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

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Abstract. In December 2017, during the One Planet Summit in Paris, a group of eight central banks and supervisory authorities launched the "Network for Greening the Financial Sector" (NGFS) to address challenges and risks posed by climate change to the global financial system. Until 06/2023 an additional 69 central banks from all around the world have joined the network. We find that the propensity to join the network can be described as a function in the country's economic development (e.g., GDP per capita), national institutions (e.g., central bank independence), and performance of the central bank on its mandates (e.g., price stability and output gap). Using an event study design to examine consequences of network expansions in capital markets, we document that a difference portfolio that is long in clean energy stocks and short in fossil fuel stocks benefits from an enlargement of the NGFS. Overall, our results suggest that an increasing number of central banks and supervisory authorities are concerned about climate change and willing to go beyond their traditional objectives, and that the capital market believes they will do so.

JEL-Classification: E58, E61, G1, Q54, Q58

Keywords: Climate finance, green central bank policy, stock market reaction, sustainable finance

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"The ECB's Governing Council is strongly committed to further incorporating climate change considerations into its monetary policy framework."

– ECB press release July 8, 2021[1]

1 Introduction

With climate change gaining momentum, arguably the need of transitioning towards a sustainable economy becomes increasingly urgent (IPCC, 2018) and many commentators claim that capital markets must play an important role in facilitating this transition (e.g., European Commission, 2021; OECD, 2021; UNCTAD, 2014).[2] As such, central banks – representing key players in financial markets – have come under increasing scrutiny to join in the efforts to combat climate change (e.g., Green Central Banking, 2023).

Different arguments have been put forward to justify the public pressure on central banks to incorporate environmental considerations, including economic and financial aspects, such as price stability, economic growth and financial stability (e.g., Brunnermeier & Landau, 2020; Gonzalez, 2021), as well as ethical concerns (e.g., Honohan, 2020). However, calls for expanding the central bank mandates have also been criticised, among others because of concerns that this may jeopardize central bank's main objectives of price stability (e.g., Binder, 2021) and economic growth (e.g., American Enterprise Institute Roundtable, 2023).

And indeed, financial market interventions by unelected technocrats for a self-selected objective raise important questions. For instance, whether central banks should lend support to financial markets in transitioning to green finance? Although this question remains contentious (Rogoff, 1985), central bankers have adopted remarkably clear positions in this debate. For instance, Mark Carney, the Governor of the Bank of England, emphasized in a speech on 29th September 2015 that central banks have "a clear interest in ensuring the financial system is resilient to any

[1] ECB Press release from 8 July 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: September 1, 2023).

[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).

transition [...] and that it can finance the transition efficiently" (Carney, 2015). The European Central Bank (ECB), echoed a similar reasoning on July 8, 2021, when announcing the institution would "incorporating climate change considerations into its monetary policy framework" (as stated in the opening quote of this paper).

Another important question is whether central banks would be able to support to financial markets in transitioning to green finance? Eventually an empirical question, researchers interested in this issue are facing identification problems. For instance, announcements regarding green monetary policy may not always be accompanied by observable actions and in many cases, such announcements are widely anticipated. Take, for instance, the aforementioned expansion of the ECB's mandate to include climate change aspects. This announcement was widely anticipated, among others because of remarks by Jens Weidmann about a month earlier during the Green Swan 2021 Global Virtual Conference, when he argued that the ECB "should only purchase securities […] if their issuers meet certain climate-related reporting obligations" (Weidmann, 2021). Given Weidmann's prior reputation to strongly oppose such measures, this statement was picked up by several news sources, such as the Financial Times (Arnold, 2021) and Reuters (Canepa, 2021), as an indication that the ECB would take a firm stance on climate change in the upcoming strategy review.

To address this issue, we examine the 'action' to join the "Network of Central Banks and Supervisors for Greening the Financial System" (NGFS). Our approach offers several advantages over other studies relying on central bank communication (Arseneau et al., 2022) or policy actions (e.g., Dikau & Volz, 2021b).

Firstly, the joining was not anticipated by market participants, enabling us to evaluate the impact of the exogenous (from the perspective of market participants) revelation of preferences. Secondly, we avoid the need to quantify the signal as it remains homogenous across all banks. Finally, while most studies focus only on the most recent years, the network allows us to analyse the impact over a "relatively" long period of 7 years.

Our analysis contributes to the literature in several ways. *First*, we contribute to the growing literature discussing the role of financial institutions for green transformation. *Second*, focussing on central banks, we study one of the dominant players in financial markets, and contribute to the literature studying central bank policy and its role for green transformation. In particular, we are – to the best of our knowledge - the first to describe the development of the NGFS in quantitative terms. So far, the scant existing literature mostly focusses on the simple description of whether a central bank has joined the network (e.g., Dikau & Volz, 2021a). Using NGFS participation as an instrument allows us to quantify the objective of greening of the financial system relative to traditional objectives. We find that the propensity to join the network is a function in the country's economic development (e.g., GDP per capita), national institutions (e.g., central bank independence), and the fulfilment of the central bank on its primary mandates (e.g., price stability and economic growth). We interpret this last aspect as an indication that central banks consider greening the financial sector to be subordinate to their remaining mandates.

Finally, our contribution extends to the literature studying the impact of central bank actions on stock markets (e.g., Altavilla et al., 2019; Gürkaynak, et al., 2005; Hayo et al., 2022; Henseler & Rapp, 2018; Nakamura & Steinsson, 2018). Specifically, we document that central banks committing to join the NGFS fuel the valuation of clean energy stocks. In economic terms, assuming a scenario, where only the US Federal Reserve would join the NGFS, our results suggests that a difference portfolio that is long in clean energy stocks and short in fossil fuel stocks will earn an announcement return of 8.4 percent over the following three days – around twice the return following the announcement of the Paris Agreement.

The remainder of this paper is structured as follows: The next section discusses the role of central banks for the green transformation and develops our hypotheses. Section 3 introduces the dataset. Section 4 describes and examines the development of the network. Section 5 examines the consequences in capital market, and section 6 concludes.

2 Central banks, NGFS, and the green transition

To achieve the targets of the Paris Agreement, financial markets will play a critical role in facilitating the green transition toward a sustainable future. Central banks, as key global entities, may occupy a dual function in this transformation. One the one hand, central banks are equipped to mitigate potential short-term economic disruptions arising from this transition (Dietrich et al., 2021), thereby ensuring a smoother path toward a more sustainable and resilient economy. This involves actions to be clarified, such as accommodative policies due to the reduction in the real interest rate. Taking a more interventionist stance, they are in a position to redirect capital flows away from energy- and carbon-intensive production models and towards the promotion of sustainable production initiatives (Papoutsi et al., 2022). The perspective presented in this paper aligns with the latter strand in the literature, since the reaction to NGFS participation by financial markets implies an (assumed) extension of the existing central bank objective function.[3]

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

[3] To clarify, think of the standard loss function (e.g., Gali, 2015), extended to include a climate damage term:

$$L = \Delta\pi^2 + \beta\Delta y^2 + \gamma c.$$

Here, $\Delta\pi$ and Δy represent deviations in inflation and output, respectively, and c denotes damages to the environment. The weights β and γ determine the relative importance of inflation, output, and climate damages. Literature, exemplified by Dietrich et al. (2021) and Darracq Paries et al. (2023), implicitly assigns a weight of zero to climate damages in this loss function ($\gamma = 0$). This assumption implies that the central bank does not consider climate disasters beyond their impact on inflation and output. In such a scenario, central banks influence financial markets exclusively by providing relevant climate damage information. However, if the announcement of participating in the NGFS (without new information on inflation and output) affects markets, it suggests a belief that $\gamma \neq 0$. This presumption indicates that central banks indeed seek to mitigate the effects of climate change, irrespective of their other objectives. Note how the announcements of NGFS participation differ from other climate-related communication in another crucial dimension: They are not accompanied by traditional communication, which might be informative about the current developments with respect to the remaining objectives. Since this is not the case for NGFS participation, we can confidently identify the objective with respect to climate change, unrelated to inflation and economic slack.

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 introduces a novel angle on this topic by examining NGFS membership.[4] The NGFS was founded December 2017 during the One Planet Summit in Paris by a group of central banks and supervisory authorities. The founding members of the NGFS are listed in Table 1. 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

[4] See Gonzalez (2021) for more details about the NGFS.

of climate change for the financial system and to redirect global financial flows in order to enable low-carbon economic growth”.[5]

[Table 1 goes about here]

Using NGFS membership to identify changes in central bankers' objectives offers a significant advantage over the quantification of more conventional signals or the analysis of central bank communications. From a central bank perspective, joining the NGFS does not violate any legal constraints, nor does it require any concrete action by policymakers, nor does it involve any communication by policymakers. Consequently, it cannot be challenged by national governments and provides a powerful uniform yet non-disruptive way for central banks to signal their commitment to addressing climate-related financial risks. Hence, joining the NGFS does reveal a central bank's preference in terms of both its awareness of the need to transition to a more sustainable economy and its general willingness to take action.

While this signal is uniform in nature across participants, there is a temporal variation in the decisions to join the NGFS. It is precisely this temporal variation that we exploit to identify the preferences and constraints of the central banks concerned. Our operational hypothesis, thus, is that network entry is not randomly distributed. Rather, it follows a process that involves national preferences and constraints, along with the trade-off in achieving the central bank's mandate.

Focusing on the former, we hypothesize that the discourse surrounding central bank participation in the NGFS is more prevalent in developed countries. As such, we expect them to be more likely to participate. In addition, geographical constraints influenced by a country's exposure to climate-related shifts also increase the likelihood of joining the NGFS. Thus:

H1.a: *Central banks of developed economies are more likely to join the NGFS.*

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

Focusing on the latter, most central banks are routinely scrutinized with respect to their short- to medium-term primary and secondary objectives, such as price stability and economic slack. Comparatively less attention is devoted to long-term concerns such as climate change. Thus, we hypothesize that policymakers are confronted with a trade-off between economic activity and climate change considerations. Given the explicit mandate regarding economic activity, we expect policymakers to view climate change as a subordinate (tertiary) objective. As a result, they are more inclined to participate in the NGFS when inflationary pressures and economic slack do not require their or their governments' immediate attention. Thus, our second hypothesis is as follows:

H1.b: *Central banks are more likely to join the NGFS when their primary and secondary objectives are fulfilled.*

Next, we turn to the impact of a central bank's participation in the NGFS. While central banks may exercise significant influence over financial markets using their conventional and unconventional monetary policy instruments (e.g., Altavilla et al., 2019; Baumgärtner & Zahner, 2023; Ehrmann & Fratzscher, 2009; Gürkaynak et al., 2005; Hayo et al., 2022; Henseler & Rapp, 2018; Schmeling & Wagner, 2019), their ability to steer these markets toward a sustainable transition is constrained by the extent to which market participants believe in the central banks' commitment. Specifically, we examine whether capital markets view this participation as a credible signal that of central banks' commitment to green and sustainable finance.

The time-varying nature of the decisions to join the NGFS proves valuable here, allowing us to analyse the reaction by capital markets, specifically stock markets. Hypothesizing that segments most exposed to climate regulation are most sensitive to an expansion of the NGFS, we build on previous contributions (Antoniuk & Leirvik, 2024; Bauer et al., 2023; Wallace & McIver, 2019) and focus on clean energy stocks and fossil fuel stocks as climate regulation-sensitive segments. Specifically, we expect that clean energy stocks (fossil fuel stocks) benefit (suffer) from a tighter climate-regulation, and thus from expansions of the NGFS.

To lend anecdotal evidence to this hypothesis, Figure 1 documents the development of green (clean) energy stocks and fossil fuel stocks around the announcement of the

Paris Agreement (United Nations, 2015) on December 12, 2015. It indicates that the announcement hurt fossil fuel stocks, while (clean) energy stocks gained in value. In quantitative terms: clean stocks gained almost 4 percent over the next three days. Given the evidence from Figure 1, we conjecture:

H2: *Clean energy stocks benefit from enlargements of the NGFS, while fossil fuel stocks suffer from enlargements of the NGFS.*

[Figure 1 goes about here]

3 Sample construction and descriptive statistics

To test our hypotheses, we create two datasets. The first dataset links country specific macroeconomic and social information corresponding participation of central banks in the NGFS. The second dataset focuses on the announcement of NGFS participation and its effects on financial markets.

In the first dataset, we collect macroeconomic data from the World Bank (World Development Indicators) and others, to create a country-year panel covering up to 217 countries over the years 2017-2022. We complement the macroeconomic data with a confidential dataset from the Deutsche Bundesbank, which provides a list of the central banks participating the NGFS and their respective joining dates. This list documents the membership for all for all current 84 central banks in the NGFS.[6]

For the second dataset, we manually gather information from press statements available on the NGFS website. Specifically, we collect the dates of the press releases announcing the network expansion. We find these press releases for 76 central banks and 17 distinct events (after the foundation event).[7] We complement this dataset with data on daily market, “brown” and “green” stock price data from Refinitiv

[6] We focus on national central banks that join the network, as macroeconomic variables are measured on country-level. Thus, we exclude central banks at the supranational level (e.g., the European Central Bank). Also, we ignore financial supervisory institutions as well as other observing institutions.

[7] We are unable to find press statements for eight cases listed in the NGFS member list provided by the Deutsche Bundesbank. In total, we find 17 events cover 69 different central banks joining the network. We ignore events when central banks join the network for which we are unable to find an official press release, as arguable it is difficult to identify the timing of the flow of information in these cases.

Datastream.[8] This dataset provides the basis for our analysis regarding the responses to network enlargements in the stock market. Table 2 provides an overview and definitions of the variables, and Table 3 provides the corresponding descriptive statistics.

[Table 2 goes about here]

[Table 3 goes about here]

4 Network development

In a first step, we examine the development of the NGFS. Specifically, we document the growth in the network over time, examine cross-sectional determinants for central bank's decision to join the NGFS, and finally study central bank-specific time-varying determinants on the country-level.

4.1 Network development over time

To date, 84 central banks from across all continents have become members of the NGFS. Table 4 Panel A shows the annual evolution of the network from the announcement of its establishment in December 2017 to the latest addition of new members in April 2023. In the final three rows, we have included data on the average GDP per capita of NGFS and non-NGFS members, the size of the incoming members, measured in GDP, as well as the overall network size. There are several interesting observations.

[8] We use daily MSCI World Index return data as a proxy for the market (portfolio) returns in the event study. More specifically, we identify sector-specific ETFs (following Antoniuk & Leirvik, 2024; Wallace & McIver, 2019) and draw daily price data for these ETFs from Refinitiv Datastream over the 01/2017-06/2023 period. We then calculate abnormal returns for an equally-weighted portfolio of sector-specific ETFs for each of the 17 events and match these abnormal returns to the initial dataset. Since most of the selected ETFs invest in firms globally and due to our event data composition, we use daily MSCI World Index return data as a proxy for the market (portfolio) returns in the event study. We use the following two windows for each event: [-1;+1] and [-1;+3].

First, most of the central banks representing large rich countries have already joined the NGFS. In fact, the NGFS represents more than 91% of the world's GDP in 2022. Second, the average size (e.g., GDP) and development (e.g., GDP per capita) of joining countries has been steadily decreasing. For instance, the founding members had an average GDP of 3.4 trillion USD, whereas those joining in 2022 only had an average GDP of 0.2 trillion USD. This suggests that large, developed countries have led the charge. An empirical test confirms this, showing a significant negative trend in both the size and development of new NGFS members over time, supporting our first hypothesis H1a. Finally, there is a notable temporal variation in the size of the network, most pronounced in 2020 when the Federal Reserve joined the network.

[Table 4 goes about here]

4.2 Cross-sectional determinants of central bank's NGFS membership

We next conduct a cross-country analysis to assess the role of national preferences and constraints in influencing central banks' participation in the NGFS. Owing to data available for such a large country sample and the inherent inertia of these dimensions, we adopt a static approach. Specifically, we estimate the following cross-sectional logit regression:

$$NGFS\ member_{i,2021} = \alpha + \beta_1 \mathrm{y_i} + \beta_2 \mathrm{X_i} + \beta_3 b_i + \epsilon_t$$

The left-hand side variable is binary indictor being 1 if central bank i was an NGFS member as of 2021, the year NGFS announced the first NGFS Climate Scenarios. The right-hand side variables $\mathrm{X_i}$ are a set of social, economic, and institutional covariates, that have been demeaned and standardized to facilitate the interpretation of the coefficients. We control for GDP per capita y_i as well as having a border to an NGFS member b_i. To address potential endogeneity concerns, we rely solely on social, economic, and institutional covariates obtained before 2021. Table 3 provides an overview of the variables, as well as the respective descriptive statistics.

[Table 5 goes about here]

Our results can be found in Table 5 and summarised as follows. In column one, we present the aforementioned positive relationship between GDP per capita and NGFS membership, while controlling for adjacent NGFS members. A one standard deviation increase in average income leads to a more than threefold increase in the probability of being a NGFS member as of 2021.

Next, we include proxies for national green production and consumption, represented by the share of renewable national production, per capita energy use, and CO2 emissions per capita. We observe that central banks from countries with lower per capita CO2 emissions are more likely to be NGFS members.

In column three, we examine proxies for economic (e.g., share of agriculture) and population (e.g., share of population living in coastal areas) exposure to climate change on membership probabilities. Notably, countries with a larger agricultural sector are significantly less likely to be members of the NGFS.

Column four investigates the relevance of national institutions, particularly those affecting central bank autonomy. We instrument this with the central bank independence (CBI) index developed by Romelli (2022). Results suggest that CBI significantly drives NGFS membership, with a one-standard-deviation increase in central bank independence (a move from the Bank of Botswana to the Brunei Darussalam Central Bank) raising the probability of participation by around 100%.

In the last column, we assess whether our results are influenced by multicollinearity. However, the findings persist, highlighting that high-income countries, with green preferences, and strong national institutions, are most likely to participate in the NGFS.

4.3 Central bank mandates and their decision to join the NGFS

As central banks' mandates generally do not explicitly encompass climate-related objectives, we examine the relationship of their primary objective (the fulfilment of price stability) and secondary objective (the degree of economic slack) on the banks' decisions to join the NGFS.[9] To test this, we estimate the following panel regression for all current NGFS members:

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

In the above equation, $NGFS\!:join_{i,t}$ is a binary variable that takes the value 1 if central bank *i* joined the NGFS in year *t* and 0 otherwise. The dependent variables are $|\pi_t - \hat{\pi}|$, representing the absolute deviation from trend inflation, x_t, denoting the output gap, and u_t representing the unemployment rate.[10] In addition, we include a set of fixed effects $f_{i,t}$, capturing unobservable factors specific to each central bank and year. For the regression, all independent variables are standardized, and observations are from the founding year of the founding of the NGFS onwards.

The coefficients of interest are denoted by β_1, β_2, and β_3. We expect to observe a negative coefficient on inflation deviations, indicating a lower likelihood of joining the NGFS when inflation deviates significantly from its long-term trend. Conversely, we expect a positive (negative) coefficient on the output gap (unemployment), as above-trend economic activity would raise the likelihood of joining.

[Table 6 goes about here]

Our results are presented in Table 6 and can be summarized as follows. An increase in inflation (output gap) significantly decreases (increases) the probability of entry of the respective institution in the respective year. In quantitative terms, a one standard deviation increase in inflation deviation from trend lowers the probability of entry by about 75% (column one). In terms of magnitude, the output coefficient is around the same (column two). Interestingly, we do not find a significant relationship with the unemployment rate in column three.

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

[10] 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.

In column four, we test whether the effect is due to multicollinearity, for which we find no evidence. Finally, in the last column, we test whether our findings are driven by central banks from developed countries, where attention to the output gap and inflation may be more prominent. Interestingly, we do not find a significant difference in the coefficients once we exclude countries with a real income below $10,000. In fact, the coefficients decrease slightly.

In summary, central banks are most likely to join the NGFS if the primary and secondary objectives are met. Thus, greening the financial system is to be pursued once the other objectives are met, suggesting that central bankers perceive climate change concerns as subordinate to addressing inflation and output deviations.

5 Response of the stock market

In a next step, we examine the consequences of network expansions, i.e., additional central banks joining the NGFS, in capital markets. Specifically, we identify segments arguably sensitive to climate-regulation and examine the aggregate response of their share prices to an expansion of the NGFS.

5.1 Empirical approach

As documented above, joining the NGFS is not purely random and thus may be predicted up to a certain probability. This potential predictability poses endogeneity concerns for typical panel-data designs, creating an identification challenge. Therefore, we employ an event study approach with relatively short event windows to examine the stock market consequences of enlargements of the NGFS. These windows range between three days around the announcement [-1;+3] to solely the announcement day [-1;+1].[11] Such an approach assumes that while entries might be predictable at low frequencies (e.g., on annual levels), entries occur relatively random at higher frequencies (e.g., on daily levels). In our case this assumption can be rationalized by a back-of-the-envelope calculation: Our sample period 01/2018 to

[11] 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).

06/2023 covers 5.5 years and we identify 17 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 1.2 percent. Accordingly, even the ceteris paribus probability for an event within a 4-day interval is below 5 percent. Moreover, we validate our identification approach by examining newspaper articles surrounding the announcement and find no instances where events were predicted by news sources.

We proxy the (global) stock market performance of specific climate-sensitive industries by the performance of thematically consistent ETFs (Antoniuk & Leirvik, 2024; Bauer et al., 2023; Wallace & McIver, 2019). Thematic ETFs are exchange traded funds that invest in specific industries, themes, or trends. We are particularly interested in two different industries: clean energy stocks and fossil fuel stocks. While 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 (Wallace & 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 A- 1 in the Appendix.

5.2 Empirical results

We obtained cumulative abnormal returns (CAR) for each ETF (clean energy and fossil fuels) and each public announcement date of our sample as described in section 3.1. To examine stock market reactions to enlargements of the NGFS we regress the CAR (in percent) on the respective enlargements of the network in terms of GDP contribution per announcement date as follows:

$$CAR_{i[t_1,t_2]} = \alpha + \beta_1 Network\ enlargement_i + \epsilon_i.$$

The coefficient of interest is β_1, which we expect to be positive for the clean energy stocks as well as the difference between clean energy- and fossil fuel stocks (difference portfolio), indicating a positive stock market response to the respective joining announcements and network enlargements.

[Table 7 goes about here]

Our findings are presented in Table 7 and can be succinctly outlined as follows. First, we examine whether the CAR of the difference portfolio over the days -1 to 3 on the respective network enlargements in column one. The results show a highly significant positive reaction of climate-sensitive segments of the financial market towards announcements of enhancing the NGFS. The reactions are more pronounced for announcements that include countries that contribute relatively more GDP to the network. The coefficient is economically meaningful, as denoted in terms of economic significance in the bottom part of Table 7. On average, a one standard deviation increase of the network enlargement is associated with an increase in cumulative abnormal returns for the difference portfolio of 2.24 percent. Additionally, we account for approximately one-third of the explained variance, signifying the substantial impact of the change in the NGFS 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 (2), controlling for the post-enlargement size of the network (3), and by narrowing the cumulative abnormal return window down to a three-day window around the respective announcement dates (4).

In column five, we re-estimate the extended model using exclusively the CARs of clean energy stocks over the days -1 to 3 as the dependent variable. The results suggest that the returns of the clean energy stocks are the main driver behind the formerly observed difference portfolio returns, given that the coefficient for network enlargement remains statistically significant and of high magnitude. This specification allows us to compare our results with those of the Paris Agreement (Figure 1). A one standard deviation increase in the network produces about half the effect of the announcement of the Paris Agreement. To illustrate, consider the Federal Reserve's entry into the NGFS on December 15, 2020. Given that the US economy represented 23.9 percent of the world GDP that year, our results suggests that, under the scenario where only the Federal Reserve joins the NGFS, the difference portfolio would yield an abnormal announcement return of 8.4 percent over the [-1;+3] interval—

approximately 2.5 times the abnormal return following the announcement of the Paris Agreement.

Overall, our results from the event study analysis indicate that financial markets are sensitive to climate-related central bank news. More specifically, both the difference portfolio, which is long in clean energy stocks and short in fossil fuel stocks, and clean energy stocks benefit from enlargements of the NGFS. We therefore conclude that these network enlargement announcements and the accompanying commitments of central banks towards green and sustainable finance are seen as a credible signal by market participants.

6 Conclusion

The Network for Greening the Financial System (NGFS) is an alliance of central banks committed to advancing the transition to a more sustainable economy. Since joining the NGFS requires no change in a new member's mandate, which might be subject to legal challenges, we use their participation as an instrument to measure these institutions' green preferences. Our analysis shows that participation is closely associated with the fulfilment of primary objectives such as maintaining stable prices and a positive output gap, suggesting that central banks consider green policies as subordinate objectives.

Next, we examine whether financial markets perceive this participation as a credible signal. We find that green stocks exhibit contemporaneous abnormal returns that are about half the magnitude of the announcement of the Paris Agreement. This suggests that central bankers' commitment to the transition to a sustainable economy is indeed perceived as a credible signal by financial markets.

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Appendix

Table A- 1: 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 event study. The ETF selection is based on Antoniuk & Leirvik (2024) and Wallace & McIver (2019) and incorporates exchange traded funds which invest in the stocks of 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: Market response to the Paris Agreement (Dec 12, 2015)

Notes: This graph illustrates the market response to the signing of the Paris Agreement on Dec 12, 2015. Cumulative abnormal returns over event days -3 to 5, normalized to the event date for both categories, clean energy and fossil fuel stocks, are shown. With December 12, 2015 being a non-trading day, the event day (announcement date) is set to the next trading day, December 14, 2015.

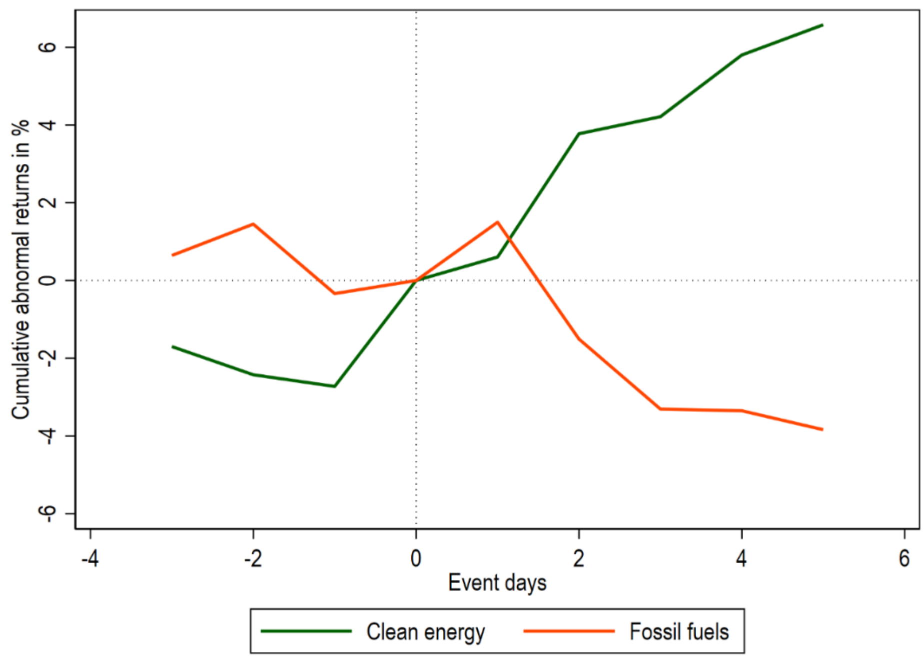


Figure 2: Network for Greening the Financial Sector - central banks as of end of 2017

Notes: This figure illustrates the countries whose central banks were members of the Network for Greening the Financial Sector as of end of 2017.

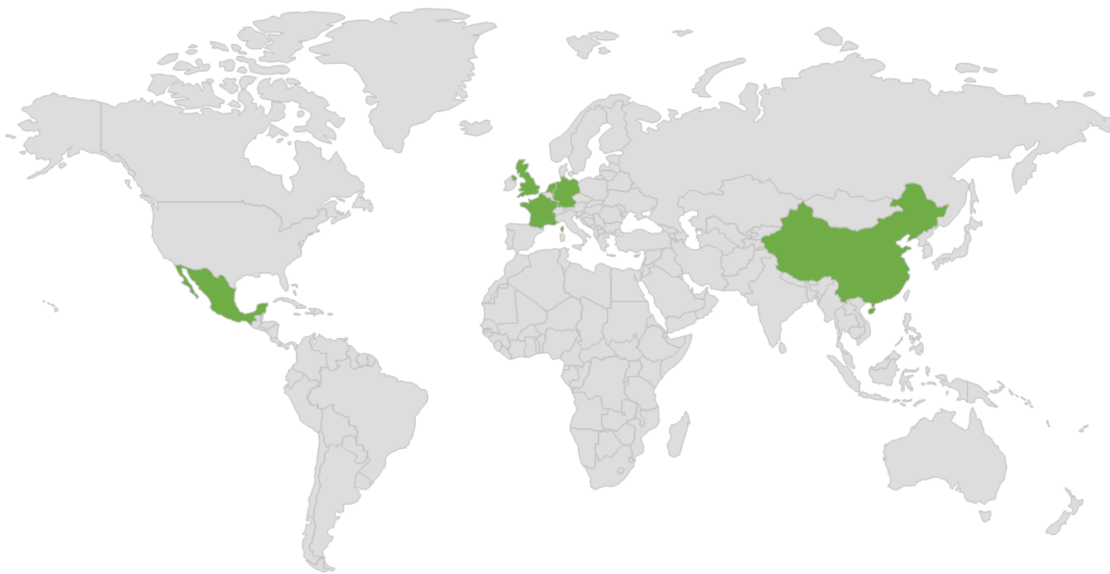
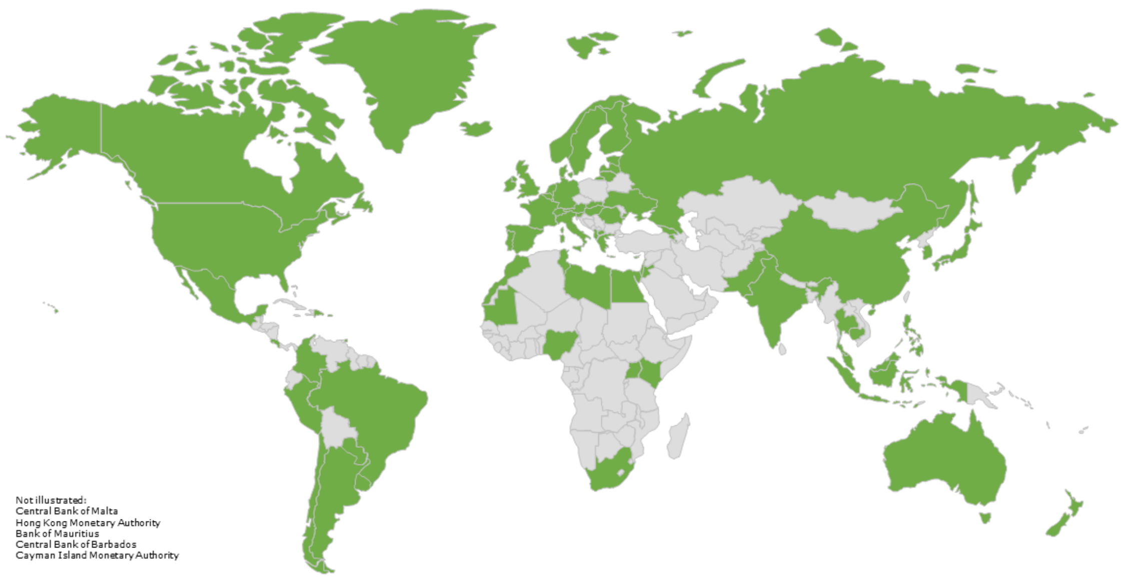


Figure 3: Network for Greening the Financial Sector - central banks as of end of 06/2023

Notes: This figure illustrates the countries whose central banks were members of the Network for Greening the Financial Sector as of end of June 2023. Countries represented by Central Bank of Malta, Hong Kong Monetary Authority, Bank of Mauritius, Central Bank of Seychelles, Central Bank of Barbados, and Cayman Island Monetary Authority not highlighted for technical reasons.



Tables

Table 1: 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 2: Variable definitions

Notes: This table provides variable definitions and sources. Panel A reports variables used in the cross-sectional determinant regressions. Panel B reports variables used in the panel-data determinant regressions. Panel C reports variables used in the stock market- and event study analysis.

Variable	Definition	Source
Panel A: Cross-sectional determinant regressions		
Membership in 2021	Binary variable measuring whether a central bank has joined the NGFS by the end of 2021.	Deutsche Bundesbank
Renewable production	Share of electricity generated by renewable power plants in total electricity generated by all types of plants. Proxy for national renewable production.	WDI: EG.ELC.RNEW.ZS
Energy use	Energy use (kg of oil equivalent per capita) refers to use of primary energy before transformation to other end-use fuels. Proxy for energy use.	WDI: EG.USE.PCAP.KG.OE
CO2 emissions (tons per capita)	Carbon dioxide emissions (metric tons per capita) are those stemming from the burning of fossil fuels and the manufacture of cement.	WDI: EN.ATM.CO2E.PC
Urban population in low elevation coastal zone	Country-level estimates of urban, rural and total population and land area country-wide and in the Low Elevation Coastal Zone, if applicable.	CIESNIN, Columbia University
Agriculture, forestry, and fishing (% of GDP)	Agriculture, forestry, and fishing corresponds to ISIC divisions 1-3 and includes forestry, hunting, fishing, cultivation of crops and livestock production. Proxy for agricultural exposure.	WDI: NV.AGR.TOTL.ZS
GDP per capita constant 2010 US$	GDP per capita is gross domestic product divided by midyear population. GDP per capita is measured in thousands of US-Dollars.	WDI: NY.GDP.PCAP.KD
Central bank independence index	Central Bank Independence Index as constructed and provided by Romelli (2022). Proxy for the institutional level and the of autonomy of countries' central banks.	Romelli (2022)
Border	Information about joint borders of neighbouring countries (binary indicator taking the value 1 if countries share borders). Based on country-level data as provided by CEPII.	CEPII
Distance capital	Distances between capitals of countries. Calculated using measures of bilateral distances between countries using city-level data as provided by CEPII.	CEPII

Table 2 (continued)

Variable	Definition	Source
Panel B: Panel determinant regressions		
Joining NGFS	Binary variable that takes the value 1 if central bank i joined the NGFS in year t and 0 otherwise.	Deutsche Bundesbank
Inflation gap	Annual CPI; HP Filtered Gap; 1980-2023.	WDI: FP.CPI.TOTL.ZG
GDP 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 C: Stock-market event study analysis		
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
Network enlargement [world]	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 3: Descriptive statistics

Notes: This table provides descriptive statistics for our variables defined in Table 2. While Panel A reports macroeconomic variables measured on the country level, Panel B reports variables used in the event the impact on capital markets. Panel A is split in two parts. Part A takes a cross-sectional perspective and reports data for all countries in our dataset (max of 152) as of 2021. The data in Part A is mostly demeaned and standardized (except for dummy variables). Part B focusses on NGFS members, and reports panel data.

Panel A: Cross-sectional- and panel determinant regressions

Variable	N	Mean	SD	Min	Max
Part A: Cross-sectional data as of 2021 (mostly de-meaned and standardized)					
Membership in 2021	152	0.43	0.50	0.00	1.00
Renewable Production	152	0.00	1.00	-1.02	2.06
Energy use	124	0.00	1.00	-0.81	5.47
CO2 emissions	151	0.00	1.00	-0.89	5.51
Urban population in coastal zone	147	0.00	1.00	-0.73	4.67
Agriculture, forestry, and fishing	148	0.00	1.00	-0.96	4.77
Central bank independence index	152	0.00	1.00	-2.51	1.42
GDP per capita	151	0.00	1.00	-0.75	4.70
NGFS Border	152	0.57	0.50	0.00	1.00
Part B: Panel-data for NGFS-members					
Joining NGFS	589	0.12	0.33	0.00	1.00
Inflation gap	589	-0.03	0.88	-2.94	3.87
GDP gap	589	0.06	1.52	-5.05	3.65
Unemployment rate	589	7.57	4.89	0.14	29.81
GDP per capita	589	22.92	22.83	0.82	104.62

Panel B: Stock-market event study analysis

Variable	N	Mean	SD	Min	Max
CAR clean energy stocks [-1;1]	17	-0.642	2.062	-4.390	2.332
CAR clean energy stocks [-1;3]	17	-0.330	2.865	-6.400	4.721
CAR difference portfolio [-1;1]	17	-0.054	3.318	-7.427	6.404
CAR difference portfolio [-1;3]	17	0.204	3.738	-8.146	8.417
Relative network enlargement [world]	17	0.035	0.060	0.001	0.240
Network size (ln)	17	3.888	0.371	3.256	4.302
Abnormal network size	17	0.000	0.371	-0.632	0.414
AR clean energy stocks	153	0.028	1.057	-2.869	3.299
AR fossil fuel stocks	153	0.041	1.608	-3.719	6.999
AR difference portfolio	153	-0.014	1.794	-6.572	3.803

Table 4: Network development over time

Notes: 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). For 2022 and 2023 the values for Barbados, Cayman Islands, Mauritania, Lebanon, Libya, Pakistan and Uganda for GDP are as of 2021, due to data availability. 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	4	4	4	1	1
Number of central banks joining the NGFS	7	12	19	18	10	6	4
GDP per capita (in tUSD)							
- NGFS members	35.0	40.1	33.5	28.9	24.6	22.6	
- non-NGFS members	13.6	10.9	8.4	6.9	6.8	6.5	
GDP of countries with central bank joining the NGFS (in trUSD)	24.1	5.8	15.9	22.4	4.1	1.1	0.4
Total GDP of countries with central bank being a NGFS member (in trUSD)	24.1	29.9	45.8	68.2	72.3	73.4	73.9
Panel B: Geographical distribution							
Africa - total	0	1	3	5	5	9	11
- joining	-	1	2	2	-	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	17	18
- joining	2	1	5	6	2	1	1
Europe - total	4	12	21	27	30	30	30
- joining	4	8	9	6	3	-	-
Oceania - total	0	2	2	2	2	2	2
- joining	-	2	-	-	-	-	-
World - total	7	19	38	56	66	72	76
- joining	7	12	19	18	10	6	4

Table 5: Cross-sectional determinants of central bank's NGFS membership

Notes: This table reports the results of logistic regressions of NGFS membership on different categories of determinants. Specifically, these categories refer to: National green preferences (specification 1), national constraints (specification 2), impact of national institutions (specification 3), and to the relevance of regional institutions (specification 4). Most of the independent variables are standardized and demeaned. T-statistics are in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels. A detailed description of variables used is provided in Table 2.

Specification	(1)	(2)	(3)	(4)	(5)
Dependent variable	Membership in 2021				
Renewable Production		-0.20			
		(-0.75)			
Energy use		0.65			
		(1.02)			
CO2 emissions		-2.55***			-1.46***
		(-3.14)			(-3.29)
Urban population in coastal zone			-0.30		
			(-1.31)		
Agriculture, forestry, and fishing			-0.65*		-1.00**
			(-1.80)		(-2.54)
Central bank independence index				0.69***	0.58**
				(3.09)	(2.23)
GDP per capita	1.51***	4.39***	1.20***	1.62***	2.84***
	(4.50)	(4.01)	(2.88)	(4.24)	(3.38)
NGFS Border	1.13***	0.82	1.04**	0.83*	0.91*
	(2.81)	(1.64)	(2.36)	(1.93)	(1.89)
Constant	-0.76**	0.57	-0.81**	-0.40	-0.36
	(-2.38)	(1.19)	(-2.27)	(-0.42)	(-0.90)
Observations	151	123	143	144	148
Log Likelihood	-79.03	-56.40	-70.40	-71.84	-61.32
Akaike Inf. Crit.	164.06	124.79	150.79	153.68	134.63

Table 6: 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). GDP gap is the deviation from the long-term GDP-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 variables used is provided in Table 2.

Specification	(1)	(2)	(3)	(4)	(5)
Dependent variable			Joining NGFS		
Inflation gap	-1.523***			-1.407***	-1.065*
	(-3.326)			(-3.036)	(-1.916)
		0.559***		0.510***	0.553**
GDP gap		(-3.161)		(2.889)	(2.210)
Unemployment rate			0.023	0.081	0.216
			(0.157)	(0.512)	(1.018)
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Countries > 10k Dollar	No	No	No	No	Yes
Observations	567	567	567	567	334
Log Likelihood	-197,855	-198,654	-205,487	-191,299	-106,991
Akaike Inf. Crit.	468,977	470,759	481,836	463,901	305,713

Table 7: Event study results

Notes: This table reports the results of OLS- and median regressions of the cumulative 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. Network enlargement is 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). The statistical significance and the magnitude of economic significance are reported in the bottom half of the table for each model specification, respectively. Robust T-statistics are in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels. A detailed description of variables used is provided in Table 2.

Specification	(1)	(2)	(3)	(4)	(5)
Method	OLS	Median	OLS	OLS	OLS
Event window	[-1;+3]	[-1;+3]	[-1;+3]	[-1;+1]	[-1;+3]
Dependent variable	CAR (clean energy - fossil fuel)				CAR clean energy
Constant	-1.00	-0.48	-1.04	-1.28	-0.98
	(-1.08)	(-0.34)	(-1.10)	(-1.61)	(-0.92)
Network enlargement [world]	34.10***	37.00**	35.23***	26.75***	26.13***
	(4.18)	(2.17)	(3.44)	(4.60)	(3.79)
Abnormal Network size			-1.913	-1.05	-1.75
			(-0.89)	(-0.69)	(-1.01)
Observations	17	17	17	17	17
R-squared	0.30	0.30	0.33	0.32	0.24
Economic significance	Mean	Median	Mean	Mean	Mean
Mean network enlargement [world] mean = 0.035	0.19	0.82	0.19	-0.34	-0.06
Mean + 1xSD netw. enlgt. [world]	2.24***	3.04*	2.30**	1.26***	1.50***
F test values	(8.53)	(3.90)	(6.92)	(11.56)	(12.46)