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RESEARCH ARTICLE

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Talking the talk vs. walking the walk: greening of central banks' speeches and policies

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ABSTRACT

The enormity of risks posed by climate change to financial stability have led many central banks to consider including its impacts to varying degrees in their operations and policymaking. Although the implementation of these policies is at a nascent stage, there is a vibrant discourse surrounding central banks' appropriate role in undertaking climate-related policies. In this context, this paper aims to develop a 'green index' which quantifies the frequency of occurrences of climate change and green finance-related words in a dataset of all central bankers' speeches from 2000 to 2021. It further explores whether central banks that are more active in delivering speeches on climate-related issues are also more likely to implement financial and regulatory policies aimed at mitigating climate-related risks to financial stability. Focusing only on early implementers of green financial and regulatory policies and examining the timing of green speeches vs policy implementation, I find speeches and policies to be highly correlated; although most central banks' speeches on climate risks come after they have implemented these policies. These results are somewhat consistent with previous studies in this area which have found that central banks walking the walk on climate policies are different from those talking the talk.

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1. Introduction

The contours of central banking have been evolving over the decades. Most recently, several central banks across countries have increasingly become vocal in enunciating the channels through which climate change can affect financial markets and various ways in which central banks could play a role in mitigating climate change (Arseneau et al., 2022; Carney, 2015; Lagarde, 2021). This focus on green central banking was marked by a landmark speech delivered by then governor of the Bank of England, Mark Carney, in September 2015, describing the grave impact of climate change on the UK's insurance sector (Carney, 2015). Following this speech, a flurry of central banks began vocalizing their concerns about how climate change could impact their core mandates, including both price and financial stability, and the need to develop policies aimed at facilitating an accurate discovery of climate risks into asset prices and financial institutions' balance sheets.

Simultaneously, a few central banks and financial authorities have also embarked upon aligning a climate objective to their conventional financial and regulatory policies, subsequently being referred to as green financial and regulatory policies (Dikau & Ryan-Collins, 2017; Gruenewald, 2020; Park & Kim, 2020).[1] Although the implementation of these policies is at a nascent stage to examine their effectiveness, there is a vibrant discourse surrounding central banks' appropriate role in undertaking policies aimed at mitigating climate change.

For instance, the ECB strongly supports an activist role for central banks to include climate change-sensitive policies into central bank mandates because climate change poses a direct risk to price stability through large price and output shocks (Lagarde, 2021; Schnabel, 2021). However, the US endorses the view that such policies are the territory of elected policymakers[2] (Brunnermeier & Landau, 2020). Asian economies have largely been excluded from this policy discussion because their central bank mandates are not premised on price stability alone, but also include supporting the design and implementation of the government's economic policies – a broad mandate which is able to incorporate the inclusion of climate-related risks to financial stability (Dikau & Ryan-Collins, 2017). For instance, the central bank of Bangladesh (Bangladesh Bank) includes among its monetary policy objectives "sustainable growth and development".[3] Similarly, the mandate of Bank Indonesia was expanded in 2023 to include "maintaining the stability of the payment system as well as preserving financial system stability to support sustainable economic growth".[4]

In this paper, I construct an index of central banks' greenness of speeches, measuring the proportion of "green" or climate-related words recurring in each speech as a proportion of all words in the speech. This green index is then compiled at the country level to yield a panel data resource. Coupled with another self-constructed measure of a central bank's green financial policy intensity, this is used to examine the

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correlation and temporality between central banks' climate-related speeches and policies by focusing our analysis on the early implementers of green financial and regulatory policies. I specifically explore whether central banks that are more active in delivering speeches on climate-related issues are also more intensive adopters of financial and regulatory policies aimed at mitigating the risks posed by climate change to financial stability. I do this by examining correlations between central bankers' speeches and policy implementation in green finance, using two-way fixed effects models and controlling for a range of other economic, financial, and institutional variables which could influence the uptake of green financial policies by central banks.

Given the increased emphasis placed on central banks' intervention in climate policymaking, analysing the way central banks have incorporated climate risks into their regulatory tools is an interesting area of research for at least two reasons. First, an examination of the correlation between central banks' climate talk and implementation of green policies sheds light on whether those central banks that talk a lot on climate are also the ones at the forefront of adopting climate-related policies, "walking the talk". It could be the case that financial markets view central bankers' communication on climate change as signals that they are beginning to incorporate climate-related risks into their policymaking process. To some extent, this could lead to central banks substituting greater climate talk for concrete policy action to mitigate these risks, or at least defer their implementation to a later date. This argument is consistent with other research documenting how 'talk is cheap' and could enable policymakers to get away without taking hard-hitting actions on these aspects (Dikau & Ryan-Collins, 2017).

Second, an examination of the temporality of central banks' green speeches and policies is interesting to ascertain whether there is an announcement effect of central banks' climate talk, as highlighted in traditional central banking and monetary policy literatures (Bernanke, 2004; Ehrmann & Fratzscher, 2005, 2007). This announcement effect states that central banks' mere communication of a policy prior to its implementation has a bigger impact on markets by calibrating market expectations than the actual implementation of the policy at a later date[5] (Guthrie & Wright, 2000; Kohn & Sack, 2003; Reeves & Sawicki, 2007). Apart from changing market expectations, communication by central banks also reduces the magnitude of subsequent policy actions (Demiralp & Jordà, 2004) (for example: open market operations) required to achieve stated policy objectives. Extrapolating from this literature, this paper focuses on recent advancements in central banks' climate talk and initiates a discussion on the temporality of central banks' speeches and policies.

Together, I believe these findings can contribute to an established field of literature examining the evolution of central banks and their reforms over the decades (Bodea & Hicks, 2015; Chwieroth, 2007; Hartwell, 2019; Romelli, 2022), along with emerging studies on central banks' role in adopting policies to mitigate climate risks posed to financial stability alongside governments (DiLeo et al., 2023; Feldkircher & Teliha, 2024; Quorning, 2022, 2024; Siderius, 2023).

The rest of the paper is organized as follows. Section 2 provides a brief overview of the literature on central bank communication and the political economy of central bank intervention in climate policymaking. Section 3 lays out the empirical modelling strategy used in the paper. Section 4 presents an overview of the data used for quantifying central bankers' green content of speeches and green policies. Section 5 presents the empirical results. Section 6 concludes.

2. Selected review of literature

2.1. Role of central bank communication

Central banks' communication through speeches, policy announcements, or press conferences helps the public get an insight into the rationale behind the decisions made by the nation's premier monetary and financial authority. Research has demonstrated the significant impact of central bank communication in moving markets, facilitating transparency, and enhancing predictability about the future trajectory of monetary policy (Blinder et al., 2008; Eusepi & Preston, 2010; Mumtaz et al., 2023; Woodford, 2005). After the 2008 global financial crisis, communication around preserving systemic financial stability and the tools deployed to achieve this objective took on increased significance alongside the traditional focus on monetary policy (Born et al., 2012, 2014). Broadly, the literature on central bank communication focuses on the content of information conveyed to the public, its impact on markets and other macroeconomic indicators, and their timing. Ehrmann and Fratzscher (2007) find that central bankers communicate more before policy changes are implemented (the so-called "announcement effects") and these announcements have a significant impact on financial markets.

A few other recent papers have delved deep into central banks' communication on climate change. The paper closest to ours is by Arseneau et al. (2022) who deploy extensive natural language processing techniques including topic modelling to investigate the content of central banks' climate-related speeches. They find that central banks tend to cover a wide range of climate-related topics in their speeches, such as how climate change can impact the economy and financial stability, and the need to facilitate sustainable finance, among others. However, little mention is made of (micro and macro) prudential policies to mitigate climate-related risks to financial stability, and the language used by central bankers is often speculative, alluding to the radical uncertainty surrounding climate phenomena and its subsequent macroeconomic impacts.

In a related paper, Arseneau and Osada (2023) examine the role of central bank mandates in determining the frequency and content of climate-related communication through central bank speeches. They find that the presence of an explicit or indirect sustainability objective is correlated with a higher frequency of central bank climate speeches, and for central banks which do not have any sustainability objective, membership in the NGFS corresponds to a higher climate communication frequency. With regard to the content of these speeches, they find that central banks' communication on climate issues is largely shaped or determined by how these institutions communicate on non-climate-related issues. This paper builds on these findings and goes further by developing a quantitative estimate

of the "green-ness" of central banks' speeches over time which yields a valuable panel data resource for conducting econometric analysis.

2.2. Political economy of central bank intervention in climate policies

An emerging set of studies examine the pace and manner in which climate change has been incorporated into speeches, mandates, and policies by Western neoliberal central banks, most notably the ECB, Bank of England, and the US Federal Reserve (Baer et al., 2021; Blondeel et al., 2024; DiLeo, 2023; DiLeo et al., 2023; Quorning, 2024). Other studies have also focused on larger country samples and non-Western developing country contexts (Dikau & Ryan-Collins, 2017; Dikau & Volz, 2021; Gupta et al., 2023b; Masciandaro & Russo, 2022). Based on a strong historical epistemic consensus framed around central bank independence, market neutrality, and free market asset pricing dynamics, the idea that tackling climate risks and achieving a net-zero transition requires a paradigm shift in central bank functioning and policymaking is slowly gathering momentum.

Together, these papers contribute to an emerging literature on the way in which central banks have intervened in climate-related issues and the determinants of this intervention. Broadly speaking, these determinants can be classified into internal and external factors, with the former including those emanating from within central banks, such as their legal mandates (Dikau & Volz, 2021) and the ideas and beliefs of officials at the helm of these institutions (Deyris, 2023), and the latter including pressure exerted from outside forces (Jabko & Kupzok, 2024; Masciandaro & Russo, 2022), including governments (Baer et al., 2021), non-state actors (Blondeel et al., 2024; Quorning, 2024) and the general public at the national level, and peer pressure at the international level through engagement in forums such as the Network for Greening the Financial System (NGFS) (Feldkircher & Teliha, 2024).

Baer et al. (2021), by contrasting risk-based informational policy instruments deployed by the ECB with more incentive-based policies used by China, identify institutional dynamics as playing a key role in determining the implementation of climate-related financial policies. Similar findings are reported in DiLeo et al. (2023), Quorning (2024) and Blondeel et al. (2024). Whereas DiLeo et al. (2023) and Blondeel et al. (2024) stress on the importance of a broader socio-political environment and central banks' reputational concerns, respectively, in catalysing or inhibiting central bank intervention on climate change using the ECB and the US Fed as case studies (along with the Bank of England in the latter study), Quorning (2024) emphasizes the significance of 'field arbitrageurs' straddling domains of climate science and finance who pushed the epistemic boundaries and exerted external pressure on central banks to address these risks.

From central banks' side, reputational concerns (Blondeel et al., 2024; DiLeo et al., 2023) and their 'indirect' or partial responsiveness to societal and political demands explains their response, or lack thereof, to demands for green central banking. Among internal forces compelling central bank action on climate issues, the case study of the Dutch central bank by Siderius (2023) offers an extraordinarily rich and nuanced account of the role played by policy staff within the central bank to bring climate change to the forefront as a key issue, alluding specifically to the crucial role played by DNB executive board member Frank Elderson in putting climate change on the bank's policy agenda.

The paper most closely related to ours among these is by Feldkircher and Teliha (2024), who examine the determinants of central banks' climate communication using a keyword-assisted topic modelling approach. They report that external forces, including a greater engagement with international bodies like NGFS and a higher degree of governmental climate engagement are positively correlated with central bank climate communication. On the other hand, they do not find sustainability mandates to be a significant determinant of central banks' climate talk.

This paper aligns very well with some of the arguments laid out and findings observed in these papers, while also taking the research agenda forward in two aspects. First, it distinguishes between central banks' speeches and policies on climate change and examines their correlation and temporality. In doing so, the empirical analysis controls for various determinants of central bank intervention identified in previous papers including central bank independence, institutional strength in a country, its susceptibility to climate-related physical risks, and other economic and financial sector variables impacting the imposition of macroprudential policies (Ademuyiwa et al., 2018; Baskaya et al., 2016). Second, in contrast to a case study approach adopted in several of these papers which offer a rich contextual account of one or a few central banks, this paper lends a bird's eye view to the evolution of climate-related speeches and policies across a much wider range of central banks globally, comprising both developed and emerging economy contexts.

3. Empirical model

To examine the correlation between central bank speeches and financial policies pertaining to climate change, I use a two-way fixed effects model, to control for country-specific invariants and time trends common to all countries. In the baseline, I regress green financial policy intensity on central bankers' green-ness of speeches, controlling for various economic, financial, institutional, and physical (climate-related) factors which could affect the implementation of green financial policies, or macroprudential policies by financial supervisors in general. Our general model specification is:

$$GreenFinancialPolicy_{i,t} = \alpha_i + \beta X_{i,t} + \delta Z_{i,t} + c_i + m_t + \varepsilon_{i,t} \quad (1)$$

Here, α_i is a constant; $GreenFinancialPolicy_{it}$ is an ordinal variable indicating the 'intensity' or number of green financial policies implemented by country i in year t (see next section on data); X_{it} is the index measure of central banks' green-ness of speeches, our key independent variable; Z_{it} refers to the controls used in our extended model (described in Table 1); c_i and

Table 1. Description of control variables/covariates.

Variable	Description	Prior	Source
Vulnerability	Measures the vulnerability of a country to climate change	+ Central banks of countries which are more exposed to physical climate risks are more likely to implement green financial and regulatory policies (Gupta et al., 2023b)	Notre-Dame Global Adaptation Initiative (ND-GAIN)
Central Bank Independence (CBIE)	Measures the extent of *de facto* independence of a country's central bank from the government/politicians	+/− More independent central banks less likely to be pressured by political actors and the general public to undertake climate-related policies	Romelli (2022)
Regulatory quality	Measures the institutional capacity of a country to implement new policies/ regulations in general	− Countries with a better institutional capacity and regulatory quality less likely to undertake green financial policies and more likely to use green fiscal policies, such as carbon taxes and green industrial policies	Worldwide Governance Indicators (WGI)
GDP (log terms)	Measures how rich a country is	−	World Bank World Development Indicators (WDI)
GDP per capita (log terms)	Measures the level of economic development of a country	Richer countries (greater GDP) and more economically developed countries (higher GDP per capita) less likely to entrust central banks with the implementation of macroprudential policies (Egawa et al., 2015)	
Capital account openness	Measures the openness of a country's financial sector (capital flows)		Chinn-Ito Index
Private credit by banks to GDP	Measures the level of financial development of a country		World Bank Global Financial Development Database
Trade-to-GDP ratio	Measures the openness of a country to trade	Higher trade openness could render a country more susceptible to carbon leakage embodied in imports	World Bank World Development Indicators (WDI)

m_t are country and time fixed effects respectively; and ε_{it} is the error term.

4. Data description

4.1. Green index of central bank speeches (explanatory variable)

To create the green speeches index, I first begin by scraping speeches delivered by central bankers from 2000 to 2021 from the Bank for International Settlements (BIS) website. This yields a dataset of over 17,000 speeches.[6] Thereafter I clean the speeches and combine all speeches into one data frame. In this step I also extract information about the year in which the speech was delivered, along with the country name of the central bank whose governor or other board members gave the speech. This is done by extracting the central bank's name from the speech text using text analysis techniques and mapping it with corresponding country names.

I then proceed to create a document-term-matrix (DTM), which tokenizes the text of each speech into words and creates a matrix wherein each row is a speech and each column within the row is a particular word. From these words, I then specify words of interest, or words referring to climate change, greening, the environment, and the net-zero transition. Henceforth, I refer to these as "green words". I obtain the frequency of these green words as a proportion of all words in a speech, for all speeches in our dataset. This normalized frequency of green words forms our green speeches index. I create three iterations of the green speeches index based on a differing choice of "green words" used to compute the numerator.[7]

Greenindex1 → includes words "climate", "environment", and "green"

Greenindex2 → includes words "climate", "green"

Greenindex3 → includes word "green"

While the first iteration of the index (Greenindex1) is the most general and could include some false positives in capturing green words in contexts other than those in which we are interested,[8] the third iteration (Greenindex3) is the most precise and with the lowest margin of false positives, although it could suffer from an opposite problem of excluding some other climate-related words which did refer to climate risks and policy responses.

The specific choice of words to be considered "green words" was based on a text analysis of all central bank speeches. Natural Language Processing (NLP) techniques were used to generate a list of combinations of two most frequently occurring words together (bigrams) in the cleaned speeches. Here, focusing only on words referring to the environment, climate change, net-zero transition, and so on, I found that word combinations like 'green bonds', 'green finance', 'greenhouse gas', 'network greening' occurred frequently together, along with bigrams 'climate change', and 'climate risks' (although climate also figured together frequently with words like investment – 'investment climate'; 'business climate'). The word "environment" occurs in very varied contexts, with not all referring exclusively to climate change.

This quantitative text analysis was complemented with qualitative coding of all climate-related speeches on the BIS website using text analysis software NVivo to better understand the context of central banks' climate-related communication and provide a further layer of robustness to the selection of "green words". An inductive approach was adopted here, wherein speeches were read and homogeneous text was iteratively classified into distinctive themes that recurred across multiple speeches. The most important themes that emerged included central banks' perception of their own role in accommodating climatic risks into their operations and functioning, through monetary and macroprudential policies, followed by the attention paid to green finance in furthering the transition to a

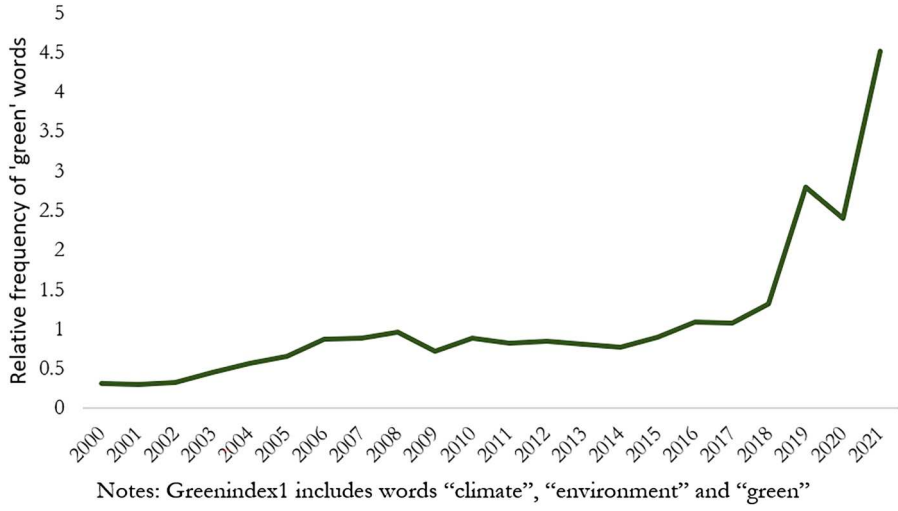


Figure 1. Green-ness of central bankers' speeches (Greenindex1) over time.

low-carbon economy.[9] I also found that at the discursive level, references to 'green finance' – which subsumes three distinct roles of central banks in mitigating climate-related risks including the identification of climate risks, disclosure and taxonomy, and greening of own portfolios, were most prominently featured in the speeches.

4.1.1. Trends in green-ness of central bankers' speeches

Figures 1–3 represent the evolution of three iterations of the green index over time, from 2000 till 2021. While Figure 1 shows a subtle increase in green words till 2016, Figures 2 and 3 show a relatively flat index of green-ness from 2000 to 2016. This could be partly due to Greenindex1 capturing some references to climate and environment in a non-climate context, as explained above. From 2017 onwards, a steep increase in all three iterations of the index can be seen, confirming the prominence of climate issues after Mark Carney's landmark speech in 2015 along with the 2015 Paris Agreement.[10]

Having described the trends in green index over time, Figure 4 shows the geographical distribution of these speeches. From the figure we see that the ECB has been the most vocal on climate change (particularly from 2015 onwards). Following this, central banks from a mix of developed and developing country contexts appear to be communicating actively on climate change, including China, Singapore, Hong Kong, Germany, and Malaysia.

4.2. Policy intensity of climate regulatory policies (outcome variable)

To measure the intensity of implementation of green financial and regulatory policies by central banks and financial supervisors, I use three iterations of the green financial policy intensity index, using data from the E-axes Green monetary and Financial Policies (GMFP) Tracker (E-axes, 2021). This tracker enumerates the financial, monetary, and additional policies adopted by central banks of 32 countries[11] beginning from 1995 until 2021.[12] Details of these policies are laid out in Table 2.

I create three versions/iterations of the green policy index. In the first version, I considered only financial policies

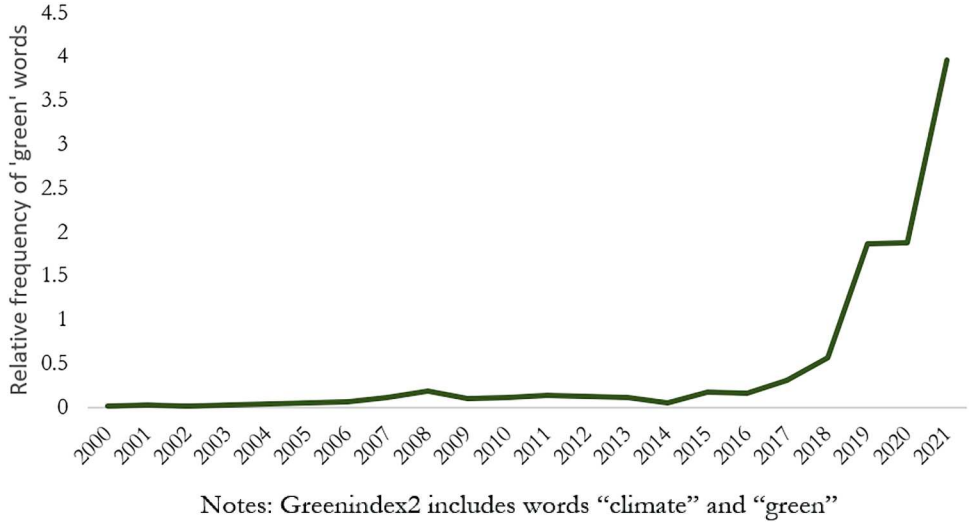


Figure 2. Green-ness of central bankers' speeches (Greenindex2) over time.

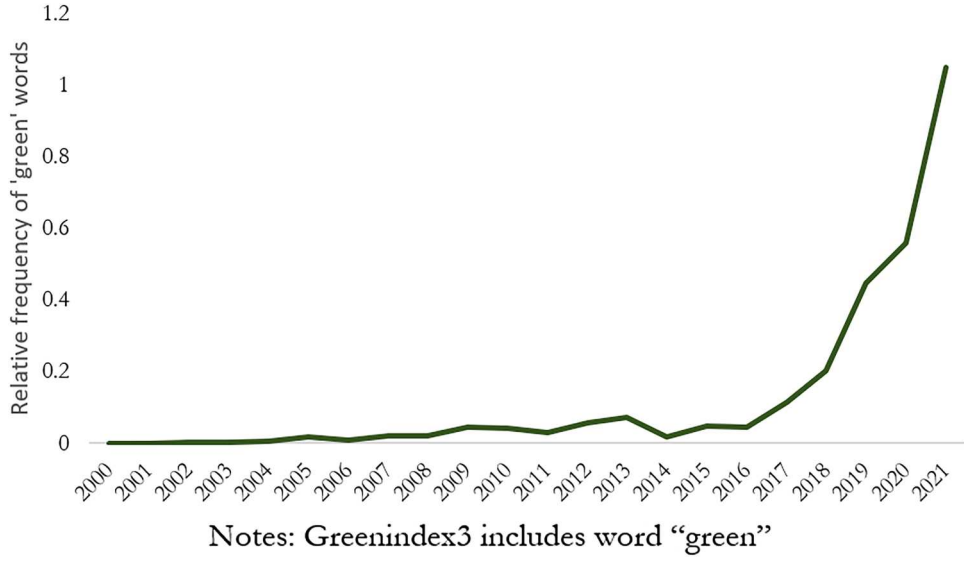


Figure 3. Green-ness of central bankers' speeches (Greenindex3) over time.

enumerated in the E-Axes GMFP Tracker, since green financial policies are specifically geared towards mitigating the risks to financial stability arising from climate change. Here, I calculated the intensity of implementation of these policies, since central banks across countries have successively built on previous policy announcements (for instance: expanding the scope of climate-related stress tests from pilots to those encompassing the entire financial sector), which is more accurately captured by measuring the intensity of these policies. Versions of this self-constructed green financial policy intensity index have been used in previous papers (Cheng et al., 2023; Gupta et al., 2023a).

In the second version, I consider all financial, monetary, and additional policies enumerated on the E-Axes tracker. I then create an ordinal index based on the intensity with which different policy tools were deployed by a country in

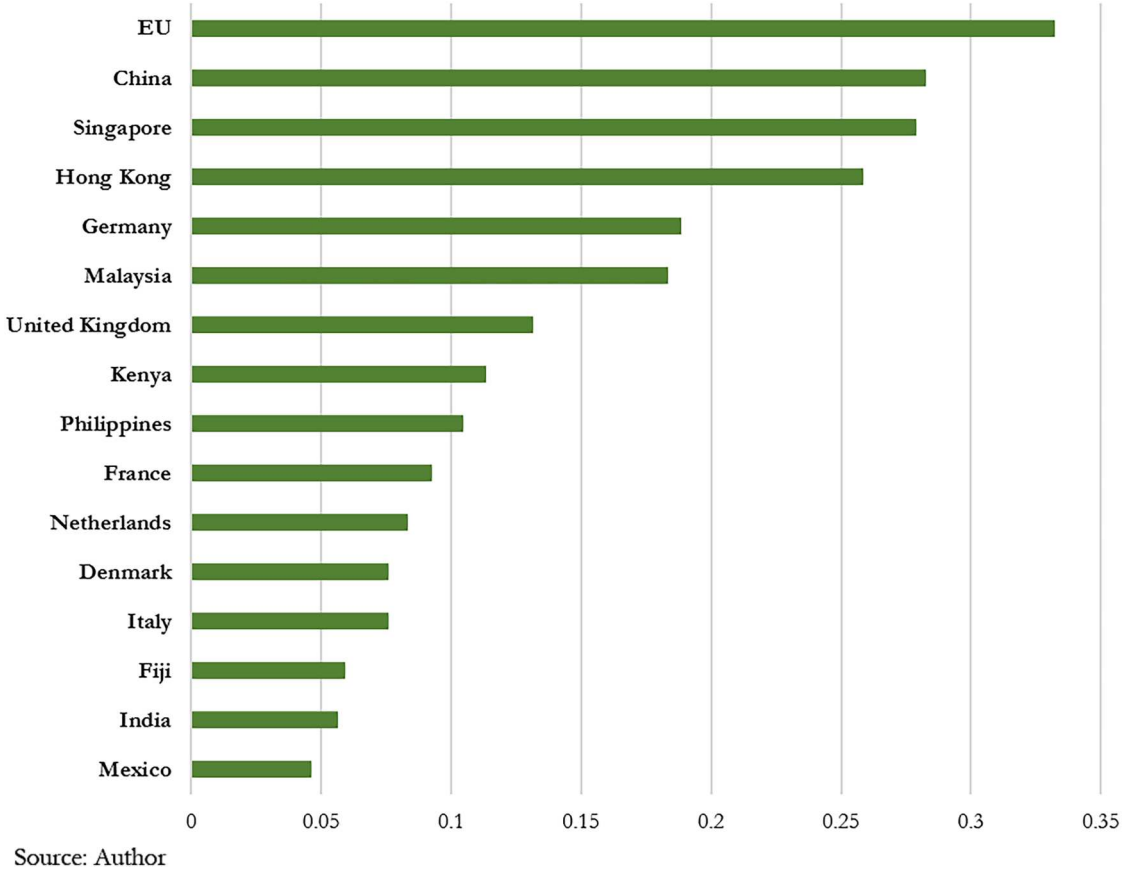


Figure 4. "Green-ness" of central bank speeches (2000-2021) – Top 16 central banks.

Table 2. Details of policies on E-Axes Green Monetary and Financial Policies (GMFP) tracker.

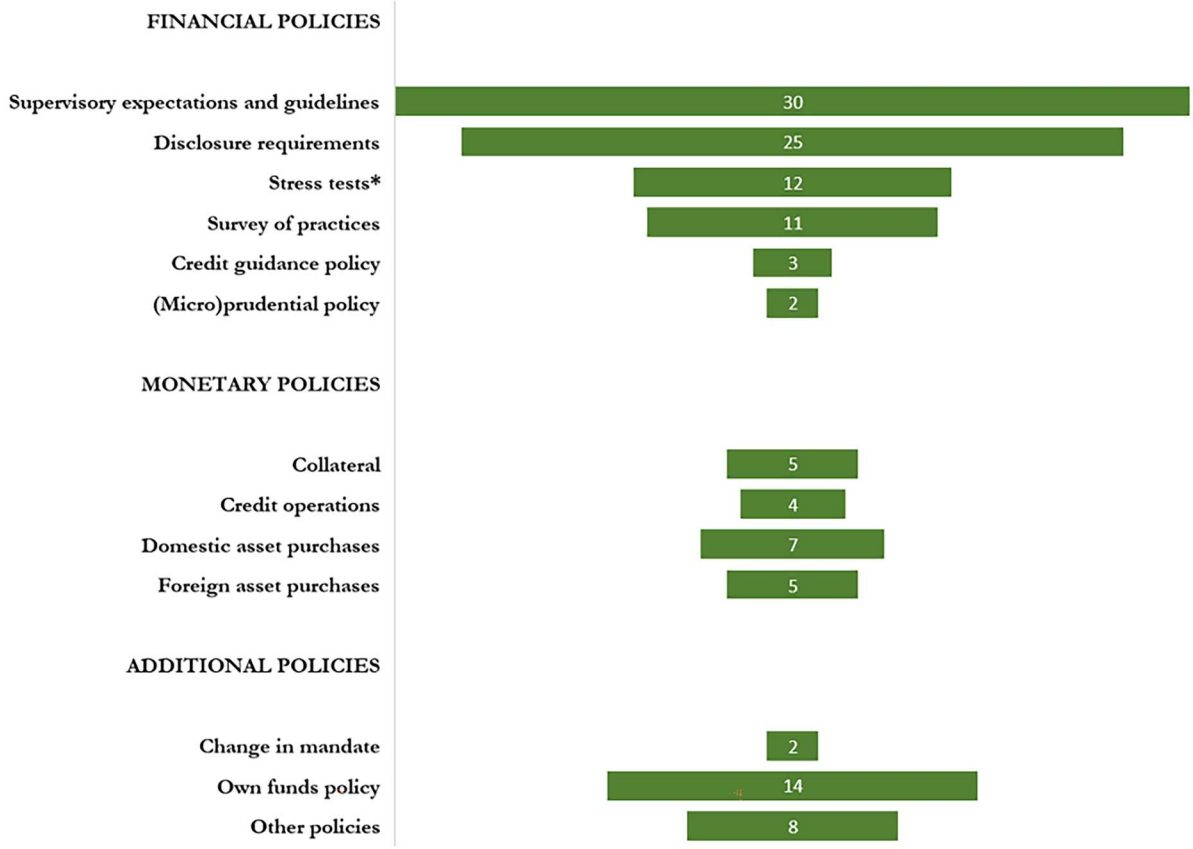
	Credit guidance policy	Priority sector lending policy
Financial policy	Prudential Policy	Preferential green capital requirements (Micro-prudential policy)
	Supervisory Policy	Climate stress test Disclosure requirements Supervisory expectations and guidelines Survey of practices
	Collateral	Incorporation of climate-related criteria for accepting collateral
	Credit operations	Aims to encourage green finance
Monetary policy	Domestic asset purchases	Incorporating climate criteria in own asset management and financial portfolio of central banks
	Foreign asset purchases	Incorporating climate criteria in own foreign exchange reserve management
	Change in mandate	Explicit change in *de jure* mandate of the central bank to include climate change or transition of the economy to net-zero
Additional policies	Other policies	Miscellaneous (green bond guidelines; inclusion of climate-related financial risks in annual report of central bank; inclusion of ESG risks by financial sector supervisors)
	Own funds	Own asset and portfolio management by central banks

Source: E-axes (2021).

successive years, beginning from 1995. If a central bank has implemented no green policy in a particular year it was assigned a score of 0. Subsequently, if a country implemented any green policy tool in a particular year, its score was incrementally adjusted by 1. There is no upper limit on how many times a given policy tool can be counted in a particular year since several central banks have issued multiple circulars/announcements pertaining to the same policy tool (for example: the expansion in scope and scale of supervisory guidelines for banks, or climate stress testing). Thus, this index seeks to measure the intensive margin of green policy intensity across central banks.

Lastly, in the third iteration, I considered all financial, monetary, and additional policies, similar to the second index, but here I sought to create a lower bound for the different policy tools deployed by central banks over time by attributing the implementation of a particular green policy tool in a given year only once. For instance, if the Banque de France published three announcements on climate stress-testing in 2014 and two on climate-related disclosure requirements and it had no prior green policy implemented, its green policy intensity score would be 5 in the first version and 2 in the second version. Thus, this version aims to capture the extensive margin of green policies adopted by central banks over time.

Although aggregating over heterogeneous financial and regulatory policies is not a perfect assumption, I adopt this strategy for three reasons. First, given the relatively nascent stage of development of green financial and regulatory policies, several of these policies are exploratory in nature and relatively narrow in scope, such as conducting surveys of practices among financial institutions, or establishing supervisory expectations about firms' handling of climate change.



Source: E-axes (2021)
NOTE: *Includes pilots, system-wide and supervisory stress tests

Figure 5. Popularity of Green Financial, Monetary and Additional Policy Tools, as of 2021.

Therefore, I surmise that the very act of a central bank adopting any of these policies sends a signal to markets that they are beginning to incorporate climate-related financial risks into their policymaking and this perhaps provides a degree of certainty to financial market participants about the future trajectory of climate policies to address climate-related risks. Thus, our green policy index aims to predominantly capture the signalling effect of these policies.

Second, I note that among these policy tools, financial policies, particularly supervisory expectations and disclosure requirements, are the most popularly implemented by central banks, as shown in Figure 5. These policies constitute the first iteration of our dependent variable, green financial policy intensity.

Lastly, this method of index construction is inspired from and consistent with other widely used indices of macroprudential policies, such as the one developed by Cerutti et al. (2017), which aggregates 12 different lender- and borrower-based macroprudential policy tools. In fact, most of the early literature on macroprudential policy was highly aggregative and focused on analyzing the nexus between monetary policy and different macroprudential policy tools, rather than attempting to compare between various macroprudential policies themselves (Gambacorta & Murcia, 2020; Lorencic & Festic, 2022; Martinez-Miera & Repullo, 2019; Mester, 2017; Svensson, 2018).

4.3. "Green-ness" of speeches and implementation of green policies by central banks

Figure 6 provides a visual representation of the evolution of green speeches and policies undertaken by central banks over time.[13] From the figure, we can see that there has been an overall uptick in both speeches and policies over time, although the surge in green financial and regulatory policies (which picked up pace from 2013) perhaps preceded the surge in speeches by central banks (which only exhibit a sustained rise 2016 onwards).

Table 3. Extended model with controls.

Variables	(1) Green financial policy intensity	(2) Green policy intensity (Intensive margin)	(3) Green policy intensity (Extensive margin)
Greenindex2	23.96***	28.88**	13.71***
	(7.343)	(11.88)	(4.281)
Vulnerability	15.16	−7.429	−3.318
	(21.15)	(29.02)	(11.03)
Central Bank Independence	−1.429*	−3.575**	−0.889*
	(0.754)	(1.453)	(0.505)
Regulatory quality	−0.249	−0.347	0.0609
	(0.445)	(0.883)	(0.288)
Log Real GDP (USD constant)	−0.692	−4.297	−0.812
	(2.737)	(5.747)	(2.079)
Log GDP per capita	1.496	4.011	0.0661
	(2.973)	(6.398)	(2.137)
Capital account Openness	−0.425***	−0.492*	−0.154
	(0.133)	(0.265)	(0.103)
Trade-to-GDP ratio	−0.00526	0.00391	−0.000127
	(0.00774)	(0.0159)	(0.00497)
Private credit extended by banks (% of GDP)	−0.00789**	−0.0169**	−0.00820***
	(0.00372)	(0.00732)	(0.00234)
Constant	1.105	84.05	24.17
	(50.61)	(102.4)	(38.32)
Observations	466	466	466
R-squared	0.565	0.529	0.577
Number of countries	28	28	28
Fixed Effects	YES	YES	YES

Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5. Results

5.1. Extended model (with controls)

I first begin by running our baseline model with a full set of controls to establish the correlation between central banks' green speeches and policies.[14] From the results shown in Table 3 below, we can see that central bankers' climate-related speeches and policies exhibit a positive correlation, and a few

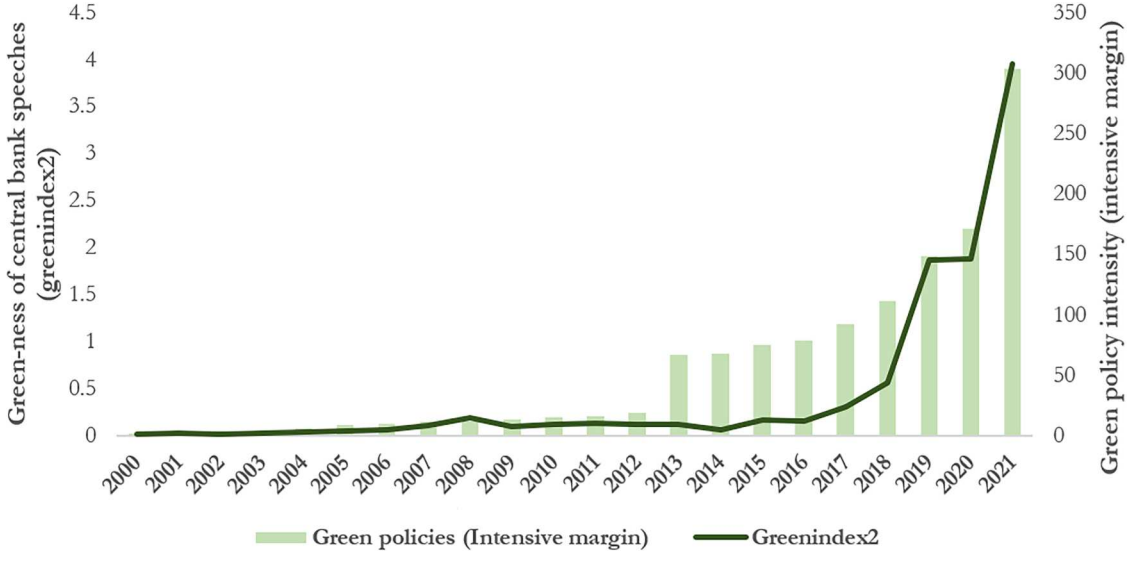


Figure 6. Evolution of central banks' green speeches and policies over time (Intensive margin).

other factors also play a significant role in determining the adoption of green financial policies.

Among these, the results suggest that a higher degree of central bank independence from the government makes it less likely to consider the adoption of green financial policies. This is consistent with previous studies (Barkawi & Monnin, 2015; Dikau & Volz, 2018; Larsen, 2022) which demonstrate that non-Western central banks have often been more active or acted earlier on climate issues perhaps because they are entrusted with a broader mandate to support the developmental agenda of the government and are more malleable to pressure exerted from governments to undertake policy responses to climate change, as part of a holistic government/regulatory response to address climate change (Arseneau & Osada, 2023; Dikau & Ryan-Collins, 2017; Dikau & Volz, 2021). However, it is perhaps counterintuitive from anecdotal evidence which indicates that more (operationally) independent central banks such as the ECB, BoE, and several Euro area central banks are at the forefront of catalysing research and collaboration on climate change and its implications for the conduct of monetary and prudential policy.[15]

Among other covariates which are mostly statistically insignificant, we notice both higher capital account openness and greater financial development (proxied by greater private sector credit extended by banks as a percentage of GDP) are negatively correlated with green financial policy intensity. This suggests that highly financially developed and open countries are less likely to undertake green financial policies, perhaps because of two reasons. First, some green policy tools such as credit guidance policies and differentiated capital requirements (included in our composite green policy index) are considered at odds with the market neutrality principle and thus less likely to be rolled out in countries where the financial sector is large and holds sway. Second, since more financially developed markets are more efficient and are able to absorb various financial risks more effectively, perhaps there is an expectation that markets in these countries do a good job at accurately discovering and pricing climate risks, thereby negating the need for regulation (Gopalan et al., 2023).

5.2. Results using leads and lags of green speeches index

The results presented above establish a robust correlation between central banks' speeches and policies related to addressing climate risks, along expected lines. However, they do not shed light on the direction of causality – whether central banks which deliver more speeches on climate change end up implementing more green financial and regulatory policies, or the other way round. Both possibilities exist, as is evident from a qualitative analysis of green speeches.

For instance, in a wide-ranging speech delivered by François Villeroy de Galhau, Governor of the Bank of France, at the NGFS conference in April 2019,[16] he provided a stocktake of the actions central banks and financial supervisors had taken across countries to incorporate climate-related financial risks into financial institutions' balance sheets and their own portfolios (Villeroy de Galhau, 2019). Similarly, R. Gandhi, Deputy Governor of the Reserve Bank of India, in a speech delivered in 2016, reiterated the country's priority sector lending scheme[17] which had been updated in 2015 to include small renewable energy projects and social infrastructure loans into its ambit[18] (Gandhi, 2016). These speeches thus reiterated green policies that had already been implemented by central banks.

On the other hand, Andreas Dombret, Executive Board Member of the Deutsche Bundesbank, in a welcome speech on banking supervision delivered in 2018, outlined the risks posed to the economy, and by extension to the financial system, from climate change, and the role of banking supervisors in "transitioning to a green financial system" (Dombret, 2018). Subsequently, two years later in 2020, Germany's Federal Financial Supervisory Authority, BaFin, published guidelines for banks and insurance agencies providing good practices for managing sustainability risks.[19]

At the outset, this relationship between green speeches and policies is highly endogenous as both speeches and policies occur contemporaneously throughout the policy process. It is difficult to isolate causality econometrically using exogeneous instruments since any instrumental variable which impacts the dependent variable (green financial policies) is also likely to impact the key independent variable, green-ness of speeches delivered by central banks, thus failing to satisfy the exclusion restriction condition. While I have tried to eliminate other confounders which impact the green financial policy intensity by controlling for a range of economic, financial, and institutional

Table 4. Leads and lags of green index of speeches (Greenindex2) with controls.

Variables	(1) Green financial policy intensity	(2) Green policy intensity (Intensive margin)	(3) Green policy intensity (Extensive margin)
$Greenindex2_{t-1}$	−2.589	−7.862	2.570
	(6.966)	(13.45)	(5.775)
Greenindex2	18.78***	22.94**	10.82***
	(5.782)	(8.877)	(3.028)
$Greenindex2_{t+1}$	11.27**	14.23	5.223
	(5.216)	(11.37)	(4.959)
Vulnerability	9.316	−14.23	−3.708
	(19.13)	(29.68)	(11.63)
Central Bank Independence	−2.598**	−5.578*	−0.955
	(1.253)	(2.994)	(0.834)
Regulatory quality	−0.250	−0.346	0.0845
	(0.460)	(0.945)	(0.298)
Log Real GDP (USD constant)	0.115	−3.454	−0.695
	(3.091)	(6.714)	(2.395)
Log GDP per capita	0.601	3.013	−0.0627
	(3.402)	(7.508)	(2.454)
Capital account Openness	−0.513***	−0.587*	−0.183
	(0.154)	(0.293)	(0.114)
Trade-to-GDP ratio	−0.00535	0.00312	−9.36e-05
	(0.00781)	(0.0164)	(0.00514)
Private credit extended by Banks (% GDP)	−0.00958**	−0.0202**	−0.00922***
	(0.00395)	(0.00854)	(0.00263)
Constant	−8.711	75.59	22.64
	(55.16)	(117.2)	(43.82)
Observations	438	438	438
R-squared	0.588	0.538	0.585
Number of countries	28	28	28
Fixed effects	YES	YES	YES

Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

variables, endogeneity persists. Therefore, I restrict the analysis to examining the temporality of green speeches and green financial policy intensity by re-running the baseline regression using leads and lags of the green-ness of speeches.[20] Results are presented in Table 4.

From the table, we observe that our baseline results continue to hold. The coefficient on the green index of speeches lagged by one period is not statistically significant and even turns negative in columns 1 and 2, whereas the coefficient on the green speeches index leading by one period exhibits weakly positive statistical significance. The contemporaneous green speeches index continues to be positive and highly statistically significant.

To isolate the impact of the leads of green speeches on green policy intensity from that of the contemporaneous green index, I re-run the previous model using only leading values of the green speeches index.[21] From the results shown in Table 5, we observe that in this model, the green speeches index leading by one period is no longer positive or statistically significant, although the one leading by two periods is positive and statistically significant for columns 1 and 2. This suggests that there is some positive correlation between green policy intensity and green speeches delivered at least two years after the policy uptake.[22]

From these tables, we observe that although neither leads nor lags are consistently significant across-the-board, there is some evidence pointing towards the green speeches index a couple years ahead of the green financial and regulatory policy intensity being positive and statistically significant, suggesting that once central banks implement climate-related financial and regulatory policies, they are likely to deliver more speeches on this topic in the following years.

Table 5. Leads of green index of speeches (Greenindex2) with controls.

Variables	(1) Green financial policy intensity	(2) Green policy intensity (Intensive margin)	(3) Green policy intensity (Extensive margin)
$Greenindex2_{t+1}$	5.206	4.024	2.711
	(4.098)	(8.740)	(3.622)
$Greenindex2_{t+2}$	9.492**	13.57*	4.931
	(3.431)	(7.401)	(2.985)
Vulnerability	9.878	−14.35	−5.996
	(19.16)	(27.16)	(10.50)
Central Bank	−1.275	−3.358**	−0.815
Independence	(0.774)	(1.494)	(0.521)
Regulatory quality	−0.313	−0.441	0.0319
	(0.403)	(0.834)	(0.274)
Log Real GDP	−0.873	−4.537	−0.905
(USD constant)	(2.572)	(5.566)	(2.047)
Log GDP per capita	1.773	4.388	0.207
	(2.792)	(6.175)	(2.084)
Capital account	−0.431***	−0.499*	−0.157
Openness	(0.131)	(0.253)	(0.0998)
Trade-to-GDP ratio	−0.00495	0.00421	2.71e-05
	(0.00760)	(0.0157)	(0.00492)
Private credit extended	−0.00690*	−0.0155**	−0.00775***
by Banks (% GDP)	(0.00387)	(0.00751)	(0.00236)
Constant	5.008	89.13	26.19
	(47.24)	(99.34)	(38.03)
Observations	466	466	466
R-squared	0.583	0.540	0.584
Number of countries	28	28	28
Fixed Effects	YES	YES	YES

Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6. Probit model – green financial policy adoption as binary variable.

Probit model	(1) gfp_binary
Greenindex2	29.62
	(23.67)
Vulnerability	−40.01
	(56.53)
Central Bank Independence	8.442
	(10.34)
Regulatory quality	1.651
	(2.507)
Log Real GDP (USD constant)	5.559
	(4.446)
Log GDP per capita	−4.466
	(6.082)
Capital account Openness	1.470
	(2.548)
Trade-to-GDP ratio	0.0218
	(0.0283)
Private credit extended by Banks	0.0381
(% GDP)	(0.0493)
Constant	−126.0
	(118.1)
Observations	1,381
Number of countries	84
Random Effects	YES

Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.3. Green financial policy adoption as binary variable

Thus far, we have been focusing on a subset of central banks who are early movers in implementing green financial and regulatory policies. In this section, instead of focusing on the intensity of implementation of green financial policies, I examine whether delivering green speeches determines the adoption of green policies by these entities. Thus, I use a probit model to assess whether a higher green speech score affects whether a central bank adopts green financial policies, controlling for the same economic, financial, and institutional variables as before.[23]

Table 6 presents results of a panel probit model, wherein I regress a binary variable of green financial policy adoption on the green speeches index and a host of previously used controls. Using the broader subset of all those central banks in our dataset which have some non-missing value of the green speeches index, the green policy adoption binary variable is constructed such that it takes on a value of 0 for all those countries which have never adopted a green financial policy from 2000 to 2021, and 1 for those which have, beginning with the year in which the policy was first implemented. From Table 6 we can see that the coefficient on green speech score turns insignificant, suggesting that delivering speeches on climate risks is not an important determinant of central banks' adoption of green financial policies. This supports our results from Section 5.2 above, wherein we found that green policies often precede speeches on climate change for those central banks which are early adopters of these policies.

6. Conclusion

This paper assesses the correlation between central banks' climate-related speeches and policies using a newly constructed measure of climate talk by central banks from 2000-2021. The empirical findings suggest that even though central

banks' speeches and policy actions are highly correlated, the temporality of speeches and action is circumspect. In most cases, central banks have first implemented green financial and regulatory policies and later embarked on communication via their speeches to draw the public's attention to climate-related risks and policies to mitigate these. Given the urgency of undertaking multi-pronged action to mitigate climate change and the collaborative role of various policy actors using multiple policy instruments, I believe that this paper can shed light on the way central banks around the world have intervened in climate policymaking.

While this paper is a useful starting point in examining central banks' communication and policies on climate change, it nevertheless suffers from certain shortcomings. Among these, I acknowledge that the relationship between speeches and policies is itself circular and iterative. Speeches delivered by central bankers on greening and climate change are often wide-ranging, beginning with an overview of how climate change affects financial stability and providing an account of the actions they have taken thus far to mitigate these risks. This is then followed, in some instances, by an action plan setting out future initiatives under consideration, or research being undertaken to strengthen or broaden already-existing policies, or to adopt newer ones. Thus, it is difficult to isolate whether this would be a case of a policy preceding a speech, or vice-versa.

I have tried to mitigate this concern to some extent by using upper and lower bounds of the green financial and regulatory policy index which provides an extensive and intensive margin of green policies being undertaken. To the extent that some green speeches enunciate broadening existing green policies, such as expanding climate stress tests at the financial sector level to an economy-wide level, the extensive margin of the green policy index only counts the stress test in the first instance when it was implemented. Therefore, in this case the climate stress test would be considered as having been implemented before the speech. However, future studies can build on our findings to develop better identification strategies to strengthen the causal relationship between central banks' climate-related speeches and policies.

Notes

1. Gupta et al. (2023b) delve deeper into the specific green financial and regulatory policy tools being deployed by central banks and undertake empirical analysis to unpack possible reasons behind the differential pace of adoption of these policies across countries.
2. Although the US Federal Reserve Chair Jerome Powell did reiterate in January 2023 that central banks have "narrow, but important, responsibilities regarding climate-related financial risks … tightly linked to our responsibilities for bank supervision" (Powell, 2023). Retrieved from: https://www.federalreserve.gov/newsevents/speech/powell20230110a.htm
3. Retrieved from: https://www.bb.org.bd/en/index.php/financialactivity/regulator#:~:text=to%20hold%20and%20manage%20the,banking%20companies%20and%20financial%20institutions.
4. Retrieved from: https://www.bi.go.id/en/fungsi-utama/stabilitas-sistem-keuangan/ikhtisar/default.aspx#:~:text=by%20Act%20No.-,4%20of%202023%20concerning%20Financial%20Sector%20Development%20and%20Strengthening%20(UU,to%20support%20sustainable%20economic%20growth.
5. This is most notably so for central bank communication around setting expectations for long term interest rates, since central bank policies can only directly affect short-term interest rates but markets and the public in general are directly affected by longer term rates they face on mortgages, investments, credit card debt, and so on.
6. I would like to acknowledge at the outset the scope of speeches included in our analysis and the shortcomings associated with using the BIS dataset of speeches. First, this paper is based on an analysis of only English language speeches delivered by central bankers, either originally or after translation. Second, I also acknowledge that the BIS database does not include all speeches delivered by central bankers, but only a subset of these public speeches submitted by national authorities themselves (including a few speeches translated by BIS staff). I restricted the analysis to these speeches since the BIS forms a reputed global institution aggregating communication across central banks on their website and thereby provides a credible source of cross-country comparable data which is widely used in an emerging set of related studies (Arseneau et al., 2022; Arseneau & Osada, 2023; Feldkircher & Teliha, 2024). I would like to thank two anonymous reviewers for raising this point.
7. A survey of current natural language processing (NLP) techniques used for analysing central bank communication reveals that most methods focused on analysing the content of the speeches (such as Arseneau & Osada, 2023) using very sophisticated methods such as topic modeling and sentiment analysis. However, in this paper, the objective was to create a quantitative measure of climate talk by central banks which could be used as a panel data resource for answering further empirical questions. Therefore, I required a measure which could distil climate talk by central bankers into one parsimonious quantitative number. I acknowledge that the green speech score is not a perfect measurement of climate talk by central bankers and is merely an indicator of the frequency with which central banks talk about climate change without revealing anything about the content or context of their communication. However, I have tried to expand the corpus of green words and tried to exclude false positives in calculating the relative frequencies of "green" words using an alternative nltk approach to quantitative text analysis, results of which are provided in Annex B. I would like to thank two anonymous reviewers for motivating this exercise.
8. For example: "environment" and "climate" are sometimes used to refer to the business environment, macroeconomic environment, investment climate etc.
9. A more detailed elucidation of the themes emerging from the qualitative text analysis of central bank speeches and a discussion of their self-perceived roles in climate risk mitigation is provided in Appendix B.
10. The slight fall in the green index in Figure 2 and flatlining in Figure 3 from 2019 to 2020 can be explained by the shift in focus of central banks during this time to the coronavirus pandemic and its response.
11. 31 countries plus the European Union (EU).
12. Although policy circulars issued by central banks could be construed as announcements, and thereby communication, or climate talk, I would like to contend that these are more closely aligned with policy implementation because of two reasons. First, they carry intricate technical details about the policy such as its scope, entities affected, and date of implementation (in most cases). These are also often published on central bank websites without a spoken communication. Second, a lot of the emerging literature on green central banking refers to central bank communication exclusively as speeches delivered by central banks (Arseneau et al., 2022; Arseneau & Osada, 2023; Campiglio et al., 2024; Feldkircher & Teliha, 2024), and this is the motivation for this paper as well. I would like to thank an anonymous reviewer for raising this point.
13. Annex A presents the evolution of central banks' green speeches and policies for developed and developing economies, respectively.

14. While I use Greenindex2 as the chosen proxy for measuring the "green-ness" of central banks' speeches, I also re-run the results using alternative proxies of the green speech score (Greenindex1 and Greenindex3) and versions of the green financial and regulatory policy intensity index in Annex B. Annex B also replicates the results using newer iterations of the green speech score (greenindex4 and greenindex5) constructed using an alternative nltk approach for quantitative text analysis.
15. Despite being a Western neoliberal financial regulator and having a high degree of central bank independence, the ECB was, and remains, one of the most vocal advocates of central bank intervention in climate change, and this could be attributed to factors including the leadership at the bank (most prominently Christine Lagarde, Sabine Mauderer) and their ideas, or the broader sociopolitical context including momentum created by financial sector non-profits and the European parliament for central banks to mitigate risks arising from 'unburnable carbon' (DiLeo, 2023).
16. Retrieved from: https://www.bis.org/review/r190429e.pdf
17. This scheme mandates banks to direct 40 percent of their lending to specified socially important or 'priority' sectors such as infrastructure (Gandhi, 2016).
18. Retrieved from: https://www.bis.org/review/r160517b.pdf
19. Available at: BaFin – Guidance Notices – Guidance Notice on Dealing with Sustainability Risks. To be sure, the German Bundestag had legislated in 2015 for pension funds to account for environmental factors in their risk management, but the scope of this policy was restricted to pension funds and the decision to implement this policy came from the German parliament. Source: https://www.bafin.de/SharedDocs/Downloads/EN/Aufsichtsrecht/dl_vag_en_va.pdf?__blob=publicationFile&v=1.
20. Although the correlation between speeches and policies is bi-directional, I consider green policies as the dependent variable and green speech score as the independent variable because there is an established literature on the determinants of imposition of prudential policies (both micro and macro) by central banks (Ademuyiwa et al., 2018; Baskaya et al., 2016; Boar et al., 2017; Borio, 2018; Egawa et al., 2015), which allows us to correctly specify our extended model with an appropriate set of controls. To maintain consistency throughout the paper, I used the same model when exploring leads and lags of green speeches as well.
21. As an additional robustness check, I also flip the model such that leading values (by one and two periods) of the green speech score are the dependent variable and green policy intensity is the independent variable. I find that the coefficient on green policy intensity remains positive and highly statistically significant across various iterations of the green policy index and green speech score, thereby confirming our main results that green policies can significantly explain green speeches by central banks one or two years after the policy has been adopted. I thank an anonymous reviewer for motivating this exercise.
22. A replica of this model is run using lags of the green speeches index instead of leads, and the model exhibits no statistical significance of the green speeches index lagged by one or two time periods. Further, this result holds across all three iterations of the green speeches index.
23. Other robustness checks include replication of our results using different iterations of our main independent and dependent variables. This is done both to establish the robustness of our findings and to establish upper and lower bounds to our empirical estimates. Results of these robustness exercises are provided in Annex B.
24. This is laid out in Article 127(1) of the Treaty on the Functioning of the European Union. Retrieved from: https://www.ecb.europa.eu/mopo/intro/html/index.en.html. Last accessed: December 15, 2023.
25. This approach is argued to be insufficient due to the radical uncertainty associated with climate phenomenon, the slow pace of markets to incorporate climate risks into asset prices, coupled with political economy constraints and regulatory capture by fossil fuel firms which could prevent credit being directed to green sectors at a rapid pace to achieve decarbonisation objectives.
26. Although managing the trade-offs between various central bank policy objectives and the consequences of adding climate change as an additional objective is beyond the scope of this paper, the lack of consensus within the central bank community on this issue is one of the reasons for their relatively slow pace of incorporating climate risks into policymaking.
27. This was a separate category of speeches on the BIS website formerly titled 'Speeches on green finance' but now updated to 'Speeches on climate change and green finance'. Retrieved from: https://www.bis.org/topic/green_finance/speeches.htm
28. D'Orazio and Popoyan (2019) and Gruenewald (2020) articulate the various 'green' prudential tools currently being discussed and the stage of their implementation across countries.
29. Advanced economies include Australia, Belgium, Canada, Croatia, Denmark, EU, Finland, France, Germany, Hungary, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Slovenia, Spain, Sweden, Switzerland, United Kingdom, and United States. Developing countries include Brazil, China, India, Indonesia, Mexico, Republic of Korea, and Turkey. Note that the restricted sample size for countries disaggregated by their development status results from a lower number of countries (32) included in the E-Axes Green Monetary and Financial Policies (GMFP) tracker on which the green policy intensity index is created. Further, central banks of three developing countries (Honduras, Paraguay, and Peru) have implemented green financial and regulatory policies but there is no record of these central banks delivering a speech referring to climate change or a greening of their policies, so their green speeches index is zero.

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Appendices

Appendix A

Central bank policy objectives and intervention in climate policymaking

The enthusiasm of autonomous central bank initiatives to 'green' monetary and macroprudential policies is rife with concerns articulated on several grounds. The first is that they do not have the mandate or legal sanction to modify policy objectives and incorporate sustainability into their framework without the explicit direction of the government. A wider criticism is that central banks, by privileging corporate bonds or projects with investment or commitments in low-carbon initiatives over high-carbon ones, act in an arbitrary and unfair manner, stepping over their legal mandate and interfering with the free-market asset pricing dynamics (Randow, 2020). Lastly, it is argued that the greening of monetary policy led by central bankers is incompatible with the notion of their independence and insulation from addressing market failures (Cochrane, 2020; Gros, 2020).

From an operational perspective, a related and pertinent question arises about how this incorporation of climate concerns could impact other central bank policy objectives, including price stability, maximum employment and financial stability (Coelho & Restoy, 2023; Masciandaro & Russo, 2022; van 't Klooster & Monnet, 2023). For instance, in the post-COVID macroeconomic environment in most advanced economies (particularly the US and EU) punctuated by high rates of inflation and low unemployment, raising interest rates was the most appropriate monetary policy response. However, higher interest rates would arguably raise the cost of accessing finance by renewable energy firms disproportionately compared to fossil fuel sectors.

This is because of two reasons. First, renewable energy projects often entail massive upfront infrastructure costs in building new projects and exploring new green technologies. Second, firms engaged in green sectors often tend to be less capital-intensive and smaller in size vis-à-vis their relatively well-endowed and established fossil fuel counterparts. For both these reasons, there are legitimate concerns about the green transformation being delayed or halted due to higher prevailing interest rates. Although both the Fed and ECB have primary mandates of preserving price stability, and the US does not include climate change considerations in its monetary policy settings, the ECB does have to 'support the general economic policies in the European Union', 'without prejudice to the objective of price stability'.[24]

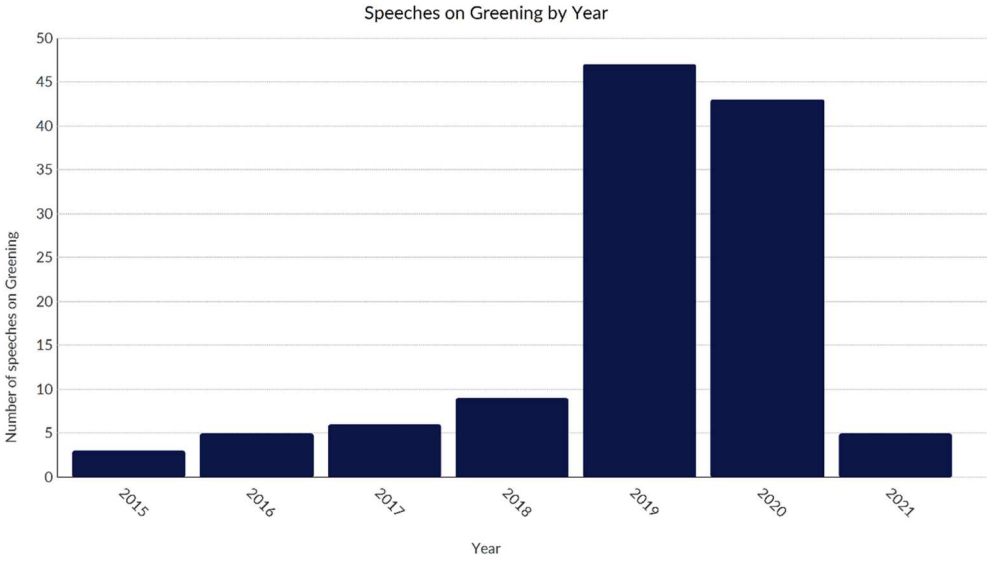
The traditional monetary policy literature proposed rules for central banks to quantify and manage the trade-offs from pursuing competing objectives of preserving price stability while maximising employment, called the Taylor rule (Taylor, 1993; Woodford, 2001). A few recent studies have examined and proposed specific policy tools through

which central banks can possibly reconcile competing objectives, such as facilitating a green transition while keeping inflation in check (Panetta, 2022) using policy tools such as green credit instruments (van 't Klooster & Monnet, 2023). Although preferential lending to green sectors is an acceptable and established practice for emerging economy central banks, it is viewed with scepticism by advanced economy central banks on grounds of such policies undermining the principles of market neutrality and free market asset pricing dynamics. However, a few recent studies have stressed the insufficiency of a risk-based approach[25] alone relied upon by advanced economies in driving credit to green sectors, suggesting the need for "allocative credit based policies" (Kedward et al., 2024; Krebel & van Lerven, 2022).[26]

Appendix B

Qualitative analysis of central bank speeches using NVivo

The data for conducting the text analysis was obtained from the Bank for International Settlements (BIS) website by referring to all speeches under the category 'green finance'.[27] This yielded a total of 118 speeches from October 2015 to February 2021, with maximum number of speeches being delivered in 2019 (refer to Figure 1) and keeping up the momentum in 2020 (albeit a little lower than 2019) despite the emergence of a global epidemiological crisis.



The analysis followed an inductive approach to analysing the text of central banks' speeches. In order to identify themes in the speeches, text analysis software NVivo was used to create various codes while going through all the speeches' content. Broadly, the themes that emerged spanned the following areas (as shown in Figure 2):

- Defining climate change and conceptualising its wide-ranging effects in terms of economic and humanitarian losses
- The impact of climate change on financial stability.
- The factors influencing climate change responses – such as the lack of proper quantitative techniques to model climate change impacts, and the unique nature of climatic risks associated with large-scale losses and critical tipping points.
- International cooperation between central banks and financial supervisors to take forward the climate agenda.
- First-best response to climate change – the carbon tax.
- Central banks' own perception of their role in responding to climate-related risks
  - Monetary policy
  - Macroprudential policy
  - Green finance

From Figure 2, it is evident that most of the content in the speeches focuses on central banks' perception of their own role in accommodating climatic risks into their operations and functioning, through monetary and macroprudential policies. This is followed by the attention paid to green finance in furthering the transition to a low-carbon economy, and the role of international cooperation (including international organisations and bilateral initiatives) to expand knowledge of climate-related financial risks (CRFRs) (Gruenewald, 2020) among central banks and create harmonised regimes on the taxonomy and disclosures of these risks by financial institutions transcending geographies.

Figure 2: NVivo codes for analysing the content of central bankers' speeches

Codes

Search Project

Name	Files	References
Carbon tax	34	49
CB Independence	1	5
Climate change responses - Influencing factors	62	132
Conceptualising climate change effect	80	170
Financial stability effect - Climate change	75	230
Green finance	87	326
Green bonds and asset purchase programs	35	68
Inflation effect - Climate change	8	9
International cooperation	96	280
Opinion on appropriate role of CB in responding to climate change	103	530
Monetary policy - Climate change impact	29	86
Prudential policies	55	121
Other responses (regulatory agencies, govt) to climate change	72	178
Fiscal policy - climate change	12	19

At the discursive level, references to 'green finance' – which subsumes the first three roles of central banks (identification of climate risks, disclosure and taxonomy, and greening of own portfolios) are the most prominent in the speeches (see Figure 3). These roles are also less controversial and do not necessarily entail an overstepping of their mandates. They fall under the 'market-fixing approach suggested by Kyriakopoulou et al. (2020).This motivates the choice for including 'green' and 'sustainable' as climate-related words in our words of interest for the green speech score, since these are both the most frequently occurring in the word clouds shown below.

Figure 3: Central banks' speeches content: Encouraging Green Finance emerges as most discussed role

NOTE: Based on results of word frequency query run on text coded in: central banks' appropriate response, monetary policy, prudential policies, green finance and green bonds.

List of excluded words: central banks climate change financial risks policy related develops including managing requires

After this, the second most discussed role is the conduct of monetary policy (see Figure 4) to incorporate climatic risks within its fold. This role is controversial and central bankers express their hesitation in pursuing this actively. Moreover, the concern is not just about whether central banks should use monetary policy to combat physical and transition risks emanating from climate change, but also how they should do so given the difficulty in modelling these risks and the problem of chasing too many policy objectives with too few policy tools (the Tinbergen principle).

Figure 4: Central banks' speeches content: Monetary Policy emerges as second most discussed role of Central Banks

NOTE: Based on results of word frequency query run on text coded in: Central banks' appropriate response, monetary policy, prudential policies

List of excluded words: central banks climate change financial risks policy related develops including managing requires

The qualitative analysis of speeches also shed further light on the content of central banks' green speeches, highlighting the way in which climate change was being talked about in their communication and what role they envisaged for themselves in responding to it. The first key result that emerged from the qualitative analysis of speeches was a consensus on the fact that central banks cannot ignore the consequences of climate change on the economy and financial systems, and therefore must incorporate its effects into their functioning. Thus, the

main area of contention is not whether central banks should participate in the fight against climate change, rather to what extent is their participation considered 'acceptable' and not 'activist' or a case of 'mission creep' (Cochrane, 2020).

As for the content of the speeches, there emerges (more or less) a consensus among central bankers on the severity and scalability of the climate change problem, the relative role of various stakeholders in drafting climate change responses, and the type of role that is most appropriate for central banks in this regard.

Firstly, central bankers acknowledge and agree that putting a price on carbon is the first-best response to mitigate the adverse effects of climate change and facilitate a smooth transition to a low-carbon economy. However, this first-best solution is fraught with problems as evidenced by its history – the reluctance of all countries to levy a homogenous price on carbon thereby resulting in international businesses shopping for investments in countries with a lax environmental policy; the political problems associated with reaching an agreement on the operationalisation of carbon prices; and the ineffectiveness of cap-and-trade schemes in various countries.

Central bankers also recognise that devising climate policy is predominantly the domain of the government (elected policymakers) through fiscal policy and negotiating international agreements. But central bankers can also play a facilitative role in propelling the transition towards a green economy. The degree and nuances of this facilitative role differ somewhat in the articulation of different central bankers. An analysis of the speeches yielded five major categories of roles envisaged by central banks for themselves in the fight against climate change, in increasing order of their controversial nature.

The first role pertains to the undertaking of research and preparation of quantitative models (such as Integrated Assessment Models (IAMs) and DSGE) to understand the impact of climate change-related financial risks (CRFRs) on various macroeconomic and financial indicators. The risks posed by climate change are conceptually and epistemologically different from conventional financial risks posed to firms (such as credit risk, liquidity risk, market risk, operational risk) and to the financial sector (systemic risk) in that they contain no precedent or historical occurrence on which to base forecasts, and they are associated with radical uncertainty in terms of when critical climate tipping points will be reached and how they will impact economies (Gruenewald, 2020).

Building on niche research on CRFRs and their impact on the economy, the second role assumed by central banks is with regard to the creation of a harmonised set of rules and standards based on which individual firms and financial institutions can incorporate climate change associated risks into their operations and disclosures to investors. This role subsumes two key functions – first, arriving at an internationally agreed set of 'taxonomy' for defining what are green and brown assets respectively and how firms can incorporate these definitions into their balance sheets. Second, encouraging financial institutions to disclose the climate risks associated with their operations and assets, so that asset prices can fully reflect the associated climate risks and the information asymmetry with regard to climate risks is eliminated.

Central banks have also introspected and realised the need to practice what they preach. Thus, their third envisaged role pertains to the greening of their own functions which encompasses several dimensions. At the most basic level, it begins with central bank buildings and offices being eco-friendly and sustainable. On the operational side, there is an argument for central banks to tilt their reserves, collateral pledged by commercial banks, and portfolios, towards green assets. Most central bankers advocate for purchasing or investing in only those assets which abide by the consensually agreed-upon climate disclosures and excluding those which abhorrently invest in brown sectors.

The fourth role pertains to maintaining the policy objective of preserving financial stability in the face of climate risks. This is achieved through prudential policies (both macroprudential and micro-prudential) which have been increasingly used post-the 2008 global financial crisis to identify and guard against incipient endogenous or exogeneous systemic risks to the financial system. However, these prudential policies traditionally do not account for CRFRs. Therefore, progress in this area is with respect to the greening of macroprudential policies through tools such as climate-related stress testing, differential capital requirements for green and brown assets, and countercyclical capital buffers to get ahead of the 'carbon cycle'.[28]

The last and most controversial role of central banks to mitigate climate change involves its incorporation as a determining factor when devising monetary policy. The use of monetary policy is justified by climate change-related physical risks resulting in demand and supply-side shocks to the economy, which in turn affect output and prices in the short run, and productivity, employment, and inflationary expectations in the long run. Thus, central banks can no longer 'look through' inflationary episodes triggered by extreme weather events or an abrupt and messy decarbonisation process, because the increase in price level associated with supply shocks may no longer be temporary. They cannot, therefore, continue to set policies as before and must account for these climate-associated shocks.

Annex A

Evolution of speeches and policies by countries' development status

Having presented the aggregate trends in the evolution of green speeches and policies over time in Section 4.3 above, Figures A1 and A2 depict the disaggregated results for countries by their development status, viz. advanced and developing economies, respectively.[29] From these figures we can see that while all central banks have embarked on greening their financial and regulatory policies over time, there is a noticeable difference in their mentions of these policies in communications to the public and to their peers. In particular, we notice that advanced economy central banks have a visibly higher green speech index vis-à-vis developing country central banks, although the mentions have almost stabilised in recent years.

Annex B

Using alternate proxies of green speech score and green financial policy intensity

In this section, I first re-run the extended model using different versions of the green index. Whereas *greenindex1* considers a bigger universe of "green" words included in central bankers' speeches thereby yielding an upper bound to our coefficients, *greenindex3* provides the narrowest measure of considered green words and thus represents the lower bound of our results.

One of the most striking results evident from the results shown in Tables B-1 and B-2 is that the upper and lower bounds have reversed from the baseline model. The economic significance of the green-ness of speeches coefficient is consistently higher when we use the narrowest measure of green words (*greenindex3)*, compared to the broader measure *greenindex1*.

Table B1. Extended model with controls (lower bound).

Variables	(1) Green financial policy intensity	(2) Green policy intensity (Intensive margin)	(3) Green policy intensity (Extensive margin)
Greenindex1	8.556*	13.98	5.916
	(4.847)	(8.453)	(3.742)
Vulnerability	15.99	−6.645	−2.904
	(23.01)	(30.18)	(10.84)
Central Bank Independence	−1.569*	−3.762**	−0.974*
	(0.793)	(1.458)	(0.530)
Regulatory quality	−0.189	−0.285	0.0922
	(0.446)	(0.877)	(0.286)
Log Real GDP (USD constant)	−1.114	−4.995	−1.106
	(2.753)	(5.769)	(2.136)

(*Continued*)

Table B1. Continued.

Variables	(1) Green financial policy intensity	(2) Green policy intensity (Intensive margin)	(3) Green policy intensity (Extensive margin)
Log GDP per capita	1.937	4.763	0.380
	(3.006)	(6.454)	(2.219)
Capital account	−0.420***	−0.488*	−0.152
Openness	(0.135)	(0.271)	(0.108)
Trade-to-GDP ratio	−0.00668	0.00162	−0.00110
	(0.00794)	(0.0162)	(0.00523)
Private credit extended	−0.00826**	−0.0170**	−0.00832***
By Banks (% GDP)	(0.00352)	(0.00704)	(0.00227)
Constant	8.018	95.43	28.97
	(51.37)	(102.6)	(38.87)
Observations	466	466	466
R-squared	0.552	0.528	0.572
Number of countries	28	28	28
Fixed Effects	YES	YES	YES

Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table B2. Extended model with controls (upper bound).

Variables	(1) Green financial policy intensity	(2) Green policy intensity (Intensive margin)	(3) Green policy intensity (Extensive margin)
Greenindex3	45.33***	56.57**	28.28***
	(13.21)	(21.38)	(6.191)
Vulnerability	16.86	−5.369	−2.328
	(22.59)	(29.96)	(10.80)
Central Bank	−1.472*	−3.626**	−0.911*
Independence	(0.754)	(1.467)	(0.506)
Regulatory quality	−0.226	−0.321	0.0711
	(0.458)	(0.901)	(0.292)
Log Real GDP	−0.565	−4.140	−0.734
(USD constant)	(2.809)	(5.789)	(2.075)
Log GDP per capita	1.318	3.792	−0.0414
	(3.058)	(6.468)	(2.146)
Capital account	−0.410***	−0.474*	−0.145
Openness	(0.131)	(0.265)	(0.105)
Trade-to-GDP ratio	−0.00553	0.00357	−0.000291
	(0.00782)	(0.0159)	(0.00494)
Private credit extended	−0.00830**	−0.0173**	−0.00840***
By Banks (% GDP)	(0.00352)	(0.00710)	(0.00231)
Constant	−1.122	81.28	22.79
	(52.20)	(103.1)	(38.04)
Observations	466	466	466
R-squared	0.555	0.525	0.572
Number of countries	28	28	28
Fixed Effects	YES	YES	YES

Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Constructing newer iterations of the green speech score using NLTK approach

In this section, I construct new iterations of the green speech score, Greenindex4 and Greenindex5, using the nltk package on Python and expand the subset of 'green' words used to compute the numerator while also excluding pre-specified unigrams and bigrams that may refer to 'green' words being used in a non-environmental context.

The 'green' words included to compute the numerator are as follows:
Greenindex4 → 'climate', 'sustainable', 'green', 'carbon', 'renewable'
Greenindex5 → 'climate', 'green', 'carbon', 'renewable'

Both iterations of the green speech score also exclude unigrams such as 'greener', 'greenspan', and 'eichengreen', and bigrams such as 'investment climate', 'business climate', 'sustainable employment', and 'sustainable growth'. The choice of 'green' words to be included and unigrams and bigrams to be excluded was predicated upon the list of bigrams obtained from the speeches using NLP techniques.

I use greenindex4 and greenindex5 to replicate the main results obtained in the paper (shown in Tables B3 to B5 below). Although I find that the correlation between climate-related speeches and policies continues to hold using these newer measures (confirming our main findings), the evidence on the temporality of speeches and policies is weaker. In Table B3, I find that the green speech score leading by one period is positive and weakly statistically significant in column 1, but not in columns 2 and 3. In Table B4, I find that neither the leads nor lags of the green speech score are statistically significant. However, probit model results presented in Table B-5 continue to remain statistically insignificant, suggesting that green speeches are not a significant predictor of the uptake of green policies by central banks, and this corroborates our probit model results in Section 5.3 of the manuscript.

Table B3. Impact of leads and lags of Green index of Speeches (Greenindex4) on green policy intensity.

Variables	(1) Green financial policy intensity	(2) Green policy intensity (Intensive margin)	(3) Green policy intensity (Extensive margin)
Greenindex4	25.25**	33.86**	7.919*
	(11.90)	(14.70)	(4.424)
$Greenindex4_{t+1}$	9.671*	9.232	−0.261
	(5.278)	(11.93)	(3.923)
$Greenindex4_{t-1}$	−6.392	−10.67	1.344
	(8.093)	(15.67)	(4.345)
Vulnerability	6.134	−24.59	−6.782
	(19.46)	(29.41)	(11.07)
Central Bank	−2.290**	−5.092*	−0.935
Independence	(1.079)	(2.665)	(0.774)
Regulatory quality	−0.252	−0.365	0.0983
	(0.484)	(0.976)	(0.327)
Log Real GDP	−1.154	−5.577	−1.299
(USD constant)	(3.211)	(7.052)	(2.526)
Log GDP per capita	1.633	4.727	0.362
	(3.625)	(8.011)	(2.643)
Capital account	−0.603***	−0.806***	−0.262**
Openness	(0.0954)	(0.218)	(0.102)
Trade-to-GDP ratio	−0.00427	0.00792	0.00158
	(0.00644)	(0.0143)	(0.00434)
Private credit extended	−0.00949**	−0.0196**	−0.00974***
by Banks (% GDP)	(0.00412)	(0.00866)	(0.00248)
Constant	16.70	120.3	36.15
	(56.68)	(121.7)	(45.30)
Observations	422	422	422
R-squared	0.605	0.569	0.600
Number of countries	27	27	27
Fixed Effects	YES	YES	YES

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
[1]Green financial policy intensity measures the intensity of implementation only of all green financial policy tools by central banks.
[2]Green policy intensity (intensive margin) measures the upper bound or intensity of all green financial, monetary and additional policy tools implemented by central banks.
[3]Green policy intensity (extensive margin) measures the lower bound or the number of discrete green financial, monetary or additional policy tools implemented by central banks.

Table B4. Impact of leads and lags of Green index of speeches (Greenindex5) on green policy intensity.

Variables	(1) Green financial policy intensity	(2) Green policy intensity (Intensive margin)	(3) Green policy intensity (Extensive margin)
Greenindex5	53.81**	50.13*	15.10
	(19.45)	(27.17)	(9.768)
$Greenindex5_{t+1}$	0.532	−6.661	−3.494
	(7.056)	(9.956)	(2.295)
$Greenindex5_{t-1}$	16.64	11.59	8.446
	(20.55)	(30.61)	(11.00)
Vulnerability	2.432	−26.74	−7.891
	(20.46)	(31.80)	(10.92)
Central Bank	−2.549**	−5.499**	−0.962
Independence	(1.063)	(2.657)	(0.787)
Regulatory quality	−0.142	−0.221	0.141
	(0.516)	(1.039)	(0.346)
Log Real GDP	−1.259	−5.402	−1.316
(USD constant)	(3.401)	(7.283)	(2.575)
Log GDP per capita	1.713	4.511	0.371
	(3.778)	(8.205)	(2.679)
Capital account	−0.639***	−0.841***	−0.271**
Openness	(0.102)	(0.223)	(0.101)
Trade-to-GDP ratio	−0.00192	0.0102	0.00214
	(0.00720)	(0.0151)	(0.00441)
Private credit extended	−0.00953**	−0.0206**	−0.00991***
by Banks (% GDP)	(0.00395)	(0.00852)	(0.00253)
Constant	20.09	118.6	36.90
	(59.96)	(126.0)	(46.32)
Observations	422	422	422
R-squared	0.600	0.562	0.599
Number of countries	27	27	27
Fixed Effects	YES	YES	YES

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
[1]Green financial policy intensity measures the intensity of implementation only of all green financial policy tools by central banks.
[2]Green policy intensity (intensive margin) measures the upper bound or intensity of all green financial, monetary and additional policy tools implemented by central banks.
[3]Green policy intensity (extensive margin) measures the lower bound or the number of discrete green financial, monetary or additional policy tools implemented by central banks.

Table B5. Probit model – impact of green speeches on probability of green policy adoption.

Variables	(1) gfp_binary	(3) gfp_binary
Greenindex4	−21.17	
	(51.39)	
Greenindex5		−8.881
		(73.51)
Vulnerability	−52.84	−46.12
	(87.98)	(67.19)
Central Bank Independence	8.753	7.220
	(11.73)	(10.67)
Regulatory quality	3.116	1.473
	(3.825)	(2.537)
Log Real GDP (USD constant)	6.688	5.405
	(8.180)	(4.385)
Log GDP per capita	−8.713	−5.029
	(11.63)	(6.941)
Capital account Openness	2.964	1.778
	(4.255)	(3.069)
Trade-to-GDP ratio	0.0334	0.0114
	(0.0535)	(0.0404)
Private credit extended by Banks	0.0522	0.0348
(% GDP)	(0.0788)	(0.0444)
Constant	−117.8	−112.1
	(150.7)	(104.1)
Observations	1,313	1,313
Number of countries	80	80
Random Effects	YES	YES

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
[1]gfp_binary is a binary variable constructed such that it takes on a value of 0 for all those countries which have never adopted a green financial policy from 2000 to 2021, and 1 for those which have, beginning with the year in which the policy was first implemented.

However, a caveat associated with the construction of these newer versions greenindex4 and greenindex5 is with regard to the suitability of the method used and the relatively greater popularity of the Document Term Matrix (DTM) approach in providing us a thorough and broad analysis of term frequencies across a corpus (Benchimol et al., 2022; Gupta & Guha, 2016). Whereas the DTM Method is beneficial for a broad, comprehensive view of term frequencies across all documents, providing detailed statistical insights into term usage patterns, which is our goal here, the NLTK Approach excels in customization and targeted analysis, offering the flexibility to focus on specific terms and filter out less relevant or noisy data.

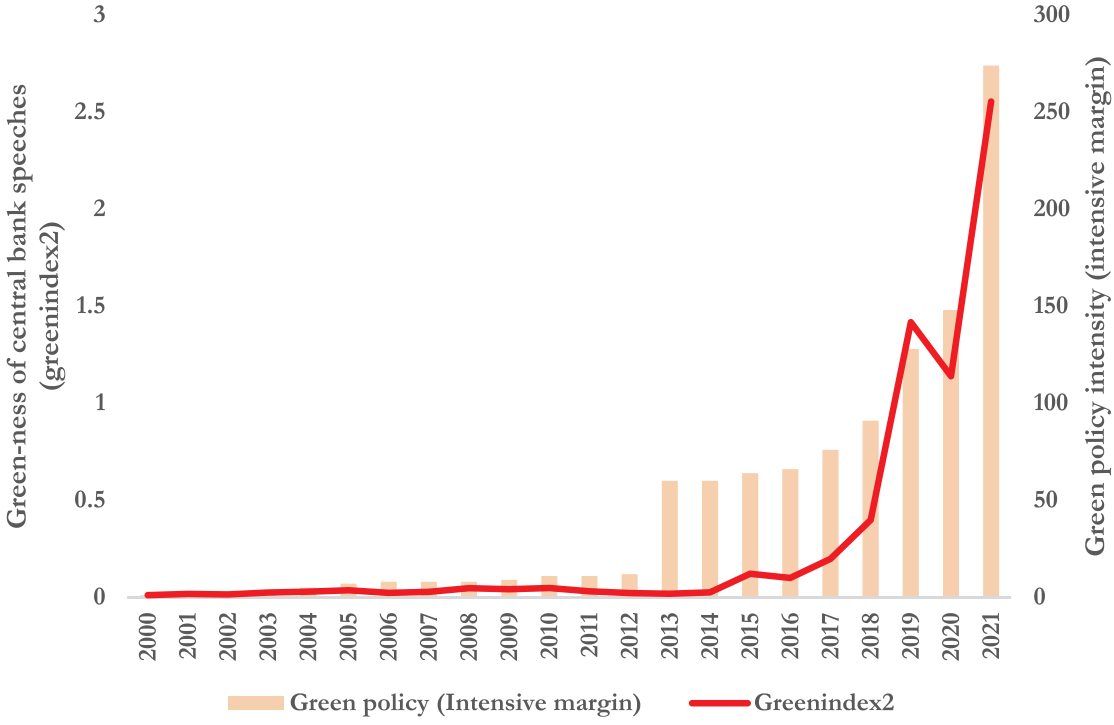


Figure A1. Advanced economy central banks' green speeches and policies.

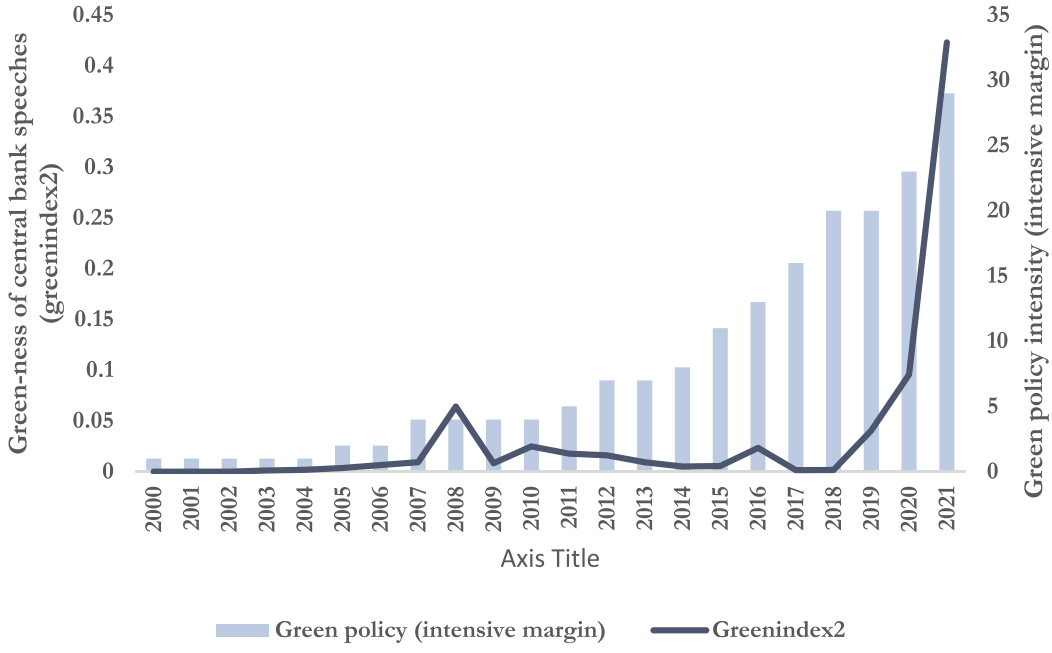


Figure A2. Developing economy central banks' green speeches and policies.