory institutions as well as central banks at the supranational level (e.g., the European Central Bank). Finally, we complement the remaining static data with macroeconomic panel-data from the World Bank (Development Indicators) and other sources.[13]

### 3.2 Network development over time

Until mid of 2023, 84 central banks from all continents have joined the NGFS. We illustrate the network's global reach in Figure 2, highlighting founding members (Table A1) in red and non-founding members in shades of green based on their entry date. A detailed descriptive overview of network expansion is presented in Table A2, which documents the network's annual expansion from its establishment in December 2017 to April 2023, alongside average GDP per capita of NGFS and non-NGFS members, size of incoming members, and overall network size. It shows that NGFS members are covering over 75% of global GDP by 2022.

In addition, Table A2 shows that central banks from large, developed economies led early participation. The average GDP of new members decreased substantially, from 3.4 trillion USD (founding members) to 0.1 trillion USD in 2023 – supporting a stance that central banks from more (economically) developed countries are more likely to join the NGFS in earlier years than from less developed countries. We confirm this pattern with a traditional empirical test below. Nevertheless, we find notable temporal variation in network size, most pronounced in 2020 when the Federal Reserve joined the network.

[13] More details are provided in the Online Appendix.

**[Figure 2 goes about here]**

**[Table A2 goes about here]**

## 3.3 Cross-sectional determinants of central bank's NGFS membership

Next, we examine the institutional, social, and economic characteristics of NGFS members relative to non-members. Specifically, we regress latent factors constructed from social, macroeconomic, and institutional variables on an indicator for NGFS membership to assess whether these characteristics systematically differ between NGFS member countries and other countries.

Table 1 summarizes the main insights, with details on the construction of the latent factors and the empirical specification provided in Appendix A1. Three key findings emerge. First, central banks from more developed economies are significantly more likely to join the NGFS. In addition, geographic proximity matters: having a neighboring central bank, defined as a central bank from a country sharing a land border, that is already an NGFS member increases the likelihood of joining. Second, central banks from countries in which climate change is perceived as a salient threat and with more stringent environmental regulation are more likely to be part of the NGFS. However, interestingly, vulnerability to physical climate risk does not increase the likelihood of NGFS membership. Finally, monetary institutional characteristics play an important role. Central banks that are more independent and more transparent are more likely to be members of the NGFS.

**[Table 1 goes about here]**

## 3.4 The Role of primary and secondary objectives

Building on the discussion of central banks' loss functions, where climate concerns are hypothesized to play a tertiary role, we now empirically examine the relationship between central banks' primary (price stability) and secondary (economic slack) objectives and their decisions to join the NGFS.[14] Specifically, we test whether the weighting of climate objectives ($\beta_3$ in Equation (1)) is relatively low compared to the weights assigned to

[14] We recognize that not all central banks have de jure objectives related to price stability and economic activity. Nevertheless, the work of Cobham (2021) highlights that most central banks worldwide have de facto mandates relating to at least one of the three.

inflation ($\beta_1$) and output ($\beta_2$), suggesting that central banks prioritize traditional mandates before committing to climate initiatives like the NGFS. To test this hypothesis, we estimate the following panel regression:

$$NGFS{:}join_{i,t} = \alpha + \beta_1|\pi_t - \hat{\pi}| + \beta_2(\mathrm{x}_t - \hat{x}) + \beta_3 u_t + f_{i,t} + \epsilon_{i,t} \quad (1)$$

where $NGFS{:}join_{i,t}$ is a binary variable equal to 1 if central bank $i$ joined the NGFS in year $t$, and 0 otherwise. The key independent variables are the absolute deviation from trend inflation $|\pi_t - \hat{\pi}|$, the output gap $(\mathrm{x}_t - \hat{x})$, and the unemployment rate $u_t$.[15] We also include a set of fixed effects $f$ to capture unobservable factors specific to each central bank and year. The coefficients of interest are the *Β's*. We expect greater inflation deviations to reduce the likelihood of joining the NGFS. Conversely, a positive (negative) output gap should increase (decrease) the likelihood of joining.

**[Table 2 goes about here]**

The regression results, presented in Table 2, confirm our hypotheses. Column 1 indicates that an increase in inflation deviation by one standard deviation significantly reduces the probability of NGFS entry in that year by around 75%. Column 2 shows that the same relationship holds for the output gap. Interestingly, we find no significant relationship between the unemployment rate (column 3) and the probability of NGFS entry. To ensure robustness, we assess multicollinearity in Column 4, finding no significant issues, indicating that central banks prioritize price stability and above-trend economic activity to NGFS membership.

Finally, in Column 5 we examine whether our findings are driven by developed countries, as there may be unobserved confounding factors, such as stronger inflation-targeting mandates. To test this, we exclude countries with a real income below $10,000, finding that the results remain consistent, which supports the generalizability of our findings across income levels.

[15] To estimate deviation in inflation and output from trend, we employ an HP filter on the annualized inflation rate and real output spanning from 1980 to 2023 sourced from the WDI. We describe our approach for building our second dataset in detail in the Online Appendix.

In summary, central banks tend to commit to climate-related objectives once their primary and secondary objectives are fulfilled. Thus, our results suggest that policy makers perceive climate change concerns as subordinate to addressing price stability and output deviations.

## 4 Short-run response to green monetary policy surprises

Our second research question asks whether joining the NGFS has any effect—particularly on capital markets? To tackle this question, we start by introducing and operationalizing the concept of *green monetary policy surprises (GMPS)*. We then use GMPS and two different event study designs to shed light on the short-run consequence in stock markets.

### 4.1 Green monetary policy surprises

Bauer & Swanson (2023) introduce the notion of monetary policy surprises—referring to the unexpected component of monetary policy announcement. We extend this idea to the subfield of green monetary policy. Specifically, we propose the notion of a green monetary policy surprises as unexpected policy actions that signal shift in a central bank's commitment to environmental objectives. Moreover, we propose to operationalize GMPS by central bank's announcement to join the NGFS.

To classify as an operationalization of a GMPS, such announcements must satisfy two criteria:

- First, they must represent a signal revealing a "greening" of central banks' attitudes towards climate change and the need to channel capital towards green projects. Given the self-defined objectives of the NGFS discussed above, this seems plausible.
- Second, it must not be anticipated by market participants. This is a challenging assumption, as our previous analysis documents some systematic pattern in central bank behavior, suggesting some predictability—at least at low frequencies (e.g., on annual levels). Regarding the predictability at higher frequencies, in particular the predictability of the exact announcement day, a back-of-the-envelope calculation supports the assumption: Our sample period 01/2018 to 06/2023 spans 5.5 years and we identify 29 distinct enlargement events. Assuming an average of 252 trading days per year, the ceteris paribus probability for an event on any given

day over our sample period is as low as 2.1 percent. Moreover, we provide three additional pieces of evidence:

- First, we examine newspaper articles surrounding the announcement and find no instances where events were predicted by news sources.
- Second, we assess whether central banks signaled their NGFS membership before official announcements. Therefore, we use the central bank speech datasets compiled by Baumgärtner and Zahner (2023) and Campiglio et al. (2025), which contain transcriptions of speeches delivered by central bank officials across various institutions. We systematically search for mentions of "NGFS" within these speech databases, and count references to NGFS over time, examining whether central banks mentioned the NGFS before becoming members and whether speech frequency changes post-membership. The results of this exercise are presented within Figure 3.[16]

**[Figure 3 goes about here]**

## 4.2 Event identification and event study design

Analyzing the consequences of green monetary policy surprises (GMPS) within an event-study framework poses two main challenges. The first is to identify the exact timing of GMPS events. To this end, we manually screen the NGFS website and archived versions of it to collect all official NGFS press releases announcing new members. In addition, we complement this with official announcements of central banks joining as per publications on their websites. After collecting the information, and in line with the efficient market hypothesis, we use the earliest publication date per central bank, if applicable.[17] In total, we identify 29 distinct accession events (excluding the founding event), which together refer to 73 central banks that joined the NGFS. Each press release includes an official publication date, which we use as the event date in our analyses.

[16] We find that, with rare exceptions, central banks did not publicly discuss the NGFS before becoming members. Among the 83 central banks analyzed, only three instances of pre-membership mentions were identified: Banco Central de Chile (on November 18, 2020), the National Bank of Serbia (on April 16, 2021), and the Croatian National Bank (on April 29, 2021). These references, however, do not provide direct signals of impending membership but rather were generally framed as congratulatory statements toward existing members. Figure 3 also shows significant increase in NGFS-mentions post-membership. On average, the term "NGFS" was used in approximately one speech in the first year after membership, rising to more than three speeches after three years, and reaching nearly ten speeches after five years, which suggests that NGFS participation significantly influences the discourse of central banks on sustainable finance.

[17] For more details on the collection of the central banks' joining dates see the Online Appendix.

Any event study rests on a number of assumptions[18]

- Most importantly, the announcement must not be anticipated. Consequently, we focus on relatively short windows around the announcement date. Specifically, we examine five-day event windows [-1;+3] and 3-day event windows [-1;+1].[19] It is worth noting that any violation of this assumption would likely bias our estimates toward zero, as markets would have already priced in part of the effect in anticipation of the announcement.
- A similarly important assumption is that it needs an unbiased performance measure. Given that we are studying a global phenomenon, this is a challenging one. We address this issue in two steps.
    - First, we opt for a global approach in which we study the 29 identified events simultaneously. However, as in most cases several central banks join simultaneously, and not all central banks are equal, we weight each of the events by its relevance, which we proxy by GDP of the represented countries. Furthermore, we use global thematic ETFs to proxy the development of different parts of the market on a global level. As the NGFS aims to mobilizing capital for the green transition we opt for two types of ETFs: ETFs investing in clean energy stocks, and ETFs investing in fossil fuel ("brown") stocks, respectively.
    - Second, we do a deep dive and study U.S. firm-level stock price data in response to the US Federal Reserve's entry announcement. This will arguably give us a more nuanced picture.

Additionally, our approach rests of three more assumptions (e.g., Bauer & Swanson, 2023):

- The first additional assumption is about the absence of reverse causation. In our setting, this requires that stock returns do not affect the decision of central banks to join the NGFS. As we opt for relatively short time windows, and central banks—as well as the NGFS—have bureaucratic internal decision processes, it is hard to

[18] Event studies are commonly used to study the consequences of green policy announcements for stock markets, see Antoniuk & Leirvik (2024), Ramiah et al. (2013) or Wallace & McIver (2019). For a general perspective on the event study method see MacKinlay (1997) or Kothari & Warner (2004).

[19] Given that the exact timing and time zone of the announcements are unavailable, we adopt five-day and three-day event windows in the event study to mitigate potential uncertainty regarding announcement timing.

argue that the decision to join the NGFS or the timing of its announcement is a reaction to returns in the stock market.

- The second additional assumption is about the absence of omitted variables that are correlated with the announcement and simultaneously—but independently—affect stock prices. Building on market-efficiency, we rule this out by (1) making sure that joining CBs have no other material communication on the day before, the same day, and the following day and (2) making sure no entry announcements coincide with COP 26 (Glasgow, 2021) nor COP 27 (Egypt, 2022).
- The third additional assumption is about the absence of information effects. In our setting, this requires that a central bank's announcement to join the NGFS does not reveal any private information about the climate change and consequences for (macro)economic expectations. Note, however, that announcements to join the NGFS are relatively brief and somehow standardized, and central banks typically do not have specialized climate researchers. Also, stock prices are found to show little evidence of information effects (Bauer & Swanson, 2023).

## 4.3 Event study I: Global financial market reaction

In a first step, we examine the reactions to all 29 announcement dates simultaneously. Acknowledging the global phenomenon, we use global thematic ETFs to proxy the development of different parts of the market on a global level, in line with the literature (e.g., Antoniuk and Leirvik, 2024; Bauer et al. 2024; Wallace and McIver, 2019). Given the explicit objective of the NGFS, we focus on two themes: clean energy and brown industries.[20] Specifically, we follow Antoniuk & Leirvik (2024) and Wallace & McIver (2019) in identifying relevant thematic ETFs and obtain return index data from Refinitiv Datastream.[21]

Our analysis centers on cumulative abnormal returns (CAR) for these ETFs around each public announcement. We estimate the stock market reaction to our green monetary policy surprises using the following specification:

[20] The clean energy ETFs cover firms operating in clean energy and wind industries, fossil fuel ETFs invest in stocks of firms in certain industries which are considered to be polluting and thus harmful to the environment (e.g., Wallace and McIver, 2019). Technically, we proxy the stock market performance of clean energy stocks and fossil fuel stocks as the equal-weighted average performance of the ETFs reported in Table A8, and the benchmark return using return index data from the MSCI All Country World Index.

[21] We provide a list of our thematic ETFs in Table A8 and more information in the Online Appendix.

$$CAR_{[t_1,t_2]} = \alpha + \beta_1 GreenMPSurprise + \epsilon_i \quad (2)$$

where the dependent variable is the average $CAR$ (in percentage) for the thematically sorted ETFs (i.e., "green" and "brown" ETFs) over the event window $[t_1, t_2]$ and $GreenMPSurprise$ is measured in terms of GDP contribution of new NGFS members. We expect the coefficient of interest, $\beta_1$, to be positive for clean energy stocks as well as the difference between clean energy- and fossil fuel stocks (difference portfolio), indicating a positive stock market response to green monetary policy.

**[Table 3 goes about here]**

Our results are presented in Table 3. First, we observe a significantly positive market response in climate-sensitive segments during the $[-1, +3]$ window following a green monetary policy surprise. The intensity of this reaction increases with the magnitude of the surprise, indicating that announcements involving countries with substantial GDP contributions to the network elicit a stronger response. The coefficient is economically meaningful: a one-standard-deviation surprise is associated with an average $CAR$ increase of 2.04 percent for the difference portfolio. Additionally, we account for approximately one-third of the explained variance, highlighting the substantial impact of our surprise on returns during these days. Column two to four report that the results are not dependent on specific model specifications. Specifically, we estimate the base model using a median regression (column 2), controlling for the post-enlargement size of the network (column 3), and by narrowing the cumulative abnormal return window down to a three-day window around the respective announcement dates (column 4). In Column 5, we exclusively re-estimate the model for clean energy stocks' $CARs$ only over the $[-1, +3]$ interval. The results suggest that the returns of the clean energy stocks are the main driver behind the formerly observed difference portfolio returns. When comparing our findings to the market reaction to the Paris Agreement (see Figure 4), we observe that a one-standard-deviation green monetary policy surprise yields approximately half the impact of the Paris Agreement announcement. To illustrate, consider the Federal Reserve's entry into the

NGFS on December 15, 2020, which represents a green monetary policy surprise corresponding to 24.5 percent of global GDP. The surprise on that day is projected to generate an estimated abnormal return of 11.9 percent (column 3) in the difference portfolio over the $[-1, +3]$ window, an effect that is nearly 1.5 times greater than the market response observed following the Paris Agreement announcement.

**[Figure 4 goes about here]**

Overall, our results indicate that financial markets react to climate-related central bank surprises. More specifically, the difference portfolio, which is long in clean energy stocks and short in fossil fuel stocks, substantially benefits from such green surprises. We show that this effect is primarily driven by the clean energy stocks.

## 4.4 Event study II: US firm-level reaction

Next, we substantiate our findings on a global level with firm-level response to green monetary policy surprises, focusing on the Federal Reserve's announcement of NGFS membership on December 15, 2020.[22] Following Bauer et al. (2024), we conduct an event study to assess the reaction of US firm returns to this announcement, using a dataset that links observed firm-level returns to the green monetary policy surprise to cross-sectional characteristics, including three distinct measures of firms' environmental performance.[23] Specifically, we run the following regression:

$$Return_i = \alpha + \beta_1 E + \beta_2 X_i + \epsilon_i \quad (3)$$

[22] The FED has officially announced that it joined the NGFS formally on December 15, 2020 before trading starts at 09:00 am. See https://www.federalreserve.gov/newsevents/pressreleases/bcreg20201215a.htm (accessed: September 1, 2023)

[23] We construct our sample by retrieving all available U.S. securities included in the Refinitiv U.S. ESG-Universe as of December 9, 2024 (Bauer et al., 2024). Our initial dataset consists of 3,649 individual securities. We then exclude securities with missing emissions score data for 2020, reducing the sample to 3,130 securities. In line with established practices, we further refine our sample by excluding non-equity and non-primary security types (e.g., Ince and Porter, 2006). As we focus on U.S. firms, we also exclude all firms not listed on either the NYSE, NASDAQ, or AMEX, following the approach of Bauer et al. (2024). Next, we exclude firms with earnings announcements or closing prices below $1 on the event days (December 14 to December 15, 2020), and require non-missing firm-level control covariates as per 2020. This refinement results in an intermediate sample of 2,693 firms. To encounter a survivorship bias (e.g., Hanauer, 2014), we supplement this sample with delisted or dead companies. By applying the same filtering criteria as above we account for additional 404 firms. In total, our fourth dataset covers a maximum of 3,097 firm observations. Given that the Federal Reserve announced to join the NGFS on December 15, 2020, and the announcement was made public at 9 a.m., we use market returns from December 14 to December 15 to capture the immediate market reaction. For the firm-level environmental and accounting data, we utilize data from the end of 2020. We opt for this approach, because the event occurred in mid-December, making end-of-year data the most relevant for capturing the firms' status close to the event date.

where Return is the raw return of firm $i$ on the announcement day, while $E$ denotes a firm-specific environmental performance indicator. We follow Bauer et al. (2024) using (i) the Environmental Score, (ii) the Emissions Score, and (iii) Emission Intensity as these firm-specific environmental performance indicators. The first two are industry-adjusted measures provided by Refinitiv. The Environmental Score aggregates over 60 metrics to capture firms' overall environmental performance, while the Emissions Score focuses on emissions-related themes such as carbon output, waste management, and biodiversity impact. Given recent criticism on these scores (e.g., Gourier and Mathurin, 2024), we also use is a direct measure, Emission Intensity, that scales a firm's CO2-equivalent emissions relative to its market capitalization, thereby accounting for firm size. Notably, data availability constraints on CO2 emissions reduce the sample size for the Emission Intensity analysis.

In all empirical specifications, we add a set of firm-specific control variables $X_i$ for size (log of market capitalization), sales growth (annual change in net sales), book leverage (total debt to total assets), profitability (net income to total assets), and the effective tax rate (ETR, calculated as the ratio of total income taxes paid to pretax income). We further incorporate industry controls based on the FamaFrench classification scheme, which categorizes firms into 17 industries using SIC codes. To mitigate the influence of outliers, all variables are winsorized at the 1% level.

The average company in our sample has an environmental and an emission score of 0.28, with higher scores reflecting more environmentally friendly practices. In terms of emissions intensity, the average firms report an average of 0.29 kilotons per million US dollars of market capitalization, where lower values signify better environmental performance. The average raw return from 14 December to 15 December 2020 was 1.88 percent. Table A6 and Table A7 provide an overview of the variables and further descriptive statistics.[24]

The regression results can be found in Table 4. We find a statistically significant coefficient for all three environmental performance indicators in the expected direction. The magnitudes of the effects are substantial, a one-standard deviation increase in the Environmental Score is associated with an additional return of approximately 0.37%, equivalent to about one-seventh of a standard deviation of raw returns. Comparing our coefficients to those of Bauer et al. (2024). we find that the effect size is roughly half the

[24] Please refer to the Online Appendix for additional explanations with regard to the sample construction process for our US firm-level sample.

magnitude of their findings, indicating that the Federal Reserve's announcement of NGFS membership has a significant, albeit somewhat smaller, influence on asset markets than the $1 trillion Inflation Reduction Act of 2022.[25]

**[Table 4 goes about here]**

In conclusion, our firm-level event study corroborates the findings from the global analysis. We show that, on average, low-carbon firms experienced significantly higher stock returns on December 15, 2020. This evidence points to a robust market response to green monetary policy surprises and suggests that investors interpret central bank commitments to sustainable finance as credible signals that shape capital allocation.

## 5 Long-term response to green monetary policy surprises

Next, we focus on the implications of green monetary policy surprises, specifically examining whether our surprises can persistently stimulate capital flows to green projects, rather than just having immediate or short-term impacts (e.g., Diluiso et al., 2021). To analyze this medium-term relationship, we merge our dataset of green monetary policy surprises with the IMF's Climate Change Green Bonds database (Mertzanis, 2024). The database compiles fixed-income instruments designed to finance or refinance sustainability projects, commonly referred to as "green bonds." It encompasses green bond issuance across 75 countries from 2010 to 2022. A statistical summary of this dataset is provided in Table A7, showing that, on average, approximately US$2.12 billion were issued annually per country within the sample.[26]

To empirically assess the causal impact of green monetary policy surprises on green bond issuance, we adopt a difference-in-differences (DiD) and a panel-regression approach, where we compare changes in green bond issuance between treated countries (those whose central banks joined the NGFS) and control countries (those that have not joined

[25] In additional unreported analyses of our baseline results using decile-portfolio regressions, we document that the observed correlations are primarily driven by the "greenest" and most "brown" firms. These results hold across all measures of greenness. Furthermore, we find that emissions directly "controlled" by firms (i.e., Scope 1 emissions)—which are more directly attributable to them by investors and the stock market—drive the negative correlation between emission intensity and equity returns on the event day. We provide these analyses as well as several robustness checks within the Online Appendix.

[26] We document the approach to build our final, fifth sample in the Online Appendix.

the NGFS), before and after NGFS participation. Specifically, we start by estimating the following panel regression model:

$$Green\ Bond_{i,t} = \alpha + \beta_1\left(Post \times NGFS_{i,t}\right) + \beta_2 X_{i,t} + \epsilon_{i,t} \quad (4)$$

where $Green\ Bond$ denotes green bond issuance (in billions of US dollars) for country $i$ at time $t$. Our variable of interest, $Post \times NGFS$, is equal to 1 if a country's central bank has joined the NGFS by time $i$ and 0 otherwise. To account for unobserved time-specific and country-specific variations, we include time and country fixed effects. Further information on the variables can be found in Table A6 and Table A7.

**[Table 5 goes about here]**

The results are presented in Table 5, columns (1) to (3). The first column shows a difference-in-means comparison, suggesting that NGFS membership is associated with an increase in green bond issuance of about US$7 billion. Qualitatively, the effect remains robust when controlling for country-specific and time-specific variations (column 2), and country size (column 3). Quantitatively, across various model specifications, NGFS membership is associated with an additional annual green bond issuance of US$2.7 billion to US$4 billion, which corresponds to about half a standard deviation of annual issuance levels.

To further assess anticipation effects and the persistence of the effect of green monetary policy surprises on green bond issuance, we turn to a DiD-approach with two-way fixed effects in columns (4) to (5). We find the following: First, the pre-treatment coefficients are insignificant, suggesting that treated and control units followed parallel trends prior to NGFS membership–an important condition for the causal interpretation of our estimates. Second, in the announcement year, we detect no significant effect, which is unsurprising given that announcements may occur late in the calendar year and which suggests that capital allocation does not adjust immediately. Third, we observe a steadily increasing and statistically significant coefficient in each subsequent year following the announcement. This effect remains robust when controlling for country- and time-specific variation (column 5). Quantitatively, the estimated effect rises from approximately US$

1.6 billion in the first year to US$ 6.5 billion by the fourth year, indicating substantial capital movement. Figure 5 provides a visual summary of these findings, suggesting that monetary policymakers can effectively foster a sustained transition towards green finance through their commitments to sustainability.

**[Figure 5 goes about here]**

## 6 Alternative explanations: Exchange Rates

A potential confounder is the possibility that exchange rate movements could distort our measured effects of NGFS announcements. If a currency systematically appreciates or depreciates following an announcement—perhaps due to speculation about future interest rate paths or capital flows—investor demand for domestic assets may shift for reasons unrelated to the central bank's climate policy stance. To assess this possibility, we collect high-frequency exchange rate data for major currencies around the relevant NGFS announcements by their issuing central banks.

Figure 6 presents our findings, revealing no systematic exchange rate response to NGFS announcements. The U.S. dollar, Canadian dollar, Chinese yuan, and British pound display appreciations, while the euro and Japanese yen depreciate, producing a mixed overall pattern. These inconclusive currency movements suggest that the observed market reactions are unlikely to be driven by exchange rate fluctuations.

**[Figure 6 goes about here]**

## 7 Conclusion

In this paper, we study the development of the Network for Greening the Financial System (NGFS) and use announcements of central banks to join the NGFS as a signal that reveals a "greening" of central banks' attitudes towards climate change and the need to channel capital towards green projects.

Empirical research assessing the effectiveness of green monetary policies faces significant

identification challenges, due to the endogeneity of these actions to broader macroeconomic conditions and market expectations. To mitigate this issue, we treat the decision of central banks to join the NGFS – a global alliance of central banks dedicated to promoting the green transition – as a quasi-natural experiment. We interpret the unexpected announcements of new memberships as green monetary policy surprises– unexpected shifts that deviate from market participants' prior expectations. Since joining the NGFS requires no modification to a central bank's mandate, we can use participation as an indicator of the institutions green preferences, thereby isolating the causal effects of green monetary policies on financial markets.

Our analysis indicates that NGFS membership correlates with the fulfillment of primary objectives, such as price stability and a positive output gap, suggesting that central banks view green policies as subordinate to their primary mandates. We then investigate the financial market reaction to such unexpected announcements of NGFS membership. Through two high-frequency event studies, we show that green stocks exhibit significant contemporaneous abnormal returns in the days following such announcements. In terms of magnitude: the market response to the Federal Reserve's accession to the NGFS is approximately twice the magnitude of the abnormal returns observed during the announcement of the Paris Agreement. Moreover, using granular firm-level data, we find reveals that these effects are especially pronounced for low-carbon firms.

Finally, we examine the transmission mechanisms of these green monetary policy surprises into capital debt markets. We find that green bond issuance in a country experiences a sustained increase following a central bank surprise announcement, with effects lasting for several years. The persistent effect underscores the ability of central banks to permanently stimulate capital flows towards environmentally sustainable projects.

Overall, our results highlight the role central banks can play in facilitating a sustained transition to a more sustainable economy through their commitments to green monetary policy.

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# Appendix

### Table A1: Founding members of the NGFS

Notes: This table reports the eight founding members of the network "Network for Greening the Financial Sector" (NGFS) launched in December 2017 during the One Planet Summit event in Paris.

| Institution | Type | Country |
|---|---|---|
| Banco de Mexico | Central Bank | Mexico |
| Bank of England | Central Bank | England |
| Banque de France and Autorité de Contrôle Prudentiel et de Résolution (ACPR) | Central Bank and supervisory authority | France |
| De Nederlandsche Bank | Central Bank | Netherlands |
| Deutsche Bundesbank | Central Bank | Germany |
| Finansinspektionen | Supervisory authority | Sweden |
| Monetary Authority of Singapore | Central Bank | Singapore |
| People’s Bank of China | Central Bank | China |

### Table A2: Network development over time

Notes: Panel A shows the evolution of the network at year-end over time, as reflected in the official press releases on the NGFS website until June 2023, along several line-by-line characteristics: The number of announced expansions of the network, the number of central banks joining the NGFS per year, the absolute number of countries whose central banks are members of the network, and the GDP contribution per announcement and in absolute terms (in trillions of U.S. dollars). Data source for GDP data: World Development Indicators (WDI). Panel B shows the geographic distribution of network development according to the United Nations geoscheme.

| Year | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|
| Panel A: Overall development | | | | | | | |
| Announcements of network enlargements (central banks join the NGFS) | 1 | 3 | 10 | 6 | 6 | 3 | 1 |
| Number of central banks joining the NGFS | 7 | 12 | 19 | 18 | 12 | 8 | 4 |
| Mean GDP per capita (in (in thousands of const. 2015 USD) | | | | | | | |
| - NGFS members | 36.4 | 41.6 | 35.3 | 29.0 | 26.8 | 25.9 | 25.1 |
| - non-NGFS members | 15.5 | 13.9 | 12.6 | 10.4 | 11.5 | 12.0 | 12.4 |
| GDP of countries with central bank joining the NGFS (in trUSD) | 24.0 | 6.1 | 17.1 | 23.9 | 4.7 | 1.4 | 0.4 |
| Total GDP of countries with central bank being a NGFS member (in trUSD) | 24.0 | 30.1 | 47.2 | 71.2 | 75.9 | 77.3 | 77.7 |
| Panel B: Geographical distribution | | | | | | | |
| Africa - total | 0 | 1 | 3 | 5 | 6 | 10 | 12 |
| - joining | - | 1 | 2 | 2 | 1 | 4 | 2 |
| Americas - total | 1 | 1 | 4 | 8 | 13 | 14 | 15 |
| - joining | 1 | - | 3 | 4 | 5 | 1 | 1 |
| Asia - total | 2 | 3 | 8 | 14 | 16 | 18 | 19 |
| - joining | 2 | 1 | 5 | 6 | 2 | 2 | 1 |
| Europe - total | 4 | 12 | 21 | 27 | 31 | 32 | 32 |
| - joining | 4 | 8 | 9 | 6 | 4 | 1 | - |
| Oceania - total | 0 | 2 | 2 | 2 | 2 | 2 | 2 |
| - joining | - | 2 | - | - | - | - | - |
| World - total | 7 | 19 | 38 | 56 | 68 | 76 | 80 |
| - joining | 7 | 12 | 19 | 18 | 12 | 8 | 4 |

### A1. Factor Analysis of Determinants for NGFS membership

This appendix investigates whether NGFS members share common structural characteristics. We consider six dimensions, each proxied by a set of observable variables (see Table A3). For each dimension, we extract a common factor using factor analysis.

1. **Economic Development:** The first dimension captures economic development, reflecting the notion that limited economic capacity may constrain engagement in climate-related initiatives. We proxy economic development using real GDP per capita, gross capital formation, indicators of technological intensity (e.g., high-technology exports), and financial development (market capitalization). All variables are transformed using logarithms to mitigate skewness.
2. **Economic Vulnerability to Climate Change:** The second dimension captures exposure to physical climate risk. We measure vulnerability using indicators of exposure of the production factors capital (agriculture, forestry, and fishing as a share of GDP; agricultural land as a share of total land area) and labor (natural-disaster-related deaths per capita). Variables are log-transformed where appropriate.
3. **Economic Vulnerability to Climate Change:** The third dimension measures public perceptions of climate risk using data from the World Risk Poll. We use the share of respondents who regard climate change as a serious or somewhat serious threat. Due to data availability, this dimension is only observed from 2017 to 2019.
4. **Green Government Action:** The fourth dimension captures the regulatory stance of the executive branch. We rely on sub-indices from the OECD Environmental Policy Stringency database, including emission limit values, environmental taxes, support for low-carbon technologies, and the existence of emissions trading schemes. Because some indices can take the value zero, we apply a log (1 + x) transformation.
5. **Monetary Institutions:** The fifth dimension measures monetary institutional quality. We use indices of formal and informal central bank independence from Romelli (2022) and measures of central bank transparency from Dincer, Eichengreen, and Geraats (2022). We construct separate factors for the 2017–2019 period and for 2021, reflecting data availability.
6. **Geographic Proximity:** The sixth dimension captures spatial spillovers. A binary indicator records whether a country shares a land border with at least one NGFS member.

For each dimension, the extracted factors load on the underlying variables with the expected signs (e.g., higher GDP per capita and investment load positively on the development factor). Summary statistics for the variables and the resulting factors are reported in Table A3.

**Table A3: Summary Statistics Determinants for NGFS membership**

| | Source | N | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|---|---|
| *Dimension 1: Economic Development* | | | | | | |
| GDP per capita (constant 2015 US$) in logs | World Bank (NY.GDP.PCAP.KD) | 762 | 2.72 | 1.09 | -0.20 | 4.71 |
| Gross capital formation / Investments (% of GDP) in logs | World Bank (NE.GDI.TOTL.ZS) | 762 | 3.11 | 0.25 | 1.68 | 3.83 |
| High-technology exports (% of manufactured exports) in logs | World Bank (TX.VAL.TECH.MF.ZS) | 762 | 2.33 | 1.09 | -3.51 | 4.33 |
| Market capitalization of listed domestic companies (% of GDP) in logs | World Bank (CM.MKT.LCAP.GD.ZS) | 762 | 3.83 | 1.10 | -1.55 | 7.48 |
| Economic Development Factor | | 762 | 0.00 | 0.80 | -2.07 | 1.87 |
| *Dimension 2: Economic Vulnerability to CC* | | | | | | |
| Number of Natural disaster deaths, excluding epidemics (per capita) in log(1+x) | International Disaster Database | 996 | 0.00 | 0.00 | 0.00 | 0.0004 |
| Agricultural land (% of land area) in logs | World Bank (AG.LND.AGRI.ZS) | 996 | 3.49 | 0.81 | -0.07 | 4.42 |
| Agriculture, forestry, and fishing (% of GDP) in logs | World Bank (NV.AGR.TOTL.ZS) | 996 | 1.28 | 1.24 | -3.46 | 3.49 |
| Economic Vulnerability Factor | | 996 | 0.00 | 1.00 | -3.83 | 1.79 |
| *Dimension 3: Public Perception of CC* | | | | | | |
| See climate change as a serious threat (% of population). | World Risk Poll | 155 | 3.88 | 0.37 | 2.73 | 4.46 |
| See climate change as a somewhat serious threat (% of population). | World Risk Poll | 155 | 3.25 | 0.45 | 1.93 | 4.07 |

**Table A3 (continued)**

| | Source | N | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|---|---|
| See climate change as a threat (% of population). | World Risk Poll | 155 | 4.37 | 0.17 | 3.86 | 4.58 |
| Public Perception Factor | | 155 | -0.00 | 1.00 | -3.11 | 1.57 |
| *Dimension 4: Green Government Action* | | | | | | |
| Carbon Dioxides (CO2) Tax | OECD (Environmental Policy Stringency Index) | 418 | 0.47 | 0.70 | 0.00 | 1.95 |
| Nitrogen Oxides (NOx) Tax | OECD (EPS Index) | 418 | 0.37 | 0.68 | 0.00 | 1.95 |
| Sulphur Oxides (SOx) Tax | OECD (EPS Index) | 418 | 0.32 | 0.62 | 0.00 | 1.95 |
| Emission Limit Value Sulphur | OECD (EPS Index) | 418 | 1.85 | 0.29 | 0.00 | 1.95 |
| Diesel Tax | OECD (EPS Index) | 418 | 1.27 | 0.49 | 0.00 | 1.95 |
| Emission Limit Value SOx | OECD (EPS Index) | 418 | 1.54 | 0.56 | 0.00 | 1.95 |
| Emission Limit Value PM | OECD (EPS Index) | 418 | 1.46 | 0.65 | 0.00 | 1.95 |
| Emission Limit Value NOx | OECD (EPS Index) | 418 | 1.53 | 0.60 | 0.00 | 1.95 |
| Technology Support Policies | OECD (EPS Index) | 418 | 1.03 | 0.54 | 0.00 | 1.95 |
| Low-Carbon R&D Expenditures | OECD (EPS Index) | 418 | 0.98 | 0.66 | 0.00 | 1.95 |
| Wind Energy Support (Auctions & FITs) | OECD (EPS Index) | 418 | 0.86 | 0.78 | 0.00 | 1.95 |
| CO2 Trading Scheme | OECD (EPS Index) | 418 | 0.67 | 0.50 | 0.00 | 1.79 |
| Renewable Energy Trading scheme | OECD (EPS Index) | 418 | 0.33 | 0.63 | 0.00 | 1.95 |
| Green Government Action Factor | | 418 | 0.00 | 0.98 | -2.60 | 0.82 |
| *Dimension 5: Monetary Institutions (2017-2019)* | | | | | | |
| Central Bank Independence Index | Romelli (2022) | 450 | 0.64 | 0.14 | 0.37 | 0.92 |
| Central Bank Independence – Board | Romelli (2022) | 450 | 0.51 | 0.15 | 0.04 | 0.80 |
| Central Bank Independence – Objectives | Romelli (2022) | 450 | 0.60 | 0.33 | 0.00 | 1.00 |
| Central Bank Independence – Constitution | Romelli (2022) | 450 | 0.34 | 0.47 | 0 | 1 |
| Central Bank Transparency Index | Dincer, Eichengreen, Geraats (2022) | 450 | 8.44 | 3.25 | 2.00 | 14.50 |
| Central Bank Transparency Index – Goal | Dincer, Eichengreen, Geraats (2022) | 450 | 2.44 | 0.66 | 1.00 | 3.00 |

**Table A3 (continued)**

| | Source | N | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|---|---|
| Central Bank Transparency Index – Procedure | Dincer, Eichengreen, Geraats (2022) | 450 | 1.37 | 0.89 | 0.00 | 3.00 |
| Central Bank Transparency Index – Decision Making | Dincer, Eichengreen, Geraats (2022) | 450 | 1.62 | 0.99 | 0.00 | 3.00 |
| Monetary Institutions Factor | | 450 | 0.00 | 1.00 | -1.97 | 1.85 |
| *Dimension 5: Monetary Institutions (2021)* | | | | | | |
| Central Bank Independence Index | Romelli (2022) | 1,106 | 0.72 | 0.16 | 0.37 | 0.93 |
| Central Bank Independence – Board | Romelli (2022) | 1,106 | 0.62 | 0.22 | 0.04 | 0.94 |
| Central Bank Independence – Objectives | Romelli (2022) | 1,106 | 0.73 | 0.32 | 0.00 | 1.00 |
| Central Bank Independence – Constitution | Romelli (2022) | 1,106 | 0.37 | 0.48 | 0 | 1 |
| Monetary Institutions Factor | | 1,106 | -0.00 | 1.00 | -2.23 | 1.36 |
| *Dimension 6: Monetary Institutions (2021)* | | | | | | |
| Border to NGFS-Member | | 1,320 | 0.28 | 0.45 | 0 | 1 |

We regress NGFS membership on each factor separately using logit models for the years 2017, 2019, and 2021. These years are chosen because they coincide with the major expansion of the network and therefore exhibit substantial variation in membership. This design also allows us to verify that the results are not driven by a single cutoff year. While the main text reports qualitative summaries across all three years, Table A4 and Table A5 present the full regression results.

The results can be summarized as follows. First, higher levels of economic development are consistently and significantly positively associated with NGFS membership across all three years. Second, exposure to physical climate risk is negatively correlated with membership, suggesting that NGFS members are less vulnerable to climate-related shocks. Next, public concern about climate change is found to be positively linked to membership,

with particularly strong and statistically significant effects observed in 2019. Fourth, green regulatory stringency is positively correlated with NGFS membership, although the estimates are less precise due to the small number of observations. Fifth, higher central bank independence and transparency are significantly connected to membership from 2017 onwards. Finally, geographic proximity to existing members displays a positive and generally statistically significant association with NGFS participation.

**Table A4: Determinants of NGFS Membership – Full Regressions Part I**

| | *Dependent variable:* NGFS-Membership | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *Economic Development* | | | *Vulnerability to Climate Change* | | | *Public Perception of Climate Change* | |
| | *2017* | *2019* | *2021* | *2017* | *2019* | *2021* | *2017* | *2019* |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Factor | 1.45** | 1.77*** | 1.69*** | -0.65 | -1.32*** | -1.71*** | 0.35 | 1.21*** |
| | (0.73) | (0.54) | (0.59) | (0.43) | (0.36) | (0.56) | (0.24) | (0.41) |
| Constant | -2.59*** | 0.23 | 2.66*** | -2.63*** | -0.14 | 2.52*** | -0.10 | 2.68** |
| | (0.64) | (0.33) | (0.67) | (0.48) | (0.26) | (0.57) | (0.23) | (0.54) |
| Observations | 52 | 52 | 53 | 78 | 76 | 73 | 80 | 75 |
| Log Likelihood | -16.14 | -27.57 | -16.59 | -20.03 | -42.77 | -23.80 | -54.23 | -19.96 |
| Akaike Inf. Crit. | 36.28 | 59.14 | 37.18 | 44.05 | 89.54 | 51.61 | 112.46 | 43.93 |
| *Note:* | | | | | | | | *p<0.1; **p<0.05; ***p<0.01 |

**Table A5: Determinants of NGFS Membership – Full Regressions Part II**

| | *Dependent variable:* NGFS-Membership | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *Green Regulation* | | *Independent Monetary Institutions* | | | *Border to NGFS-Member* | | |
| | *2017* | *2019* | *2017* | *2019* | *2021* | *2017* | *2019* | *2021* |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Factor | 0.95 | 0.69* | -0.33 | 0.70** | 0.87*** | 1.28 | 1.32*** | 1.99*** |
| | (1.04) | (0.38) | (0.51) | (0.35) | (0.33) | (0.82) | (0.45) | (0.63) |
| Constant | -1.95*** | 1.19*** | -2.35*** | -0.46 | 1.83*** | -2.82*** | -0.93*** | 0.56 |
| | (0.64) | (0.41) | (0.54) | (0.33) | (0.36) | (0.51) | (0.33) | (0.36) |
| Observations | 38 | 38 | 45 | 45 | 79 | 88 | 88 | 88 |
| Log Likelihood | -15.76 | -19.03 | -13.29 | -28.39 | -31.44 | -23.31 | -55.73 | -35.97 |
| Akaike Inf. Crit. | 35.51 | 42.07 | 30.58 | 60.78 | 66.89 | 50.63 | 115.47 | 75.93 |
| *Note:* | | | | | | | | *p<0.1; **p<0.05; ***p<0.01 |

## Table A6: Variable definitions

Notes: This table provides variable definitions and sources. Panel A reports variables used in the panel-data determinant regressions. Panel B and C report variables used in the stock market- and event study analyses (part I and II), respectively. Panel D reports the variables used for analysis of the medium-term transmission, focusing on green bonds issuances.

| Variable | Definition | Source |
|---|---|---|
| ***Panel A: Panel determinant regressions*** | | |
| Joining NGFS | Binary variable that takes the value 1 if the country's central bank was recorded as joining the NGFS in a particular year (and 0 otherwise) | Deutsche Bundesbank |
| NGFS member | Binary variable that takes the value 1 if the country's central bank was recorded as being a NGFS member in a particular year | Deutsche Bundesbank |
| Inflation gap | Annual CPI; HP Filtered Gap; 1980-2023. | WDI: FP.CPI.TOTL.ZG |
| Output gap | GDP in 2010 US$; HP Filtered Gap; 1980-2023. | WDI: NY.GDP.MKTP.KD |
| Unemployment rate | Unemployment as % of total labor force. Unemployment refers to the share of the labor force that is without work but available for and seeking employment. | WDI: SL.UEM.TOTL.ZS |
| ***Panel B: Event study I - Global financial market reaction*** | | |
| AR clean energy stocks [t] | Abnormal returns for clean energy stocks on each day of the specified event window. Calculated using an event study methodology. | Own calculation \| Datastream |
| AR fossil fuel stocks [t] | Abnormal returns for fossil fuel stocks on each day of the specified event window. Calculated using an event study methodology. | Own calculation \| Datastream |
| AR difference portfolio [t] | Difference between abnormal returns for clean energy and fossil fuel stocks on each day of the specified event window. | Own calculation \| Datastream |
| CAR clean energy [$t_1$;$t_2$] | Cumulative sum of the calculated abnormal returns for clean energy stocks and the respective time interval specified. | Own calculation \| Datastream |
| CAR fossil fuel [$t_1$;$t_2$] | Cumulative sum of the calculated abnormal returns for fossil fuel stocks and the respective time interval specified. | Own calculation \| Datastream |
| CAR difference portfolio [$t_1$;$t_2$] | Cumulative sum of the difference between abnormal returns for clean energy and fossil fuel stocks and the respective time interval. | Own calculation \| Datastream |
| GreenMPSurprise | Relative GDP contribution per joining date, measured in relation to the world-wide year end GDP in the respective joining year. | Own calculation \| WDI: NY.GDP.MKTP.KD |
| Network size (ln) | Size of the network measured as the sum of each members' GDP after the respective announcement date. | Own calculation \| WDI: NY.GDP.MKTP.KD |
| Abnormal network size | Demeaned size of the network measured as the sum of each members' GDP after the respective announcement date. | Own calculation \| WDI: NY.GDP.MKTP.KD |

**Table A6 (continued)**

| Variable | Definition | Source |
|---|---|---|
| ***Panel C: Event study II - US firm-level event study analysis*** | | |
| Environmental score | Environmental pillar score as provided by Refinitiv | Datastream |
| Emissions score | Emissions score as provided by Refinitiv. | Datastream |
| Emission intensity | Calculated as the sum of Scope 1- and Scope 2 emissions (in tons) scaled by market capitalization (measured in thousands of US-Dollars). | Own calculation \| Datastream |
| Size | Logarithm of the market capitalization (measured in thousands of US-Dollars). | Own calculation \| Datastream |
| Sales growth | Year-on-year growth of net sales. | Own calculation \| Datastream |
| Leverage | Total debt divided by the book value of total assets. | Own calculation \| Datastream |
| Profitability | Net income scaled by the book value total assets. | Own calculation \| Datastream |
| ETR | Measure of cash effective tax rate following Bauer et al. (2024). Calculated as (total) income tax paid scaled by pre-tax income. | Own calculation \| Datastream |
| Return (Price), raw | Equity market returns from December 14 to December 15, 2020, based on adjusted closing prices. | Own calculation \| Datastream |
| ***Panel D: Green bond issuance reaction*** | | |
| Green Bonds | Issue amount of green and sustainability-linked bonds, designed specifically to support climate and environmental projects. Reported in billion US-Dollars per country and year. | IMF Dataset |

## Table A7: Descriptive statistics

Notes: This table provides descriptive statistics for our variables defined in Table A6 and adopts the structure. Panel A reports variables used in the panel-data determinant regressions. Panel B and C report variables used in the stock market- and event study analyses (part I and II), respectively. Panel D reports the variables used for analysis of the medium-term transmission, focusing on green bonds issuances.

***Panel A: Panel determinant regressions***

| Variable | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Joining NGFS | 590 | 0.12 | 0.33 | 0.00 | 1.00 |
| Inflation gap | 590 | -0.03 | 0.88 | -2.94 | 3.87 |
| Output gap | 590 | 0.05 | 1.52 | -5.03 | 3.71 |
| Unemployment rate | 590 | 7.61 | 5.08 | 0.12 | 34.01 |
| GDP per capita | 590 | 23.05 | 22.92 | 0.83 | 104.62 |

***Panel B: Event study I - Global financial market reaction***

| Variable | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| CAR clean energy stocks [-1;1] | 29 | -0.908 | 1.996 | -4.618 | 2.380 |
| CAR clean energy stocks [-1;3] | 29 | -0.817 | 3.251 | -8.535 | 6.083 |
| CAR difference portfolio [-1;1] | 29 | -0.908 | 4.502 | -14.545 | 8.336 |
| CAR difference portfolio [-1;3] | 29 | -1.640 | 5.945 | -16.142 | 8.414 |
| GreenMPSurprise | 29 | 0.021 | 0.046 | 0.001 | 0.246 |
| Network size (ln) | 29 | 3.896 | 0.375 | 3.258 | 4.353 |
| Abnormal network size | 29 | 0.000 | 0.375 | -0.639 | 0.457 |
| AR clean energy stocks | 261 | -0.088 | 1.150 | -4.323 | 3.923 |
| AR fossil fuel stocks | 261 | 0.121 | 1.779 | -3.720 | 11.634 |
| AR difference portfolio | 261 | -0.209 | 2.172 | -12.976 | 6.921 |

***Panel C: Event study II - US firm-level event study analysis***

| Variable | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Environmental score | 3,097 | 0.28 | 0.27 | 0.00 | 0.98 |
| Emissions score | 3,097 | 0.28 | 0.31 | 0.00 | 1.00 |
| Emission intensity | 1,034 | 0.29 | 0.91 | 0.00 | 6.51 |
| Size | 3,097 | 14.52 | 1.83 | 10.89 | 19.14 |
| Sales growth | 3,097 | 0.08 | 0.63 | -0.87 | 4.66 |
| Leverage | 3,097 | 0.25 | 0.24 | 0.00 | 1.05 |
| Profitability | 3,097 | -0.05 | 0.20 | -1.05 | 0.29 |
| ETR | 3,097 | 0.09 | 0.42 | -2.60 | 1.61 |
| Return (Price), raw | 3,097 | 1.88 | 2.58 | -6.79 | 10.63 |

**Table A7 (continued)**

***Panel D: Green bond issuance reaction***

| Variable | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Green Bonds | 975 | 2.125 | 7.772 | 0.000 | 99.429 |
| NGFS-Membership | 975 | 0.237 | 0.425 | 0 | 1 |
| Year-Dummy | 975 | - | - | 2010 | 2022 |

### Table A8: ETFs underlying the industry proxies

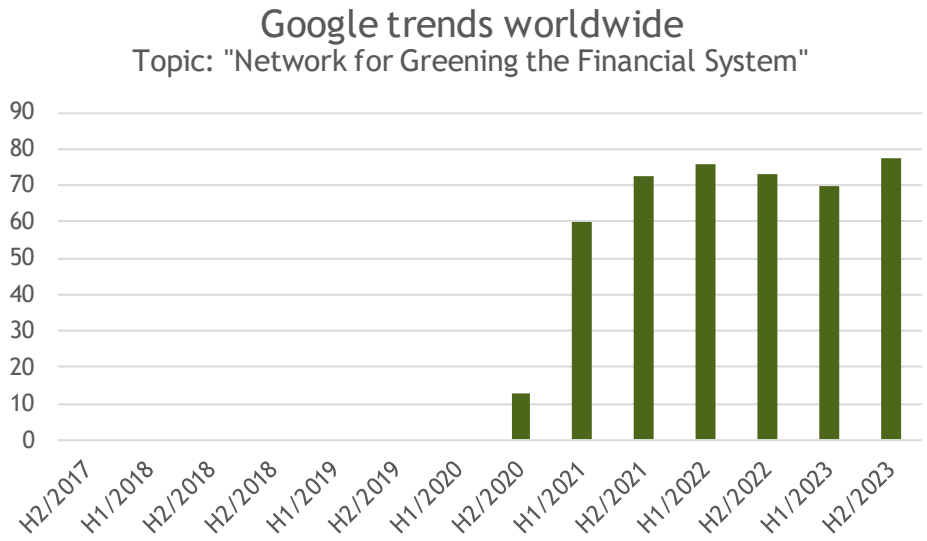
Notes: This table provides details on the ETFs used to calculate the stock market performance of the industry proxies used in the global event study (part I). The selection follows Antoniuk & Leirvik (2024) and Wallace & McIver (2019) and includes exchange-traded funds that invest in stocks of firms within the respective industries.

| Industry | ETF | ISIN |
|---|---|---|
| **Clean energy** | | |
| | VanEck Vectors Environmental Svcs ETF | US92189F3047 |
| | First Trust ISE Global Wind Energy Index Fund | US33736G1067 |
| | VanEck Low Carbon Energy ETF | US92189F5026 |
| | iShares Global Clean Energy ETF | US4642882249 |
| | Invesco Global Clean Energy ETF | US46138G8472 |
| | Invesco Wilderhill Clean Energy ETF | US46137V1347 |
| | First Trust NASDAQ Clean Edge Green Energy Index Fund | US33733E5006 |
| | Invesco Solar ETF | US46138G7060 |
| **Energy intensive** | | |
| | First Trust Energy AlphaDEX ETF | US33734X1274 |
| | iShares US Oil & Gas Explor&Prodtn | US4642888519 |
| | iShares Global Energy | US4642873412 |
| | iShares United States Energy | US4642877967 |
| | VanEck Vectors Oil Services ETF | US92189H6071 |
| | Invesco S&P 500 Equal Wt Energy ETF | US46137V3657 |
| | United States Oil ETF | US91232N2071 |
| | Vanguard Energy ETF | US92204A3068 |
| | SPDR S&P Oil & Gas Equipment & Svcs ETF | US78468R5494 |
| | Energy Select Sector SPDR ETF | US81369Y5069 |
| | SPDR S&P Oil & Gas Explor & Prodtn ETF | US78468R5569 |

## Figures

### Figure 1: Interest in “Network for Greening the Financial System”

Notes: This illustrates the raising interest in the “Network for Greening the Financial System” over time. It documents the average interest in the topic “Network for Greening the Financial System” according to Google trends. Raw data from https://trends.google.com/trends/explore?date=2017-12-01%202023-12-31&q=%2Fg%2F11fqxxz1yr&hl=en (accessed October 4, 2025)




### Figure 2: World-map of NGFS membership

Notes: This table illustrates the evolution of global membership in the NGFS. Founding members are highlighted in red, while non-founding members are shown in varying shades of green, reflecting their respective entry dates. Non-members are represented in gray. Detailed data can be found in Table A2.

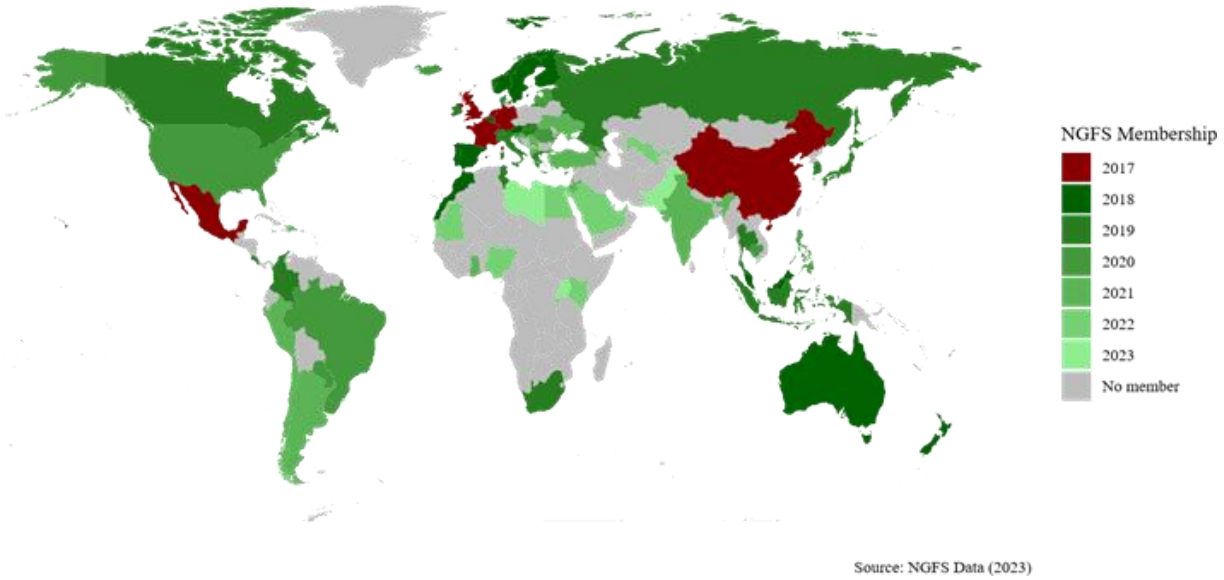


**Figure 3: Mentioning of NGFS in central banks speeches over time**

Notes: This graph depicts the frequency of "NGFS" mentions in central bank speech databases. Specifically, it tracks NGFS references over time and plots the average cumulative number of speeches against the days relative to NGFS membership entry.

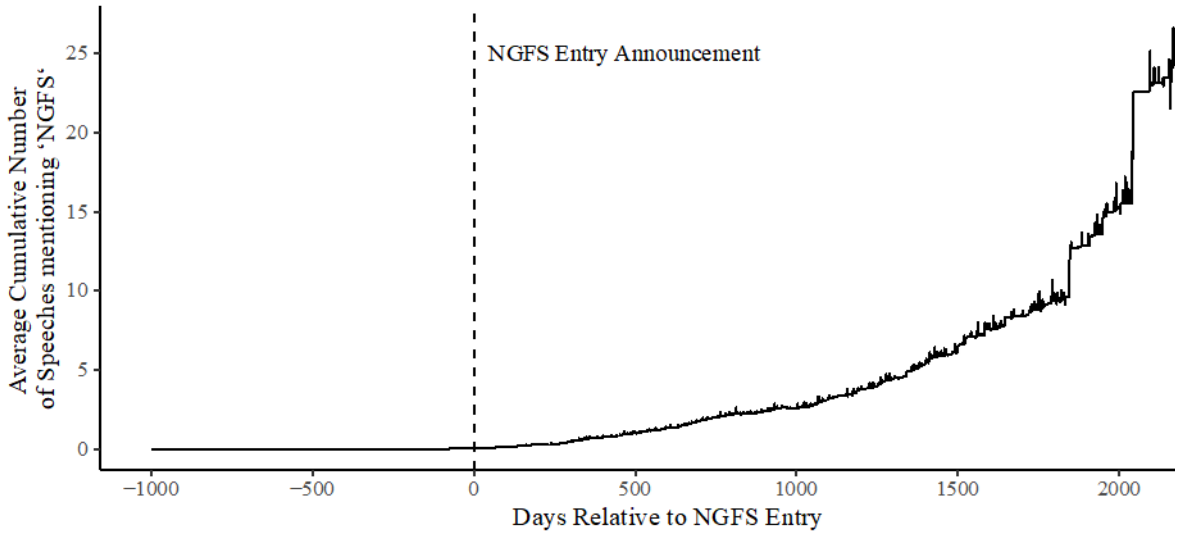



**Figure 4: Market response to the Paris Agreement (Dec 12, 2015)**

Notes: This graph presents the market response to the signing of the Paris Agreement on December 12, 2015. It reports cumulative (average) abnormal returns over event days -3 to 5, normalized to the event date, for clean energy and fossil fuel stocks. Since December 12, 2015, was a non-trading day, the event day (announcement date) is defined as the next trading day, December 14, 2015.

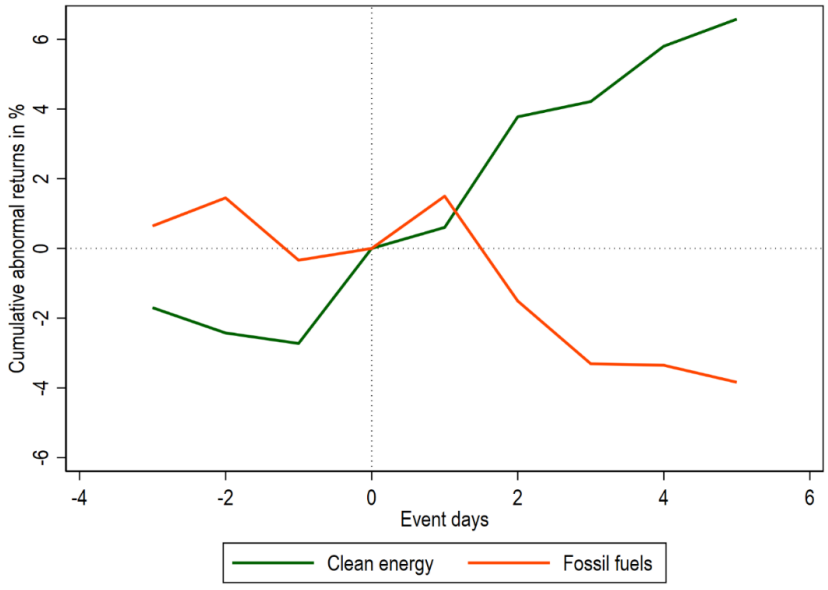


**Figure 5: Green bond analysis - Evolution of the NGFS coefficients**

Notes: This graph illustrates the coefficients in equation (5) from Table 5. The error bars show the 95% confidence intervals for the coefficients.

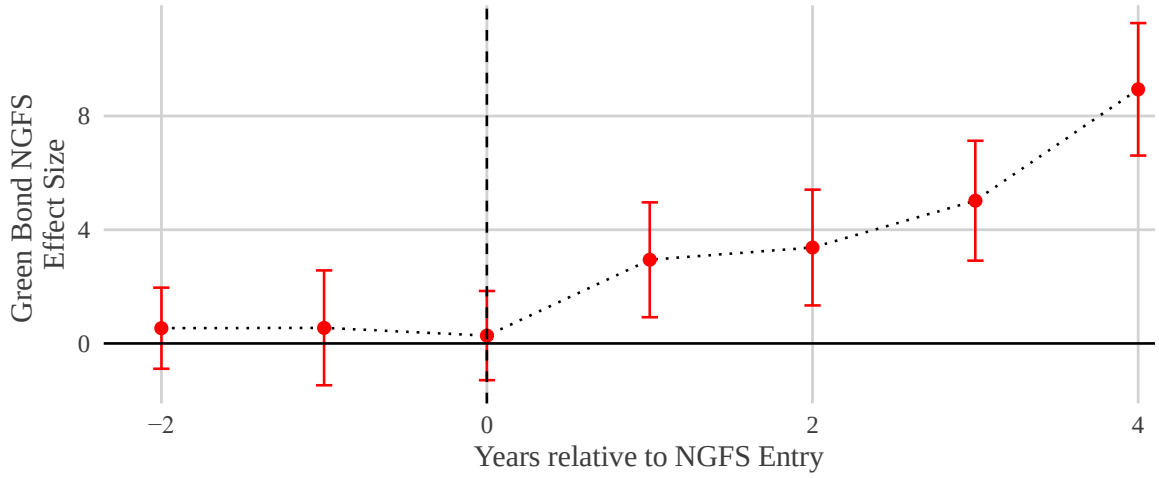
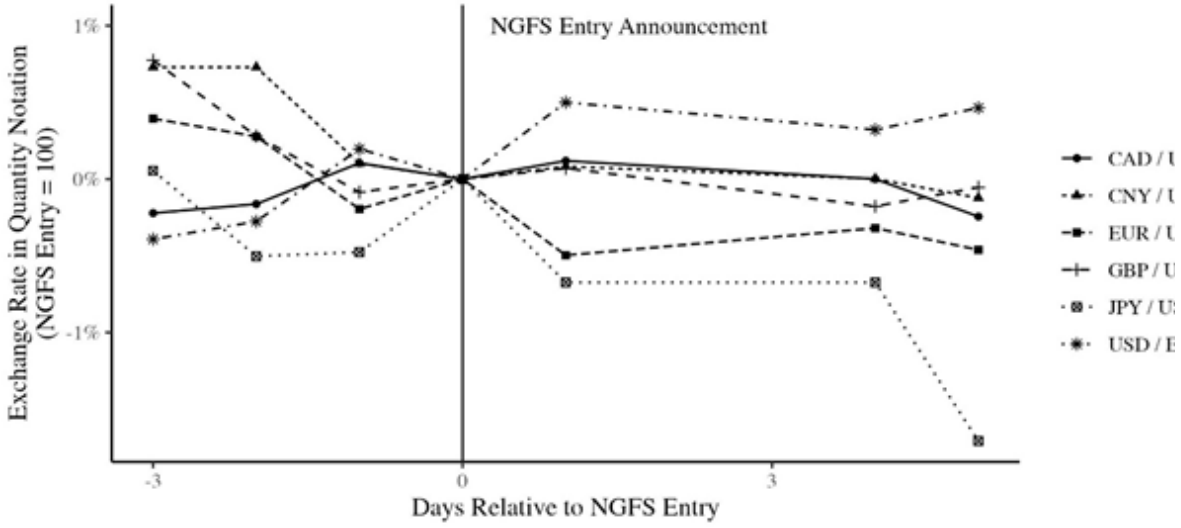


**Figure 6: Exchange rates around NGFS entries**

Notes: This graph depicts selected exchange rates relative to the respective NGFS entry announcements of the Bank of Canada, the Central Bank of the People's Republic of China, the ECB, the Bank of England, the Bank of Japan, and the Fed. The exchange rates are sourced from the FRED database in quantity notation. The base currency is the USD, for the Fed it is the EUR.



## Tables

### Table 1: Determinants of NGFS Membership

Notes: This table summarizes insights from an extended descriptive analysis regressing latent factors, constructed from social, macroeconomic, and institutional variables, on NGFS membership to assess whether these characteristics are systematically different between NGFS member countries and other countries. Details of the analysis are outlined in Appendix A1.

| | *Economic Development* | *Border to NGFS-Member* | *Public Perception of Climate Change* | *Green Government Regulation* | *Vulnerability to Physical Risk* | *Monetary Institutions* |
|---|---|---|---|---|---|---|
| NGFS-Membership | + | + | + | + | - | + |

**Table 2: More on central bank's decision to join the NGFS**

Notes: This table reports the results of logistic panel regressions of Joining the NGFS on several objectives of central banks. Inflation gap is the deviation from the long-term inflation trend (specification 1). Output gap is the deviation from the long-term Output-trend (specification 2). Deviations from long term trends are estimated using HP-filtered time series. Unemployment rate is measured as % of total labor force (specification 3). Specification (5) excludes countries with a real income below 10,000 US-Dollars. All specifications account for time- and individual-specific fixed effects. T-statistics are in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels. A detailed description of the variables used is provided in Table A6.

| Dependent variable | Joining NGFS | | | | |
|---|---|---|---|---|---|
| Specification | (1) | (2) | (3) | (4) | (5) |
| Inflation gap | -1.400*** | | | -1.390*** | -1.243** |
| | (-3.680) | | | (-3.588) | (-2.340) |
| Output gap | | 0.404*** | | 0.418*** | 0.450* |
| | | (2.587) | | (2.618) | (1.884) |
| Unemployment rate | | | 0.143 | 0.201 | 0.292 |
| | | | (1.087) | (1.405) | (1.330) |
| Country FE | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes |
| Countries > 10k Dollar | No | No | No | No | Yes |
| Observations | 590 | 590 | 590 | 590 | 352 |
| Log Likelihood | -187.838 | -192.54 | -195.521 | -183.641 | -105.467 |
| Akaike Inf. Crit. | 539.676 | 549.081 | 555.042 | 535.283 | 318.934 |

**Table 3: Event study results – global financial market reaction**

Notes: This table reports the results of OLS- and median regressions of the cumulative (average) abnormal returns (CAR) of clean energy stocks and a difference portfolio on the respective network enlargements by national banks joining the Network for Greening the Financial System. The difference portfolio is computed as the difference in cumulative returns between clean energy and fossil fuel stocks, mimicking a portfolio that is long in clean energy- and short in fossil fuel stocks. GreenMPSurprise is defined as the network enlargement, and calculated as the relative GDP contribution per joining date, in relation to the world-wide year end GDP in the respective joining year. Abnormal network size is calculated as the demeaned size of the network measured as the sum of each members' GDP after the respective announcement date (Specifications 3 to 5). Robust t-statistics are in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels. A detailed description of the variables used is provided in Table A6.

| Dependent variable | *CAR* | | | | |
|---|---|---|---|---|---|
| | clean energy – fossil fuel | | | | clean energy |
| Specification | (1) | (2) | (3) | (4) | (5) |
| *GreenMPSurprise x Network enlargement* | 44.38*** | 38.85** | 48.38*** | 31.49*** | 28.77*** |
| | (5.20) | (2.38) | (4.49) | (4.03) | (6.68) |
| Abnormal network size | | | -5.91* | -4.86** | -3.69** |
| | | | (-2.01) | (-2.59) | (-2.56) |
| Constant | -2.57** | -1.16 | -2.66** | -1.86** | -1.42** |
| | (-2.22) | (-0.96) | (-2.35) | (-2.09) | (-2.34) |
| Observations | 29 | 29 | 29 | 29 | 29 |
| R-squared | 0.12 | 0.12 | 0.26 | 0.25 | 0.29 |
| Method | OLS | Median | OLS | OLS | OLS |
| Event window | [-1;+3] | [-1;+3] | [-1;+3] | [-1;+1] | [-1;+3] |

**Table 4: Event study results – US firm-level reaction**

Notes: This table reports the results of regressions of the raw equity returns of US firms on three environmental measures and a set of firm controls. While specifications (1) and (2) employ the environmental and emissions score as proxies for measuring firms' greenness, specification (3) uses firms' emission intensity. All models include controls for firm size, sales growth, leverage, profitability, and effective tax rate. Additionally, specification (3) incorporates industry fixed effects based on the Fama-French classification (17 industries). Robust t-statistics that allow for clustering at the industry-level are in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels. A detailed description of the variables used is provided in Table A6.

| Dependent Variable | Raw Return (Dec 14-15, 2020) | | |
|---|---|---|---|
| Method | OLS | | |
| Specification | (1) | (2) | (3) |
| Environmental Score | 1.369*** | | |
| | (3.36) | | |
| Emission score | | 0.905** | |
| | | (2.92) | |
| Emission intensity | | | -0.280*** |
| | | | (-2.94) |
| Size | -0.238*** | -0.219*** | -0.268*** |
| | (-3.97) | (-3.55) | (-4.97) |
| Sales growth | -0.250*** | -0.280*** | -0.591 |
| | (-3.30) | (-3.68) | (-1.32) |
| Leverage | 0.264 | 0.256 | 0.208 |
| | (1.22) | (1.12) | (0.78) |
| Profitability | 1.718*** | 1.843*** | -0.234 |
| | (5.65) | (5.96) | (-0.31) |
| Effective tax rate | 0.053 | 0.082 | -0.201** |
| | (0.67) | (0.96) | (-2.73) |
| Constant | 4.998*** | 4.851*** | |
| | (7.95) | (7.61) | |
| Observations | 3,097 | 3,097 | 1,034 |
| R-squared [adj.] | 0.041 | 0.036 | 0.124 |
| Industry fixed effects | No | No | Yes |

**Table 5: Regression results - green bond issuance reaction**

Notes: T-statistics are in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels. A detailed description of the variables used is provided in Table A6.

| Dependent variable | Green Bond Issuance | | | | |
|---|---|---|---|---|---|
| Specification | (1) | (2) | (3) | (4) | (5) |
| NGFS | 6.94*** | 3.42*** | 2.65*** | 4.05*** | |
| | (12.82) | (4.48) | (4.06) | (3.04) | |
| $NGFS_{-1}$ | | | | 0.55 | -0.07 |
| | | | | (0.53) | (-0.11) |
| $NGFS_0$ | | | | 0.27 | 0.41 |
| | | | | (0.34) | (0.59) |
| $NGFS_1$ | | | | 2.94*** | 1.67** |
| | | | | (2.86) | (2.28) |
| $NGFS_2$ | | | | 3.37*** | 1.46* |
| | | | | (3.25) | (1.83) |
| $NGFS_3$ | | | | 5.02*** | 2.97*** |
| | | | | (4.66) | (3.34) |
| $NGFS_4$ | | | | 8.94*** | 6.46*** |
| | | | | (7.53) | (6.31) |
| GDP | | | 5.58*** | | 4.66*** |
| | | | (18.37) | | (8.91) |
| Constant | 0.48* | -0.83 | -2.13 | -2.76 | -2.08 |
| | (1.82) | (-0.46) | (-1.38) | (-0.62) | (-1.44) |
| Observations | 975 | 975 | 975 | 593 | 593 |
| R-squared [adj.] | 0.14 | 0.40 | 0.57 | 0.15 | 0.68 |
| Regression Type | Panel | Panel | Panel | DiD | DiD |
| Year effects | No | Yes | Yes | No | Yes |
| Country effects | No | Yes | Yes | No | Yes |

## Online Appendix for

# "Central banks sowing the seeds for a green financial system? NGFS membership and market reactions"

## not for publication

This online appendix provides supplementary material. Section I details the construction of the various datasets used in the paper. Section II presents additional analyses, expanding upon the results presented in the paper.

## I. Datasets

In the paper we use three empirical settings, which build on different datasets. In the following, we provide detailed information on the construction of these datasets.

### I.1 Starting point

Starting point of much of the analysis is a dataset provided by the Deutsche Bundesbank (German Federal Bank). This dataset, an Excel file which we received end of April 2023, lists a total of 146 institutions that were affiliated with the NGFS, either as a member or as an observer. Moreover, the file also reports an *internal* joining date for each institution.

Interested in the role of central banks for greening the financial system, we exclude (i) non-central bank financial supervisory institutions, (ii) central banks at the supranational level (e.g., the European Central Bank), and (iii) institutions listed as "observers" (e.g., the OECD). This resulted in a list of 84 central banks from around the world, including the *internal* joining date.

Reviewing the data and in particular the internal joining dates, we notice that these internal joining dates probably refer to the date when the NGFS Chair issued the official acceptance letter approving the NGFS application of the institution—a date that is (according to the rules and procedures of the network) private information.

To construct economically meaningful event dates, we therefore rely on publicly available information on NGFS accessions from 2018 onwards. We combine two sources: (i) official NGFS press releases announcing network enlargements as announced via NGFS press releases on the NGFS website (NGFS, 2023), and (ii) accession announcements published by the respective central banks on their websites. This is necessary because NGFS

accessions involve two distinct communicating parties, and there is no standardized disclosure protocol governing the timing of announcements (see also section 2.2 of the main text). This institutional setting gives rise to asynchronous information disclosure. NGFS press releases typically cluster multiple accessions into a single announcement, reflecting internal coordination processes. In contrast, central banks may communicate their accession decisions independently, sometimes before and sometimes after the corresponding NGFS announcement.[27] As a result, accession-related information is disseminated gradually rather than at a single, perfectly synchronized point in time.

To account for this feature, we define the event date as the earliest publicly available announcement across both sources. This approach identifies the first point in time at which market participants could have observed the information and mitigates the clustering induced by NGFS press releases.

Applying this procedure yields 30 distinct announcement dates. As our analysis focuses on accession events, we exclude the initial formation of the NGFS in December 2017. The final event dataset therefore consists of 29 accession events covering a total of 73 central banks.[28]

## I.2 Country-level dataset

To examine our first research question—*which central banks do join the NGFS?*—we create a panel dataset at the country level. We use this dataset to (1) analyze cross-country determinants of central bank NGFS membership and (2) investigate the roles of both primary (price stability) and secondary (economic slack) central bank objectives on NGFS membership. Furthermore, we use this dataset to study the mid- to long term consequences of central banks joining the NGFS in the bond market.

We create this dataset in several steps.

- First, we download macroeconomic data from the World Bank's World Development Indicators for all available countries worldwide.
- Second, we add information from the initial data set. Specifically, we create

[27] For instance, the recorded joining date for the Bank of Greece is January 25, 2019. And indeed, reviewing the official press release of the Bank of Greece from January 31, 2019, it announces that "[t]he Bank of Greece became a member of the Network of Central Banks and Supervisors for Greening the Financial System (NGFS) on 25 January 2019." As such, however, the "event" that the Bank of Greece joins the NGFS, did not become public information of January 25, 2019.

[28] We are unable to find press statements or statements on the central banks' websites for six cases listed in the NGFS member list as provided by the Deutsche Bundesbank. We ignore events when central banks join the network for which we are unable to find an official press release, as it is arguably difficult to identify the timing of the flow of information in these cases. In total, we find 29 accession events covering 73 different central banks joining the network from 2018 onwards.

    - an indicator variable $Joining\ NGFS$ equal to 1 if a country's central bank was recorded as joining the NGFS in a particular year (and 0 otherwise), and
    - an indicator variable $NGFS\ member$ equal to 1 if a country's central bank was recorded as being a NGFS member in a particular year (and 0 otherwise).
- Third, we add
    - population data from the CIESIN (Center for Integrated Earth System Information, Columbia University),
    - the central bank independence index developed by Romelli (2022), and
    - geographical data from the CEPII (Centre d'Etudes Prospectives et d'Informations Internationales).
- *Fourth*, we complement this panel dataset with IMF's Climate Change Green Bonds database (Mertzanis, 2024). This database compiles fixed-income instruments designed to finance or refinance sustainability projects, commonly referred to as 17 "green bonds". In total, this dataset encompasses green bond issuances across 75 countries from 2010 to 2022, and up to 975 country-year observations.

### I.3 ETF dataset (Event study I)

Interested in the short-run consequences of green monetary policy surprises in global equity markets, we collect information on global thematic ETFs to proxy the development of different parts of the global equity market (Antoniuk & Leirvik, 2024; Bauer et al., 2024; Ramiah et al. (2013); Wallace & McIver, 2019). As the NGFS aims to mobilizing capital for the green transition we opt for two types of ETFs: ETFs investing in clean energy stocks, and ETFs investing in fossil fuel stock, respectively.

### I.4 US listed firm dataset (Event study II)

To substantiate the ETF analysis, we also collect firm-level information. Specifically, we use the most important enlargement event, the announcement that the US Fed has joined the initiative, and—following the methodology of Bauer et al. (2024)—use firm-level data of US listed firms.

Given that the Federal Reserve announced to join the NGFS on December 15, 2020, and the announcement was made public at 9 a.m., we use (raw) equity market returns from December 14 to December 15, 2020 to capture the short-term market reaction. Interested

in the role of "green" and "brown" firm characteristics in the cross-section we include three different measures of firms' greenness: (1) Environmental score, (2) emissions score and (3) emission intensity.[29]

In constructing the dataset, we proceed in five steps. *First*, we carefully start constructing our sample by retrieving all available U.S. securities included in the Refinitiv U.S. ESG-Universe as of December 9, 2024 (Bauer et al., 2024).[30] Our initial dataset consists of 3,649 individual securities. *Second*, we then exclude securities with missing emissions scores for 2020, reducing the sample to 3,130 securities. *Third*, in line with established practices, we further refine our sample by excluding non-equity and non-primary security types (e.g., Ince & Porter, 2006). *Fourth*, as we focus on U.S. firms (more precisely, equity returns of firms being traded on U.S. stock exchanges on our event day), we also exclude all firms not listed on either the NYSE, NASDAQ, or AMEX, following the approach of Bauer et al. (2024). *Fifth*, we exclude firms with earnings announcements or closing prices below $1 on the event days (December 14 to December 15, 2020), and require non-missing firm-level control covariates as per 2020.[31] These refinements result in an intermediate sample of 2,693 firms.

To encounter a survivorship bias (e.g., Hanauer, 2014), we supplement this sample with delisted or dead companies.[32] By applying the same filtering criteria as above we account for additional 404 firms. In total, our fourth dataset covers a maximum of 3,097 firm observations.

[29] While the first two metrics, as designated by Refinitiv, offer *indirect* measures of environmental performance, we incorporate firms' self-reported emissions data to provide a more direct and granular assessment of their greenness. We calculate emission intensity as the sum of Scope 1 and Scope 2 emissions, standardized by market capitalization.

[30] This constituent list corresponds to Refinitiv list identifier *LA4CTYUS*.

[31] These control covariates include: firm size (measured as the natural logarithm of market capitalization), sales growth (year-on-year change in net sales), book leverage (total debt scaled by total assets), and profitability (net income scaled by total assets), the effective tax rate (ETR, calculated as the ratio of total income taxes paid to pretax income), and industry controls based on the Fama-French classification scheme, which categorizes firms into 17 industries based on SIC codes. To account for potential outliers, we winsorize all variables (except for E-/emission scores) at the 1% percentiles.

[32] Given that the U.S. ESG-Universe exclusively encompasses active companies, we supplement our intermediate sample with delisted and dead firms that satisfy the same selection criteria as the U.S. sample mentioned above. These firms are identified via the global ESG/Sustainable Finance inactive list (*LA4GLINA*).

## II. Robustness of results and additional analyses

This section details robustness checks and supplementary analyses, focusing primarily on the U.S. firm-level event study examining stock market reactions to the Federal Reserve's December 2020 NGFS membership.

### II.1 Event study II: US firm-level reaction

In this section, we provide additional robustness tests and analyses regarding the firm-level stock market reaction following the NGFS joining of the FED on December 15, 2020. We proceed in several steps. *First*, following Bauer et al. (2024) we utilize the Frisch-Waugh-Lovell Theorem to examine the cross-sectional baseline regressions (see Table 4) in more detail. *Second*, as common in empirical finance studies, we check whether our estimates are robust to the exclusion of financial firms. *Third*, we re-estimate our baseline regression from Table 4 using lagged control variables. *Finally*, we conduct additional analyses regarding the emission intensity.

To examine our baseline regression results of the US firm-level analysis in more detail, we further investigate the cross-sectional correlations between firms' green characteristics and their returns by utilizing portfolio (decile) regressions.

We follow Bauer et al. (2024) and orthogonalize returns and green characteristics by our control covariates. Invoking the Frisch-Waugh-Lovell theorem, by regressing the orthogonalized returns on the respective orthogonalized green characteristics, we exactly recover our regression coefficients for the E-/Emissions score and emission intensity from Table 4. We then sort our greenness characteristics in decile portfolio and plot them against their respective mean portfolio returns. By conducting this exercise, we end up with three plots which allow us to inspect the correlations in more detail. The corresponding results are depicted within Figure A.II.1: .

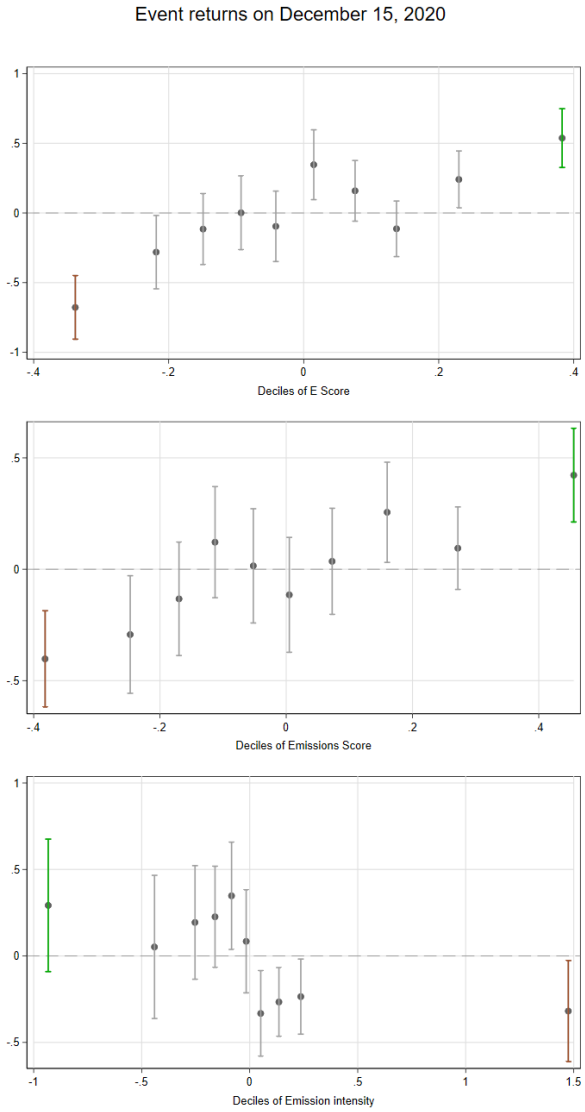
Overall, we corroborate our initial regression results for all of our greenness characteristics. More precisely, we show that the overall statistical significances in our event return regressions are primarily driven by firms which are sorted into the lowest and highest deciles of E-/Emission scores, and emission intensities, respectively. Green firms, as characterized by high E-/Emission scores and low emission intensities outperform their counterparts on the event day.

Our findings reveal that, in magnitude, the returns of green firms exceed those of brown firms by approximately 1.25 percentage points when proxied using E scores and emissions scores, and by approximately 0.5 percentage points when proxied using emission intensity

Finally, the (mostly) non-overlapping green and brown confidence intervals confirm the statistical significance of our results for all three greenness measures (Bauer et al., 2024).

### Figure A.II.1: Event returns across decile portfolios

Notes: This figure reports additional information on our baseline regressions as illustrated in Table 4. It presents event returns for decile portfolios sorted on three greenness metrics: Environmental scores, emission scores, and emission intensities. Portfolios are formed for the FEDs entry to the NGFS (on December 15, 2020). Event returns are calculated for each decile, controlling for firm-level covariates by orthogonalizing them with respect to firm size, sales growth, leverage, profitability, and effective tax rate (additionally, we account for industry-fixed effects when running regressions with emission intensity as our key independent variable of interest). All regressions include robust t-statistics that allow for clustering at the industry-level. For the emission intensity portfolios, all calculations incorporate industry fixed effects based on the Fama-French classification (17 industries). In all illustrations, the vertical bars represent 90% confidence intervals. Greenest (brownest) deciles are visually highlighted in green (brown).



Following standard practice in empirical finance research, we assess the robustness of our estimates by excluding financial firms. Specifically, we reestimate our baseline regression model from Table 4, omitting financial firms as defined by the Fama-French 17 classification scheme. The results, presented in Table A.II.1, confirm the robustness of our findings, with coefficients for E scores and emissions scores exhibiting slightly higher statistical significance, while those for emission intensity show slightly lower significance. These results reinforce our initial conclusions.

**Table A.II.1: Event study results – US firm-level reaction excluding financials**

Notes: This table reports the results of regressions of the raw equity returns of US firms on three environmental measures and a set of firm controls, excluding financial firms based on the Fama-French classification (17 industries). While specifications (1) and (2) employ the environmental and emissions score as proxies for measuring firms' greenness, specification (3) uses firms' emission intensity. All models include controls for firm size, sales growth, leverage, profitability, and effective tax rate. Additionally, specification (3) incorporates industry fixed effects based on the Fama-French classification (17 industries). Robust t-statistics that allow for clustering at the industry-level are in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels. A detailed description of the variables used is provided in Table A6.

| Dependent Variable | Raw Return (Dec 14-15, 2020) | | |
|---|---|---|---|
| Method | OLS | | |
| Specification | (1) | (2) | (3) |
| Environmental Score | 1.518*** | | |
| | (4.46) | | |
| Emission score | | 1.054*** | |
| | | (3.64) | |
| Emission intensity | | | -0.272** |
| | | | (-2.87) |
| Constant | 5.413*** | 5.162*** | |
| | (11.41) | (9.38) | |
| Observations | 2,401 | 2,401 | 863 |
| R-squared [adj.] | 0.041 | 0.036 | 0.118 |
| Industry fixed effects | No | No | Yes |
| Firm-level controls | Yes | Yes | Yes |

In our baseline regressions, we use firm-level environmental and accounting data from the end of 2020, as our event of interest took place in mid-December 2020, making year-end data the most relevant for capturing the firm's characteristics near the event date. To address potential concerns with this approach, we follow a standard methodology by lagging all control covariates by one period (i.e., by one year). Table A.II.2 presents the

results of this exercise. Our results remain robust to this analysis, with slightly reduced statistical significance across all greenness measures. However, all measures remain statistically significant at the 5% level.

**Table A.II.2: Event study results – lagged control covariates**

Notes: This table reports the results of regressions of the raw equity returns of US firms on three environmental measures and a set of firm controls. While specifications (1) and (2) employ the environmental and emissions score as proxies for measuring firms' greenness, specification (3) uses firms' emission intensity. All models include controls for firm size, sales growth, leverage, profitability, and effective tax rate. All control covariates are lagged by one period. Additionally, specification (3) incorporates industry fixed effects based on the Fama-French classification (17 industries). Robust t-statistics that allow for clustering at the industry-level are in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels. A detailed description of the variables used is provided in Table A6.

| Dependent Variable | Raw Return (Dec 14-15, 2020) | | |
|---|---|---|---|
| Method | OLS | | |
| Specification | (1) | (2) | (3) |
| Environmental Score | 1.218** | | |
| | (2.74) | | |
| Emission score | | 0.786** | |
| | | (2.48) | |
| Emission intensity | | | -0.223** |
| | | | (-2.37) |
| Size $_{t-1}$ | -0.192** | -0.157** | -0.226** |
| | (-2.92) | (-2.52) | (-2.92) |
| Sales growth $_{t-1}$ | -0.340*** | -0.355*** | -0.756 |
| | (-4.43) | (-4.70) | (-1.54) |
| Leverage $_{t-1}$ | 0.345 | 0.319 | 0.125 |
| | (0.78) | (0.72) | (0.34) |
| Profitability $_{t-1}$ | 1.617*** | 1.644*** | -1.609 |
| | (5.01) | (5.06) | (-1.50) |
| Effective tax rate $_{t-1}$ | 0.014 | 0.024 | -0.114** |
| | (0.14) | (0.24) | (-2.46) |
| Constant | 4.244*** | 3.860*** | |
| | (5.36) | (5.07) | |
| Observations | 2,916 | 2,916 | 1,013 |
| R-squared [adj.] | 0.022 | 0.017 | 0.152 |
| Industry fixed effects | No | No | Yes |

Finally, following recent literature (e.g., Perdichizzi et al., 2023), we conduct a more detailed analysis of the correlation between emission intensity and firms' event returns.

Defining emission intensity as the sum of Scope 1 and Scope 2 emissions standardized by market capitalization allows us to further decompose this measure into separate Scope 1 and Scope 2 intensities.

Table A.II.3 presents the results: Model (1) replicates our baseline results for total emission intensity, while Columns (2) and (3) report the estimates for Scope 1 and Scope 2 emission intensities, respectively. Our findings indicate that the observed correlation between emission intensity and firms' event returns is primarily driven by Scope 1 emissions, as the coefficient for Scope 1 intensity is statistically significant, whereas that for Scope 2 intensity is insignificant. These results enhance our previous findings by demonstrating that emission activities directly "controlled" by firms - and thus more directly attributable to them by investors and the stock market - drive the observed negative correlation between emission intensity and equity returns on our event day.

### Table A.II.3: Event study results – $CO_2$ Scope analysis

Notes: This table reports the results of regressions of the (individual) raw returns of US firms on three different measures of $CO_2$ emission intensities and a set of firm controls. Specification (1), (2) and (3) employ firms' emission intensities as based on their total, Scope 1, and Scope 2 emissions, respectively. All models include controls for firm size, sales growth, leverage, profitability, and effective tax rate. All specifications incorporate industry fixed effects based on the Fama-French classification (17 industries). Robust t-statistics that allow for clustering at the industry-level are in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels. A detailed description of the variables used is provided in Table A6.

| Dependent Variable | Raw Return (Dec 14-15, 2020) | | |
|---|---|---|---|
| Method | | OLS | |
| Specification | (1) | (2) | (3) |
| $CO_2$ Scope | Total | Scope 1 | Scope 2 |
| Emission intensity | -0.280*** | -0.318*** | -0.708 |
| | (-2.94) | (-2.96) | (-1.10) |
| Size | -0.268*** | -0.267*** | -0.248*** |
| | (-4.97) | (-5.04) | (-4.50) |
| Sales growth | -0.591 | -0.596 | -0.597 |
| | (-1.32) | (-1.34) | (-1.34) |
| Leverage | 0.208 | 0.213 | 0.126 |
| | (0.78) | (0.81) | (0.45) |
| Profitability | -0.234 | -0.209 | -0.189 |
| | (-0.31) | (-0.27) | (-0.25) |
| Effective tax rate | -0.201** | -0.202** | -0.190** |
| | (-2.73) | (-2.83) | (-2.47) |
| Observations | 1,034 | 1,034 | 1,034 |
| R2 [adj.] | 0.124 | 0.126 | 0.114 |
| Industry fixed effects | Yes | Yes | Yes |

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