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Warning words in a warming world: Central bank communication and climate change*

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Abstract

We study climate-related central bank communication using a novel dataset containing 35,487 speeches delivered by 131 central banks from 1986 to 2023. We employ natural language processing techniques to identify and trace the evolution of key climate-related narratives centred around (i) green finance, and (ii) climate-related financial risks. We find that central bank public communication strategies are primarily driven by underlying institutional factors, rather than exposure to climate-related risks. We then study the impact of climate-related communication on financial market dynamics through both a portfolio and a firm-level analysis. We find that equity returns of 'green' firms outperform those of 'dirty' firms when central banks engage more frequently and intensely with climate-related topics.

Keywords: Central banking; Climate change; Low-carbon transition; Central bank communication; Climate-related risks; Green finance; Text analysis; Topic modelling; Asset pricing.
JEL codes: C38, E44, E58, Q54, Z13.

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1 Introduction

Central banks are now among the most active players in the public debate on climate change and the low-carbon transition (Campiglio et al., 2018; Bolton et al., 2020; NGFS, 2024). In addition to publishing academic research and policy reports on the topic, many central banks have started issuing recommendations to the financial institutions they supervise and incorporating climate-related dimensions into their monetary policy strategies (see Batten et al., 2016; Rudebusch, 2019; ECB, 2020, 2022; DNB, 2023, among many others). An international platform of central banks and supervisors – the Network for Greening the Financial System (NGFS) – was created to advance their common understanding of how climate-related dimensions matter for their operations (NGFS, 2019).[1] Central bank governors and board members routinely give public speeches on climate change, the energy transition, sustainable finance and other climate-related matters, to the point that some of them have attracted criticism for their hyper-activism (Hansen, 2021).

How did previously obscure technocratic institutions become key leaders in shaping the public conversation around issues traditionally outside of their remit? And what implications does their prominence in the debate have? In this paper, we address these questions by focusing on central banks' public communication strategies. To do this, we build a novel dataset containing 35,487 speeches delivered by 131 central banks, over the 1986-2023 period.[2] This represents a substantial expansion with respect to the repositories commonly used in the literature on central bank communication, such as the one managed by the Bank for International Settlements (BIS, 2024). Our dataset confirms the recent shift in communication strategies by central banks, which have become significantly more outspoken and transparent to the public (Masciandaro and Russo, 2024).

We then use our dataset to conduct three interrelated sets of analyses. First, we build an original dictionary of climate-related key expressions to identify and explore a sub-collection of 2,968 'climate-related speeches'. We highlight the rapid recent expansion of climate-related communication by central banks and point to the strong geographical and temporal heterogeneity across institutions. Western Europe and Southeast Asia and the Pacific are the regions steadily exhibiting the strongest climate-related communication strategies. While Southeast Asian central banks were giving the majority of speeches before 2015, Western European central banks took a more dominant role in recent years. Other regions have been lagging behind. The number of climate-related speeches has risen sharply over the years and, since 2021, it has stabilized at approximately 550 global speeches annually. We then implement a structural topic model (STM) on this sub-collection of speeches and identify two climate-related narratives, or 'shades of green', characterised by distinct lexicons. We classify them as: (i) 'Green finance'; and (ii) 'Climate-related risks'. While most central banks exhibit some combination of the two narratives in their communication strategies, we

[1] The NGFS was created in December 2017 by eight central banks and supervisors. As of December 2024, the network counts 144 members and 21 observers.

[2] The dataset is freely available at https://cbspeeches.com.

observe a clear dichotomy between two groups of central banks, which also reflects an underlying difference in their institutional positioning. A group of them – mostly located in developing and emerging economies and characterised by 'promotional' financial policy-making and/or the presence of international financial hubs – predominantly focused on green financial market opportunities, as a strategy to address the climate change challenge while supporting economic development. Others, mainly located in market-oriented high-income countries, proposed instead a more 'prudential' narrative centred around the potential impact of climate change and the energy transition on financial stability and, later, on price stability. This narrative, spearheaded by a well-known 2015 speech by Mark Carney – then governor of the Bank of England – has become the dominant one. However, even high-income central banks have been starting to gradually shift towards more promotional 'green finance' narratives in more recent years.

Second, we investigate the main drivers of central banks' climate-related communication through the implementation of a pseudo-Poisson maximum likelihood regression. We define four variables of 'climate-related focus': two indicators of general attention ('Climate frequency' and 'Climate salience') and the two climate-related topics identified through the structural topic modelling ('Green finance' and 'Climate-related risks'). We find that institutional dimensions – such as the degree of central bank involvement in financial sector supervision, the width of their mandate, and their affiliation to the NGFS – are stronger drivers of climate-related communication compared to the exposure of the country to climate-related risks. Interestingly, this is particularly true when explaining the drivers behind a prudential communication narrative centred around climate-related risks. While the carbon intensity of a country contributes to explaining the climate salience of central bank communication and their reliance on green finance narratives, the exposure to climate disasters (our proxy for physical risks) does not have any discernible effect.

Third, we examine the impact of central bank communication on equity asset prices and find that, compared to firms with worse environmental scores, the returns of greener firms are positively associated with the frequency and salience of central banks' climate-related speeches, especially when the dominant topic is climate-related financial risks. This result emerges from both a portfolio analysis (for the United States) and a more granular firm-specific analysis (for 41 countries). We consider alternative market measures of greenness: (i) carbon emission intensity; (ii) a wider rating on the 'Environmental score' of the firm provided by LSEG (London Stock Exchange Group); and (iii) a sub-category of the latter index focusing on emissions, the 'Emission score'. We test two main econometric specifications including: (i) firm fixed effects; and (ii) country-by-industry-by-date fixed effects. We also run a battery of robustness checks, looking at different specifications of our topic model and different methods of calculating emission intensity. All of them confirm our results, clearly highlighting the nuanced and significant role of central bank communications in climate finance. Finally, we also make sure that spillover effects across jurisdictions have no significant impact.

Our research builds upon and contributes to three interconnected streams of research. First, we connect to the literature studying the role of central banks and financial supervisors in addressing the climate change challenge (NGFS, 2019). Several contributions have explored the legitimacy of central banks in addressing – or even acting on – climate-related matters (D'Orazio and Popoyan, 2019; Bolton et al., 2020; Dikau and Volz, 2021; Schoenmaker, 2021; DiLeo et al., 2023; Kedward et al., 2024). In this literature, Baer et al. (2021) stress how the underlying institutional framework in which central banks operate defines the admissible motives for their actions. While advanced economies' central banks are generally motivated by *prudential* motives, aimed at protecting the financial systems in the face of material climate-related risks, central banks in many emerging and developing economies are more accustomed to implement *promotional* policies, proactively steering capital flows to facilitate the low-carbon transition.[3]

Second, we contribute to the large literature studying central bank communication – especially regarding monetary policy decisions – and how this affects economic behaviour and macroeconomic dynamics (Blinder et al., 2008; Gorodnichenko et al., 2023; Blinder et al., 2024; Masciandaro et al., 2024). Communication helps central banks to steer expectations and increase the effectiveness of their policies, while contributing to their legitimacy as public institutions (Moschella and Romelli, 2022). There is clear evidence that central bank communication can influence financial asset price dynamics (see Gürkaynak et al., 2005; Swanson, 2021, among others). In recent years, this stream of work has benefited from the advances in natural language processing (NLP) techniques, allowing researchers to analyse 'text as data' (Gentzkow et al., 2019). Several contributions have used NLP methods to analyse the nature and meaning of the language used by central bankers (Ferrara et al., 2022; Baumgärtner and Zahner, 2023; Byrne et al., 2023), but only a limited number of them have specifically focused on climate-related communication.[4]

Third, we connect to the rapidly expanding literature – mainly rooted in finance and management – studying how climate-related risks affect the pricing of financial assets. More specifically, we build on the stream of contributions focusing on the relative financial performance of clean and dirty firms in the face of prospective or realised transition risks (see Bolton and Kacperczyk, 2021; Ramelli et al., 2021; Pástor et al., 2022; Faccini et al., 2023; Hengge et al., 2023; Bauer et al., 2024, among others). Two studies are particularly relevant for our analysis. Ardia et al. (2023) create

[3]However, institutional frameworks evolve. In 2021, the annual letter from the UK Treasury defining the remit of the Bank of England's Monetary Policy Committee included for the first time mentions to the "transition to an environmentally sustainable and resilient net zero economy" (Sunak, 2021). After two years without any reference to environmental dimensions, the 2024 remit letter again mentioned the government's objective to "accelerate the transition to a climate resilient, nature positive and net zero economy" (Reeves, 2024). In 2021, the mandate of the Magyar Nemzeti Bank (Hungary) was also changed to incorporate the promotion of environmental sustainability in its statutory objectives (MNB, 2021).

[4]Other contributions apply text analysis methods to climate-related research questions that do not include central banks. For instance, Savin et al. (2020) and Savin et al. (2022) use textual responses from the general public. Cabrales et al. (2024) go beyond central bank speeches, to include mentions of climate-related terms into mainstream news media, economic and other scientific journals, and European Parliament questions.

an index of Media Climate Change Concerns using a corpus of media text from the United States. Similarly to our work, they implement a topic model to disaggregate their corpus into different topics. Employing a firm fixed-effect panel regression model on firm daily returns, they find that unexpected increases in climate-related concern tend to increase the price of cleaner stocks and depress the price of dirtier ones.[5] Bauer et al. (2023) investigate instead the impact of occurrences related to the Inflation Reduction Act in the United States on equity prices and find significant differential effects between green and dirty stocks, using three alternative firm-level measures of greenness.

Only a handful of very recent works have tried to combine these streams of literature. The closest to our paper are Arseneau et al. (2022) and Arseneau and Osada (2023), who apply a supervised word scoring method to identify climate-related speeches within the BIS dataset. Arseneau et al. (2022) study how central banks associate climate-related matters with other topics, such as financial stability and macroprudential policy. Arseneau and Osada (2023) examine the role of the central bank mandate in shaping their climate-related communication strategies. Feldkircher and Teliha (2024) also study the drivers of climate-related communication, including a larger number of institutional, macroeconomic and climate-related variables. Other contributions include an analysis of the financial implications of central bank communication: Neszveda and Siket (2023) run an event study analysis to see how the top 5 'green' ECB speeches affected stocks of German, French and Italian markets, finding that green portfolios tend to outperform dirty ones on the day of the speeches; Ebeling (2024) obtains similar results on a wider set of ECB speeches; Cizmic et al. (2023) study the impact of ECB climate-related communication on CDS spreads in North America; while Fischer et al. (2024) find that the announcement of an expansion of the number of members of the NGFS has a positive impact on the returns of clean energy stock, relative to fossil-related stocks.

Against this background, this paper provides two broad novel contributions. First, our dataset of central bank speeches is much larger and more diversified across both geography and time than any other used in the literature so far. This allows us to perform a significantly more granular and robust analysis of the evolution of climate-related central bank communication. Second, whereas past contributions have focused on specific dimensions of climate-related central bank communication, we are the first to provide an integrated analysis including language investigations, political economy considerations, an analysis of communication drivers, and a study of its financial implications. Our analysis of central bank communication on equity prices, in particular, provides a novel firm-level international perspective on the topic.

The remainder of the paper is structured as follows. Section 2 presents our dataset of central bank speeches. Section 3 focuses on climate-related communication and discusses the two main

[5]Other significant contributions developing measures of climate attention and investigating their impact on asset prices include Engle et al. (2020), Bua et al. (2021), Meinerding et al. (2022) and Bessec and Fouquau (2022). Most studies in this area have focused on the effect of media attention on climate change on stock prices. The prevailing conclusion is that the relative valuation of firms more exposed to climate-related risks is negatively impacted.

climate-related central bank narratives emerging from our structural topic model. Section 4 presents the results of the empirical analysis investigating the drivers of central bank communication on climate-related issues. Section 5 studies the effects of climate-related communication on clean and dirty financial asset prices. Section 6 concludes.

2 A new dataset of central bank speeches

In this section, we present our novel dataset of central bank speeches. Section 2.1 discusses our data sources and the methodological approach used for the creation of the dataset. Section 2.2 offers an overview of its main features.

2.1 Data sources and methodology

We collect central bankers' speeches using three different data sources: (i) the dataset of the Bank for International Settlements (BIS); (ii) central banks' websites; and (iii) central banks' archives. Figure 1 provides an overview of the data collection process.

We start by retrieving the 18,802 speeches published on the Bank for International Settlements (BIS) website for the period September 1996 to December 2023.[6] After removing duplicates and irrelevant documents, such as reports or speeches by speakers not affiliated with central banks, we are left with 18,045 unique speeches from 118 different central banking institutions – 108 central banks and 10 Federal Reserve Banks. Although this data source has provided a useful basis for numerous studies of central bank communication, it has three main limitations. First, some central banks are completely absent, or they are present only with a limited number of speeches. For instance, no speeches are available from the central banks of Bangladesh, Venezuela or Kazakhstan; only a single speech is present from Uruguay and Jordan; only two speeches are available from Cambodia. Second, the collection of speeches has not been fully consistent across countries and periods. Some significant gaps are present, especially for emerging economies (e.g. no speech of the Banco Central de la República Argentina is available from October 2010 to June 2019). Third, the BIS only recently started to collect speeches given in languages other than English. This leads to an under-representation of speeches from central banks that tend to communicate in their native language and do not systematically provide English translations for all the speeches on their website (e.g. Banca d'Italia and Deutsche Bundesbank).

We thus augment the BIS dataset by collecting speeches directly from all central banks with an online presence. We identify 154 central bank websites, of which 143 contain speeches delivered by

[6]The BIS dataset is available at: https://www.bis.org/cbspeeches/index.htm. Speeches are provided in PDF format and are accompanied by a unique web page containing metadata such as title, subtitle (sometimes containing information on the context of the speech), institution, date and speaker's name.

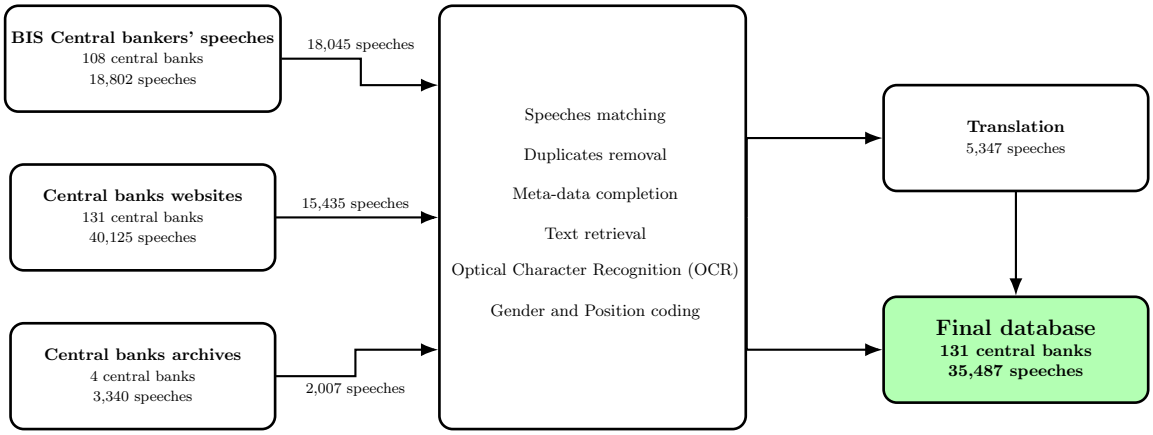


Figure 1: Summary of the dataset construction and cleaning

central bankers.[7] Whenever possible, we choose to access their website in the original language, not to limit ourselves to speeches delivered in – or officially translated to – English.[8] Scraping central bank websites allows us to collect a total of 40,125 speeches. After removing irrelevant documents (e.g. interviews, slide decks) and, more importantly, all the speeches already featured in the BIS dataset to avoid duplicates, we obtained a total of 15,435 additional speeches for the period 1986-2023.[9]

Finally, we expand the coverage of our dataset by scraping digital archives (such as the FRASER website curated by Fed St Louis) and requesting access to central banks' archives, especially when their website only features recent communication. This approach yields 3,340 additional speeches, including 2,007 unique entries not found in either the BIS repository or central bank websites.[10]

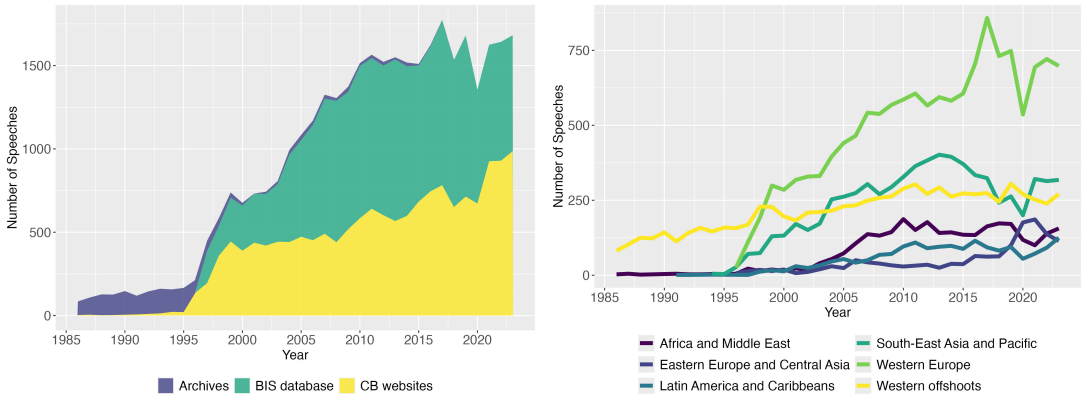
We then perform some final arrangements for the dataset. We normalise metadata (e.g. names of speakers and institutions) across data sources. We perform optical character recognition (OCR) on all speeches that are not already machine-readable, using the machine learning algorithm Tesseract. We manually check all the speeches with less than 1,000 words to identify remaining presentations or speeches for which only a part of the transcript was made available. We then detect the language

[7]These 143 websites include those of 131 sovereign central banks and the 12 Federal Reserve Banks of the US Federal Reserve System.

[8]For example, the website of the Banca d'Italia features 433 speeches in English (either delivered in English, or translated ex-post), but also 611 speeches delivered only in Italian. Similarly, the Deutsche Bundesbank website contains 917 speeches in English and 527 in German.

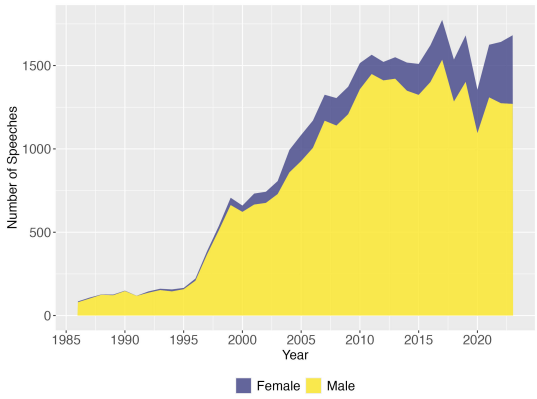
[9]For the European Central Bank, the BIS dataset contains a high number of interviews (296) and press conferences' introductory statements (231), which are not present in ECB's own repository of speeches. Given the nature of these documents, and the choice of the central bank to not include those in their speeches repository, we excluded them from our dataset.

[10]Of the 2,007 unique speeches, 1,702 have been obtained from the Federal Reserve archives (1986-2003), 197 from the De Nederlandsche Bank (2002-2018), 88 from Banque de France (2002-2015) and 20 from Banque de Belgique (2005-2013).

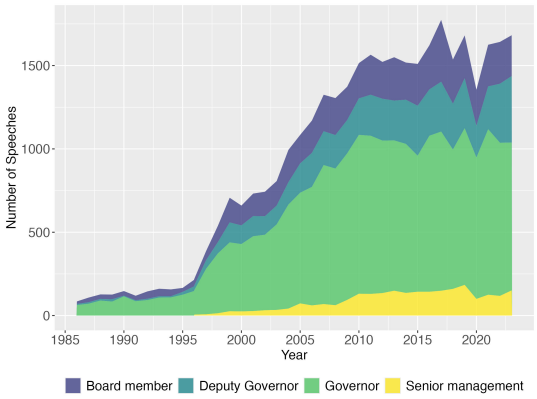


(a) Speeches by source

(b) Speeches by region



(c) Speeches by gender



(d) Speeches by role

Figure 2: Central bank speeches over time, 1986-2023

of the speeches, identifying 5,347 speeches delivered in 38 languages different from English. We translate all these speeches to English using *Microsoft Translator*, a multilingual machine translation cloud service.[11] Finally, we add original metadata for all speeches by coding the gender and role (governor, deputy governor, board member or senior management) of each speaker using information publicly available online.

Table 1: Summary statistics: comparison with the BIS dataset

		Number of central banks	Number of speeches	Speeches per year per CB	Words per speech
Full database	Advanced	38	24,066	18.1	2,962.1
	Emerging and developing	93	11,421	6.9	2,052.0
	Total	131	35,487	12.5	2,507.1
Of which BIS	Advanced	38	12,457	11.6	3,074.7
	Emerging and developing	70	5,588	4.8	2,330.7
	Total	108	18,045	8.2	2,702.7

2.2 Thirty-seven years of central bank communication

Our final dataset contains 35,487 unique speeches from 131 central banks, for the period going from the beginning of January 1986 to the end of December 2023. This represents a 89% increase in speech coverage compared to the BIS repository. Table A.1 in Appendix A provides an overview of the number of speeches extracted for each country and geographical region, as well as information on their data source and language.

Figure 2 plots the temporal evolution of the speeches included in our dataset. We confirm the well-known increase in central bank public communication since the 1990s (Lustenberger and Rossi, 2020). After 2010, the number of speeches has stabilised at around 1,500 per year on average, although with some volatility. This general upward trend hides significant geographical diversity, as shown in Figure 2b, with several regions experiencing stages of stagnation or decline in communication over time. The central banks of Western Europe and Western offshoots[12] appear to be particularly active in their public communication, producing more than 62% of the total number of speeches. Figure 2c highlights how the wide majority of speeches are given by men, reflecting the biased gender composition of central banks' boards (see Masciandaro et al., 2023). The share of speeches delivered by women has nonetheless gradually increased, moving from less than 4% in the 1990s to around 24% in 2023, thus accounting for roughly 13% of total speeches. Finally, Figure 2d reports the number of yearly speeches by role. Despite slight variations, the proportion remains very stable over time, with the majority of speeches (approximately 60%) being delivered by the central bank governor.

Table 1 provides an overview of the dataset's country representation, using the IMF classification to split between (i) Advanced economies and (ii) Emerging and developing countries (IMF, 2021). While most speeches in our dataset still belong to advanced economies, all the central banks we have in addition to the ones covered by the BIS dataset are located in emerging and developing

[11] While the use of automated machine translation might lead some meaning to get 'lost in translation', the risk of this affecting the results of text analysis using a bag-of-words approach is limited (Shaikh et al., 2016; de Vries et al., 2018).

[12] Western offshots include Australia, Canada, New Zealand and the United States (Maddison, 2006).

countries. Our dataset therefore leads to an upward re-estimation of the heterogeneity of central bank communication. Our additional speeches only marginally decrease the average length of speeches, suggesting that they are similar to the ones gathered by the BIS.

Figure 3 provides additional insights into the evolution of central bank communication. Central banks in advanced economies have been communicating publicly almost every year since the 2000s (see Figure 3a). Over time, both the absolute and average frequency of their communication have increased (see Figure 3b and Figure 3c).[13] At the same time, speeches have become more concise, moving from an average of around 3,400 words in 1996 to 2,600 in recent years (see Figure 3d). Central banks from emerging and developing countries exhibit partially distinct characteristics. The number of central banks engaging in public communication in our sample has increased constantly since 1995. These central banks communicate less often than those from advanced economies, with an average of 10 speeches per year, a number that has been stalling since the early 2000s. In addition, their speeches are consistently shorter than their advanced economies counterparts, and their average length has been decreasing faster.

As we also collect speeches in the original (non-English) language of each country, we are able to explore how the language used by central bankers in their speeches has evolved over time.[14] While financial integration and the rise of forward guidance might suggest that central banks have increased their communication in English over the years, our data show that this is not the case. The share of speeches in the original language and not translated to English is 15.1 percent in the whole corpus, with a slight trend towards more original language untranslated speeches.

3 Central bank communication and climate change

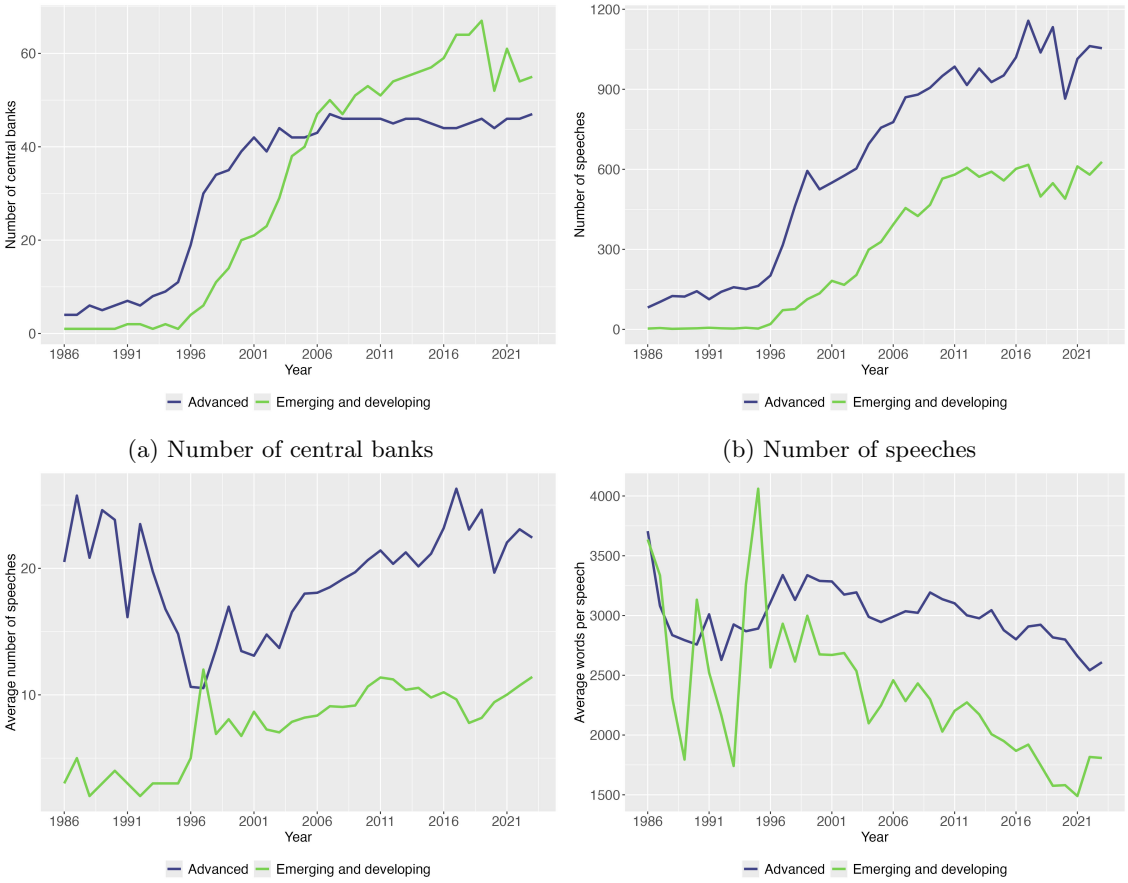
This section dives into our new dataset of central banker speeches to explore the evolution of climate-related communication. In Section 3.1, we discuss our dictionary-based approach to identifying climate-related speeches. In Section 3.2, we provide an overview of the evolution of climate-related communication across time and regions. Section 3.3 implements a structural topic model to identify and discuss the major climate-related narratives used by central banks.

3.1 Identifying climate-related speeches

We start by identifying a sub-set of 'climate-related speeches' to investigate more in detail the nature and evolution of central bank communication on climate-related issues. Performing our analysis on the entire dataset would be feasible, but the narratives specific to our topics of interest would

[13] Note that the pre-1995 values in Figure 3c are driven by the presence of only a limited number of institutions in our dataset, for each of which we have a large number of speeches.

[14] Whenever a speech is available in both English and non-English, we only retrieve the English version. Therefore, the share of speeches in the original language discussed here only concerns those for which no translation to English is provided.



(a) Number of central banks

(b) Number of speeches

(c) Avg. number of speeches per central bank

(d) Avg. number of words per speech

Figure 3: Central bank speeches over time (Advanced vs Emerging and developing), 1986-2023

be drowned out by the extensive range of topics discussed by central bankers in their speeches. Techniques such as Latent Dirichlet Allocation (LDA) or Structural Topic Modelling (STM) – aimed at identifying the main themes treated in a corpus of text based on the joint probability of the appearance of words – tend to perform better on smaller, more consistent bodies of text.[15]

We rely on a dictionary approach. This method ensures transparency and replicability. It involves building a dictionary of keywords or key expressions and counting their occurrences in the corpus, before deciding on the threshold above which a speech is considered relevant. Due to the absence of a pre-conceived dictionary in the literature, Arseneau et al. (2022) build their own via

[15]In our case, implementing such analysis on our entire dataset would force us to include an excessively large number of topics in order to gain sufficient insight into climate-related narratives, thus worsening the performance of the topic model.

Table 2: Dictionary of climate-relevant n-grams

Keyword	Speeches #	Keyword	Speeches #	Keyword	Speeches #	Keyword	Speeches #
abrupt transition	19	brown penalising factors	3	carbon emission	68	carbon emissions	265
carbon price	62	carbon prices	56	carbon pricing	92	carbon tax	72
carbon taxes	62	climate action	177	climate actions	19	climate adaptation	29
climate aligned	8	climate change	2007	climate changes	34	climate crisis	122
climate damage	2	climate data	47	climate economics	5	climate event	4
climate events	60	climate exposure	1	climate exposures	7	climate extremes	6
climate finance	75	climate friendly	56	climate goals	67	climate harm	1
climate hazard	2	climate hazards	7	climate impact	44	climate impacts	19
climate metrics	3	climate minsky moment	15	climate policies	108	climate policy	151
climate protection	57	climate related	745	climate relevant	6	climate risk	432
climate risks	480	climate scenario	50	climate scenarios	110	climate science	20
climate sensitivity	3	climate shock	1	climate shocks	25	climate stability	9
climate stress test	63	climate stress tests	51	climatologist	2	climatologists	7
climatology	1	cotwo	174	decarbonise	43	decarbonised	10
decarbonising	23	decarbonization	59	decarbonize	9	decarbonized	9
decarbonizing	6	disorderly transition	51	disorderly transitions	4	environment risk	4
environment risks	3	environmental risk	122	environmental risks	276	global warming	341
green bond	240	green bonds	300	green economy	115	green finance	458
green finances	1	green investment	114	green investments	118	green monetary	6
green policies	10	green policy	13	green qe	6	green quantitative easing	8
green supporting factor	10	green supporting factors	5	green swan	27	green swans	8
green technologies	82	green technology	48	green transition	254	green transitions	6
greener	325	greenhouse	378	greening	529	low carbon	432
ngfs	357	paris agreement	274	physical risk	91	physical risks	237
stranded asset	4	stranded assets	68	sustainable finance	607	sustainable finances	12
sustainable investing	50	tcfd	139	transition risk	117	transition risks	310

Note: This table reports the list of keywords used in our dictionary. Speeches # indicates the number of speeches using each n-gram at least once.

a seeding method aimed at identifying relevant key expressions in an endogenous manner. Using the expression 'climate change' as a seed, they identify the set of expressions most likely to co-occur with it and which appear less likely in unrelated speeches. Considering the wider temporal extension of our dataset, we instead prefer to create our own dictionary. Indeed, the results of the seeding method are very sensitive to the expression chosen as seed. While 'climate change' and related expressions found by Arseneau et al. (2022) are very common in the contemporary debate, the public conversation in past decades might have used alternative terminologies (e.g. 'global warming').

Our dictionary of climate-related keywords aims to be specific to central banking while being as comprehensive, time-agnostic, and transparent as possible. We start from the few available dictionaries – i.e. the 'Environment' Thesaurus of the World Bank (WBG, 2018) and the one proposed by Arseneau et al. (2022) – and complement them with our knowledge of the green central banking literature. Whenever possible, we favour bigrams and trigrams (i.e. expressions composed of two or three words) over single keywords.[16] After obtaining an initial dictionary of approximately 200 expressions, we undertake an iterative process of corrections to remove n-grams that capture false positives.[17] This iterative process allows us to retain a rather conservative dictionary. While this may lead to an underestimation of the intensity of climate focus by central bankers, it allows us to minimise risks of capturing false positives, which we consider more important.

[16] For instance, 'environment' is excluded, as it is sometimes used in expressions such as 'economic environment'. Instead, we include 'environmental risks' and similar expressions that are more specific to our research question.

[17] For example, we drop the expression 'smooth transition' because it appears in speeches about the democratisation of authoritarian countries. We also drop all the hypothesised keywords which returned zero hits from our corpus.

The final version of the dictionary comprises 104 n-grams. Table 2 presents the list of the keywords in our dictionary, together with the number of speeches in which these keywords are present.[18] Unsurprisingly, 'climate change' is the most salient expression, being present in 2,007 speeches. Other very common keywords are 'climate related' (745 speeches), 'sustainable finance' (607), 'greening' (529), 'climate risks' (480), 'green finance' (458), 'climate risk' (432) and 'low carbon' (432).

While alternative strategies exist, we believe this process of identifying climate-related speeches is the most effective and transparent. An alternative option would have been to rely on the 'climate change and green finance' collection of speeches classified by the BIS.[19] However, this collection only contains speeches that: (i) are part of the BIS dataset; (ii) have been delivered after 2015; and (iii) are almost entirely focused on climate-related topics. We are instead interested in expanding the geographical and temporal representation of central bank communication and are interested in including also speeches where climate-related topics are mentioned *en passant*, as part of a larger discussion centred on some other topics. An alternative option could have been to rely on a machine learning algorithm – such as a Large Language Model (LLM) – trained on the manual classification of a small random sample of speeches (Baumgärtner and Zahner, 2023; Do et al., 2022). While promising and time-saving, the chosen dictionary approach allows us to more comfortably trust the identification of climate-related speeches and avoid false positives.[20]

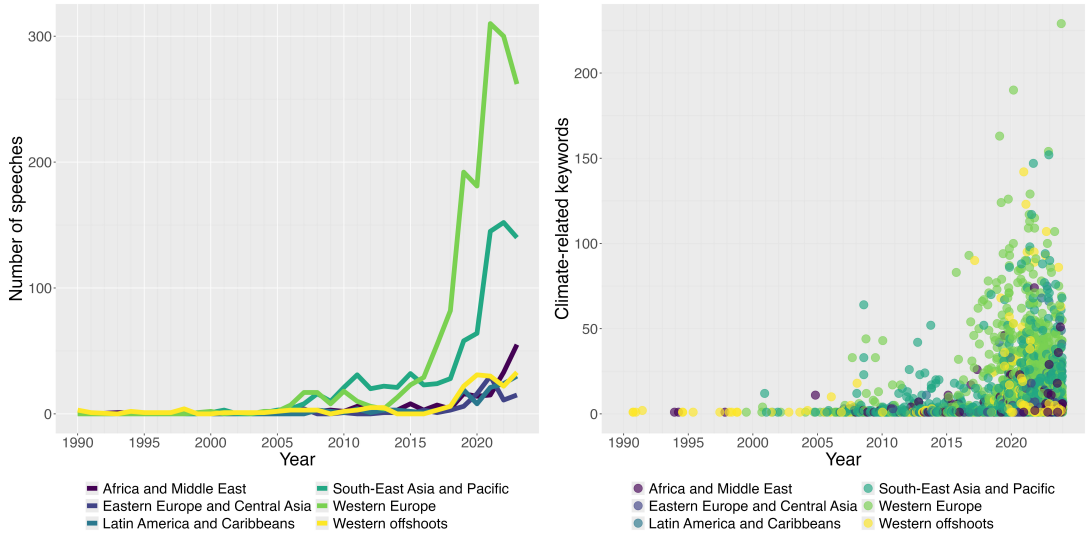
3.2 Climate-related speeches: an overview

Our dictionary allows us to identify 2,968 speeches that mention climate-related keywords at least once. A significant proportion of them (1,366) are not present in the BIS dataset, with 413 of them originally published in a non-English language. These speeches come from 99 distinct central banks, with important differences. Most central banks (52) have less than 10 climate-related speeches, while a small number of institutions (11) are responsible for more than half of them. The number of climate-related keywords per speech is also very heterogeneous. Indeed, around half of the speeches (1,381) contain only one or two climate-related keywords, while 147 speeches contain 50

[18] Before looking for the frequency of climate-related keywords, we first clean the corpus of text to make sure we correctly spot all occurrences in which these words are mentioned. For instance, we replace all '-' by ' ' and transform special characters (such as ligatures, accents, uppercase and special characters) into standard lowercase characters. Before removing numbers, we also identify and transform all possible spellings of CO2 into 'cotwo'. Whenever a keyword could be present with two spellings, e.g. decarbonise/decarbonize, or in both singular and plural forms, e.g. tax/taxes, both spellings were tested. If the final dictionary only features one spelling, it means that the other(s) gave zero results in our dataset.

[19] Speeches are available at https://www.bis.org/topic/green_finance/speeches.htm.

[20] We have tested what is currently the most prominent pre-trained LLM focusing on climate-related topics – ClimateBERT (Bingler et al., 2022) – with unsatisfactory results. We believe this is mainly due to the fact that the model had been trained on newspaper data, whose nature is radically different from central bank speeches. For example, the sentence 'we need to maintain a climate of price stability' is identified by ClimateBERT as being climate-related with a certainty of 99.5%. We therefore do not consider it a viable option for our purposes.



(a) Climate speeches per year and region

(b) Climate-related keywords per speech

Figure 4: Temporal evolution of central bank climate-related communication

or more keywords.[21] Figure 4a shows the evolution of climate-related speeches by world regions, while Figure 4b plots speeches according to their number of climate-related keywords mentions.

The analysis of the main features of our dataset of climate-related speeches offers several interesting insights. First, climate-related communication by central bankers started taking place well before the notorious 2015 speech by Mark Carney (Carney, 2015). Starting from the mid-2000s, several central banks – especially those from Southeast Asian countries – began engaging steadily with climate-related topics, with roughly 30 speeches per year. In the same period, the intensity of the climate focus of speeches, proxied by the number of climate-related keywords per speech, also increased, as central bankers started making more focused interventions around environmental issues (see Figure 4b).

Second, the seminal speeches of the early 2000s are thematically diversified and sometimes anticipate issues that would become mainstream a few years later. For instance, the 2000 speech by David Carse of the Hong Kong Monetary Authority already links climate change to financial risks for banks and investors. The former Governor of the Reserve Bank of New Zealand, Alan Bollard, already discussed the inflationary dynamics of carbon pricing in 2008. Climate physical impacts and their implications for central bankers are also discussed by Atiur Rahman, Governor of the Bank of Bangladesh, on multiple occasions during 2012-13. These speeches also touched on topics that have since been marginalised in central bank communication, such as international climate

[21] The most climate-intensive speech counts 229 iterations. It was delivered by Catherine L. Mann of the Bank of England in November 2023.

justice.

Third, climate-related communication exhibits strong geographical heterogeneity. From 2005 to 2010, central bankers from Western Europe and Southeast Asia were virtually the only ones to address the issue. Between 2010 and 2015, Southeast Asian central banks further strengthened their focus on climate, increasing both the number of speeches and the amount of climate-related keywords per speech. Central bankers from Bangladesh, Indonesia, India, Malaysia, and Thailand have been particularly active in this period. On the contrary, Western European central bankers stopped engaging with the issue. In 2015, they picked up the topic again, overtaking their Asian counterparts as early as 2016 in terms of the number of speeches, but also strongly increasing the intensity of their focus on sustainability and environmental issues, as shown by the rise in the number of climate-related keywords per speech in that period. Overall, approximately one quarter (32) of the central banks in our dataset did not deliver any speech containing climate-related keywords; while others – such as Centrale Bank van Aruba, Bangladesh Bank, People's Bank of China, Banco de España, Banque de France, Bank of Greece, Bank Al-Maghrib (Morocco), Banka Slovenije, and Central Bank of Samoa – have 20% or more of their speeches mentioning at least one climate-related keyword.

Finally, we confirm the widely-observed boom in the interest of central banks on climate-related topics since the second half of the 2010s, both in terms of the number of speeches and in the number of climate-related keywords per speech (Arseneau et al., 2022). While the average number of climate-related speeches remains relatively stable at around 30-60 speeches per year in the 2007-2016 period, in the period 2021-2023 we record around 550 speeches per year. Both Carney's 2015 speech and the creation of the NGFS in late 2017 are likely to have given an important impulse to this stream of central bank communication. Interestingly, we also observe a drop in speeches in 2023 in both Western Europe and Southeast Asia and the Pacific, which might indicate a future recalibration of central banks' attention away from climate-related topics.

3.3 A tale of two climate-related narratives

After having discussed *when* and *where* central bank communication has engaged with climate-related topics, we now move to understand *how* these topics have been approached. To do so, we run a topic model on our sub-collection of 2,968 climate-related speeches.

Topic models are unsupervised algorithms aimed at discovering latent topics in a corpus. To do so, they consider each document as a 'bag of words' and base their categorisation on the co-occurrence probabilities of expressions. The intuition is that if two words appear frequently together, there is a high chance for them to be thematically related. Once words are categorised into latent topics, the model can represent each document as a combination of topics, shedding light on its underlying themes, and allowing us to capture how the overall topical interest evolved across time

and space. We decide to implement a Structural Topic Model (STM) (Roberts et al., 2013, 2014), an amended version of the Latent Dirichlet Allocation (LDA) algorithm proposed by Blei et al. (2003). This approach allows us to include document-level covariates, i.e. variables providing additional structure to the STM algorithm so as to inform the identification of topics and the analysis of how these vary across different document characteristics. Before launching our model, we follow standard practices by pre-processing our corpus to reduce its dimensionality.[22]

We then run several STM models using the R package designed by Roberts et al. (2019), including *Year* and *Central bank* document-level covariates,[23] and varying the number of topics. While there is no 'right' number of topics, it is ideal to select a model on the semantic coherence-exclusivity frontier (Roberts et al., 2014). Among the ones on the frontier, researchers can choose the model that more appropriately addresses the nature and granularity of the specific research question being studied (Grimmer et al., 2022). In our case, the model with 10 topics stands out due to its high score in terms of both semantic coherence and exclusivity, as well as to its salient and straightforward interpretability (for more information on model selection, see Appendix B.1). To label the 10 topics, we look at the 50 most frequent words, the 20 most frequent and exclusive (FREX) words and the 30 speeches with the highest topic scores for each of them.[24] Table 3 presents the 10 labelled topics emerging from the model, together with their 10 most frequent words. For more details on topic labelling, see Appendix B.2.

We identify two topics – reported in bold in Table 3 – directly related to climate change and the environment. Topic 1 (*Green finance*) features a large number of themes linked to green investments. Environment-related keywords appear at the very top of the ranking ('green', 'climate', 'sustainable', 'transition', 'energy', 'carbon' and many others), together with terms about financial markets and business opportunities (e.g., 'finance', 'investment', 'financial', 'bank', 'company', 'bond'). The top exclusive words include words such 'emission', 'taxonomy', 'green', 'carbon', 'esg', 'renewable' and 'fossil'. This lexicon appears to be oriented towards a promotional approach – with terms such as 'support', 'development', 'government', 'action', 'initiative' and 'invest' appearing among the top 50 topic keywords – characterised by the desire to support private market solutions and green financial investments.

[22] We transform all text into lowercase letters. We remove special characters, numbers, punctuations, and a large list of 'stop-words', i.e. frequent terms carrying low-meaning content such as 'and', 'that', 'the', 'be' and many others. The list of stop-words is available at: https://gist.github.com/sebleier/554280. We also remove URLs, frequent footers, central bank names and abbreviations (e.g. ECB), country names and adjectives, as well as mentions of the months of the year. We also lemmatise all remaining words, i.e. we replace them with their neutral form. This allows us to treat words such as 'bank', 'banks' or 'banking' as one. A final step could have been to create bigrams allowing to capture expressions such as 'central bank' or 'financial stability' as single units rather than as separate tokens. However, after testing, we found that adding bigrams increased the computational time without leading to any significant difference in topic identification.

[23] Adding time and central bank covariates allows the STM to form topics taking into stronger consideration the differences in communication across years and jurisdictions.

[24] The topic labelling process was conducted independently by each author, before choosing a commonly agreed final label.

Table 3: Topics and their most frequent words in a 10-topic Structural Topic Model

N.	Topic label	Most frequent words
1	**Green finance**	green, climate, finance, sustainable, investment, transition, energy, carbon, financial, sustainability
2	**Climate-related risks**	risk, climate, financial, change, bank, insurance, impact, central, transition, economy
3	European economy	policy, european, euro, economic, monetary, country, crisis, europe, market, central
4	Financial markets	financial, market, finance, global, asia, industry, development, technology, growth, trade
5	Social economy	people, economic, time, country, datum, social, economy, change, public, future
6	Financial stability	bank, financial, risk, market, asset, central, regulatory, regulation, sector, credit
7	Economic outlook	price, economy, growth, economic, percent, increase, rate, global, investment, bank
8	Inflation and monetary policy	inflation, policy, rate, monetary, price, bank, economy, target, term, market
9	Debt and crisis	increase, economic, crisis, economy, debt, growth, financial, sector, public, level
10	Financial inclusion and development	bank, financial, development, economic, sector, policy, country, percent, finance, support

Topic 2 (*Climate-related risks*) is instead unequivocally centred around the intersection between climate change ('climate', 'change', 'impact', 'transition', 'physical', 'nature' and other related terms in the top-50 keywords) and financial risks ('risk', 'financial', 'bank', 'insurance', 'scenario', 'supervisor'). The narrative emerging from it is more strongly aligned with a prudential – rather than promotional – perspective, as it focuses on how climate-related dynamics might have disruptive impacts on financial markets and the strategies to manage these risks. Topic 2 most exclusive words are almost entirely related to climate change and decarbonisation, including mentions of the NGFS and the TCFD (Task Force on Climate-Related Financial Disclosures).

Topics 3 to 10 do not have an equally strong link to climate-related themes, despite occasional appearances of terms related to climate or sustainability. Topic 10 on *Financial inclusion and development* includes 'sustainable' among its top 50 keywords, in recognition of the need for financial development in lower-income economies to be sustainable. Both Topic 7 on *Economic outlook* and Topic 8 on *Inflation and monetary policy* exhibit the term 'energy', as energy commodities and production are key variables in driving both economic activity and inflation. However, despite their focus being oriented elsewhere, it's useful to remember that all these topics emerge from our sub-set of climate-related speeches. Hence, their heterogeneity – ranging from macroeconomic dynamics to international trade and beyond – highlights how climate-related matters can emerge in speeches focusing on a very diverse array of topics.

Figure 5 shows how the different topics evolved within our corpus of climate-related speeches from 2006 onwards.[25] The *Green finance* topic has expanded rapidly in the early 2010s and then remained roughly stable. The *Climate-related risks* topic has instead occupied a significant space in central bank communication only after 2016. This is consistent with the observed spike in the climate-related activities of central banks, especially within the NGFS framework, which tend to be more aligned to prudential – rather than promotional – discourses. We also observe, within our set of climate-related speeches, a recent expansion of attention around *Financial stability* and, later on,

[25] 2006 marks the first year in which more than ten climate-related speeches were delivered in a single year.

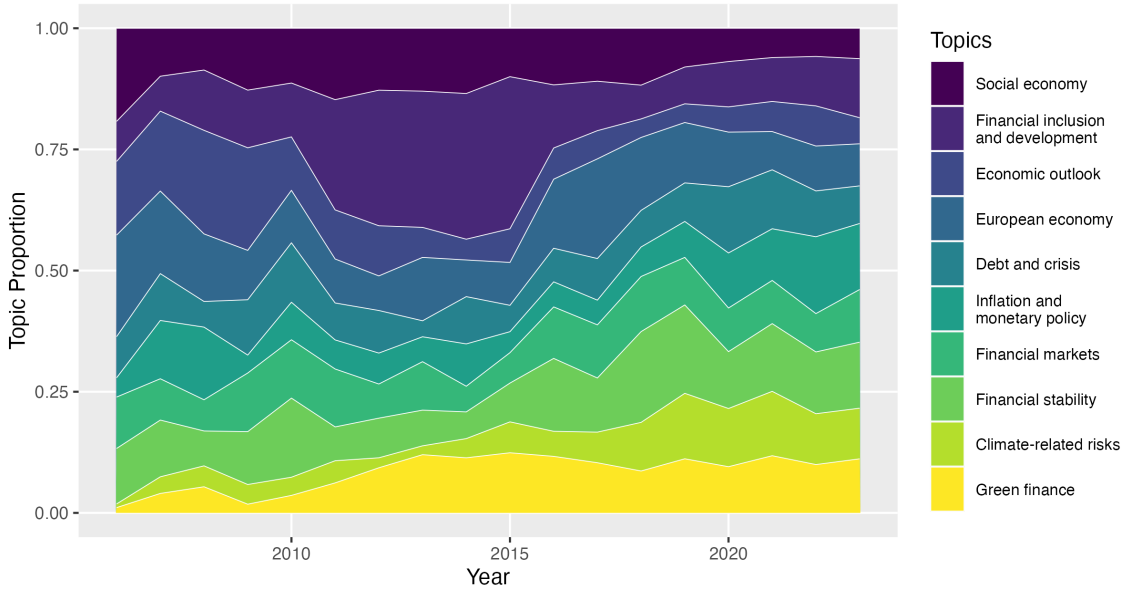


Figure 5: Temporal evolution of topics in climate-related speeches

around *Inflation and monetary policy*. This is consistent with the growing focus of central bankers on the impacts of climate-related factors on financial dynamics and, more recently, inflation and the design of monetary policy. On the other hand, topics such as *Social economy* and *Financial inclusion and development* have seen their share decline over time.

Disentangling the geographical origins of climate-related topics provides additional insights into the evolution of climate-related central bank communication. Figure 6 reports the share of the two climate-related topics in the communication strategies of the 30 central banks with the highest number of climate-related speeches (from left to right). The aggregate share of the two climate-related narratives already offers some information concerning the relative weight of climate-related topics within each central bank. For instance, despite delivering among the largest number of speeches in our climate-related dataset, the central banks of the Philippines and Japan dedicate less than 10% of their climate-related speech content to climate-related topics. The share for the European Central Bank, Banca d'Italia, the Reserve Bank of India and others remains below 20%. This suggests that, while a large number of speeches from these central banks contain climate-related references, they usually do so briefly, while mostly focusing on other topics. On the contrary, the central banks of other countries – e.g. the Netherlands, Norway, Mexico and Hungary – exhibit much higher proportions, indicating the tendency to have more focused climate-related speeches.

However, the most interesting information can be obtained by examining the differences in the

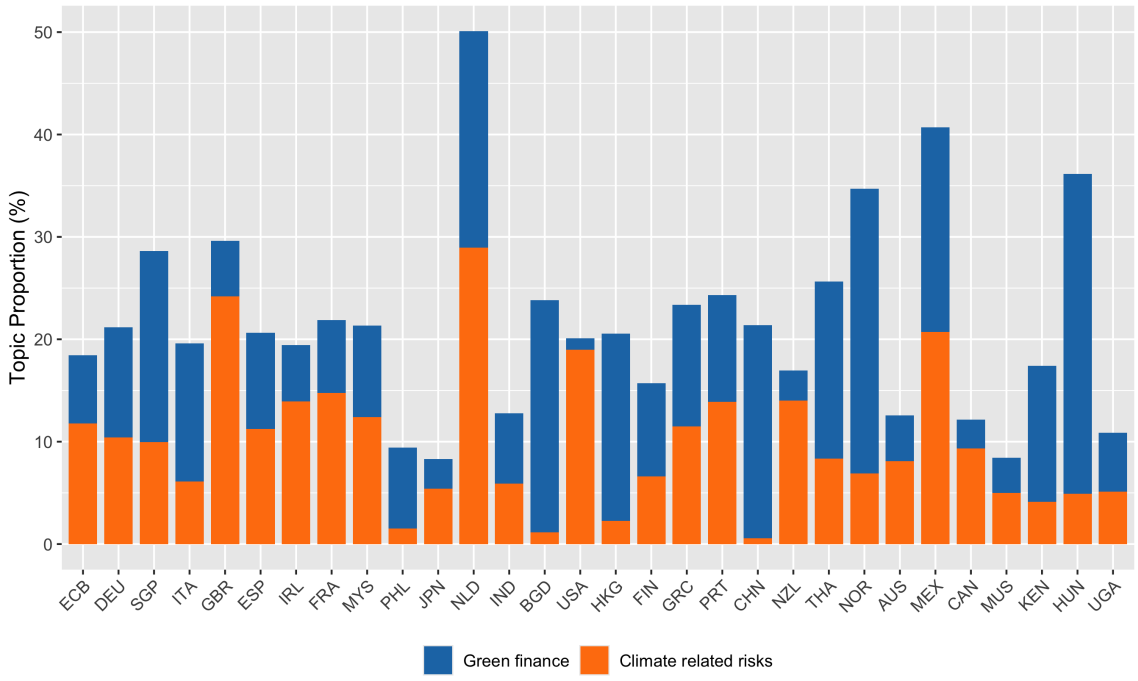


Figure 6: Frequency of climate-related narratives in the top 30 central banks by number of climate-related speeches

prominence given to each climate-related topic in relation to each other. Two main groups of central banks seem to emerge, relying on different types of narratives. A first group of central banks is characterised by a predominant share of their climate-related communication dedicated to the *Green Finance* topic. China, Bangladesh, Hong Kong and the Philippines are prominent examples of countries for which *Green finance* represents more than 80% of their overall climate-related communication. This group includes several other countries characterised by either: (i) a proactive approach of financial policymakers in pursuing developmental objectives; or (ii) the presence of financial centres of regional or global importance in pursuit of expanding their influence; or both. These include Singapore, Turkey, Russia, Sri Lanka, Kenya, Thailand and others. Central banks from these jurisdictions tend to have broader mandates and explicit support objectives for government priorities (Dikau and Volz, 2021; Romelli, 2022). This has led them to put in place strategies driven by promotional purposes, with instruments ranging from preferential interest rates to credit floors or window guidance (Dikau and Ryan-Collins, 2017), and to actively push for green finance as an opportunity for economic development. The top speeches in terms of *Green finance* topic content often revolve around the transformative potential of sustainable financial instruments such as green bonds, green indexes, and other policy-driven market innovations aimed at facilitating

the low-carbon transition, attracting foreign investments and fostering domestic growth.[26] However, the group is not entirely homogeneous: Hungary, Lithuania and Norway also have a strong focus on the *Green Finance* topic, highlighting how narratives transcend geographical and institutional boundaries.

A second group of central banks has mainly devoted their climate-related communication to the *Climate-related risks* topic. These are mostly institutions located in high-income Western economies: among the countries with at least 80% of climate-related communication focusing on this topic, we find the United States, New Zealand and the United Kingdom. Other relevant countries in this group include Canada, Ireland, Switzerland, France, Japan, Australia and the European Central Bank.[27] With high degree of independence from their political counterparts and greater prudential responsibilities since the 2008 global financial crisis, these central banks have integrated climate-related dimensions in an instrumental way, seeking to address how they might threaten their financial stability – and, more recently, price stability – objectives. Policy strategies being discussed in speeches often revolve around financial disclosure and transparency, climate stress testing and scenario analysis.[28]

Thus, it appears that the variety of green central banking narratives is rooted in the underlying institutional contexts and modes of regulation, which puts them in different positions in the face of the climate crisis: (i) high-income economies have been mostly trying to manage the threats posed by the low-carbon transition to the profitability and stability of their financial sectors, although they seem to be adopting more promotional discourses in recent years; (ii) developing and emerging economies are seeking to leverage sustainable finance and to pursue climate objectives as part of broader development strategies.

[26] Top *Green finance* speeches include Yi Gang from the People's Bank of China ("We have provided central bank lending for financial institutions at low interest rates, and institutions receiving such low-cost funds are required to support carbon emission reduction projects and disclose relevant information to the public."); Ravi Menon from the Monetary Authority of Singapore ("The Monetary Authority of Singapore has been working with financial institutions and a broader set of ecosystem players to support the managed phase-out of coal-fired power plants in Asia"); and Norman Chan from the Hong Kong Monetary Authority ("The HKMA has been very supportive of responsible investment, and has incorporated environmental, social and governance, or ESG, principles into our investment processes.")

[27] Curaçao and Fiji also appear as strong climate-related communication contributors with a focus on *Climate-related risks*, which we attribute to their exposure to sea level rise and other climate-driven physical impacts.

[28] Among the top speeches in terms of dominance of the *Climate-related risks* topic we find those given by Frank Elderson from the European Central Bank ("Climate and environmental risks are a source of financial risk"); Lael Brainard from the US Federal Reserve ("We are developing scenario analysis to model the possible financial risks associated with climate change and assess the resilience of individual financial institutions and the financial system to these risks"); and Sarah Breeden from the Bank of England ("We are working domestically with industry (..) to build intellectual capacity and establish best practice in how to manage the financial risks from climate change)."

4 Climate-related communication drivers

In the previous section, we discussed the heterogeneity – across both time and space – of central bank climate-related communication strategies. We now explore the possible drivers behind such strategies. We start by identifying key indicators of central banks' focus on climate-related issues in Section 4.1. In Section 4.2, we define and discuss a set of hypotheses and present our data sources. Finally, in Section 4.3, we test our hypotheses through a Poisson Pseudo-Maximum Likelihood (PPML) empirical strategy.

4.1 Green central bank communication indices

The analysis performed in Section 3 allows us to create multiple indicators able to provide information on the degree of engagement of central bankers with climate-related issues. The structural topic modelling results offer us two ready-to-use measures, each focusing on a specific climate-related narrative: *Green finance*, and *Climate-related risks*. For each speech, we extract the value indicating the prevalence of the topics, i.e. the percentage of each speech dedicated to a specific topic.[29]

In addition to topic-specific indicators, we construct two measures of general climate attention using our dictionary of climate-related keywords (see Table 2). First, the *Climate frequency* index captures the total number of climate-related expressions mentioned in a speech. It is thus a simple word count indicator. Second, the *Climate salience* indicator reflects instead the relative importance of climate-related issues in each speech. This is obtained as the ratio between the *Climate frequency* measure and the total number of words used in a speech, multiplied by 100, i.e. expressed in percentage points. These four speech-level climate attention metrics are then aggregated at the year and central bank level, leading to a set of yearly indicators of the climate focus of each central bank communication strategy.

4.2 Climate-related communication drivers

We focus on three main potential drivers affecting the shades of green used by central banks in their public communication. First, one might expect central banks operating in countries that are more exposed to climate-related risks — either on the physical or transition side – to be more likely to communicate about climate-related issues. Indeed, there is increasing empirical evidence that both climate change and decarbonisation could have repercussions for central banks' missions (Faccia et al., 2021). It is not trivial to find appropriate measures of climate-related risks that could fit with our dataset of central bank speeches. We identify two key variables for which we have available data for the whole 1986-2023 time period and for most (114) of the 131 countries in our sample.

[29] For speeches with zero iteration of any climate-related word, we set these values at zero.

We define *Physical exposure* as the monetary value of all economic losses directly or indirectly due to climate-related disasters, scaled by the total GDP of the country.[30] This measure – which acts as a proxy for the exposure of a country to climate physical impacts – is provided by the EM-DAT database.[31] In addition, we rely on *Carbon intensity*, defined as the level of CO2 emissions per GDP, as our proxy for the exposure to transition risks. The intuition is that a country whose economy is more reliant on CO2 emissions would suffer more while transitioning away from fossil fuels. We take the data for CO2 emissions from the Global Carbon Project.[32] GDP values are taken from the World Bank.[33]

Second, central bank institutional responsibilities might affect the strength and nature of their focus on climate-related topics. Indeed, central banks across jurisdictions operate under distinct mandates and, hence, enjoy different climate-related policy spaces (Baer et al., 2021; Dikau and Volz, 2021). More specifically, one might hypothesise that: (i) central banks more involved in the supervision of financial institutions are more likely to engage with climate-related topics – and especially with the climate-related financial risks of Topic 2 – due to the potential financial instability concerns associated with both climate change and the low-carbon transition; and (ii) central banks with broader mandates are more likely to engage with climate-related topics compared to central banks narrowly focused on price stability. We thus adopt two variables as proxies for central bank spheres of responsibility. We use the 'Objectives' sub-component of the Central Bank Independence Extended (CBIE) index created by Romelli (2022) and updated in Romelli (2024). *CB Objectives* represents five increasing levels of central bank focus on price stability, taking a value from 0 (if price stability does not even appear in the list of objectives) to 1 (if price stability is the single or primary objective of the central bank).[34] We then capture central bank financial supervision responsibilities by using the Central Bank Involvement in Supervision (CBIS) index proposed in Masciandaro and Romelli (2018) and updated until 2023. *CB Supervision* characterises six increasing levels of central bank involvement in the supervision of the financial sector. To facilitate interpretation and comparison with other variables, we normalise this index from 0 to 1.[35]

Third, the nature of the language and narratives used by central bankers is likely to be affected by the choices of their peers. Perceptions of norms and trends within the central banking epistemic

[30] We include droughts, extreme temperatures, floods, landslides, storms and wildfires.

[31] EM-DAT is maintained by the Centre for Research on the Epidemiology of Disasters (CRED) and is available at https://public.emdat.be.

[32] CO2 emission values are compiled by Our World In Data, based on the Global Carbon Project, and are available at https://github.com/owid/co2-data.

[33] Country GDP series are available at https://data.worldbank.org/indicator/NY.GDP.MKTP.CD.

[34] Intermediate values are: 0.25 if the objectives focus on economic growth and/or development, 0.50 if price stability appears with other conflicting objectives such as financial stability; and 0.75 if there are other but non-conflicting objectives.

[35] The levels of central bank involvement in supervision are classified as: no involvement in supervision (0); shared banking supervision between the central bank and another authority (0.2); supervision by the central bank over the banking sector only (0.4); supervision by the central bank over the banking and insurance sectors (0.6); supervision by the central bank over the banking and securities markets sectors (0.8); and supervision by the central bank over the entire financial sector (1).

community can boost institutional changes (Horvath, 2020). For what concerns the climate-related focus, the most important network of central banks is certainly the Network for Greening the Financial System – NGFS (Deyris, 2023; Helleiner et al., 2024). We, therefore, hypothesise that becoming a member of this network has a positive effect on climate-related communication. In particular, considering the NGFS's main areas of interest, and the thematic focus of its work packages, we expect an increase in engagement with climate-related financial risks (Topic 2) and, to a lesser extent, with green finance (Topic 1). We thus rely on NGFS annual reports and press releases to create a dummy variable that takes the value of one if a country is a member of the NGFS network in a given year and 0 otherwise. As this network was created in 2017, this variable takes the value of 0 for all years before 2017. Summary statistics for NGFS membership, as well as the other dependent and independent variables are provided in Appendix C.1.

4.3 Evidence on climate-related communication drivers

Our empirical analysis aims to investigate the drivers of central bank communication on climate-related topics. Approximately 73% of our country-year observations do not include climate-related speeches, with the consequence that the four measures of climate focus described above take values different from 0 in around 27% of the cases. Given the structure of our data, we rely on a Poisson Pseudo-Maximum Likelihood (PPML) regression in the spirit of Silva and Tenreyro (2006).[36] In particular, we estimate the following PPML model:

$$\begin{aligned}\text{Climate Focus}_{c,t} = exp(&\beta_0 + \beta_1 \text{Physical exposure}_{c,t} + \beta_3 \text{Carbon intensity}_{c,t} \\ &+ \beta_4 \text{CB Supervision}_{c,t} + \beta_5 \text{CB Objectives}_{c,t} \\ &+ \beta_6 \text{NGFS Membership}_{c,t} + \theta' \text{X}_{c,t} + \gamma_c + \mu_t) + \epsilon_{c,t}.\end{aligned} \tag{1}$$

where *Climate Focus*$_{c,t}$ is one of the four indicators of climate-related attention discussed in section 4.1; *Physical exposure*$_{c,t}$ represents the monetary damages from climate-related disasters in year t in country c, weighted for the country's GDP; *Carbon intensity*$_{c,t}$ captures CO2 emissions per GDP for country c in year t; *CB Supervision*$_{c,t}$ represents the degree of involvement of the central bank of country c in financial supervision in year t; *CB Objectives*$_{c,t}$ is the index capturing the breadth of the objectives of the central bank of country c in year t; and *NGFS membership*$_{c,t}$ is a dummy variable representing whether the central bank of country c is a member of the NGFS in year t. We also introduce a vector of control variables $X_{c,t}$: the level of inflation for country c in

[36] Unlike log-linearised models, PPML estimates are consistent even in the presence of heteroskedasticity and a large number of zeros (Silva and Tenreyro, 2006). Furthermore, PPML exhibits robustness against distributional misspecification (Gourieroux et al., 1984). Since a large number of our dependent variable observations take a value of zero – i.e. a central bank not giving climate-related speeches in a given year – this method applies particularly well in our context.

Table 4: Drivers of climate-related communication

	(1) Green finance	(2) Climate-related risks	(3) Climate frequency	(4) Climate salience
Physical exposure	-0.114	-0.003	-0.216	-0.089
	(0.222)	(0.076)	(0.202)	(0.099)
Carbon intensity	5.634*	9.978	4.557	7.093**
	(3.155)	(7.902)	(3.282)	(2.690)
CB Supervision	1.503	7.739**	6.363**	7.097**
	(2.263)	(2.378)	(2.126)	(1.989)
CB Objectives	-0.793	-3.837**	-2.191*	-2.861
	(1.282)	(1.139)	(1.260)	(1.761)
NGFS membership	0.958**	1.342**	0.669*	0.835*
	(0.396)	(0.601)	(0.383)	(0.444)
Inflation	0.078	0.149	0.051	0.084
	(0.085)	(0.104)	(0.042)	(0.063)
Output gap	-5.287	-0.260	-2.781	-7.369
	(4.290)	(6.376)	(5.202)	(5.311)
GDP per capita	0.159**	-0.010	0.212**	0.264**
	(0.080)	(0.077)	(0.071)	(0.096)
Insurance company assets to GDP	0.014	-0.005	0.020	0.007
	(0.023)	(0.022)	(0.019)	(0.015)
Private credit to GDP	-0.002	0.012	0.002	0.011
	(0.009)	(0.012)	(0.008)	(0.008)
Constant	-10.519**	-8.974*	-9.992**	-14.245**
	(2.983)	(4.791)	(3.125)	(3.583)
Observations	929	929	929	929
R-Squared	0.313	0.356	0.626	0.399

Note: Central bank and year-fixed effects are included. Standard errors are clustered at the country level. *, **, *** represent significance at 10, 5, and 1%, respectively.

year t ($Inflation_{c,t}$) and the country's *Output gap*$_{c,t}$, as both measures may matter for the ability of central bankers to engage with topics outside their traditional mandates; *GDP per capita*$_{c,t}$ controls for the level of material prosperity of country c in year t; while *Insurance company assets to GDP*$_{c,t}$ and *Private credit to GDP*$_{c,t}$ control for the relevance of the financial sector within the economic system of country c. Finally, we include two types of fixed effects in our analysis. First, γ_c indicates country fixed effects, which allows us to control for time-invariant economic and institutional factors at the country level, such as the tendency of central bankers of certain countries to dedicate more attention to climate-related topics. Second, we include year fixed effects (μ_t) to account for time-variant factors common to all countries, such as the generalised tendency to increase the attention dedicated by central bankers to climate-related issues in recent years.

Table 4 presents the results of our baseline estimation.[37] Exposure to climate-related physical risks, *Physical exposure*, is not significantly associated with a higher level of climate-related attention

[37]Due to limitations in the availability of some of our control variables, we restrict our analysis here to a sample of 59 countries, from 1986 to 2020. We provide an alternative regression model in Appendix C with a longer period of analysis and countries' coverage (78), although at the cost of fewer control variables.

in central bankers' communication.[38] The *Carbon intensity* of a country has instead a positive impact on climate-related communication, but only when measured as climate salience, i.e. the intensity of climate keywords within their speeches, or when focusing on the *Green finance* narrative, although with a lower significance. The set of institutional drivers offers more solid results. The degree of central bank involvement in supervision – *CB Supervision* – is positively and significantly associated with our two measures of general climate attention, as well as to the prominence of the *Climate-related risks* topic. The sign of these coefficients is consistent with our initial hypothesis. Based on the coefficient estimates for the *CB Supervision* variable presented in Column (4), a one-standard-deviation increase (0.29) in the degree of central bank involvement in financial sector supervision is associated with an increase of the salience measure from 0.2% (its mean value) to 0.34%, i.e. almost doubling it. The *CB Objectives* variable has a weaker impact than financial supervision, but it is significant for both the *Climate frequency* measure and the focus on the *Climate-related risks* narrative. That is, a central bank with narrower objectives centred around price stability will engage less with climate-related financial risks in its public communication. Finally, in line with Feldkircher and Teliha (2024), belonging to the NGFS network is positively associated with the prominence of climate-related financial risks and green finance narratives, as well as with greater general climate-related attention, although the statistical significance of the latter relationship is weaker.

Overall, it appears that countries' exposure to climate-related risks is not a particularly strong driver of climate-related communication by central banks, with only carbon intensity playing any role. In contrast, both institutional variables and participation in the NGFS network are key drivers in mainstreaming climate-related discussions among central bankers. These results are robust to several alternative specifications, which we discuss in Appendix C.2.

5 Effects of climate-related communication

We now move to investigate whether climate-related communication has any impact on financial asset prices. More specifically, we aim to test whether a higher focus on climate-related issues by central bankers influences the returns of 'green' and 'dirty' firms. We start by presenting our data sources in Section 5.1. We then perform two complementary investigations: a portfolio analysis centred on the US (Section 5.2) and a more granular analysis focusing on firm-level returns (Section 5.3).

[38] A possible explanation for this is that central banks affected by climate disasters may prioritise conventional economic interventions to address the aftermath of such disasters and their associated economic and financial repercussions, rather than actively engaging with climate-related issues.

5.1 Data

The analysis of the effects of central bank communication on climate-related issues relies on the indicators presented in section 4.1 (*Climate frequency*, *Climate salience* and the two climate-related topics) but also on data on daily stock returns, firms' balance sheet data and measures of firms' 'greenness'. Concerning the latter, we extract three firm-level measures from LSEG (formerly Refinitiv).[39] First, we use the *Emission intensity* of the firm, defined as the ratio between total greenhouse gas emissions and its net revenue.[40] Emission intensity is a very common measure in the literature, calculated as a share of either revenues (Ardia et al., 2023; Bolton and Kacperczyk, 2021; Hengge et al., 2023; Görgen et al., 2020) or market capitalisation (Bauer et al., 2023; Ilhan et al., 2021; Ramelli et al., 2021). Greener firms will be characterised by a lower level of this indicator. Second, the *Environmental score* indicator is obtained by rating companies based on approximately 70 variables, grouped into three environmental category scores: emissions, innovation, and resource use. Broad environmental indicators rooted in ESG (Environmental, Social and Governance) rating methodologies have also been quite commonly used in the related literature (e.g. Engle et al., 2020; Pástor et al., 2021; Alareeni and Hamdan, 2020; Rzeźnik et al., 2022) and are offered by a variety of providers – e.g. Sustainalytics, MSCI and others. In this case, greener firms will showcase a higher level of this indicator. Finally, we follow Bauer et al. (2023) in also considering the LSEG *Emissions score* - one of the three sub-components of *Environmental score* measure - as a stand-alone indicator. It measures a company's commitment and effectiveness in reducing environmental emissions in its production and operational processes. Both the *Environmental* and the *Emission score* are industry-specific: greener firms are identified as those characterised by better scores compared to their industry peers. Greenness indicators are available from 2001 onwards. Data imported by the LSEG platform show that 7,589 firms have the Emissions Intensity measure, 11,189 firms have the Environmental Score measure, and 11,189 firms have the Emissions Score measure.

Using the same data source, i.e. LSEG, we are also able to extract daily stock prices and a range of additional firm-level control variables for all firms for which data on at least one of the greenness indicators mentioned above is available. These include proxies for firms' size (log total assets), performance (cash flow to sales), market leverage (EBIT divided by interest expenses), revenue growth (annual growth rate in revenues), and profitability (return on assets). As our interest is to investigate stock returns, we compute daily stock returns by computing the percentage change of stock market prices between day t and day $t-1$ (excluding weekends). In addition, we also collect

[39] For more details on how these scores are computed, see LSEG (2023).

[40] We include both Scope 1 and Scope 2 emissions, i.e. direct emissions and indirect emissions resulting from the purchase of electricity, steam, heat, or cooling. We only use the values of greenhouse gas emissions reported by firms. See Bauer et al. (2022) for a discussion on the benefits of focusing on reported data for CO2 emissions, rather than using the estimated ones computed by data providers. We anyway run robustness checks using (i) only Scope 1 direct emissions; (ii) estimated emissions instead of only reported emissions; and (iii) market capitalisation – in place of revenues – when defining the intensity. See Section D.1.

country-level data on market excess returns, the 'Size' (SMB factor) and 'Value' (HML factor) factors from Jensen et al. (2023), measures which are commonly used in the finance literature. Due to the absence of climate-related speeches for some countries, and financial data for certain countries and years, our firm-level analysis is run on a sample of 9,325 firms (6,422 in the case of the *Emission intensity* measure) across 41 countries.

5.2 Portfolio analysis

Previous literature has shown that climate-related news and events have significant impacts on green and dirty portfolios and stock market indices (Bauer et al., 2023; Ardia et al., 2023; Bua et al., 2021; Meinerding et al., 2022; Bessec and Fouquau, 2022; Pástor et al., 2021). To test whether this is the case also with central bank climate-related communication, we analyse the contemporaneous relation between our climate-related indicators and the daily return of green-minus-dirty industry-level portfolios. For each sector, these portfolios can be considered to be long in green firms and short in dirty ones. These portfolios are created by ranking all firms operating in a given industry based on their measure of greenness and including firms above or below a certain percentile range. We consider two such ranges: 25-75th and 10-90th percentiles, respectively. In the case of *Environmental* or *Emissions score*, the portfolio of green firms is formed by selecting all firms with a measure of the score above the 75th (90th) percentile, while dirty firms are those for which these indicators have a value below the 25th (10th) percentile of the distribution. In the case of *Emission intensity*, green firms are those with a measure of the index below the 25th (10th) percentile, while firms above the 75th (90th) percentile are classified as dirty.

We then estimate the following linear regression model:

$$r_{s,c,t}^{GMD} = \beta_0 + \beta_1 \text{Climate Focus}_t + \beta_2 Mkt_t + \beta_3 Value_t + \beta_4 Size_t + + \beta_5 \Delta Oil_t + \mu_m + \epsilon_{s,c,t} \quad (2)$$

where $r_{s,t}^{GMD}$ is the return of the green-minus-dirty portfolio within industry s at day t; *Climate Focus*$_t$ is one of the four measures of climate-related focus computed for the US Federal Reserve at day t. Finally, additional control variables include the excess market return, Mkt_t; proxies for high-minus-low and small-minus-big Fama-French factors, $Value_t$ and $Size_t$; daily crude oil returns, ΔOil_t; and monthly fixed effects μ_m.

Our analysis is here centred on the United States. This focus is not only motivated by the US being the largest market in terms of both capitalisation and the number of listed companies but also by the fact that the creation of industry-level portfolios requires a large enough number of firms to be listed within each industry.[41] The results from the industry-level portfolio analysis are

[41] We here use the entire set of central bank speeches, rather than the subset of climate-related speeches, as their count for the United States would be insufficient to obtain solid results.

Table 5: US Daily Portfolios' Returns

	(1) Green finance	(2) Climate-related risks	(3) Climate frequency	(4) Climate salience
		Panel A: 25-75th percentiles		
Environmental score	2.066	0.114	0.002*	0.085**
	(2.621)	(0.080)	(0.001)	(0.036)
Emission score	2.472	0.121	0.002**	0.082**
	(2.514)	(0.078)	(0.001)	(0.035)
Emission intensity	4.516*	0.277**	0.003**	0.123**
	(2.356)	(0.100)	(0.001)	(0.046)
		Panel B: 10-90th percentiles		
Environmental score	1.949	0.171	0.003**	0.124**
	(4.518)	(0.147)	(0.001)	(0.053)
Emission score	5.991*	0.220**	0.003**	0.137**
	(3.230)	(0.094)	(0.001)	(0.033)
Emission intensity	6.117	0.575**	0.006**	0.226**
	(3.934)	(0.174)	(0.002)	(0.072)
Controls	Yes	Yes	Yes	Yes

Note: Standard errors are clustered at the sector level. *, **, *** represent significance at 10, 5, and 1%, respectively.

presented in Table 5.[42] Panel A shows the estimations obtained focusing on the 25-75th percentiles of the distribution of the greenness measures within industries. Overall, the results presented in this table show a positive and statistically significant relationship between the returns of the green-minus-dirty portfolio and the greenness measures, with stronger results for the *Climate-related risks*, *Climate frequency* and *Climate salience* indicators, as opposed to the *Green finance* one. These results suggest that greener firms tend to outperform dirty ones when the speeches delivered by the Federal Reserve are more focused on climate-related issues. Stronger and more statistically significant results are obtained by analysing portfolios created using the 10th to 90th percentiles of the distribution of the greenness measures within industries (Panel B).

5.3 Climate-related speeches and individual firm returns

The analysis of the previous section only included US-listed companies and focused on aggregate portfolio returns. We now test whether the positive relationship between climate-related central bank communication and the stock returns of green firms is confirmed when focusing on a more granular analysis at the level of individual firms. This approach allows us to extend our analysis to all the firms for which data on greenness measures are available. In addition, as our analysis aims to investigate the effect of climate-related speeches on firms' stock returns, we focus our attention

[42] We use the WC06011 Industry group classification from the Worldscope Database at the two-digit level, as provided by LSEG. This allows us to consider 27 unique industry groups.

on the subset of climate-related speeches discussed in Section 3. We thus estimate the following fixed-effects panel regression model:

$$\begin{aligned} r_{i,c,t} =& \beta_0 + \beta_1 \text{Climate Focus}_{c,t} + \beta_2 \text{Greenness}_{i,t} + \beta_3 \text{Climate Focus}_{c,t} \times \text{Greenness}_{i,y} \\ &+ \theta' X_{i,c,t} + FE + \epsilon_{i,c,t} \end{aligned} \tag{3}$$

where $r_{i,c,t}$ is the stock return of firm i of country c at day t; *Climate Focus*$_{c,t}$ is one of the four measures of climate-related focus by central bank of country c at day t; *Greenness*$_{i,t}$ is one of the three measures of greenness introduced in Section 5.1 for firm i at year y.[43,44] $X_{i,c,t}$ is a vector including all the control variables specified in Section 5.1. Finally, FE stands for the two alternative fixed-effect specifications we use. First, we include firm fixed effects, which allows us to control for time-invariant firm-specific characteristics. Second, we include three-way fixed effects (country-by-sector-by-date).

The results from our firm fixed effect model are presented in Table 6. The regression coefficients represent the average within-firm effect over time. Similar to the analysis implemented in Section 4, column (1) focuses on the *Green finance* topic extracted from the STM model; column (2) on the *Climate-related risks* topic; column (3) on the count of climate-related keywords per speech (*Climate frequency*); and column (4) on the share of climate-related keywords over the total amount of words in a speech (*Climate salience*). We present three distinct panels of results employing the *Environmental score* (Panel A), the *Emission score* (Panel B) and *Emission intensity* (Panel C) as the measure for firm greenness.

Our focus is on the interaction term between the indicator of central bank focus on climate-related issues and the measures of greenness, i.e. *Climate Focus*$\times$ *Greenness*, as we are interested in investigating whether greener firms experience higher returns when central bank communication is more focused on climate-related issues. Our results clearly highlight how greener firms experience stronger returns when central bankers engage more with climate-related topics in their speeches. We observe this for both the *Environmental* and *Emission score* – where positive coefficients indicate that firms characterised by higher scores perform better – and for *Emission intensity* – where negative coefficients indicate that the more carbon-intensive firms perform worse. The results for *Emission intensity* are significant across all measures of climate-related central bank focus, with a particularly strong coefficient for the *Green finance* topic. The latter is however not significant for the other two measures of greenness, with the *Climate-related risks* narrative driving the strongest

[43] It is important to notice that the measure of *Climate Focus*$_{c,t}$ for Euro area countries could be derived by looking at either (i) the focus dedicated to climate-related issues by the members of the board of their national central bank; or (ii) the attention dedicated to the topic by the members of the Executive Board of the European Central Bank. Recognising the potential impact of both types of speeches on asset prices, the measure of climate focus for these countries is measured considering both groups of speeches. The results are unchanged using the two groups individually and are available upon request.

[44] As firms typically submit their data on emissions by mid-August and these data are released in October (Ilhan et al., 2021), the greenness indicators reflect the emissions generated by firms in the previous year.

Table 6: Effects of climate-related communication - Firm fixed effects

	(1) Green finance	(2) Climate-related risks	(3) Climate frequency	(4) Climate salience
	Panel A: Environmental score			
Climate focus	-0.109*	-0.077**	-0.002**	-0.037**
	(0.058)	(0.032)	(0.000)	(0.012)
Emission score	-0.018	-0.031**	-0.031**	-0.033**
	(0.012)	(0.012)	(0.013)	(0.013)
Climate focus × Emission score	-0.012	0.102**	0.001**	0.035**
	(0.038)	(0.022)	(0.000)	(0.007)
Observations	381092	381092	381092	381092
R-Squared	0.149	0.150	0.150	0.150
	Panel B: Emission score			
Climate focus	-0.113*	-0.077**	-0.002**	-0.037**
	(0.058)	(0.031)	(0.000)	(0.012)
Environmental score	-0.015	-0.029**	-0.030**	-0.032**
	(0.012)	(0.011)	(0.012)	(0.011)
Climate focus × Environmental score	0.003	0.104**	0.001**	0.039**
	(0.045)	(0.022)	(0.000)	(0.007)
Observations	381092	381092	381092	381092
R-Squared	0.149	0.150	0.150	0.150
	Panel C: Emission intensity			
Climate focus	-0.144**	-0.073**	-0.002**	-0.027**
	(0.052)	(0.030)	(0.000)	(0.010)
Emission intensity	0.001	0.001	0.002*	0.002
	(0.001)	(0.001)	(0.001)	(0.002)
Climate focus × Emission intensity	-0.039**	-0.016**	-0.001**	-0.005**
	(0.009)	(0.002)	(0.000)	(0.002)
Observations	254975	254975	254975	254975
R-Squared	0.163	0.163	0.164	0.163
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes

Note: This table reports the results of regressing firms' daily returns on Climate focus, a measure of greenness and their interaction term. Controls include firm-specific accounting measures and daily control variables for the Market, Size and Value factors. Firm and year-fixed effects are included. Standard errors are clustered at the country-industry level. *, **, *** represent significance at 10, 5, and 1%, respectively.

effect on asset prices.

As for the other coefficients, the negative coefficient attached to the greenness measure suggests that green firms have, on average, lower returns than dirty ones. This evidence is similar to the one found in Ardia et al. (2023) and is motivated by the investors' willingness to pay more for greener firms, accepting therefore lower expected returns. The negative and statistically significant coefficient associated with *Climate focus* points instead to a prevailing overall negative impact of climate-related communication on equity returns, suggesting that markets still perceive climate-related discussions and strategies as potentially detrimental to economic activity. Based on the

Table 7: Effects of climate-related communication - Country-industry-date fixed effects

	(1) Green finance	(2) Climate-related risks	(3) Climate frequency	(4) Climate salience
	Panel A: Environmental score			
Emission score	0.002	-0.002	-0.008	-0.009
	(0.007)	(0.008)	(0.009)	(0.009)
Climate focus × Emission score	0.085**	0.055**	0.001**	0.031**
	(0.042)	(0.020)	(0.000)	(0.008)
Observations	372581	372581	372581	372581
R-Squared	0.219	0.219	0.219	0.219
	Panel B: Emission score			
Environmental score	-0.005	-0.011	-0.016*	-0.018**
	(0.007)	(0.009)	(0.010)	(0.009)
Climate focus × Environmental score	0.074*	0.065**	0.001**	0.034**
	(0.042)	(0.022)	(0.000)	(0.009)
Observations	372581	372581	372581	372581
R-Squared	0.219	0.219	0.219	0.219
	Panel C: Emission intensity			
Emission intensity	-0.001	-0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Climate focus × Emission intensity	-0.051**	-0.022**	-0.001**	-0.007**
	(0.006)	(0.002)	(0.000)	(0.001)
Observations	245424	245424	245424	245424
R-Squared	0.257	0.257	0.257	0.257
Country × Industry × Date FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes

This table reports the results of regressing firms' daily returns on Climate focus, a measure of greenness and their interaction term. Controls include firm-specific accounting measures. Country-industry-date fixed effects are included. Standard errors are clustered at the country-industry level. *, **, *** represent significance at 10, 5, and 1%, respectively.

coefficients estimated in Panel A, column (4), we find that these effects are economically meaningful: a 'dirty' firm with an environmental score one standard deviation below the average experiences a decline in its stock return (-1.42%) compared to a firm with a score one standard deviation above the average (+1.35%), holding climate salience at its mean level.

We then repeat the empirical exercise in Eq. (3), by replacing firm fixed effects with three-way fixed effects at the country-by-industry-by-date level. This implies that identification comes from variation in returns between green and dirty firms within the same country-industry and on the same day. The results are shown in Table 7.[45] All the results obtained with firm fixed effects are confirmed with this much more stringent specification, suggesting that, when central bankers engage with climate-related themes in their public communication, green firms experience higher daily returns as compared to dirty firms operating in the same country-industry. The effect is

[45] Given that fixed effects at the country-industry-day level allow for specific stock market response to each climate-related speech, the *Climate focus* coefficient drops out from the regression.

particularly strong when the chosen narrative is centred around *Climate-related risks* or *Green finance*.

In Appendix D.1 we run a large battery of robustness checks. First, we run our three-way fixed effect estimation using alternative topic models: (i) the 13-topic model; (ii) the best model emerging from an STM based on the subset of climate-related speeches (1,955) that mention at least twice – instead of once – climate-related keywords; and (iii) the best model emerging from an STM based on the subset of speeches (30,140) published in English. Second, we test alternative methods to compute emission intensity, including (i) focusing only on direct emissions; (ii) controlling for estimated emissions; and (iii) weighing emissions by market capitalisation instead of revenues. Finally, in Appendix D.2 we control for the possibility of international spillovers of central bank communication. We find no significant result when looking at the US Fed, suggesting that climate-related speeches from a central bank are not producing effects on equity prices traded in another jurisdiction.

6 Conclusion

This paper presents a comprehensive analysis of central bank communication on climate-related issues. We study its temporal, geographical and topical evolution, investigate its drivers, and assess its impact on asset prices.

First, we create a novel dataset of central bankers' speeches through systematic web-scraping of central bank websites and archival work. This dataset of 35,487 speeches spans over 131 central banks and 37 years (1986-2023), making it significantly larger than any existing dataset. The dataset is freely available and can be used to investigate additional research questions linked to central bank communication.

Second, we develop a novel dictionary of 'climate-related keywords' and use it to identify a sub-sample of 2,968 'climate-related speeches'. We show how climate-related communication was primarily originating from Southeast Asia and the Pacific, before being surpassed by Western Europe central banks after 2015. In aggregate, the number of climate-related speeches increased steeply in recent years, before stabilizing at around 550 speeches a year since 2021, representing almost a third of total speeches. We then explore this corpus of text using a Structural Topic Model (STM). This allows us to detect two distinct 'shades of green' in central bank communication: (i) 'Green finance'; and (ii) 'Climate-related risks'. We observe how central banks characterised by different institutional features and economic environments adopt different combinations of the two narratives. Central banks in developing and emerging economies and/or supervising international financial hubs tend to use a more 'promotional' perspective and push green finance opportunities as a driver of economic development, reflecting their stronger involvement in markets and adherence to political strategies. Central banks in high-income economies tend instead to prefer a 'prudential'

approach focused on the concept of climate-related financial risks, which aligns with their independence and narrower mandates. However, we also observe how this distinction has been gradually fading in more recent years, with some high-income central banks partially shifting more towards the green finance topic.

Third, we investigate the potential drivers of central bank communication on climate-related issues. We find that a country's exposure to climate-related risks – on both the physical and transition side – only has a weak impact on its central bank's climate attention. By contrast, institutional dimensions such as the degree of central bank involvement in financial supervision or the breadth of central bank mandates have a positive and significant effect on central bank climate-related engagement, and especially on their use of the 'Climate-related risks'. Being a member of the Network for Greening the Financial System is also an important driver of climate-related attention. This suggests that rather than being the consequence of country-specific exposure concerns, climate-related communication is mainly the outcome of the underlying institutional framework in which the central bank operates, as well as of its embeddedness in the associated epistemic community of central bankers.

Finally, we estimate the association between central bank communication and the returns of 'green' and 'dirty' financial assets, using three different market measures of greenness. We first perform a portfolio analysis focusing on the US market and find that the returns of green-minus-dirty portfolios are positively affected when central bank communication has a stronger focus on climate-related topics. We then proceed with a more granular analysis using firm-specific data for 41 countries, showing that stock returns of greener firms benefit from a higher frequency and salience of climate-related focus in central bank speeches, especially when climate-related financial risks are the dominant topic. We implement both a firm fixed-effect panel regression and a more stringent specification including three-way fixed effects at the country-industry-date level, which enables identification from variation in returns between green and dirty firms in the same country-industry on the same day. Our results are solid to a number of robustness alternative specifications. This highlights the critical role of central bank communications in signalling and shaping market expectations and valuations in the context of the low-carbon transition. In particular, it appears that the 'warning words' of central bankers on climate-related risks have significant effects on firms' valuations, at least in the short run.

Several further research avenues can be considered, building on our work. For instance, our focus on central bank speeches might not fully grasp the overall communication of central banks on climate-related issues – which also includes written communications, policy reports and academic papers – nor does it capture the discussions happening within or between central banks in informal settings. We also do not capture tone or perform sentiment analysis, which could offer more nuanced insights into central bank communication strategies. In addition, it would be interesting to explore further consequences of climate-related communication. While we explore the impact of central

bankers' speeches on firm stock prices, additional analysis could be performed on other financial instruments, such as bond or derivative markets. Identifying the propagation channels through which topics diffuse within the central banking networks would also shed further light on the drivers of central bank communication. Finally, the direct and indirect impacts of these communications on policy implementation can be investigated. In principle, a central bank could be vocal about climate-related topics but refrain from implementing any policy, or vice-versa. Further work is needed to understand how words translate into effective climate action.

Nonetheless, the findings of this paper offer novel solid insights on the nature of climate-related central bank communication, with strong policy implications. Most prominently, we show that central banks, by actively engaging in climate-related discourse, can significantly influence market behaviours and investment patterns towards more sustainable practices. This calls for enhanced disclosure requirements: an improvement of the quality of firm greenness measures is required for financial markets to appropriately price equities, especially in the context of central banks opting for a green promotional strategy. More in general, our work emphasises the importance of clear, consistent, and forward-looking communication strategies that align financial sector practices with global sustainability goals.

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Appendices

Appendix A Dataset overview

Table A.1: Summary of the data-sources

Country or central bank	BIS	Non-BIS	English	Non-English	Total
Africa and Middle East					
Algeria	8	44	11	41	52
Angola	0	93	2	91	93
Bahrain	51	2	53	0	53
Botswana	45	35	80	0	80
Burundi	0	2	1	1	2
Cabo Verde	0	71	0	71	71
Comoros	0	7	0	7	7
Eswatini	0	15	15	0	15
Gambia	1	0	1	0	1
Ghana	58	106	164	0	164
Israel	109	52	117	44	161
Jordan	1	0	1	0	1
Kenya	183	92	275	0	275
Kuwait	6	96	94	8	102
Lesotho	0	5	5	0	5
Liberia	0	4	4	0	4
Malawi	25	12	37	0	37
Mauritania	0	1	0	1	1
Mauritius	162	81	228	15	243
Morocco	6	57	20	43	63
Mozambique	5	73	9	69	78
Namibia	36	52	88	0	88
Nigeria	31	22	53	0	53
Qatar	0	5	4	1	5
Rwanda	0	11	11	0	11
São Tomé and Príncipe	0	16	0	16	16
Saudi Arabia	28	50	78	0	78
Seychelles	22	60	70	12	82
Sierra Leone	12	13	25	0	25
South Africa	407	46	453	0	453
Tanzania	1	0	1	0	1
Uganda	151	214	365	0	365
United Arab Emirates	10	25	30	5	35
Zambia	156	40	196	0	196
Zimbabwe	0	10	10	0	10
Subtotal	**1,514**	**1,412**	**2,501**	**425**	**2,926**
Eastern Europe and Central Asia					
Armenia	1	15	2	14	16
Bulgaria	46	218	201	63	264
Czechia	58	52	94	16	110
Hungary	11	252	263	0	263
Kazakhstan	0	42	28	14	42

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Table A.1: Summary of the data-sources (continued)

Country or central bank	BIS	Non-BIS	English	Non-English	Total
Poland	19	13	23	9	32
Romania	69	43	112	0	112
Russia	39	125	129	35	164
Slovakia	5	37	12	30	42
Turkey	99	172	197	74	271
Ukraine	29	82	111	0	111
Subtotal	**376**	**1,051**	**1,172**	**255**	**1,427**
Latin America and Caribbeans					
Argentina	34	21	55	0	55
Aruba	1	15	14	2	16
Bahamas	17	14	31	0	31
Barbados	95	69	164	0	164
Belize	1	6	7	0	7
Bolivia	1	0	1	0	1
Brazil	11	30	26	15	41
Cayman Islands	3	0	3	0	3
Chile	131	205	167	169	336
Colombia	8	38	45	1	46
Costa Rica	0	6	0	6	6
Curaçao and Sint Maarten	39	87	103	23	126
Dominican Republic	0	34	0	34	34
Eastern Caribbean (ECCB)	18	50	68	0	68
Ecuador	1	0	1	0	1
El Salvador	0	3	0	3	3
Guatemala	1	0	1	0	1
Guyana	2	1	3	0	3
Haiti	0	29	0	29	29
Jamaica	20	111	131	0	131
Mexico	95	230	120	205	325
Nicaragua	0	94	0	94	94
Paraguay	0	13	0	13	13
Suriname	0	10	9	1	10
Trinidad and Tobago	104	42	146	0	146
Uruguay	1	77	1	77	78
Venezuela	0	1	0	1	1
Subtotal	**583**	**1,186**	**1,096**	**673**	**1,769**
South-East Asia and the Pacific					
Bangladesh	0	254	254	0	254
Cambodia	2	52	47	7	54
China	146	75	221	0	221
Fiji	132	37	169	0	169
Hong Kong	274	237	434	77	511
India	903	168	1,071	0	1,071
Indonesia	64	127	124	67	191
Japan	652	175	826	1	827
South Korea	94	96	131	59	190
Macao	29	0	29	0	29
Malaysia	529	170	699	0	699
Maldives	5	4	9	0	9
Nepal	15	27	40	2	42
Pakistan	135	133	267	1	268

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Table A.1: Summary of the data-sources (continued)

Country or central bank	BIS	Non-BIS	English	Non-English	Total
Papua New Guinea	61	21	82	0	82
Philippines	548	444	990	2	992
Samoa	6	14	18	2	20
Singapore	308	606	914	0	914
Solomon Islands	18	24	42	0	42
Sri Lanka	68	6	74	0	74
Thailand	225	267	291	201	492
Vanuatu	2	0	2	0	2
Subtotal	**4,216**	**2,937**	**6,734**	**419**	**7,153**
Western Europe					
Albania	299	331	299	331	630
Austria	81	20	92	9	101
Belgium	38	33	41	30	71
Bosnia and Herzegovina	15	33	45	3	48
Croatia	12	59	14	57	71
Cyprus	9	125	75	59	134
Denmark	109	54	121	42	163
Estonia	22	25	47	0	47
European Central Bank	1,789	876	2,522	143	2,665
Finland	179	418	282	315	597
France	395	151	435	111	546
Germany	851	567	903	515	1,418
Greece	162	61	198	25	223
Iceland	89	98	105	82	187
Ireland	353	375	728	0	728
Italy	387	648	428	607	1,035
Kosovo	35	19	52	2	54
Latvia	11	8	19	0	19
Lithuania	31	66	63	34	97
Luxembourg	39	43	54	28	82
Malta	59	7	66	0	66
Montenegro	0	6	6	0	6
Netherlands	212	263	283	192	475
North Macedonia	92	77	113	56	169
Norway	290	99	308	81	389
Portugal	84	376	185	275	460
Serbia	121	52	173	0	173
Slovenia	11	44	42	13	55
Spain	363	249	419	193	612
Sweden	494	269	532	231	763
Switzerland	406	228	493	141	634
United Kingdom	782	572	1,354	0	1,354
Subtotal	**7,820**	**6,252**	**10,497**	**3,575**	**14,072**
Western offshoots					
Australia	547	94	641	0	641
Canada	566	74	640	0	640
New Zealand	200	52	252	0	252
United States of America	2223	4384	6607	0	6607
— Board of Governors of the Federal Reserve	1,698	960	2,658	0	2,658
— Federal Reserve Bank of Atlanta	2	525	527	0	527
— Federal Reserve Bank of Boston	5	226	231	0	231

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Table A.1: Summary of the data-sources (continued)

Country or central bank	BIS	Non-BIS	English	Non-English	Total
— Federal Reserve Bank of Chicago	10	408	418	0	418
— Federal Reserve Bank of Cleveland	0	353	353	0	353
— Federal Reserve Bank of Dallas	19	211	230	0	230
— Federal Reserve Bank of Kansas City	16	154	170	0	170
— Federal Reserve Bank of Minneapolis	23	134	157	0	157
— Federal Reserve Bank of New York	413	201	614	0	614
— Federal Reserve Bank of Philadelphia	32	250	282	0	282
— Federal Reserve Bank of Richmond	2	264	266	0	266
— Federal Reserve Bank of San Francisco	3	446	449	0	449
— Federal Reserve Bank of St Louis	0	252	252	0	252
Sub-total	**3,536**	**4,604**	**8,140**	**0**	**8,140**
Total	**18,045**	**17,442**	**30,140**	**5,347**	**35,487**

Appendix B Structural Topic Modelling

B.1 Model selection

Following Roberts et al. (2014), we run several models, each time with a different number of topics (ranging from 5 to 50), to find the specifications offering the best performance in terms of (i) semantic coherence; and (ii) exclusivity. A high semantic coherence means that frequent words for a topic tend to co-occur within documents. This measure is generally associated with better interpretability of each topic. A high exclusivity refers instead to a situation in which the top words characterising a topic are unlikely to appear in other topics. This allows us to get well-differentiated topics. As shown in Figure B.1, models with fewer topics offer a strong semantic coherence but lower exclusivity, as top words are likely to be featured in a large number of topics. On the contrary, models with many topics usually offer lower semantic coherence but high exclusivity, as more topics tend to be more narrowly defined. Model 10, our choice, clearly stands out as one of the best models, on the exclusivity/coherence frontier. We also retain Model 13 for our robustness analysis.

It should be noted that topics appear very stable across models. Increasing the number of topics usually leads to the split of one former topic into two sub-parts, without re-dispatching words into very different clusters.

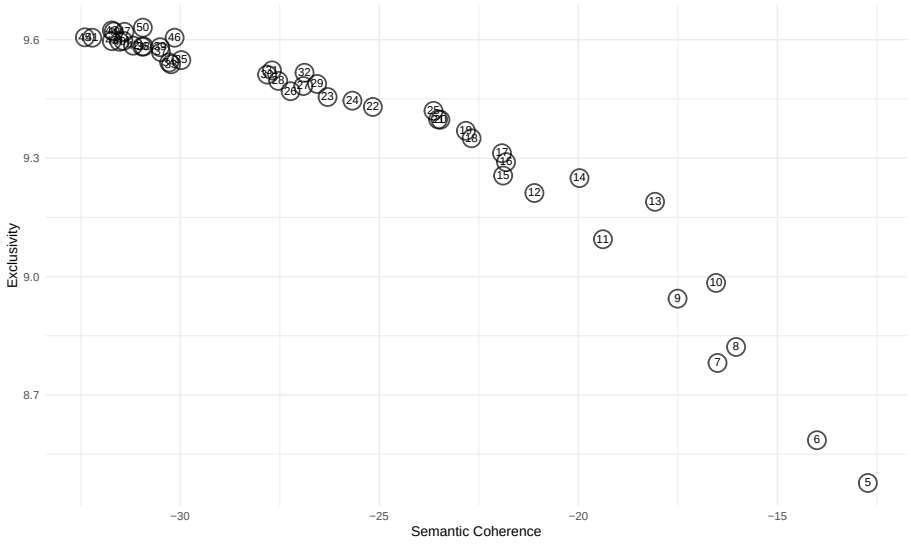


Figure B.1: Structural Topic Models (5 to 50 topics) according to semantic coherence and exclusivity

B.2 10-topic model

We provide below some of the supplementary materials that we used to label topics: (i) top most frequent and exclusive (FREX) words for each topic in Model 10; and (ii) word clouds for our two climate-related topics.

Table B.1: Most frequent and exclusive (FREX) words in the STM with 10 topics

N.	Topic label	Most frequent words
1	**Green finance**	emission, taxonomy, green, carbon, esg, renewable, fossil, environmental, sustainability, greenhouse
2	**Climate-related risks**	insurer, biodiversity, ngfs, policyholder, physical, supervisor, insurance, tcfd, flood, climate
3	European economy	cesee, duisenberg, treaty, seite, monnet, emu, europe, weidmann, sovereignty, union
4	Financial markets	rmb, takaful, mainland, asia, islamic, asean, ibf, asian, vcc, fintech
5	Social economy	ethnic, ethnicity, aruba, female, student, school, child, gender, haldane, minority
6	Financial stability	crypto, basel, bitcoin, macroprudential, regulate, regulatory, pca, regulation, stablecoins, systemic
7	Economic outlook	chg, prefecture, tri, tankan, yen, ovidio, reyes, export, cpi, oil
8	Inflation and monetary policy	inflation, mpc, mpr, ination, persistent, inflationary, equilibrium, tighten, phillips, shock
9	Debt and crisis	espana, debt, ngeu, banco, expenditure, budget, ratio, revenue, budgetary, profitability
10	Financial inclusion and development	rupiah, bou, sharia, diokno, philippine, msmes, wbg, taka, microfinance, afi

(a) Green finance

(b) Climate related risks

Figure B.2: Wordclouds of the two climate-related topics. The size of the words is proportional to the weight of the term in defining the topic.

Appendix C Drivers of climate attention

C.1 Descriptive statistics

Table C.1 provides summary statistics for the dependent and independent variables.

Table C.1: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Green finance	929	.6	2.22	0	20.94
Climate-related risks	929	.45	2.38	0	51.37
Climate frequency	929	.47	1.76	0	21
Climate salience	929	.02	.08	0	1.02
Physical exposure	929	.23	1.36	0	27.3
Carbon intensity	929	.28	.17	.04	1.15
CB Supervision	929	.33	.29	0	1
CB Objectives	929	.7	.32	0	1
NGFS membership	929	.09	.29	0	1
Inflation	929	3.71	5.52	-4.72	85.65
Output gap	929	0	.03	-.13	.19
GDP per capita	929	23.39	19.7	.59	79.44
Insurance company assets to GDP	929	30.29	30.44	.73	134.51
Private credit to GDP	929	83.9	47.83	7.61	216.56

C.2 Robustness tables

We test the robustness of our Section 4 results along three main dimensions. First, we repeat the baseline estimation excluding the NGFS dummy, to control for the possibility of NGFS membership having an excessively strong effect on climate-related communication drivers. The results are shown in Table C.2.

Second, we extend the timeline of the analysis up to 2023. In order to do this, however, we are forced to drop some of the control variables we use in the main specification (*Insurance company assets to GDP* and *Private credit to GDP*). Results are reported in Table C.3.

Finally, we test whether our results are robust to the use of an alternative topic model to estimate the importance assigned to the various topics. Table C.4 shows the result of the baseline estimation with the 13-topic model. Tables C.5 and C.6 repeat the estimation on the 13-topic model excluding the NGFS dummy and extending the timeline, respectively.

Our robustness checks confirm the solidity of our baseline results. While the significance of some coefficients may vary, the qualitative insights we provide in Section 4 remain valid.

Table C.2: Drivers of climate-related communication - NGFS dummy excluded

	(1) Green finance	(2) Climate-related risks	(3) Climate frequency	(4) Climate salience
Physical exposure	-0.075	0.046	-0.165	-0.043
	(0.184)	(0.097)	(0.182)	(0.105)
Carbon intensity	5.605*	8.930	4.030	6.607**
	(2.970)	(7.528)	(3.099)	(2.460)
CB Supervision	1.941	7.934**	6.312**	7.211**
	(2.118)	(2.226)	(2.052)	(1.850)
CB Objectives	-0.999	-4.170**	-2.447**	-3.258**
	(1.299)	(1.193)	(1.191)	(1.656)
Inflation	0.096	0.172*	0.066	0.102*
	(0.085)	(0.094)	(0.041)	(0.062)
Output gap	-5.514	1.056	-3.579	-7.775
	(4.105)	(6.928)	(5.224)	(5.371)
GDP per capita	0.190**	-0.003	0.233**	0.298**
	(0.086)	(0.075)	(0.076)	(0.102)
Insurance company assets to GDP	0.008	-0.004	0.019	0.005
	(0.019)	(0.020)	(0.018)	(0.015)
Private credit to GDP	-0.002	0.012	0.001	0.009
	(0.010)	(0.012)	(0.008)	(0.008)
Constant	-10.848**	-8.048*	-9.791**	-14.152**
	(3.259)	(4.495)	(3.245)	(3.710)
Observations	929	929	929	929
R-Squared	0.310	0.350	0.623	0.396

Note: Central bank and year fixed effects are included. Standard errors are clustered at the country level. *, **, *** represent significance at 10, 5, and 1%, respectively.

Table C.3: Drivers of climate-related communication - Extended timeline

	(1) Green finance	(2) Climate-related risks	(3) Climate frequency	(4) Climate salience
Physical exposure	-0.288	-0.050	-0.238	-0.339*
	(0.280)	(0.087)	(0.209)	(0.195)
Carbon intensity	0.366	4.338	-0.691	-0.237
	(4.494)	(6.460)	(3.200)	(3.862)
CB Supervision	1.696	7.239**	3.522**	6.197**
	(1.437)	(2.824)	(1.598)	(2.202)
CB Objectives	-0.109	-1.547**	0.663	0.513
	(0.920)	(0.645)	(0.638)	(0.585)
NGFS membership	0.535	1.089**	0.761**	0.592
	(0.391)	(0.431)	(0.292)	(0.378)
Inflation	-0.012	-0.034	-0.062**	-0.026
	(0.036)	(0.036)	(0.027)	(0.034)
Output gap	-0.752	-2.578	-6.105*	-3.839
	(3.244)	(4.045)	(3.169)	(3.068)
GDP per capita	0.057*	-0.010	0.040**	0.069**
	(0.031)	(0.030)	(0.018)	(0.034)
Constant	-1.328	-2.650	-2.226*	-7.248**
	(1.408)	(2.459)	(1.240)	(1.665)
Observations	1431	1431	1431	1431
R-Squared	0.632	0.675	0.649	0.401

Note: Central bank and year fixed effects are included. Standard errors are clustered at the country level. *, **, *** represent significance at 10, 5, and 1%, respectively.

Table C.4: Drivers of climate-related communication - 13-topic STM - Baseline model

	(1) Green finance	(2) Climate-related risks	(3) Climate frequency	(4) Climate salience
Physical exposure	-0.246	-0.129	-0.216	-0.089
	(0.161)	(0.167)	(0.202)	(0.099)
Carbon intensity	-0.492	12.413**	4.557	7.093**
	(3.719)	(3.860)	(3.282)	(2.690)
CB Supervision	1.189	6.330**	6.363**	7.097**
	(0.992)	(2.226)	(2.126)	(1.989)
CB Objectives	0.104	-3.468*	-2.191*	-2.861
	(1.265)	(1.892)	(1.260)	(1.761)
NGFS membership	0.589	1.202**	0.669*	0.835*
	(0.386)	(0.523)	(0.383)	(0.444)
Inflation	-0.032	0.115	0.051	0.084
	(0.062)	(0.113)	(0.042)	(0.063)
Output gap	3.475	-12.154**	-2.781	-7.369
	(7.150)	(6.045)	(5.202)	(5.311)
GDP per capita	-0.045	0.289**	0.212**	0.264**
	(0.041)	(0.108)	(0.071)	(0.096)
Insurance company assets to GDP	0.025	0.009	0.020	0.007
	(0.017)	(0.022)	(0.019)	(0.015)
Private credit to GDP	-0.005	0.007	0.002	0.011
	(0.009)	(0.010)	(0.008)	(0.008)
Constant	-3.314	-17.081**	-9.992**	-14.245**
	(2.023)	(4.315)	(3.125)	(3.583)
Observations	929	929	929	929
R-Squared	0.387	0.372	0.626	0.399

Note: Central bank and year-fixed effects are included. Standard errors are clustered at the country level. *, **, *** represent significance at 10, 5, and 1%, respectively.

Table C.5: Drivers of climate-related communication - 13-topic STM - NGFS dummy excluded

	(1) Green finance	(2) Climate-related risks	(3) Climate frequency	(4) Climate salience
Physical exposure	-0.241	-0.045	-0.165	-0.043
	(0.175)	(0.145)	(0.182)	(0.105)
Carbon intensity	-2.043	12.354**	4.030	6.607**
	(3.840)	(3.685)	(3.099)	(2.460)
CB Supervision	1.338	6.952**	6.312**	7.211**
	(0.995)	(2.136)	(2.052)	(1.850)
CB Objectives	-0.481	-4.012**	-2.447**	-3.258**
	(1.214)	(1.918)	(1.191)	(1.656)
Inflation	-0.047	0.118	0.066	0.102*
	(0.069)	(0.118)	(0.041)	(0.062)
Output gap	3.378	-11.981*	-3.579	-7.775
	(6.844)	(6.396)	(5.224)	(5.371)
GDP per capita	-0.027	0.348**	0.233**	0.298**
	(0.031)	(0.124)	(0.076)	(0.102)
Insurance company assets to GDP	0.025	0.003	0.019	0.005
	(0.017)	(0.020)	(0.018)	(0.015)
Private credit to GDP	-0.005	0.006	0.001	0.009
	(0.009)	(0.011)	(0.008)	(0.008)
Constant	-2.970	-17.583**	-9.791**	-14.152**
	(2.051)	(4.730)	(3.245)	(3.710)
Observations	929	929	929	929
R-Squared	0.386	0.367	0.623	0.396

Note: Central bank and year fixed effects are included. Standard errors are clustered at the country level. *, **, *** represent significance at 10, 5, and 1%, respectively.

Table C.6: Drivers of climate-related communication - 13-topic STM - Extended timeline

	(1) Green finance	(2) Climate-related risks	(3) Climate frequency	(4) Climate salience
Physical exposure	-0.105	-0.325	-0.238	-0.339*
	(0.099)	(0.242)	(0.209)	(0.195)
Carbon intensity	-0.962	7.626*	-0.691	-0.237
	(2.913)	(3.940)	(3.200)	(3.862)
CB Supervision	3.071*	6.310*	3.522**	6.197**
	(1.581)	(3.235)	(1.598)	(2.202)
CB Objectives	1.865	-0.780	0.663	0.513
	(1.412)	(0.640)	(0.638)	(0.585)
NGFS membership	0.290	1.159**	0.761**	0.592
	(0.264)	(0.417)	(0.292)	(0.378)
Inflation	0.069**	-0.044	-0.062**	-0.026
	(0.035)	(0.046)	(0.027)	(0.034)
Output gap	3.842	-6.664*	-6.105*	-3.839
	(3.842)	(3.434)	(3.169)	(3.068)
GDP per capita	-0.033	0.094*	0.040**	0.069**
	(0.022)	(0.057)	(0.018)	(0.034)
Constant	-5.449**	-10.372**	-2.226*	-7.248**
	(1.904)	(2.656)	(1.240)	(1.665)
Observations	1431	1431	1431	1431
R-Squared	0.392	0.354	0.649	0.401

Note: Central bank and year fixed effects are included. Standard errors are clustered at the country level. *, **, *** represent significance at 10, 5, and 1%, respectively.

Appendix D Effects on equity returns

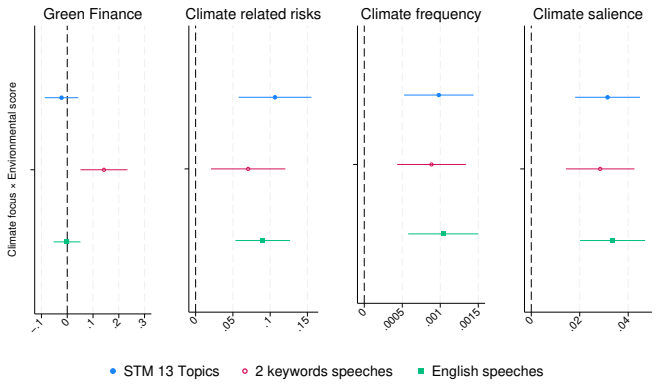
D.1 Robustness analysis

In this Appendix, we perform a number of robustness exercises to test the solidity of our results.

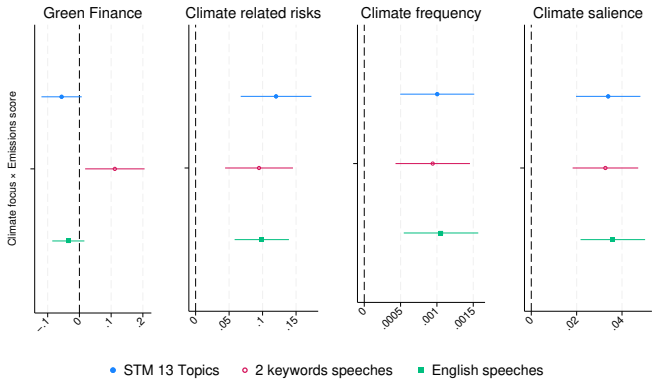
First, we re-run our three-way fixed effect estimation (see Table 7) using three alternative specifications for the structural topic model: (i) the 13-topic model we have been using for robustness analysis; (ii) a different topic model based on a subset of speeches (1,955 in total, i.e. 66% of our baseline sample) which mention climate-related keywords at least two times – instead of only once as in our baseline estimation; and (iii) another topic model based on a the subset of speeches (2,555 in total) that were published in English. Results for our interaction term (*Climate focus* × *Greenness*) are shown in Figure D.1. They confirm both that the regression coefficients remain significant (with the exception of the *Green finance* topic, which is less significant in the baseline as well) and that their numerical value remains in a similar range.

Second, we test for alternative measures of emission intensity. In Figure D.2a we show the coefficients for the interaction term obtained when using estimated – instead of only reported by firms – or direct (Scope 1) – instead of direct and indirect (Scope 2) emissions. In Figure D.2b, we present instead the results obtained when scaling emissions for firms' market capitalisation – rather then their revenues. In this case as well, we also look at the case of estimated and direct emission values.

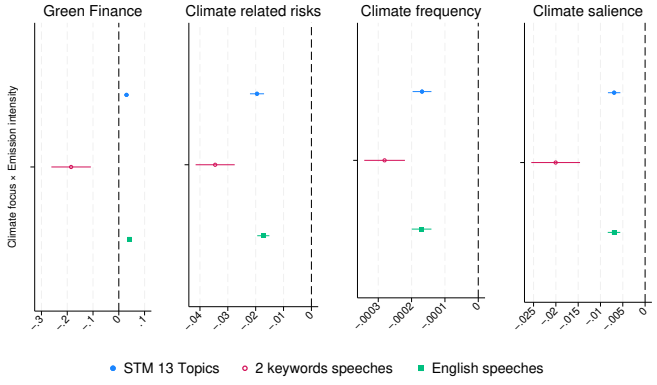
Finally, we repropose both the firm and three-way fixed effect baseline estimation but add a dummy capturing the presence of emission reduction targets at the firm level. This measure, sourced from LSEG, represents firms' binary responses (yes/no) to the question of whether they have set specific targets for emission reductions. This is shown in Table D.1. Our qualitative results are confirmed, in that the interaction term suggests that firms with explicit emission reduction targets outperform firms without targets when central banks engage more with climate-related topics in their public communication.



(a) Environmental score

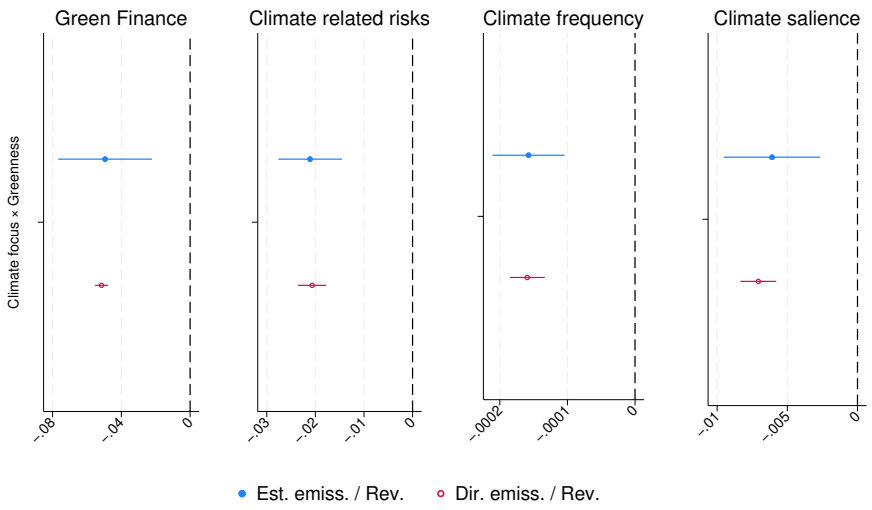


(b) Emission score

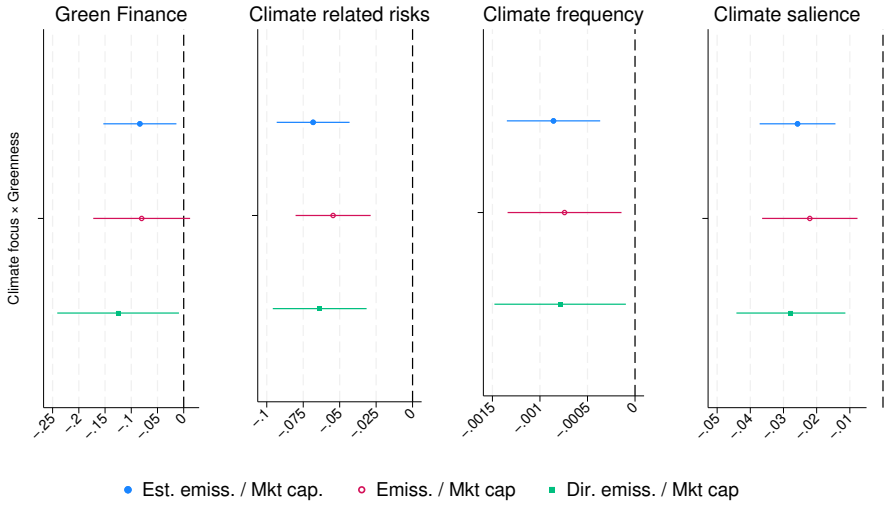


(c) Emission intensity

Figure D.1: Effects of climate-related communication - Robustness using alternative STM models



(a) Estimated and direct emissions



(b) Market capitalisation (reported, estimated and direct emissions)

Figure D.2: Effects of climate-related communication - Robustness using alternative emission intensity values

Table D.1: Effects of climate-related communication - Emission reduction target

	(1) Green finance	(2) Climate-related risks	(3) Climate frequency	(4) Climate salience
	Panel A: Firm fixed effects			
Climate focus	-0.110*	-0.080**	-0.002**	-0.034**
	(0.056)	(0.031)	(0.000)	(0.011)
Emission reduction targets	0.001	-0.015	-0.013	-0.015*
	(0.008)	(0.009)	(0.009)	(0.009)
Climate focus × Emission reduction targets	-0.000	0.111**	0.001**	0.034**
	(0.039)	(0.022)	(0.000)	(0.008)
Observations	378061	378061	378061	378061
R-Squared	0.150	0.150	0.150	0.150
	Panel B: Date × Country × Industry fixed effects			
Emission reduction targets	-0.003	-0.014*	-0.014	-0.016*
	(0.007)	(0.008)	(0.009)	(0.009)
Climate focus × Emission reduction targets	0.031	0.075**	0.001**	0.028**
	(0.038)	(0.018)	(0.000)	(0.008)
Observations	369555	369555	369555	369555
R-Squared	0.218	0.218	0.218	0.218
Additional controls	Yes	Yes	Yes	Yes

This table reports the results of regressing firms' daily returns on Climate Focus, a dummy for firms' commitment to reduce their emissions, firm-specific accounting measures and daily control variables for the Size and Value factors. *, **, *** represent significance at 10, 5, and 1%, respectively.

D.2 Spillover effects

Here we control for the possibility of spillovers of central bank communication across countries. That is, could the effects we find in Section 5 for some countries be driven by the public communication of the central banks of another country? To test this hypothesis, we focus on the United States, who play a crucial role in the international finance system (Bruno and Shin, 2015; Miranda-Agrippino and Rey, 2020). More specifically, we look at the potential effect of climate-related speeches by Fed officials on non-US asset prices. We consider the returns of non-US asset prices on all the trading days in which Fed officials delivered climate speeches, except those in which some other national central bank has also given a climate-related speech. That is, we only consider trading days in which only the Fed and not the national central bank delivered a climate-related speech. The results of this robustness check are presented in Table D.2. The absence of a statistically significant relationship between asset returns and the interaction term suggests the absence of any spillover effects from Fed climate-related speeches.

Table D.2: Spillover effects of US climate-related communication

	(1) Green finance	(2) Climate-related risks	(3) Climate frequency	(4) Climate salience
	Panel A: Environment score			
Emission score	0.021	0.042	0.030	0.037
	(0.026)	(0.032)	(0.030)	(0.030)
Climate focus × Emission score	-0.591	-0.129	-0.001	-0.051
	(0.541)	(0.087)	(0.001)	(0.033)
Observations	17195	17195	17195	17195
R-Squared	0.186	0.186	0.186	0.186
	Panel B: Emission score			
Environmental score	0.041*	0.057**	0.049*	0.053**
	(0.023)	(0.029)	(0.027)	(0.026)
Climate focus × Environmental score	-0.090	-0.087	-0.001	-0.031
	(0.407)	(0.093)	(0.001)	(0.037)
Observations	17195	17195	17195	17195
R-Squared	0.186	0.186	0.186	0.186
	Panel C: Emission intensity			
Emission intensity	0.069*	0.011	0.005	0.015
	(0.036)	(0.043)	(0.008)	(0.048)
Climate focus × Emission intensity	-14.144*	-0.164	-0.001	-0.094
	(7.748)	(1.094)	(0.008)	(0.412)
Observations	13785	13785	13785	13785
R-Squared	0.199	0.199	0.199	0.199
Date × Country × Industry FE	Yes	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes	Yes

This table reports the results of regressing firms' daily returns on Climate Focus, a measure of greenness, and firm-specific accounting measures. Country-industry-time fixed effects are included. Standard errors are clustered at the country-industry level. *, **, *** represent significance at 10, 5, and 1%, respectively.