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Speeches in the green: The political discourse of green central banking

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Abstract

In this paper, we employ a keyword-assisted topic model to quantify the extent of climate-related communication of central banks. We find evidence for a significant increase in climate-related speeches by central banks, which address the topic mostly in parallel with topics on financial stability, payment innovations, and the banking sector. Price stability concerns play a minor role. Finally, we examine factors that can explain the extent of green communication by central banks. Controlling for macroeconomic and climate-related variables, we identify two external factors that can prompt central banks to prioritize climate research on their agenda: First, peer pressure, measured by membership of a working group on green financing, increases green communication. Second, a high degree of governmental climate engagement, reflected by the extent of national climate laws, is positively related to green communication by central banks. Whether the central bank has an implicit or explicit sustainability mandate, however, does not explain the extent of green communication.

Keywords:	Central banking; Climate change; Narrative analysis; topic modeling
JEL Codes:	E58; E61

1 Introduction

Established as a platform for central banks seeking an active role in addressing climate change, the Network for Greening the Financial System (NGFS) featured in 2023 had 129 members and 21 observers. This clearly demonstrates the growing involvement and interest of central banks in the impact climate change can have on monetary policy and financial stability. This influence can stem from either the direct effects of climate change and extreme weather events on production structures (NGFS, 2020b) or indirectly through changes triggered by national climate policies in pursuing the transition towards more sustainable energy (Batten et al., 2016). Both effects can have serious repercussions on the financial system and hence have to be taken into consideration by central banks (NGFS, 2020a,b). The tools central banks could employ range from enhanced information disclosure, climate stress tests of the banking systems to more active roles by fostering a green capital market union and considering predominantly green bonds for their monetary policy operations (Deyris, 2023). Some consider the latter as a crucial contribution of central banks to reach the goals outlined in the Paris Climate Agreement (Arseneau et al., 2022; Li et al., 2023).

We measure the focus of central banks on climate related policies indirectly by examining their green communication with the public. We observe an increase in central bank speeches on climate-related topics. By the same token, climate change lacks prominence in central bank legislation (AlAjmi et al., 2023). Dikau and Volz (2021) analyze central bank mandates and show that only a few have an implicit and even fewer an explicit sustainability mandate. The mandate status might be related back to the degree of central bank independence, which is an important feature of central banks to address their main objective, price stability, properly and without governmental influence (Berger et al., 2001). Baer et al. (2021) emphasizes that central banks' mandates tend to be more narrowly defined in countries where the central bank is highly independent. This implies fewer explicit sustainability mandates for high income countries, a finding which is in line with Dikau and Volz (2021).

As central banks grapple with the challenges posed by climate change, they face pressure from governments. Traditionally tasked with maintaining price stability, an ongoing debate questions whether combating climate change falls within the central banks' mandate or if it is more of a political matter. According to the 2015 Paris Agreement, governments are politically empowered to address market failures causing climate change, utilizing policy tools such as emission pricing and regulatory frameworks. Scholars argue that relying solely on governments to address climate change may be inefficient, suggesting that central banks can support climate policy within their existing mandates (Boneva et al., 2022). Research by Volz (2017) advocates for a proactive role for central banks in sustainable development but cautions against expanding mandates to preserve institutional independence. Hansen (2022) argues for fiscal policy as the primary tool to address climate change, cautioning against a proactive engagement of central banks. (Volz et al., 2020) shows the impact of climate change on sovereign risk and national debt burden. While Diluiso et al. (2021) also stress governments' primary responsibility for climate action, they see an important role to coordinate policies with central banks. Campiglio et al. (2018) suggests policy cooperation between central banks and financial regulators if climate risks threaten stability. In the same vein, Bolton et al. (2020) advocates a coordinating role for central banks in climate action.

To showcase how central banks deal with the lack of mandate and growing importance of climate change, one can take the case of the European Central Bank (ECB), which has a primary objective and mandate to maintain price stability. In 2021, the ECB emphasized the need for alignment between climate and monetary policy for effective action and improved macroeconomic modeling frameworks (Deyris, 2023; McKibbin et al., 2020). Even in case central banks lack a clear legal framework to monitor and address climate change, they might consider its consequences for their operations to align with international policy goals (Boneva et al., 2022).

In this paper, we use the keyword assisted topic model of Eshima et al. (2023) and analyze 18,902 central bank speeches over the period from 1996 to 2023. The text data are drawn from the Bank for International Settlements (BIS) archive, which to date has been analyzed by text analysis techniques

only by a small but growing number of studies (see e.g., Armelius et al., 2020; Arseneau et al., 2022; Feldkircher et al., 2022) The keyword assisted topic model allows us to quantify the extent of "green communication" per central bank. A high share – or topic prevalence – of green communication is reminiscent of more active engagement of the central bank in climate research and policies. A similar approach using a different methodology, has been recently carried out in Arseneau et al. (2022) who use a scoring method that yields a binary categorization of speeches into climate related and non-climate related. In contrast to Arseneau et al. (2022), we further focus on the legislative tension between political bodies and central banks by drawing on a second set of text data, climate laws.

Our main results are three-fold: First, we show that topics often mentioned in parallel with climate risks include financial stability, payment innovation, and banking sector issues but not price stability. Second, we investigate green narratives that central banks use when communicating with the public. Here, we find that a role for climate policy of central banks is mostly argued by pointing out the risks for financial stability. Third, we analyze the drivers of green communication. Our results reveal that membership in the NGFS network, a measure of peer pressure (Deyris, 2023), and national engagement in climate policies, measured by the extent of climate laws, lead to more green communication. Macroeconomic and environmental factors play a minor role, and the presence of a legal sustainability mandate in the central bank does not explain the extent of green communication.

The paper is structured in two parts: First, in the next section, we introduce the data and the keyword-assisted topic model that we use to identify climate-related speeches. We also present descriptive statistics for the set of climate-related speeches. Second, we delve deeper and analyze the narratives central banks use to communicate their climate engagement to the public, followed by an empirical analysis to identify drivers of green communication. Finally, Section 4 concludes.

2   Identifying green speeches

In this section we identify climate related speeches by using a keyword assisted topic model.

2.1   Data & preprocessing

To assess the extent of climate-related communication, we download central bankers' speeches from the BIS archive. The archive contains speeches from central bankers and monetary authorities delivered by these authorities and in English language. We download the speeches from the BIS archive (`www.https://www.bis.org/cbspeeches/index.htm`) and in PDF format. Our corpus consists of $D = 18,902$ documents, with the earliest dating back to 1996-09-10 and the latest being from 2023-10-26.[1] The speeches in the corpus where delivered by 117 different entities, with the vast majority being central banks. To a small extent, the corpus also covers financial market authorities and working groups / committees of central banks and financial market authorities. The full list of entities is provided in Table 9 in the appendix.

We preprocess the documents by first, removing non-English characters, stopwords and punctuation and second applying lemmatization to find root forms of the words. The length of speeches ranges from 27 to 25,105 tokens. The average speech consists of around 1500 tokens.

To showcase the information contained in our corpus, we further used a part of speech tagger (POS) to label each token according to its grammatical function. POS is done by using the `R` implementation of the `udpipe` framework (Wijffels, 2021), fully described in Straka and Straková (2017). In Figure 1, we show the most frequent nouns in the BIS corpus.

The figure provides an idea of the kind of data which is represented in the corpus. The most frequent nouns comprise "bank", "policy", "market", "rate", "economy" and "inflation" followed by "risk". The right hand side panel of Figure 1 shows a word network of words co-occurring together, where we focus on nouns and adjectives. The word cloud identifies three "hubs". One is centered on the word

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[1]From these, around 140 PDFs have been non-readable and had to be converted into text in order to be able to process them.

Figure 1: Word cloud full corpus

Notes: The left panel shows the most frequent nouns, the right panel a words occurring most frequently together.

"financial", leading to word combinations such as financial crisis, financial stability but also financial inclusion and the like. Another hub is related to policy with the largest co-occurrence being the one between monetary and policy. But also macroprudential and fiscal policy are terms often mentioned in the BIS corpus. Both graphs show that frequent terms relate to the dominating mandates of central banks, price stability and financial stability. Our interest is in an additional topic, which can also be spotted on the provided word cloud, monetary policy addressing climate change, depicted in the northeastern quadrant of the graph. Note that central bank speeches use the word "climate" frequently in other context, when talking about the "business climate" for example. Still, these co-occurrences seem of less importance, since they do not appear on the word cloud.

2.2 Methodology: A keyword assisted topic model

To identify climate-related speeches, we use a new variant of topic models. In a nutshell, the main idea behind topic models is to assume that each document is comprised of a mixture of different topics and that each topic in turn is characterized by its own probabilistic distribution of terms (Blei et al., 2003; Hansen and McMahon, 2016). Topic models are considered as data-driven methods for exploratory purposes. To put more structure on these models, Eshima et al. (2023) propose a *keyword assisted topic model*.

This model assumes that we have a total of K topics, of which the first $\tilde{K} \leq K$ are keyword topics and the rest no-keyword topics. In what follows, we specify keywords for 7 topics, one of which is the primary interest of this study, the "climate-related" or "green" topic. On top of that, we allow for 3 no-keyword topics.

For each word j then in document d, the latent topic variable $z_{dj} \in 1, 2, \ldots, K$ is drawn from the *topic distribution* of the document,

$$z_{dj} \overset{indep.}{\sim} \text{Categorial}(\theta_d), \tag{1}$$

with θ_d being the K-dimensional vector of topic probabilities for document d with $\sum_{k=1}^{K} \theta_{dk} = 1$. A no-keyword, or residual topic, a word w_{di} is then drawn from the corresponding word distribution of the topic

$$w_{dj}|z_{dj} = k \overset{indep.}{\sim} \text{Categorial}(\phi_k), \tag{2}$$

with ϕ_k denoting a V-dimensional vector of word probabilities for topic k, representing the *relative* word frequency within topic k. The set-up changes in case the topic is one of the key-word assisted

topics. In that case, the word distribution is as follows:

$$w_{dj}|z_{dj} = k \overset{indep.}{\sim} = \begin{cases} \text{Categorical} & (\theta_k) \text{ if } s_{dj} = 0 \\ \text{Categorical} & (\tilde{\theta}_k) \text{ if } s_{dj} = 1 \end{cases}$$

with $s_{dj}|z_{dj} = k \overset{indep.}{\sim}$ Bernoulli (ϕ_k), for $k \in 1, 2, \ldots, \tilde{K}$, a Bernoulli variable indicating whether the w_{dj} should be drawn from the specified set of keywords based on $V-$dimensional probability vector $\tilde{phi}_k$), with L_k (the number of keywords for topic k) non-zero entries. For the prior distributions and the sampling algorithm, see Eshima et al. (2023).

We identify keywords using different strategies. First, we look at speech titles that contain the words "climate". We display the word distribution of these speeches by word clouds and pick the most frequent terms. Alternatively, we form bigrams of the lemmatized tokens, which we screen for climate related terms.[2]This approach left us with the following selection of climate related bigrams (L_k) that help identifying the topic of interest: climate_change","climate_risk","climate_policy","green_finance", "agreement_paris","paris_agreement"

On top of the focal topic, we provide keywords to help identifying other topics frequently addressed by central banks. More specifically, we follow Feldkircher et al. (2021) who use the same data source and provide keywords for the topics monetary policy and financial stability as well as for the topics global economy, payment systems and banking supervision. The full list of keywords are listed in Table 5 in the appendix. We also allow for three non-assisted topics that might pick up tonality and word usage specific to certain central banks. This leaves us with $K = 10$ topics of which $\tilde{K} = 7$ are keyword assisted.

2.3 Descriptive results

In this section, we present the results from the keyword assisted topic models. Since our ultimate goal is to identify climate related speeches, we have to systematically label the speeches according to their topic proportions. In what follows, we identify those speeches as climate related for which the highest topic proportion is attributed to the green topic, $\theta_{d,gr}$ This approach yields 791 speeches, which is in the ballpark of climate-related speeches identified in Arseneau et al. (2022). From this set of speeches, the median topic proportion is around 0.3. Alternatively one could identify climate speeches by considering only those speeches for which $\theta_{d,gr}$ exceeds a certain threshold value, or for which there is a strong discrimination between the climate topic on the one hand and the remaining topics on the other hand, i.e., looking at differences in topic proportions. To better assess the accuracy of our identification procedure, we list the top 20 speeches in Table 4 in the appendix. Simply looking at the titles of these speeches suggests that the keyword assisted topic model provided a useful classification.

Having identified the set of climate related speeches, we proceed by showing some descriptive statistics. First, we show the number of speeches over time in Figure 2.

The figure shows that the topic gained considerable popularity after 2002, but emphasis on green speeches was overshadowed by the global financial crisis, which brought other topics to the fore. From 2016 on, there is a steep increase in both the topic proportion of θ_{gr} and the number of climate-related speeches. In 2022, again, geopolitical events put emphasis on other, non-climate related topics, which resulted in a decrease of the number of speeches and content devoted to the green topic.

Next, we show the number of climate-related speeches per central bank. Our analysis reveals 69 out of 117 entities with at least one climate-related speech. For these central banks, we indicate the ones with either an implicit or an explicit mandate to pursue climate related policies. For that purpose, we draw on recent work by Dikau and Volz (2021), who analyzed mandates based on the IMF's Central Bank Legislation Database and central banks' web-pages. This analysis lists central banks

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[2]We dropped frequently occurring bigrams that do not help distinguishing between topics. These include the following terms "lady_gentleman", "bis_central", "banker_speech","central_banker".

Figure 2: Climate-related speeches over time
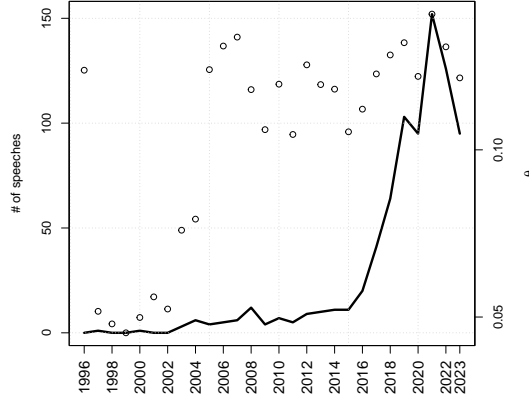
Notes: The panel shows on the left axis the number of climate-related speeches, aggregated per year (black, solid line) on on the right-axis the topic proportion attached to the climate topic (dots). The latest observation is from September 2023.

as those with an *implicit* mandate in case they have an objective to enhance, promote or support sustainability / sustainable development / growth or support the government's policy goals. As one of the central banks with most speeches in our corpus, the ECB is also classified as having an implicit mandate in Dikau and Volz (2021). This can be motivated again through the indirect mandate the ECB has to help - in this case the EU's policy objectives. For example, Frank Elderson, a member of the executive board of the ECB, stresses that "although not conferring a specific mandate for ECB climate change action, do require us to take into account the EU's environmental objectives and policies when pursuing both our primary and secondary objectives" (Dikau and Volz, 2021; Elderson, 2021). A smaller fraction of central banks has an *explicit* mandate. In our corpus, 43 entities have an implicit mandate and 12 an explicit mandate. Cross-country differences in the definition of the mandate can also be related back to central bank independence, a concept introduced by (Dincer and Eichengreen, 2014). In countries with higher central bank independence, central banks' mandates tend to be defined more narrowly to "avoid institutional drift" (Baer et al., 2021). This typically applies to high-income countries. By contrast, in low-income countries with central banks being more exposed to political control, central banks' mandates tend to be more broadly defined. As a consequence, explicit green mandates are adopted mainly in countries with low central bank independence (D'Orazio and Popoyan, 2020).

Figure 3 shows the results, in light-green central banks with an implicit mandate, and dark-green those with an explicit mandate.

The top panel of Figure 3 lists the number of climate-related speeches given by central banks. The top contributing central banks are the Bank of England, euro area central banks and the ECB, as well as the US Fed. Also two banks from Asia show strong green communication, namely the Singapore monetary authority and the central bank of Malaysia. Among the top 10 contributors, only the US Fed has neither an explicit nor an implicit mandate to pursue green policies. As an alternative to simply looking at the number of speeches, we next show the sum of the topic proportion (θ_{gr}) related to the green topic. This is shown in the middle panel of Figure 3. If we consider again the top contributors, the ranking barely changes; most speeches come from big central banks in Europe, the US and representatives of the Singapore monetary authority and the central bank of Malaysia.

To see, how much a central bank communicates about climate change relative to its overall communication content, we investigate in the bottom panel of Figure 3 the relative topic proportion. To that end, we have calculated the relative proportion of $\tilde{\theta}_{gr} = \theta_{gr} / \sum_{j=1}^{K} \theta_j$. The picture reveals that the
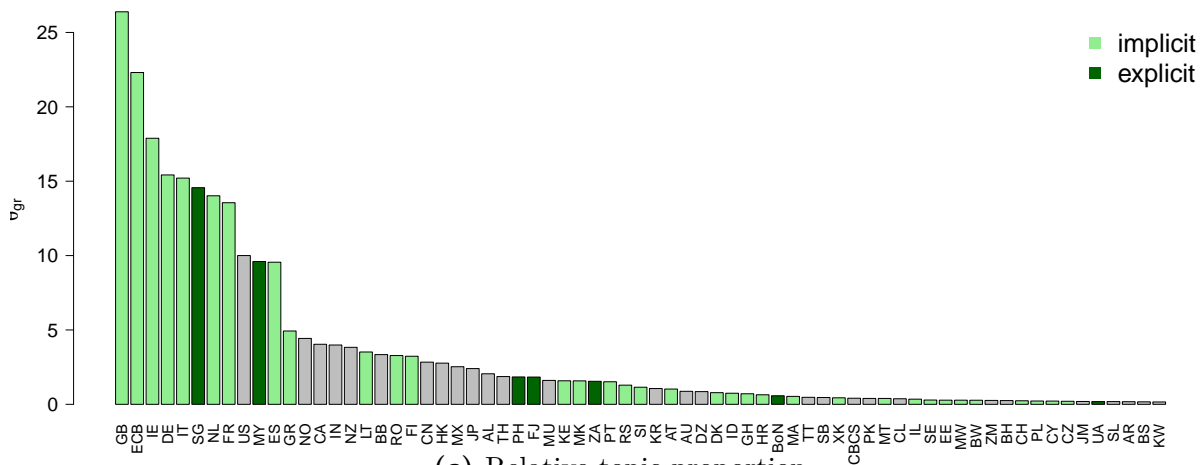
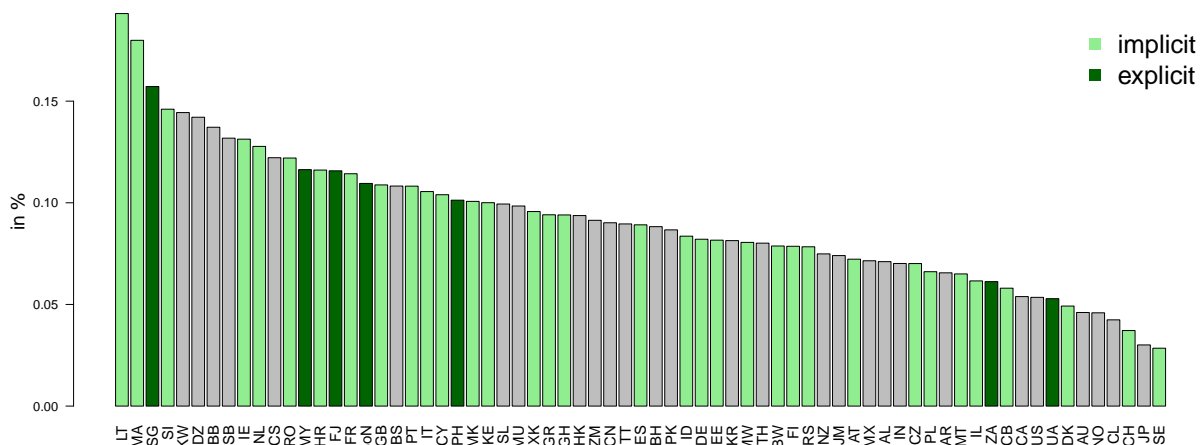**Figure 3:** Climate-related speeches and central banks' mandates

**(a)** Absolute number of speeches
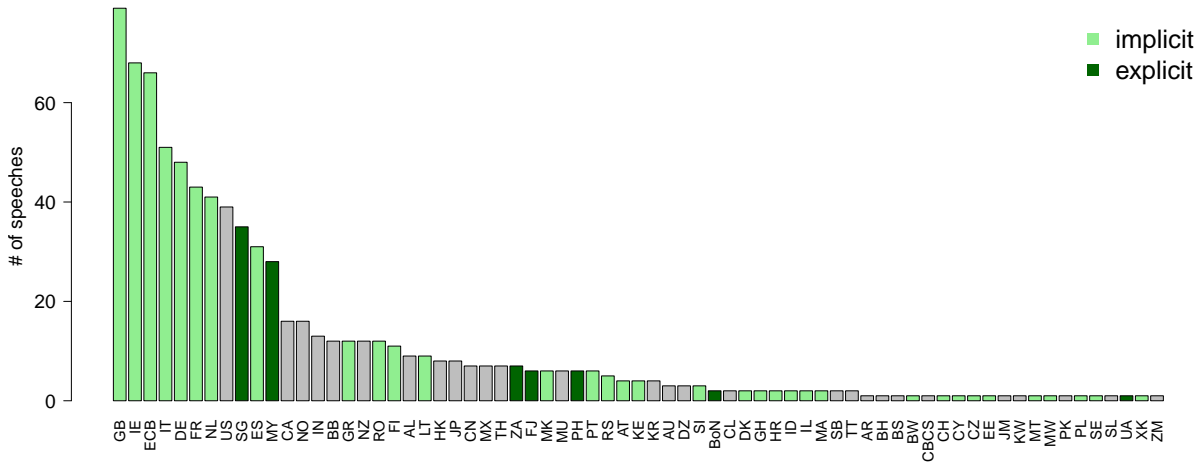
(b) Topic proportion

(c) Relative topic proportion

Notes: The top panel shows the absolute number of climate related speeches, the middle panel the sum of θ_{gr} and the bottom panel the share of θ_{gr} in all topics per central banks. The classification of explicit and implicit mandate follows Dikau and Volz (2021). For entity abbreviation, see Table 9.

Figure 4: Which other topics are mentioned when talking green?
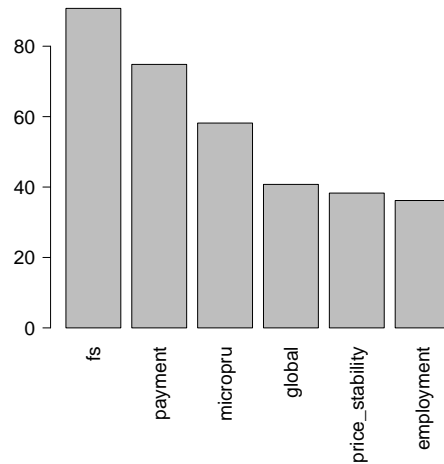
two Asian central banks are still among the most contributing central banks. On top of that, other smaller central banks devote a significant share of their speech content to the topic under study. These feature small islands on the one hand, such as the central bank of Solomon Islands, Fiji and Barbados, or oil exporting countries on the other hand such as Morocco, Bahrain and Kuwait.

3 Digging deeper: Green narratives and drivers of green communication

3.1 Green narratives

In this section, we examine narratives that are used when central bankers talk about climate change. There is a fast growing literature in social sciences that analyzes how narratives impact political and economic outcomes (see Ash et al., 2023, and the references therein). To remain economically relevant, a story must help individuals make sense of a complex social context and suggest actions to a social group. Simandan et al. (2023) use a qualitative approach to analyze climate narratives for the ECB and the Bank of England. They postulate a narrative which builds upon a global climate crisis (setting) which is then causally linked to increased financial stability risks. To be consistent with the traditional mandate of most central banks, which is price stability, according to Simandan et al. (2023) major central banks often emphasize the implications of climate change and price stability.

We first examine which topics are mentioned in parallel when talking about climate change. This is a natural by-product of our analyses from the previous section, which yields topic proportions for all analyzed topics. For that purpose, we sum up the proportions of the key-word assisted topics for the previously identified "green" speeches. These are displayed in Figure 4 below:

By far, the largest proportion of "green" speeches is devoted to financial stability and financial stability risks. As example, one can consider the interview of Luis de Guindos, then vice-president of the ECB, to Bloomberg on climate-related risks. The second topic, that is frequently addressed in tandem with climate change is the payment and digital innovation topic. An exemplary text would be the remarks of Ravi Menon, Managing Director of the Monetary Authority of Singapore on FinTech for an inclusive society and a sustainable planet. In fact, climate policies are considered to be transformative and hence often mentioned together with technological innovations. The third topic that is often part of green speeches are microprudential / banking sector issues. An exemplary speech would be the one of Kevin Stiroh, Federal Reserve Bank of New York on Climate change and risk management in bank supervision. By contrast, the topics "global", "economic activity / employment" and "price stability" are less related to climate change in central bankers' speeches. In particular the fact that central

Figure 5: Word co-occurrences

Verbs, nouns & adjectives
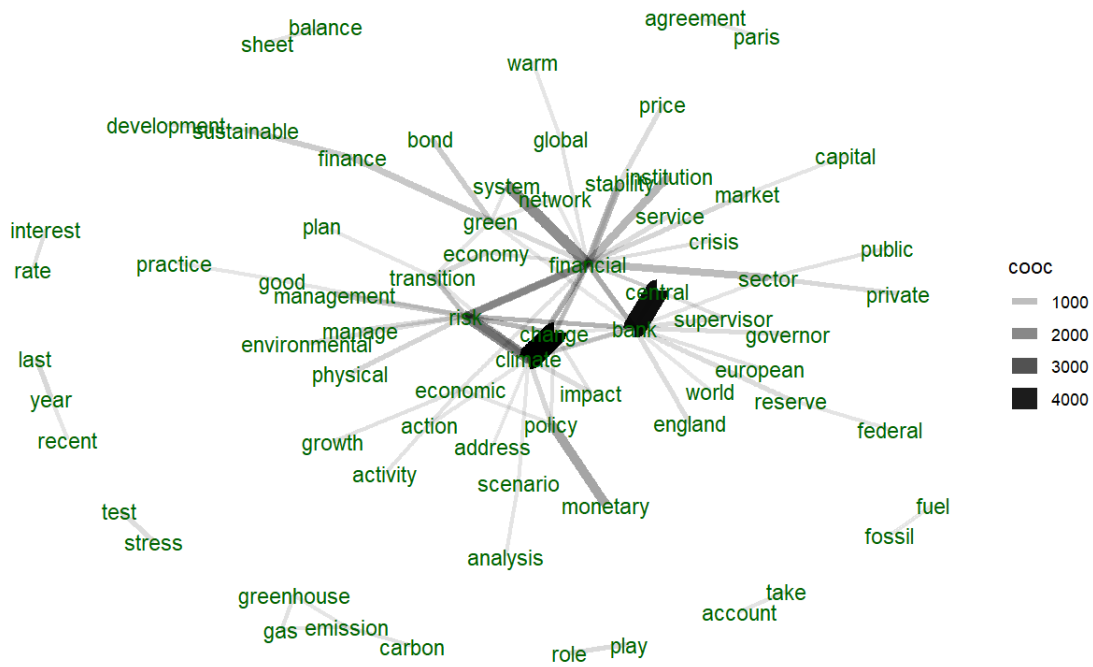
banks view climate change not through the lens of price stability is intriguing, given the most recent experience of high energy prices worldwide. This finding is in line with Simandan et al. (2023) who highlight that the trade-off between a rapid green transition and higher prices is not directly assessed by central bankers. They point out that, ECB representatives gave evidence in interviews that in case climate policies would interfere with the primary mandate of price stability, "[T]he precedence of price stability over other objectives implies that if monetary policy needs to be tightened to achieve our price stability objective for reasons unrelated to climate change [...] then we must not hesitate to act".[3] The lack of economic activity content in green speeches is also surprising given that recent research (see e.g., Mora et al., 2022, and the references therein) argues with a decline in global economic activity as a consequence of extreme weather conditions.

Next, we delve deeper into analyzing narratives by drawing part-of-speech tagging analysis and co-occurrences of different word types in the corpus of green speeches. The analysis is related to Ash et al. (2023), who identify agents (who), verbs (what) and patients (to whom) in sentences and use dimensionality reduction methods to be able toe aggregate similar narratives / expressions. In this paper, we use a simpler approach where we use parts of speech (POS) tagging and then look at co-occurrences of nouns and verbs. To identify a narrative, we first, look at the subset of nouns, verbs and adjectives and second calculate their co-occurrence, where we consider a word window of up to three to mark words as adjacent. The network of the top 100 most frequent co-occurrences is then displayed in Figure 5

The plot shows some interesting features of the data. The central hub in the network consists of three dominant nodes, first climate change, which should be addressed by, next to it, central banks. The reason can be seen by looking at the left node next to climate change, which is risk that spills over

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[3]Isabelle Schnabl, ECB, retrieved from `https://www.ecb.europa.eu/press/key/date/2021/html/ecb.sp210303_1~f3df48854e.en.html`

to the node financial, which then has implications for more broader, stability related topics. We also see that both public and private sector are brought into the picture through risk implications for the financial sector, a narrative that is in line with Simandan et al. (2023).

By contrast, we do not find a hub of using strong expressions that set the stage for urgent policy actions. There is no cluster among the most frequent occurring words that points at climate crisis, global warming, extreme weather conditions and the like. To dwell on this point further, we provide a sentiment analysis for the whole set of speeches. Our aim is to find out, whether the sentiment in climate change speeches is different from sentiment used in other speeches. For that purpose, we conduct a simple dictionary-based sentiment analysis using the dictionary of Loughran and Mcdonald (2011). The results are provided in Table 1

Table 1: Positive and negative words per topic

	neg	pos
price_stability	3487.00	919.00
employment	929.00	488.00
fs	1885.00	966.00
micropru	1591.00	558.00
global	1800.00	1107.00
payment	723.00	3022.00
green	379.00	412.00

The table shows that central banks address climate change with a balanced wording of positive and negative words. This is in stark contrast to the other two mandates price and financial stability, where central banks address much more often risks as a justification of their actions.

Summing up, we find that climate related speeches often contain information about financial stability, payment innovation and banking sector topics. The topic is also addressed using a balance of positively and negatively connoted words. This is in contrast to central bankers' speeches addressing the traditional price stability mandate, where sentiment is much more negative probably to justify policy actions. This analysis is consistent with results from a word co-occurrence analysis which shows that climate change should be addressed by central banks to mitigate financial market implications.

3.2 Why do some central banks talk more about climate change than others?

The previous analysis allowed us to identify climate related speeches and to assess an overall narrative of central banks' green communication to the public. In this section, we extend this analysis to examine why some central banks show a higher extent of green speeches than others. For that purpose, we gather additional variables capturing economic, geographic and political characteristics of the countries under study. We include three types of variables, first we use a set of time-varying, macro-economic data. To be precise, we include data on year-over-year inflation (Dp_yoy) and real GDP growth (y_yoy) to capture potential trade-offs with the more traditional mandates of central banks. We also include nominal GDP in US dollar (y_nom) to capture size effects and GDP per capita in international (purchasing power parity adjusted) dollars (y_pcap) to control for cross-country differences in income. The second set of variables relates to geographic characteristics of the countries and their exposure to climate change. More specifically, we include the World Bank's Standardised Precipitation-Evapotranspiration Index ($spei$), which is a drought index based on climatic data and should capture extreme weather conditions. We also include the average temperature from 1997-2022 ($temp\_avg$) from the World Bank's new climate change knowledge portal. Temperature on single years is unfortunately not available for all countries considered. We then include the relative size of coastal area to overall boarder area to see whether islands and central banks in countries exposed to (potentially) rising sea levels have a stronger focus on climate related policies. The third set of variables relates to the central banks' mandates. More specifically, we include time constant dummy variables

for the implicit ($impl\_m$) and explicit ($expl\_m$) green mandates, as defined in Dikau and Volz (2021). We complement these data with a time-varying dummy variable that shows whether the central bank under study is a member of the NGFS network. This variable should reflect peer pressure as advocated in Deyris (2023). Data and sources are listed in Table 6.

To estimate the drivers of green communication, we use a multilevel panel data framework, implemented in the R package `panelr` (Long, 2020). The multilevel model combines fixed and random effects estimation which allows for the inclusion of time-constant variables and builds upon work by Allison (2009); a detailed exposition can be found in Schunck (2013). The model is particularly appealing to us since the explicit and implicit mandate variables are time-constant. To estimate drivers of green communication, we focus on $\theta_{d,gr}$ for the full set of speeches; that is also speeches with a low topic proportion of green communication are considered informative. Our dependent variable, denoted by y_{it} is the extent of green communication, measured by the sum of $\theta_{d,gr}$ per central bank and per year. Out of the 117 central banks, for 88, we have at least two annual observations. Our panel thus consists of $i = 1, ..., n = 88$ central banks (=entities). The time period for the panel is thus annual and runs from $t = 1, ..., T = 26$ spanning the years from 1996 to 2023. Not that not for all entities a complete set of annual observations is available. We denote by t_i the number of yearly observations available for entity i. This leads to a total number of observations of 1310. Next, we have to distinguish time varying and time-constant predictors. We collect the data into a $k_y \times 1$ vector $x_{it} = (y\_yoy_{i,t}, Dp\_yoy_{i,t}, y\_pcap_{i,t}, y\_nom_{i,t}, spei_{i,t}, NGFS_{i,t})'$ that contains time-varying variables and a $k_z \times 1$ vector $z_{it} = (expl\_mi, impl\_mi, temp\_avg_i, coast_i)'$ that contains the time-constant variables. We can now estimate within effects in a random effects model by decomposing the time-varying variables into a between $\bar{x}_i = n_i^{-1} \sum_{t=1}^{t_i} = x_{it}$ and a within component $x_{it} - \bar{x}_i$. The within-between or hybrid model can then be written as:

$$y_{it} = \beta_0 + \beta_1(x_{it} - \bar{x}_i) + \beta_2\bar{x}_i + \gamma z_i + \mu_i + \epsilon_{it} \tag{3}$$

Here, μ_i denotes a random individual-specific slope, β_1 captures within variation in the data, while γ and β_2 help predicting cross-sectional differences.

Our estimation strategy is as follows. First, we start with analyzing the drivers of green communication estimating the full model including all variables. The results of this model are provided in Table 7 in the appendix. We then proceed further by performing variable selection based on the BIC information criterion. The model with the best fit according to the BIC is presented in Table 2 below.

The model reveals two variables that account for within-variation in the data, namely nominal GDP as a measure for the size of the economy as well as the time-varying NGFS member ship variable. An increase in both variables is associated with a higher topic proportion of the green topic. The middle panel shows variables that can account for cross-country differences. These can be both, time-varying and time-constant variables, such as the dummy variables for climate related mandates. The results show that nominal GDP and the drought indicator both are higher in countries where central banks devote more resources to communication about climate change. The only time constant variable that can contribute to differences in cross-country fixed effects is the measure of long-run average temperature. In countries with higher average temperature, central banks invest more into green communication. The Intra-Class Correlation (ICC), as a measure of the proportion of total variance in the dependent variable that is attributable to variation between entities, is around 0.3. We do not find an effect of neither the implicit nor the explicit sustainability mandate on green communication.

Summing up, we find evidence for the size of the economy and climate related variables such as an indicator of droughts and temperature, to be positively related with "green communication". On top of that, we find evidence for a variable reflecting peer pressure to become active in green communication, namely NGFS membership. Other variables, such as inflation or economic growth do not significantly affect the topic proportion of climate related speeches. We also do not find evidence for having a sustainability mandate to explain within or between variation in the data.

Table 2: Multilevel panel model: 1996-2023 (variable selection)

Variable	Est.	S.E.	t val.	d.f.	p
Within Effects					
y_nom	0.58	0.07	8.00	1253.01	0.00
spei	0.01	0.03	0.21	1251.80	0.84
NGFS	1.40	0.10	14.47	1252.99	0.00
Between Effects					
(Intercept)	-0.76	0.36	-2.12	88.54	0.04
imean(y_nom)	0.23	0.04	5.22	96.07	0.00
imean(spei)	0.48	0.16	2.98	98.04	0.00
imean(NGFS)	0.36	0.87	0.41	106.20	0.68
expl_m	0.44	0.29	1.52	89.15	0.13
impl_m	0.12	0.19	0.65	86.11	0.52
temp_avg	0.02	0.01	1.95	86.08	0.05

p values calculated using Satterthwaite d.f.

Model Information	Model Fit
Entities: 89 (41 impl_m, 9 expl_m)	AIC: 3872.68
Time periods: 1-26	BIC: 3935.04
Dependent variable: θ_{gr}	Pseudo-R² (fixed effects): 0.27
Model type: Linear mixed effects	Pseudo-R² (total): 0.53
Specification: within-between	Entity ICC: 0.35

Notes: Authors' calculations. Variables with p-value<= 0.10 in bold

3.3 The political dimension: The interaction between national governance and central banking

In this section, we want to elaborate further on potential factors driving climate related communication of central banks. In particular, we shed light on the relationship between national governments and central banks in pursuing climate policies. That central banks are exposed to political pressure has been evidenced by numerous studies, see e.g., Boettke et al. (2021) and the references therein or the recent study by Drechsel (2023). Focusing on Europe, Deyris (2023) lists various sources of examples of external pressure on central banks to pursue active climate policies. As such, he mentions increasing peer pressure and reputational costs for central banks not to join initiatives such as the NGFS (Deyris, 2023). But influence can also be exerted through political bodies. One way of exerting pressure on central banks in Europe has been through member of parliaments forming coalitions with "green" central bankers (Massoc, 2022); others have exerted more direct influence by issuing directives. As an example, Deyris (2023) lists interventions of the french government requesting the Banque de France to consider more formally climate-related risks. To analyze this potential link, we draw on a second set of text data, namely national climate laws. A higher frequency of climate laws can be viewed as an indicator of the government's stance[4] on climate policy which can lead to pressure on the central bank. An alternative way of thinking about the link between climate laws and central banks' interest in climate policies by looking at the potential side effects climate policies can have for financial markets. In this regard, the European Central Bank has publicly recognized that the European climate law,

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[4]In a recent contribution, Wang et al. (2022) has shown that this also depends on the political ideology of the country's current government, making a distinction between left-wing and right-wing governments' enthusiasm for active climate policy.

which has a goal to decrease greenhouse gas emissions and attain climate neutrality, has substantial implications for the financial system.[5] In other words, in countries that have very stringent climate laws or countries with governments actively revising national laws, central banks can be more sensitive to the topic which could be reflected in a higher topic proportion of climate related speeches.

The data we use are scrapped from `https://climate-laws.org/`, which is a Climate Change Laws of the World dataset that contains over 5000 national climate laws and policies.[6] In addition, this dataset includes documents from United Nations Framework Convention on Climate Change (UNFCC) portals submitted from every country `https://unfccc.int`. The database covers all UNFCCC parties, which account for 196 countries plus the European Union, covering all the respective countries' central banks from our main corpus. The database excludes all non-climate change-related laws and policies and focuses only on those defined by owners of database legal documents that are directly related to preventing, adapting to, or managing the risk of climate change, loss, or damage. The climate law texts we download cover a wide range of areas, including energy, transport, land use, and climate resilience. Central banks, on the other hand, address climate change issues in their communication (Arseneau et al., 2022) and look for ways to incorporate climate concerns into their operations (Boneva et al., 2022). They recognize that climate change and the transition to a carbon-neutral economy pose substantial challenges for the economy and the financial system with the potential to influence growth, inflation, and financial stability, which are key concerns within the central bank mandate (ECB, 2021). The law data spans the period from 2006-06-02 to 2023-05-17. For 64 central banks, we have climate law data. The shorter time period reduces the number of observations for our analyses; however, as shown in Figure 2, the largest part of climate-related speeches appears in the most recent part of our sample, especially so since 2016.

Figure 6: Frequency of climate laws
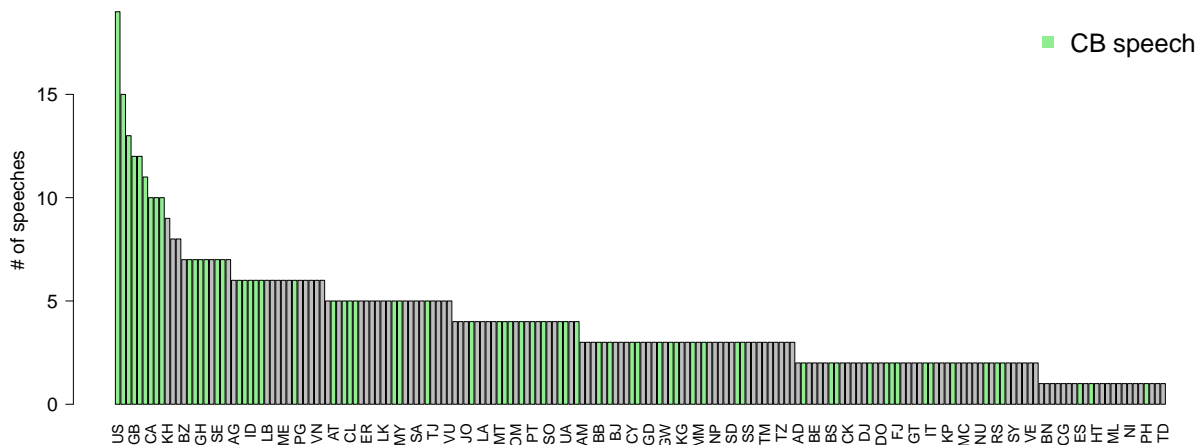
Notes: The plot shows the number of climate law texts per country; in light green those countries of which central banks also contribute "green" speeches; countries with < 5 texts excluded from the graph.

The climate law text data has been pre-processed in a similar way as the BIS speeches. The length of climate law texts ranges from 7 tokens to 197,729, with an average length of 20,000 tokens. To give an impression about the law context, we provide the most frequent nouns and verbs in Figure 7 in the appendix. Words frequently used in climate law texts comprise, "emission", "climate" and "energy", most frequent verbs feature "include", "use" and "provide".

We expand the estimation set-up from subsection 3.2 by including two more variables, one is the length of climate law texts per country (*nword_law*) and the second one captures sentiment in climate law

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[5]`https://www.ecb.europa.eu/press/key/date/2022/html/ecb.sp221201_1~435e6ea81a.en.html`
[6]The data base also contains texts from institutions, think tanks and universities which we do not analyze in this study.

texts (*sent_law*)[7]. Our estimation strategy is as before: We start with the full model (results provided in Table 8) and then perform variable selection based on the BIC criterion. This strategy leaves us with the variables depicted in Table 3. The panel set-up allows us further to include cross-level interactions of time-constant and time-varying variables, which allows us to assess the effect of more national climate engagement depending on the sustainability mandate status of the country under study. As mentioned in section 3, countries with implicit mandate tend to have a higher central bank independence score than those with an explicit mandate. Using data from Romelli (2022) this is indeed the case for the set of countries covered in the panel (0.8 explicit, 0.49 implicit and 0.5 no mandate; averaged over the period from 2006 to 2017, no more recent data available). More precisely, we interact the length of climate law texts with the implicit and explicit mandate dummy (labeled Model 1 and 2, respectively). We then perform a further regression analysis by choosing an overall mandate variable (the sum of implicit and explicit mandate) as the interaction term. All interaction variables are modelled by "double-demeaning", as proposed in Giesselmann and Schmidt-Catran (2020).

The table reveals a positive within-effect of the length of climate law texts and climate related communication. We also see that central banks that are members of the NGFS working group do talk more about climate related topics – a measure that might capture peer pressure (Deyris, 2023). The effects are positive and significant throughout all three specifications. This implies that both sources of pressure, peer from other central banks and from political bodies through more engagement in crafting laws enhance green communication of central banks.

Next, we identify which variables can explain cross-central bank differences. Here we find that NGFS membership is positively and significantly related to green communication of central banks Moreover, the sentiment variable of law texts is positively related to green communication. That said, we do not find evidence for a direct impact of the sustainability mandates in explaining cross-country differences of green communication. Coupled with the finding on NGFS membership, this implies that central banks do not engage in green communication once they have a mandate to do so. Rather, central banks become active against the back of heightened governmental focus on climate issues reflected in more law texts and peer pressure measured by NGFS membership.

Last, we examine the effects of climate laws on green communication focusing on different subgroups of the panel. Here, we do not find a significantly different effect for the group of countries with an implicit or explicit mandate. However, if we include an overall mandate variable (implicit plus explicit) we do find a significantly and negative effect on green communication. This implies that countries where central banks already pursue (indirectly or explicitly) climate policies, an increase in climate laws reflecting more active government policies has a detrimental effect on green communication.

Summing up, we find that two variables reflecting different forms of pressure, are significantly related to the extent of green communication by central banks. First, peer pressure, captured by a membership variable of the NGFS workgroup on green finance and second, the proactive stance of governments measured by the extent of climate laws. This second effect, however, becomes negative for central banks with either an implicit or explicit mandate. Taken at face value this implies that, for central banks already pursuing a sustainability mandate, pressure through a proactive government becomes detrimental to climate communication. That said, we do not find evidence for a direct effect of either having an implicit or explicit sustainability mandate on green communication.

4   Conclusions

In this paper, we analyze the extent of which central banks communicate about climate change. For that purpose, we analyze over 18,902 central bank speeches from the period from 1996 to 2023 and using the recently proposed keyword assisted topic model of Eshima et al. (2023). Our analysis reveals that 69 out of 117 central banks and financial authorities addressed at least once a speech mainly devoted to climate related issues and the topic gained overall popularity from 2016 onward. Looking

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[7]To calculate sentiment, we use the general purpose Harvard-IV dictionary; for more details, see `https://inquirer.sites.fas.harvard.edu/homecat.htm`

Table 3: Multilevel panel model: 2006-2023

Variable	Model 1					Model 2					Model 3				
	Est.	S.E.	t val.	d.f.	p	Est.	S.E.	t val.	d.f.	p	Est.	S.E.	t val.	d.f.	p
Within Effects															
spei	-0.01	0.12	-0.12	103.42	0.91	-0.02	0.12	-0.19	103.49	0.85	-0.01	0.12	-0.07	103.47	0.94
nword_law	**0.17**	**0.08**	**2.01**	**103.97**	**0.05**	**0.12**	**0.07**	**1.70**	**105.53**	**0.09**	**0.23**	**0.09**	**2.43**	**104.15**	**0.02**
sent_law	4.60	3.32	1.38	104.95	0.17	5.38	3.39	1.58	105.11	0.12	5.19	3.29	1.58	104.96	0.12
NGFS	**0.69**	**0.22**	**3.16**	**104.40**	**0.00**	**0.69**	**0.22**	**3.15**	**104.48**	**0.00**	**0.65**	**0.22**	**3.01**	**104.51**	**0.00**
Between Effects															
(Intercept)	-9.45	5.89	-1.60	37.58	0.12	-9.52	5.86	-1.63	37.66	0.11	**-9.50**	**5.65**	**-1.68**	**39.05**	**0.10**
imean(spei)	0.15	0.44	0.35	37.60	0.73	0.16	0.44	0.36	37.69	0.72	0.15	0.43	0.36	38.64	0.72
imean(nword_law)	0.49	0.42	1.16	37.62	0.25	0.49	0.42	1.17	37.71	0.25	0.49	0.40	1.23	39.22	0.23
imean(sent_law)	**36.14**	**20.64**	**1.75**	**37.75**	**0.09**	**36.62**	**20.51**	**1.79**	**37.83**	**0.08**	**36.35**	**19.85**	**1.83**	**39.01**	**0.07**
imean(NGFS)	**2.36**	**1.19**	**1.98**	**37.72**	**0.06**	**2.30**	**1.18**	**1.94**	**37.77**	**0.06**	**2.34**	**1.12**	**2.09**	**38.78**	**0.04**
expl_m	0.76	1.31	0.58	37.30	0.56	0.79	1.30	0.61	37.36	0.55	0.80	0.69	1.15	38.17	0.26
impl_m	0.82	0.72	1.13	36.99	0.26	0.83	0.72	1.16	37.04	0.25	–	–	–	–	–
overall_m	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
temp_avg	0.03	0.04	0.66	37.29	0.51	0.03	0.04	0.65	37.36	0.52	0.03	0.04	0.65	37.36	0.52
Cross-Level Interactions															
nword_law:impl_m	-0.17	0.12	-1.39	104.76	0.17	–	–	–	–	–	–	–	–	–	–
nword_law:expl_m	–	–	–	–	–	-0.19	0.21	-0.92	103.84	0.36	–	–	–	–	–
nword_law:overall_m	–	–	–	–	–	–	–	–	–	–	**-0.23**	**0.12**	**-1.94**	**104.45**	**0.05**
Model information															
Entities: 44 (22 impl_m, 4 expl_m)															
AIC / BIC	558.97 / 602.23					558.96 / 604.22					557.46 / 599.71				
Pseudo-R^2 (fixed Eff.)	0.15					0.15					0.16				
Pseudo-R^2 (total)	0.82					0.82					0.82				
Entity ICC	0.79					0.79					0.79				

Notes: Authors' calculations. P-values calculated using Satterthwaite d.f. Estimates with p-value≤ 0.10 in bold

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at non-climate related topic proportions, we find that speeches with a climate focus often address in parallel issues related to financial stability, payment innovations and microprudential, banking sector related topics. By contrast, price stability is not mentioned in speeches devoted mostly to climate issues. This finding is striking given the obvious trade-off that a green energy transition can have on pursuing a (low) inflation target.

We proceed by looking at the narratives central banks use when addressing climate issues. Most speeches postulate an active role for the central bank in order to prevent stability risks for the financial sector. We do not find evidence for a particularly negative, or alarming tonality in these speeches. In comparison, negative sentiment induced by flagging risks is more pronounced in central bank speeches that relate to the traditional mandates of price and financial stability, though.

Finally, we analyze why some central banks engage more in green communication than others. For that purpose, we draw particular attention to a potential link between climate actions from political bodies, enacted in climate laws and the extent of green communication. Our results reveal two variables as significantly and positively related to green communication. First, membership in the central banking NGFS network is positively linked to both within and between variation in climate communication. Peer pressure and the fear of reputational costs can be considered motives for the central banks to join the network (Deyris, 2023) and becoming a member then increases the bank's extent of green communication. Second, our results show that countries with a government actively engaging in climate policies also have central banks that address more frequently climate issues in their speeches. The implications of this finding could be two-fold: On the one hand, governments enacting climate laws affect the financial systems and central banks, as financial stability guardians, naturally have to keep an eye on these developments. On the other hand, this finding could also imply that we see pressure on central banks from pro-active governments resulting in more central banks climate communication. Last, and regardless of these lines of interpretations, we do not find evidence that links the extent of green communication to central banks' mandates.
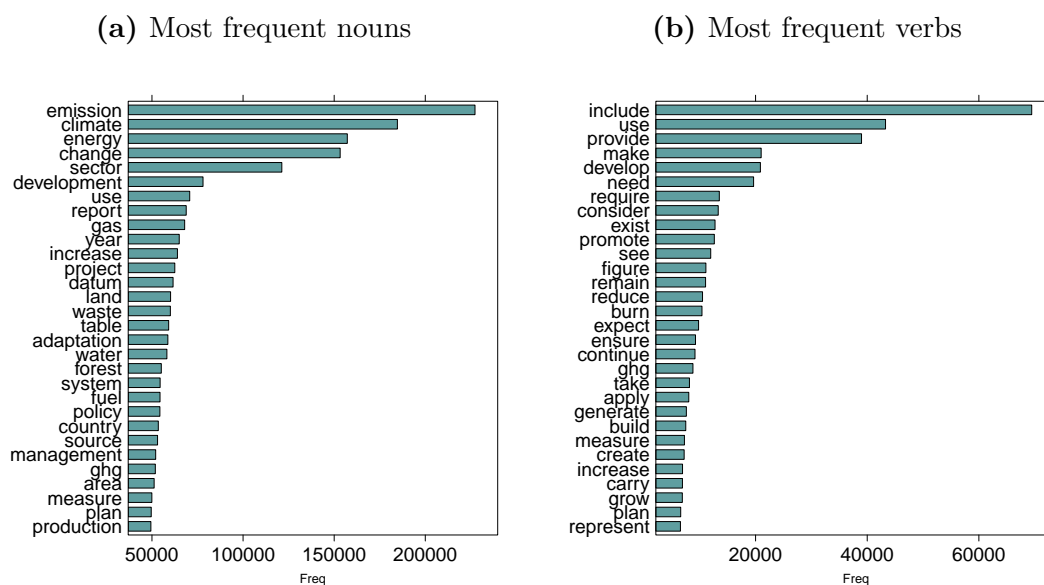
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A   Appendix

Figure 7: Climate law corpus

(a) Most frequent nouns

(b) Most frequent verbs

Notes: The left hand side shows the most frequent nouns, the right hand side the most frequent verbs in the climate law corpus.

Table 9: Mandates and cross-entity coverage of the BIS corpus

Entity	explicit mandate	implicit mandate	NGFS	Panel 1996-23	Panel 2006-23	Entity	explicit mandate	implicit mandate	NGFS	Panel 1996-23	Panel 2006-23
AE	0	0	✓	✓	0	JM	0	0	0	✓	0
AL	0	0	✓	✓	✓	JO	0	0	✓	0	0
AM	0	0	✓	0	0	JP	0	0	✓	✓	✓
AN	–	–	0	0	0	KE	0	✓	✓	✓	✓
AR	0	0	✓	✓	0	KH	0	✓	✓	0	0
AT	0	✓	0	✓	✓	KR	0	0	✓	✓	✓
AU	0	0	✓	✓	✓	KW	0	0	0	✓	✓
AW	–	–	0	0	0	KY	–	–	✓	0	0
BA	0	0	0	✓	0	LK	0	0	0	✓	0
BAIG	–	–	0	0	0	LT	0	✓	✓	✓	✓
BB	0	0	✓	✓	✓	LU	0	✓	✓	✓	0
BCBS	–	–	0	0	0	LV	0	✓	✓	✓	0
BE	0	✓	✓	✓	0	MA	0	✓	0	✓	0
BG	0	✓	0	✓	0	MK	0	✓	✓	✓	✓
BH	0	0	✓	✓	0	MO	–	–	0	0	0
BIS	–	–	0	0	0	MT	0	✓	✓	✓	✓
BO	0	0	0	0	0	MU	0	0	0	✓	✓
BoN	✓	0	0	0	0	MV	0	0	0	✓	0
BR	0	✓	✓	✓	0	MW	0	✓	0	✓	0
BS	0	0	0	✓	0	MX	0	0	✓	✓	✓
BW	0	✓	0	✓	0	MY	✓	0	✓	✓	✓
BZ	0	0	0	0	0	MZ	0	0	0	✓	0
CA	0	0	✓	✓	✓	NG	0	0	✓	✓	0
CBCS	–	–	0	0	0	NL	0	✓	✓	✓	✓
CH	0	✓	✓	✓	✓	NO	0	0	✓	✓	✓
CL	0	0	✓	✓	✓	NP	✓	0	0	✓	0
CN	0	0	✓	✓	0	NZ	0	0	✓	✓	✓
CO	0	0	✓	✓	0	PG	0	0	0	✓	✓

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Table 9: Mandates and cross-entity coverage of the BIS corpus

Entity	explicit mandate	implicit mandate	NGFS	Panel 1996-23	Panel 2006-23	Entity	explicit mandate	implicit mandate	NGFS	Panel 1996-23	Panel 2006-23
CPMI	–	–	0	0	0	PH	✓	0	✓	✓	0
CY	0	✓	✓	✓	0	PK	0	0	✓	✓	✓
CZ	0	✓	0	✓	✓	PL	0	✓	0	✓	0
DE	0	✓	✓	✓	✓	PT	0	✓	✓	✓	✓
DK	0	✓	✓	✓	✓	RO	0	✓	✓	✓	0
DZ	0	0	0	✓	0	RS	0	✓	✓	✓	0
EC	0	0	0	0	0	RU	✓	0	✓	✓	✓
ECB	0	✓	✓	✓	✓	SA	0	0	✓	✓	0
ECCB	–	–	0	0	0	SB	0	0	0	✓	0
EE	0	✓	✓	✓	0	SC	0	0	✓	✓	0
ES	0	✓	✓	✓	0	SE	0	✓	✓	✓	✓
FI	0	✓	0	✓	✓	SFBC	–	–	0	0	0
FJ	✓	0	0	✓	0	SG	✓	0	✓	✓	✓
FR	0	✓	✓	✓	✓	SGF	–	–	0	0	0
FSA	–	–	0	0	0	SI	0	✓	✓	✓	0
GB	0	✓	✓	✓	✓	SK	0	✓	0	✓	0
GH	0	✓	✓	✓	✓	SL	0	0	0	✓	0
GM	✓	0	0	0	0	TH	0	0	✓	✓	✓
GR	0	✓	✓	✓	✓	TR	0	✓	✓	✓	0
GT	0	0	0	0	0	TT	0	0	✓	✓	0
GY	0	0	0	0	0	TZ	✓	0	0	0	0
HK	0	0	✓	0	0	UA	✓	0	✓	✓	0
HR	0	✓	✓	✓	0	UG	0	0	✓	✓	✓
HU	✓	0	✓	✓	0	US	0	0	✓	✓	✓
IADB	–	–	0	0	0	UY	0	0	✓	0	0
ID	0	✓	✓	✓	✓	VU	0	0	0	✓	0
IE	0	✓	✓	✓	0	WS	0	0	0	✓	0
IL	0	✓	✓	✓	✓	XK	0	✓	0	0	0
IN	0	0	✓	✓	✓	ZA	✓	0	✓	✓	✓
IS	0	✓	✓	✓	✓	ZM	0	0	0	✓	0
IT	0	✓	✓	✓	✓	ZM	0	0	0	✓	0

Notes: Entity codes refer to ISO 2 codes, except for the following abbreviations: BAIG (Basel Accord Implementation Group), BCBS (Basel Committee on Banking Supervision), BIS (Bank for International Settlements), BoN (Central bank of Namibia), CBCS (Central Bank of Curaçao and Sint Maarten), CPMI (Committee on Payments and Market Infrastructures), ECB (European Central Bank), ECCB (Eastern Caribbean Central Bank), FSA (Financial Services Authority of the UK), IADB (Inter-American development bank), SFSC (Swiss Federal Banking Commission), SFG (Swiss Society for Financial Market Research) Curaçao and Sint Maarten, "BCBS" the Basel Committee on Banking Supervision and "ECCB" the Eastern Caribbean Central Bank

Table 4: Top 20 green speeches

	θ_{gr}	date	title	cc
1	0.68	2021-10-21	Gediminas Šimkus: Speech at Economics Conference Creating Pathways Towards the Green Economy	LT
2	0.68	2021-10-21	Gediminas Šimkus : Creating pathways towards the green economy	LT
3	0.66	2019-12-10	Mark Carney: Remarks at a panel to launch the third annual Americas Pledge report	GB
4	0.60	2019-04-03	Yannis Stournaras: Climate change - threats, challenges, solutions for Greece	GR
5	0.59	2017-06-30	Yannis Stournaras: Climate change - challenges, risks and opportunities	GR
6	0.58	2019-10-08	Mark Carney: TCFD - strengthening the foundations of sustainable finance	GB
7	0.58	2018-10-01	Yannis Stournaras: Challenges and prospects for sustainable growth	GR
8	0.58	2021-05-20	Ravi Menon: A vibrant carbon market for a low carbon future	SG
9	0.58	2019-03-21	Mark Carney: A New Horizon	GB
10	0.57	2019-04-17	Frank Elderson: Network for Greening the Financial Systems recommendations for policymakers, central bankers and supervisors	NL
11	0.57	2021-11-03	Frank Elderson: The NGFS Glasgow Declaration From a coalition of the willing to a coalition of the committed	ECB
12	0.57	2018-11-21	Mark Carney: Remarks at the Accounting for Sustainability Summit 2018	GB
13	0.56	2022-09-29	François Villeroy de Galhau: Biodiversity, macroeconomics and finance - what we do know, what we dont know yet, and what we have to do	FR
14	0.55	2021-06-09	Ravi Menon : Being the change we want to see - a sustainable future	SG
15	0.55	2021-09-08	Ravi Menon: What we need to do to make green finance work	SG
16	0.55	2019-09-23	Mark Carney: Remarks given during the UN Secretary Generals Climate Action Summit 2019	GB
17	0.55	2020-10-13	Ravi Menon: Harnessing the power of finance for a sustainable future	SG
18	0.55	2020-02-27	Mark Carney: The road to Glasgow	GB
19	0.55	2022-06-08	Ravi Menon: Towards net zero in Asia	SG
20	0.54	2022-07-28	Ravi Menon: From green finance to transition finance	SG

Table 5: Keywords

Price Stability	Employment	Financial System	Micropru
price_stability	unemployment_rate	financial_system	bank_system
inflation_target	economic_activity	financial_market	balance_sheet
inflation_expectation	domestic_demand	financial_stability	credit_risk
monetary_policy	labor_market	financial_sector	bank_supervision
interest_rate	economic_growth		stress_test

Global	Payment	Green
exchange_rate	payment_system	climate_change
foreign_exchange	financial_service	climate_risk
current_account	new_technology	climate_policy
capital_flow	payment_service	green_finance
global_economy		agreement_paris
		paris_agreement

Table 6: Variable Definitions and Sources

Variable	Definition	Source
y_yoy	Real GDP growth rate, in year-over-year terms	IMF, WEO 2023-10
Dp_yoy	CPI inflation rate, in year-over-year terms	IMF, WEO 2023-10
y_pcap	GDP per capita, in international Dollars and logarithmic transform	IMF, WEO 2023-10
y_nom	GDP in current prices and US dollar, logarithmic transform	IMF, WEO 2023-10
temp_avg	Average temperature in 1996-2022	World Bank's climate change knowledge portal
coast_area	Coast/area ratio (m/km^2)	https://en.wikipedia.org/wiki/List_of_countries_by_length_of_coastline
spei	Standardised Precipitation-Evapotranspiration Index (SPEI), 1996 to 2021	World Bank
impl_m	Implicit green mandate	Dikau and Volz (2021)
expl_m	Explicit green mandate	Dikau and Volz (2021)
NGFS	NGFS membership	https://www.ngfs.net/en/about-us/membership
sent_law	Dictionary-based sentiment indicator of law texts	Law texts retrieved from climate-laws.org
nword_law	Number of words of law text, in logarithmic transform	Law texts retrieved from climate-laws.org

Table 7: Multilevel panel model: 1996-2023 (full model)

Variable	Est.	S.E.	t val.	d.f.	p
Within Effects					
y_yoy 0.01	0.01	1.64	1252.07	0.10	
Dp_yoy	0.01	0.01	1.49	1254.61	0.14
y_pcap	0.29	0.34	0.84	1251.70	0.40
y_nom	0.52	0.14	3.66	1250.69	0.00
spei	0.00	0.03	0.18	1247.57	0.86
NGFS	1.38	0.10	14.17	1248.87	0.00
Between Effects					
(Intercept)	-1.83	1.09	-1.68	90.71	0.10
imean(y_yoy)	0.02	0.04	0.41	113.15	0.68
imean(Dp_yoy)	-0.02	0.02	-0.92	85.33	0.36
imean(y_pcap)	0.12	0.11	1.12	90.14	0.26
imean(y_nom)	0.21	0.05	4.13	91.86	0.00
imean(spei)	0.47	0.16	2.85	90.67	0.01
imean(NGFS)	0.22	0.89	0.25	101.99	0.80
expl_m	0.37	0.29	1.29	85.35	0.20
impl_m	0.09	0.19	0.48	82.14	0.63
temp.avg	0.03	0.01	2.17	83.06	0.03
coast	-0.00	0.00	-0.09	79.64	0.93

p values calculated using Satterthwaite d.f.

Model Information	Model Fit
Entities: 89 (41 impl_m, 9 expl_m)	AIC: 3919.74
Time periods: 1-26	BIC: 4018.47
Dependent variable: θ_{gr}	Pseudo-R² (fixed effects): 0.29
Model type: Linear mixed effects	Pseudo-R² (total): 0.53
Specification: within-between	Entity ICC: 0.35

Notes: Authors' calculations. Variables with p-value<= 0.10 in bold

Table 8: Multilevel panel model: 2006-2023 (full model)

Variable	Est.	S.E.	t val.	d.f.	p
Within Effects					
y_yoy	0.03	0.03	0.87	100.36	0.38
Dp_yoy	0.01	0.03	0.35	100.95	0.73
y_pcap	0.02	2.65	0.01	106.30	0.99
y_nom	-0.69	1.13	-0.61	104.66	0.55
spei	-0.01	0.12	-0.09	99.85	0.93
NGFS	0.78	0.25	3.09	101.13	0.00
nword_law	0.08	0.07	1.20	102.20	0.23
sent_law	4.83	3.50	1.38	101.72	0.17
Between Effects					
(Intercept)	-13.42	6.35	-2.12	32.43	0.04
imean(y_yoy)	0.22	0.18	1.21	33.28	0.24
imean(Dp_yoy)	-0.05	0.08	-0.66	34.11	0.51
imean(y_pcap)	0.56	0.42	1.36	30.81	0.19
imean(y_nom)	0.56	0.20	2.78	31.49	0.01
imean(spei)	0.17	0.39	0.43	31.95	0.67
imean(NGFS)	0.65	1.13	0.57	32.48	0.57
imean(nword_law)	0.29	0.38	0.75	32.38	0.46
imean(sent_law)	10.82	20.26	0.53	32.40	0.60
expl_m	0.86	1.17	0.74	31.99	0.47
impl_m	0.74	0.66	1.12	31.89	0.27
temp_avg	0.05	0.04	1.39	31.68	0.17
coast	-0.00	0.00	-0.55	33.90	0.59

p values calculated using Satterthwaite d.f.

Model Information	Model Fit
Entities: 45 (22 impl_m, 4 expl_m)	AIC: 579.58
Time periods: 15-26	BIC: 648.98
Dependent variable: θ_{gr}	Pseudo-R^2 (fixed effects): 0.5
Model type: Linear mixed effects	Pseudo-R^2 (total): 0.83
Specification: within-between	Entity ICC: 0.72

Notes: Authors' calculations. Variables with p-value<= 0.10 in bold