CEC Dauphine | PSL

N°2023 – 09 • DECEMBER 2023

WORKING PAPER

Don’t Lead Me This Way: Central Bank Guidance in the Age of Climate Change

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This paper delivers a two-pronged analysis: first, it harnesses topic modeling to unravel the European Central Bank (ECB)’s climate change dialogue from 1997 to 2021, revealing a sharp focus on climate risk from 2013, peaking in 2018 onward. Second, it connects the dots between this heightened ECB rhetoric and the default probabilities for North American firms, as mirrored in CDS spread returns. A quantile regression analysis reveals a compelling dynamic: in the short run, ECB climate talk tempers default risks, fades in the medium run, but significantly drives up long-term risk. Our results, robust across various event studies, spotlight the power of central bank communication in steering market dynamics and flag industries poised for a green transition.

JEL CODES: E52; E58; G28; G32 ; Q54

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Acknowledgments*: We extend our sincere thanks to experts from ACPR Banque de France, and other scholars and experts at the Conference on Climate and Finance and at the GRASFI Conference, for their invaluable insights on our paper. Their constructive feedback, especially on methodology, has enhanced the quality of our research. We appreciate their intellectual contributions and collaborative spirit in advancing economic research.*

KEYWORDS

Climate change | Central banking | Monetary policy | Credit risk | ECB | Credit default swap | Regulation

Executive summary

In recent years, a growing body of scientific publications, exemplified by the six IPCC Reports published between 1990 and 2023, presents unequivocal evidence of the impending impact of climate change on the entirety of our economic system. Since the endorsement of the Paris Agreement in 2015, there has been a notable upswing in global acknowledgment of climate change as a disruptive force within the economic structure and financial system. The adverse shocks affecting both the supply and demand functions of the real economy serve as vectors of instability within the financial system. The imperative shift from a high- to a low-carbon economic system, as stipulated by net-zero carbon emissions policies, necessitates a profound transformation of our productive system. All stakeholders, including central banks, must actively participate in this transformative process. The significant surge in the membership of the Network for Greening the Financial System, from 8 in December 2017 to 121 in October 2022, stands as compelling evidence of central banks recognizing climate change as a growing threat meriting continuous vigilance. Despite climate change not traditionally falling within the customary purview of central banks' mandates for price and financial stability, an expanding body of research underscores the profound linkages between climate change, the financial system, and the real economy. Contrary to neglect, central banks have proactively embarked on communication efforts to address the multifaceted implications of climate change.

This study examines the communication strategies of the European Central Bank (ECB) regarding climate change and investigates the potential impact of the ECB's perception of climate change on financial market actors. Analyzing a database of 2,430 speeches by ECB Executive Board Members from January 1997 to December 2021, our textual analysis and topic-modelling algorithm identify 70 topics, with a notable increase in the frequency of a topic labeled "Climate Change" since mid-2018. Within this topic, the most frequently used words include "risk," "climate," "change," "transition," and "green." Our findings indicate an augmented emphasis on climate change in ECB communications, particularly framing it as a risk to financial stability. This suggests that the ECB employs its communication as a signal to financial markets, signaling a potential regulatory response to address and mitigate the impacts of climate change on the financial system. We then use panel quantile regression to isolate the impacts of an increase in ECB communication on the topic of climate change on the expected probability of default for 168 firms (proxied by their CDS spread returns). We investigate 5-, 10- and 30-year contracts. Our findings show an overall positive relationship between lenders' perceived exposure to a regulatory risk from the ECB and the firms' cost of default protection. In addition, we include sector dummies and interaction terms with our communication variable in our baseline quantile regression and show proof of the existence of nonlinear effects across the short, medium and long term. Our findings show significant and negative coefficients on the short term (5-year maturity), that prove that market actors seem to have integrated a potential implementation of regulation coming from the ECB to mitigate the effects of climate change on financial markets. These results also prove that firms are already seen as capable of transitioning to a low-carbon economy in the short term. In the medium term (10-year maturity), our estimated coefficients are all non-significant, it seems that financial actors are uncertain of how the ECB will act regarding climate risk. Finally, in the long-term (30-year maturity), our estimated coefficients are positive and strongly significant. CDS market participants expect a higher probability of default for firms across all sectors in the very long-term with the increase in ECB communication on climate change.

Overall, we highlight how ECB communication can impact investors' expectation of the probability of different firms defaulting at different time horizons. Our findings are particularly relevant to the regulation of climate risk. Our findings also have important policy implications. They suggest that firms are ready to transition in the short term, and that central banks should take a more active role to help this transition to a low-carbon system, even by using regulatory tools. Not taking action now will raise uncertainty about climate change impacts on financial markets, leading to a rise in the probability of firms defaulting, which could be the detonator of a new financial crisis.

1 Introduction

Since the adoption of the Paris Agreement in 2015, climate change has been extensively acknowledged as a harbinger of economic and financial instability. The increasing membership of the Network for Greening the Financial System (from 8 in December 2017 to 121 in October 2022) underscores central banks' acknowledgment of climate change as an imminent threat requiring vigilant oversight.[1]

Central bank communications have long been proven to be an effective monetary tool to guide markets' expectations on the future path of overnight interest rate.[2] Since the 2007-2008 financial crisis, the strategic deployment of 'forward-guidance' has come to the fore as an unconventional yet critical monetary policy tool (Swanson, 2021; Ehrmann & Fratzscher, 2007). Beyond monetary cues, central bank pronouncements also offer a window into their overarching goals, strategies, and economic forecasts (Haldane & McMahon, 2018; Kryvtsov & Petersen, 2021).

While climate change historically falls outside the traditional central bank mandates of price and financial stability, the interplay between climate-induced financial risk and economic impact is garnering increasing evidence and attention. This evolving landscape calls for more refined data to shape monetary and prudential instruments (Campiglio et al., 2018; Chenet et al., 2021; Weitzman, 2009). But far from ignoring it, central banks are no longer sideline spectators; their communications now integrate climate change, amplifying their credibility[3] and influence on market stability (Hansen, 2022).

Our research scrutinizes the European Central Bank's (ECB) discourse on climate change and its influence on financial market actors. Through textual analysis of 2,430 ECB Executive Board speeches from January 1997 to December 2021, we deploy machine learning topic modeling to extract thematic prominence. In total 70 topics can be identified, with 'Climate Change' surging forth as a dominant topic post-2013, especially from 2018 onwards. Our focus highlights the ECB's lexical choices–'risk', 'climate', 'change', 'transition', and 'green'–painting a picture of their narrative stance.

We present a threefold contribution. First, we innovate by applying advanced machine learning topic modeling to ECB communications. Second, our findings reveal the ECB's escalating emphasis on climate discourse. Third, we interpret the ECB's characterization of climate change as a financial stability 'risk', signaling intent to shape market expectations and strengthen financial resilience against a backdrop of anticipated regulatory shifts favoring green investments.

[1] Dikau and Volz (2021) highlight significant differences in how climate objectives do and do not fit within central banks mandates across different countries.

[2] See, for example, Blinder et al. (2008) for an early survey of the literature.

[3] See (Bholat et al., 2015) for a discussion on the credibility of central banks.

The ripple effect of ECB climate communication on financial actors forms the crux of our second inquiry. We propose three testable hypotheses to study how climate regulatory risks, as measured by communications, are mirrored in the market pricing of firms' credit default swap (CDS) contracts, impacting credit risk across industries. Credit default swaps are derivatives that offer insurance against the risk of a bond issuer - such as a company, a bank or a sovereign government - not paying their creditors. Bond investors hope to receive interest on their bonds and their money back when the bond matures. But they have no guarantee either of these things will happen and so have to bear the risk of holding that debt. CDS thus help to mitigate the risk by providing a form of insurance. In particular, CDS spreads serve as proxies for market-perceived risk and the financial solidity of firms for several reasons. Their trade on standardized terms allows for heightened sensitivity to new market information. Their liquidity surpasses that of corporate bonds. Lastly, with maturities extending up to 30 years, they provide insights into lenders' assessments of future risk.

Our analysis questions whether ECB portrayal of climate risk permeates firms' default risk perceptions, inferred through CDS spread movements. We investigate the influence of ECB climate change communications on CDS spreads. We analyze CDS data from 168 North American firms across 10 sectors, with maturities of 5, 10, and 30 years. This analysis aims to discern how ECB's increasing focus on climate-related issues shapes investor expectations regarding the default probabilities of firms in various industries and across different time horizons.

Following Blasberg et al. (2021), we adopt a panel quantile regression approach to encapsulate the full distributional impact of ECB climate communications on CDS spread returns, controlling for established fundamental determinants (Han & Zhou, 2015; Hull et al., 2004). This methodology also presents the advantage of mitigating empirical problems frequently encountered in the CDS literature (e.g. non-normality and the presence of outliers) that could also affect our data.

Our findings are novel with respect to the existing literature: ECB climate narratives exert a significant, sector-wide influence on CDS spreads, with acute effects on short-term securities (5-year maturity). The short-term results suggest that markets are discounting the potential of future ECB regulations aimed at climate risk mitigation, while in the medium term (10-year maturity), there is marked uncertainty. Long-term expectations (30-year maturity), however, reflect a stark anticipation of default risk escalation in tandem with increased ECB climate communications.

Overall, we elucidate ECB climate change dialogue as a determinant of investor expectations regarding firm default probabilities over varying time frames. These insights are pivotal to understanding the dynamics of climate transition risks.

The rest of the paper is organized as follows. Section 2 offers a comprehensive literature review that contextualizes our research within the existing academic discourse. Section 3 delineates

our novel contribution using Natural Language Processing to examine ECB speeches. Section 4 outlines the empirical methodology that connects ECB climate communication with firm credit risk. Our empirical findings are explored in Section 5. Section 6 extends the analysis by providing additional results and conducting robustness checks. The paper concludes with Section 7.

2 Literature Review

In this section, we highlight our contribution by aligning the impact of ECB greening narratives with various strands of literature. We offer insights into climate transition risk and explain the rationale behind considering central bank communication as a crucial factor in understanding its forward-looking impact on credit risk, which is one dimension of transition risks. Finally, we delve into the core of our paper by addressing our testable hypotheses.

2.1 Climate Transition Risk and ECB communication

Climate transition risk (CTR) stems from shifts in regulations, technological advancements, and evolving consumer attitudes that facilitate the move toward a low-carbon economy. Such shifts can jeopardize cash flows, thereby influencing a firm's capacity to service its debt and consequently elevating its overall risk profile. To gauge this vulnerability, it is essential to scrutinize how carbon risks permeate firms operations, products, services, and supply chain — all of which vary significantly based on the firm's sector. Existing literature often quantifies CTR through carbon risk pricing models. In these models, firms with high emissions are generally more susceptible to incurring additional costs due to regulatory changes and necessary adjustments to their product offerings. Numerous studies have proposed market-based CTR metrics, focusing on portfolio allocation (Alessi et al., 2021; Blasberg et al., 2021; H. Jung et al., 2021; Pástor et al., 2021; and Gourdel & Sydow, 2022), fund flows (Briere & Ramelli, 2022), and the Sustainalytics carbon risk Index (Ugolini et al., 2023). These metrics primarily assess the impact on investment choices and financial instruments[4]. However, the tangible effects of climate transition risk continue to be a forward-looking, somewhat abstract concept, largely influenced by perceptual beliefs rather than empirically substantiated impacts.

Our approach distinguishes itself from previous research by anchoring its analysis in the narrative literature. Specifically, we examine the role of central bank communication as an indicator of carbon transition risk and its subsequent influence on investors' perceptions of climate change risk. This analytical angle is motivated by several factors. First, although the tangible

[4]See, Krueger, Sautner, and Starks (2020); Reboredo and Otero (2021); Ilhan, Sautner, and Vilkov (2021); Bolton and Kacperczyk (2020); Monasterolo and de Angelis (2020); Painter (2020); and Reboredo and Ugolini (2022)).

outcomes of climate change remain uncertain, existing literature has extensively explored the influence of narratives–from both media and professionals–on shaping investors' perceptions of risk and uncertainty (Engle et al., 2020, Bessec & Fouquau, 2022, and El Ouadghiri et al., 2021). Second, from a regulatory perspective, central banks serve as critical agents in shaping market expectations and providing guidance to financial market participants (Morris & Shin, 2002). Previous research has underlined the signaling function of central banks in financial markets, both under normal conditions (Cross & Greene, 2020; D'Orazio & Popoyan, 2019; and Bennani et al., 2020), and during uncertain times (Gardner et al., 2022). Third, in the context of environmental sustainability, the ECB has taken a leading role in climate change policy, aligning its stance with the obligations set forth in the EU Treaty (Feldkircher et al., 2021; Dikau & Volz, 2021; Campiglio et al., 2018; Chenet et al., 2021; and Arseneau et al., 2022). This pattern increases the significance of examining central banks, and the ECB in particular, as key players in the ongoing climate change discourse.

Furthermore, existing research has largely centered on stock markets (Bolton & Kacperczyk, 2020), bond markets (Seltzer et al., 2022; Zhan et al., 2023; Kleimeier & Viehs, 2018; and Vozian, 2022), and option prices (Ilhan et al., 2021) to study transition risk. However, there are recent exceptions that bear some resemblance to our work, albeit from differing perspectives. This new strand of studies suggests that assessing credit risk exposure via credit default swap spreads is crucial for evaluating the impact of carbon transition risk on firms. Firms must estimate expected credit losses to comply with accounting standards and unexpected credit losses to determine regulatory credit risk capital. Both rely on estimates of probabilities of default. Investors also pay close attention to credit ratings and default rates. Changes in climate will increase firm default rates. Studies investigating the impact of climate change on default probabilities are limited because this is a novel field and data are still relatively scarce. For example, Blasberg et al. (2021) introduce a carbon risk factor based on median CDS spreads and examine its influence on firms in Europe and the United States. Kölbel et al. (2020) used text analysis to discover that disclosure of transition risks led to increased CDS spreads, while physical risks had a contrary effect. Ugolini et al. (2023) underscore the asymmetric consequences of carbon transition risk factors on CDS spreads, revealing both economically and statistically significant impacts. Focusing on Environmental, Social, and Governance (ESG) factors, Duong et al. (2022) demonstrate that effective carbon risk management leads to reduced CDS spreads. Finally, Barth et al. (2022) find that enhanced ESG ratings were associated with a decrease in firms' credit risk, as evidenced by lower CDS spreads.

The transmission channels that link risk exposure via credit default swap spreads and carbon transition risk are detailed in the following Section.

2.2 CDS and ECB speeches: hypothesis development

To summarize, our primary focus lies in evaluating whether communications about CTR from the ECB significantly influence the market's perception of default probability, as evidenced by CDS spreads. We specifically aim to examine a core assertion made by Blasberg et al. (2021), which suggests that, *"When policy events trigger a rise in carbon risk (e.g. expectation of a tighter future regulatory framework), the demand for protection of more (less) exposed firms increases (decreases), resulting in a widening of the wedge. Conversely, if the market expects a loosening of the regulatory framework, there is a narrowing of the wedge (or possibly even a negative wedge)"*. From our standpoint, ECB speeches are important guides for investors looking to hedge against CTR for international firms, predicated on the notion that central bank communications have global spillover effects (Armelius et al., 2020). We outline our testable hypotheses below and depict the channels of propagation in Figure 1.

Hypothesis 1. *Climate regulatory risk, as gauged by ECB climate-related communications, has a positive impact on credit default swap spread for North American firms.*

We contend that ECB public remarks on climate change serve as a form of forward guidance, shaping investor strategies for evaluating long-term climate risks. We hypothesize that increased ambiguity in climate policy and immediate vulnerabilities will likely prompt actions from central banks. A greater emphasis in ECB communications on climate issues indicates heightened perceived regulatory risk, encouraging demand for CDS and thereby exerting upward pressure on CDS spread. Given the transatlantic spillover effects of central bank communications (Armelius et al., 2020), we anticipate that North American investors will adjust their strategies based on ECB communications, expecting that the Federal Reserve might adopt a similar stance.

Hypothesis 2. *The impact of climate regulatory risk on maturity is both significant and positive, exhibiting a pronounced effect over short-term horizons and diminishing in significance over medium- and long-term horizons.*

We then explore how the time horizon of new ECB regulations impacts climate regulatory risk. For example, if immediate compliance is required for new regulations, the costs of short-term transition will likely be elevated compared to longer time frames. We therefore anticipate a decline in the statistical significance of the estimated coefficients as maturity tenors lengthen.

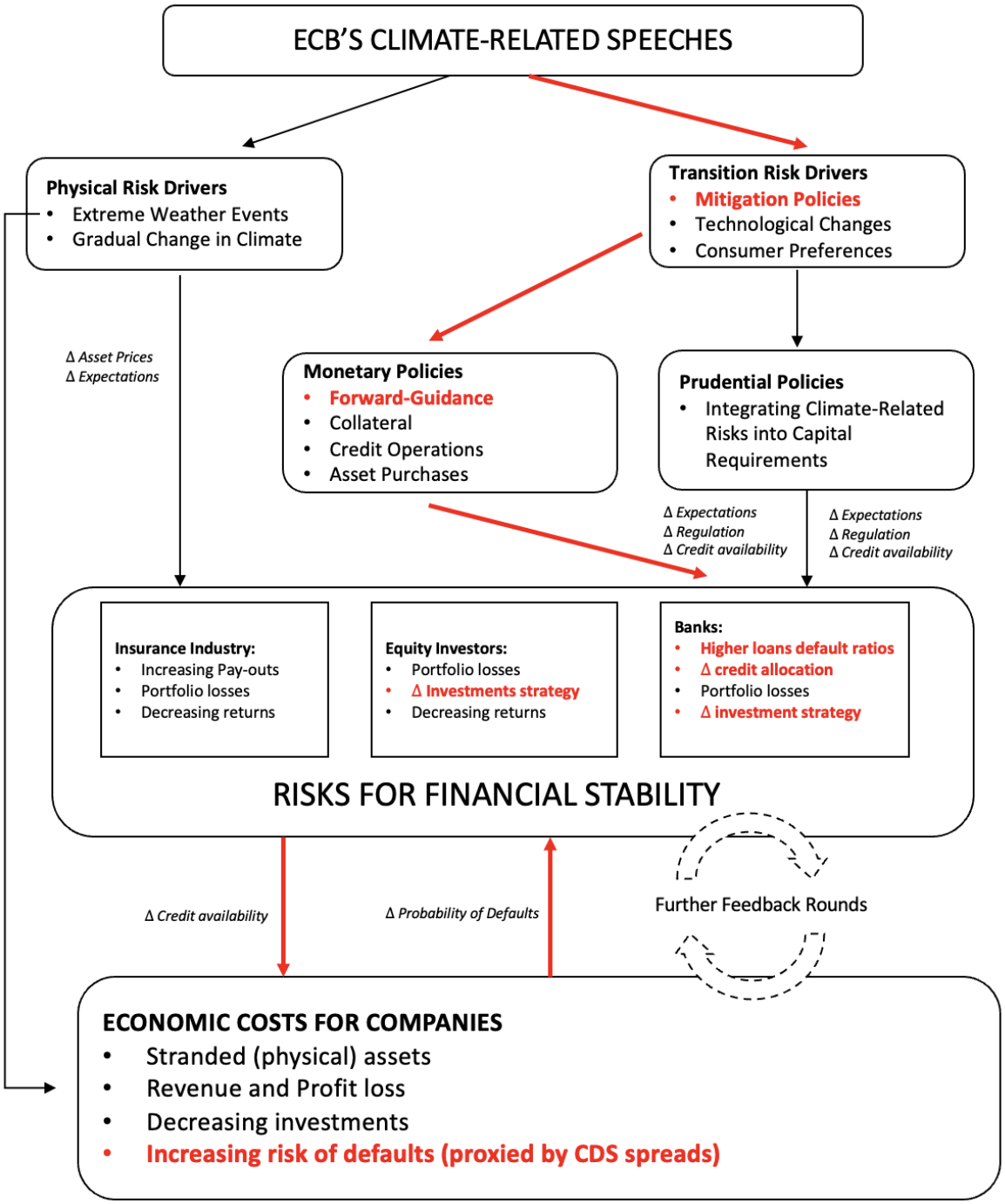
Hypothesis 3. *Carbon-intensive industries are more affected by climate regulatory risk than low-intensity firms, particularly in the short term.*

Existing literature has emphasized sectoral exposure to transition risks (Dietz et al., 2016; Dietz et al., 2020). Accordingly, we posit that carbon-intensive sectors, such as energy and basic materials, are more susceptible to climate regulatory risk and stranded assets relative

to low-intensity sectors.

To encapsulate our discussion, Figure 1 illustrates the transmission pathway from ECB climate-related communications to the amplified default risks for firms, represented in red.

Figure 1: Schematic View of the Chain of Transmission from ECB Communication on Climate Change to its Impacts



Note: This figure illustrates the chain of transmission from ECB communication on the topic labeled "Climate Change" to its impacts on the financial system. The legend indicates that the transmission channel studied in this research is highlighted in red, and Δ signifies "change in."

3 Measuring climate risk with ECB communication

This section details our approach to measuring climate-related ECB communication, which serves as a proxy for forward-looking climate risk. First, we describe our ECB speeches database and discuss the natural language processing algorithm we used to model climate communication. Second, we analyze the content and change over time of the estimated ECB climate narratives, as well as the connection with other macroeconomic-oriented topics.

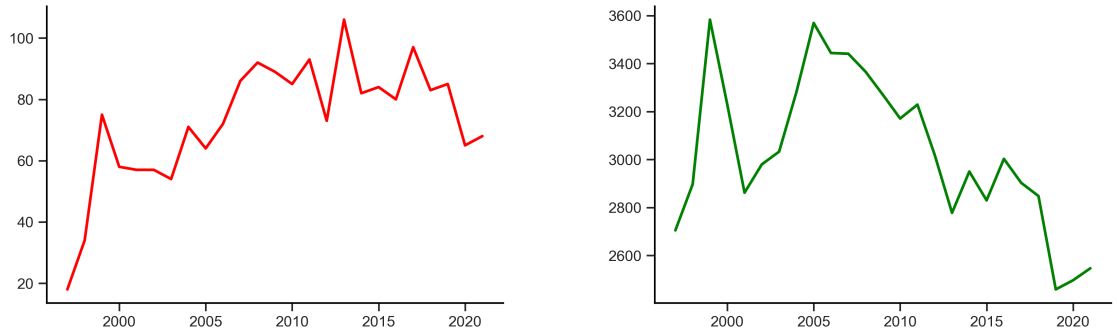
3.1 From speeches to data: A topic model approach

We rely on speeches from ECB Executive Board Members (and related figures), extracted from the institution's website.[5] The data corpus spans the period from February 1997 to December 2021, encompassing a total of 2,430 speeches, including all announcements from representative members of the institution. Due to varying frequency of communication based on the economic context, our corpus is slightly unbalanced. Irregularities are manifested in two forms: (i) time gaps ranging from more than a day to less than a week between two speeches, and (ii) more than one speech occurring in a single day. While problem (i) is discussed in Section 4, we address problem (ii) by aggregating speeches within the same day. After excluding non-English speeches and non-topical talks, our final corpus consists of 1,829 announcements spanning the period from February 7th, 1997 to December 10th, 2021. The left panel of Figure 2 shows the annual total number of ECB speeches over the period under consideration. The speech count increases steadily until 2007 and then plateaus, before experiencing a gradual decline starting in 2017. On the other hand, the right panel of Figure 2 reveals a sharp increase in the average length of speeches, rising from approximately 2,700 words to around 3,600 words between 1997 and 1999, and maintaining a substantial decrease from 2005 onward.[6]

[5] https://www.ecb.europa.eu/press/key/html/downloads.en.html

[6] Additional descriptive statistics can be found in Appendix A.1.

Figure 2: Temporal Distribution of ECB Speeches from 1997 to 2021



Note: This figure reports the annual total number of ECB speeches (left panel) and the average number of words per speech (right panel) for the period from 1997 to 2021.

To ensure consistent communication measures from ECB speeches, we implement an unsupervised probabilistic topic models approach. Among various topic models, we opt for a mixed-membership algorithm akin to Blei et al. (2003)'s Latent Dirichlet Allocation (LDA). This approach considers each document (speech) as a mixture of topics, with each topic being characterized as a mixture of words. Although LDA has shown efficiency across several fields, it does suffer from limitations, such as the assumption of independent topics within documents/speeches over time (uncorrelated). However, it is reasonable to expect highly correlated subsets of latent topics. In our ECB speeches corpus, a speech about monetary policy may involve interest rates and inflation but may not be related to climate change. To overcome this limitation, we adopt the Structural Topic Model (STM) proposed by Roberts et al. (2013).

Similarly to LDA, STM estimates two primary quantities: topic proportions θ_d for each document $d \in 1, 2..., D$ (document-topic probability distributions), and word proportions β_k for each topic $k \in 1, 2..., K$ (topic-word probability distributions). However, the estimation procedure for these quantities makes the assumption of a Logistic-Normal distribution and a multinomial logit model. This facilitates capturing dependencies between topic distributions. Another advantage of STM is its capability to condition topic and word distributions on exogenous factors captured in the covariance matrix. Given our focus on the consequences rather than the causes of ECB communications, we exclude exogenous factors from topic modeling.

The intuitive procedure is as follows:

1. Assign all topics to a document/speech by randomly providing it with a distribution over topics from a Logistic-Normal distribution as:

$$\theta_d \mid X_{d\gamma}, \Sigma \sim Logistic - Normal(\mu = X_{d\gamma}, \Sigma)$$

where X_d represents a vector of covariates, $\gamma \sim N(0, \sigma_k^2)$ is a matrix of coefficients, and Σ signifies the covariance matrix.

2. For each word in the document/speech:

   - Select one topic from the distributions chosen in step 1.
   - Given that topic, randomly choose a word from this topic using a multinomial logit distribution:

   $$\beta_{d,k} \propto exp(m + \kappa_v^k + \kappa_v^y + \kappa_v^{y,k})$$

   where m is the baseline word frequency, and $(\kappa_v^k + \kappa_v^y + \kappa_v^{y,k})$ denotes a collection of coefficients representing topic (κ_v^k), covariates (κ_v^y), and topic-covariate interaction $(\kappa_v^{y,k})$. These coefficients are further characterized by $\kappa_v^{y,k} \sim Laplace(0, r_v^{y,k})$, with $r_v^{y,k} \sim Gamma(s^\kappa, r^\kappa)$.

3. Iterating over steps 1 and 2 generates a set of documents/speeches described by the set of topics that best represent each document.

3.2 ECB climate change narratives

The document-term matrix is sized (1829 x 16,992,663), featuring 94% scarcity. To address the challenge of high-dimensionality and data scarcity in computing the ECB climate change narrative, we preprocess the data sample to remove irrelevant terms. This includes the elimination of stopwords[7] such as 'but', 'is', 'a', numbers, punctuation, given names, and surnames. We then convert the remaining words into their linguistic roots.

As suggested by Roberts et al. (2016), we employ a semi-collapsed variational EM algorithm to estimate the topics within our processed speeches database. For additional details, refer to Blei et al. (2003) and Roberts et al. (2016). Given that mixed-membership topic models are unsupervised, a crucial task is determining the latent space dimension, i.e., the number of topics K to consider per speech. Following the discussion by Chang et al. (2009), we must strike a balance between topic interpretability (lower K) and statistical performance (higher K) during the estimation process. We explore a range of values for K, from 10 to 80, and compute various statistical criteria (see Appendix B.1). These lead us to optimally converge on $K = 70$ topics. We generate topic and word distributions using a 70-topic STM applied to ECB announcements from February 1997 to December 2021. The labels for each topic are based on the most probable words and bigrams, as detailed in Appendix B.2.

[7] For the full list of stopwords see http://snowball.tartarus.org/algorithms/english/stop.txt.

To provide an overview of the main ECB narratives, Figure 3 presents top keywords from selected topics along with corresponding labels (see Appendix B.2 for a discussion). Notably, a majority of topics revolve around the bank's primary missions, including payment systems (Topic 3), monetary policy and price stability (Topics 11 and 64), exchange rates (Topic 29), and bank supervision (Topic 16). Intriguingly, within the set of macro-oriented topics, one narrative stands apart: Topic 56, labeled "Climate Change, Climate Risk, and Green Bond." A closer examination of the word distribution within this topic reveals that, although not directly aligned with its mandate, the ECB perceives climate change as a significant source of (forward-looking) risk and uncertainty for the financial system. Key terms within this context include "climate," "risk," "change," "bank," "green," "will," "transition," "financial," "need," and "can."

Figure 3: Selected Narratives from ECB Speeches

(a) Topic 3: Payment System

(b) Topic 11: Price Stability

(c) Topic 16: Bank Supervision

(d) Topic 29: Exchange Rate

(e) Topic 56: Climate Change, Risk & Green Bond

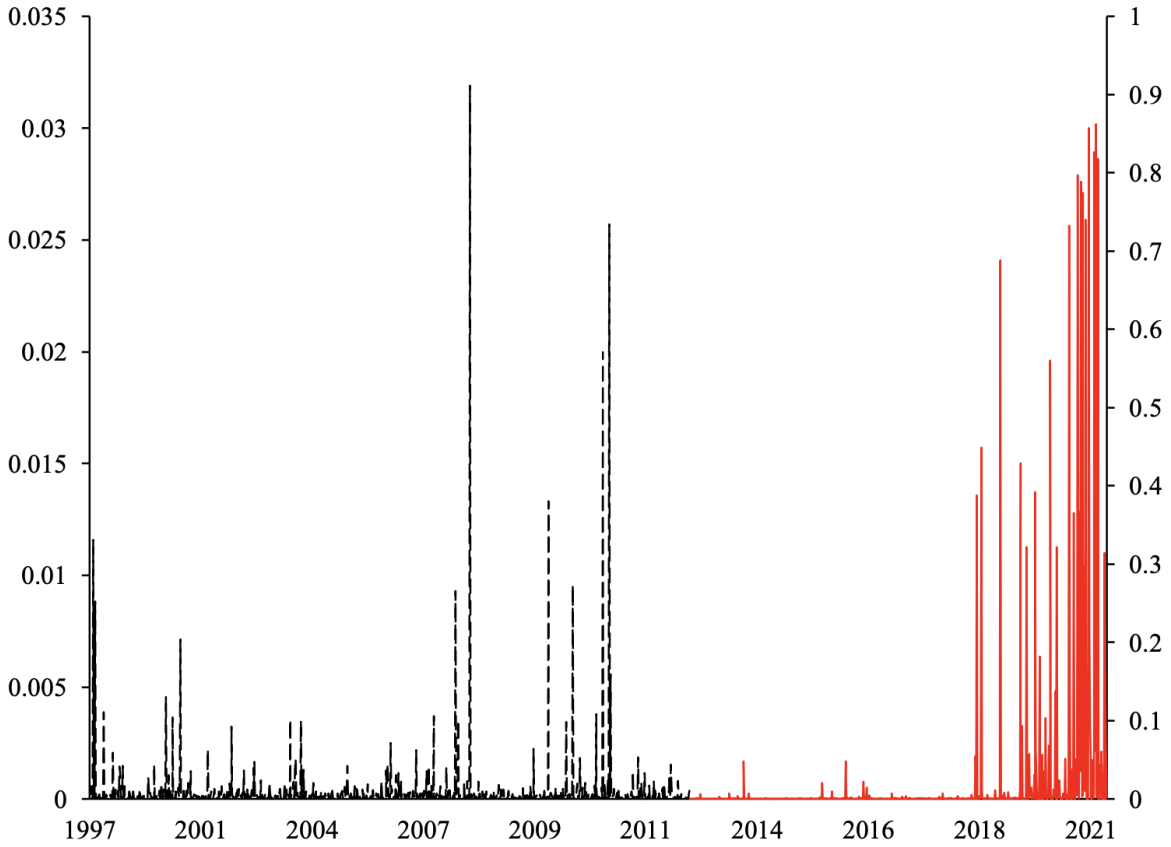
(f) Topic 64: Monetary Policy & Price

Note: These figures report the top 100 (stemmed) keywords from some selected topics as word clouds. The size of each word denotes the probability of occurrence in the given topic (i.e., the larger, the more important).

Figure 4 offers a temporal perspective, illustrating the proportion of climate-related Topic 56 from 1997 to 2021. The plot displays fluctuations in climate-related discourse over time, characterized by periods of both high and low intensity. Two trends are visible. First, from 1997 to 2012 (black dotted line, left axis), climate change communication shows up, yet

remains a relatively minor topic (topic probability distribution reaching up to 3.3% of the ECB's total communication spectrum). Second, from 2013 to the end of the period (red line, right axis), climate change communication gradually gains prominence, becoming one of the dominant themes with topic proportion soaring to 90% over the past five years. This pattern is confirmed by CUSUM- and MOSUM-structural break tests. Further insights into this intensive climate communication period are explored in empirical Section 5.

Figure 4: When ECB Talks Climate to the Market



Note: This figure depicts the topic proportion of Topic 56: "Climate Change, Risk and Green Bond" over the period 1997-2021. The black dotted line (left axis) represents the topic proportions during periods of less intensive communication, while the red line (right axis) illustrates the proportions during periods of intensive communication.

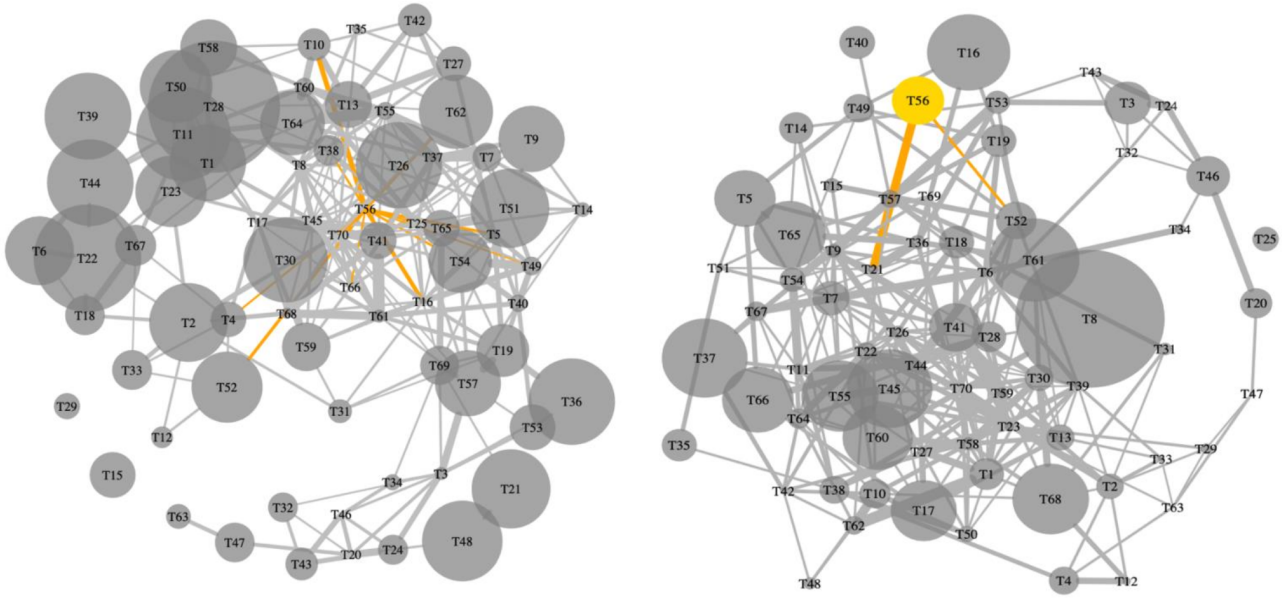
Lastly, Figure 5 offers a compelling visualization of how ECB's communication patterns and connections evolved over time, particularly in relation to climate-related narratives. During the moderate climate communication period (Panel (a), 1997-2012), Topic 56 appears to be relatively peripheral, as represented by its smaller node size compared to narratives more directly related to the direct mandate of the central bank (such as interest rates, exchange rates, and so on). The connections (edges) between Topic 56 and other topics are also either

non-existent or weak, illustrating that climate narratives were not strongly correlated with other macroeconomic discussions in ECB communications during this time. In contrast, the period of intense climate communication (Panel (b), 2013-2021) represents a significant shift in the ECB's communication strategy. The node related to Topic 56 is notably larger, signifying that climate-related communication becomes a more prominent component of ECB discourse. Notably, this topic increases up to 50 times compared to the 1997-2012 period. Topic 56 has not only grown in size but also appears to be more central in the network, suggesting that climate-related communication has become more intertwined with other topics in ECB's discourse. The edges connecting Topic 56 to Topic 21 (financial (bond) market) and Topic 52 (central bank forward mission) are particularly strong. These connections are highlighted in orange, emphasizing the increased correlation between climate narratives and these key financial topics. Edges are generally thicker in Panel (b), indicating stronger correlations between topics during the period of intense climate communication. This could be interpreted as a more integrated and cohesive communication strategy by the ECB in recent years. Overall, Figure 5 visually encapsulates the evolving nature of the ECB's communication. It vividly portrays the transition from a period where climate narratives were relatively peripheral in ECB communication (1997-2012) to a period (2013-2021) where these narratives have become central and are significantly correlated with key financial and strategic topics. This transformation is emblematic of the growing recognition by the ECB of the importance of climate-related issues, not just as standalone concerns but as integral factors influencing financial markets and the central bank's forward-looking mission.

Figure 5: How Climate Narratives Connect to Macroeconomic Topics

(a) Moderate ECB climate communication (1997-2012)

(b) Intense ECB climate communication (2013-2021)

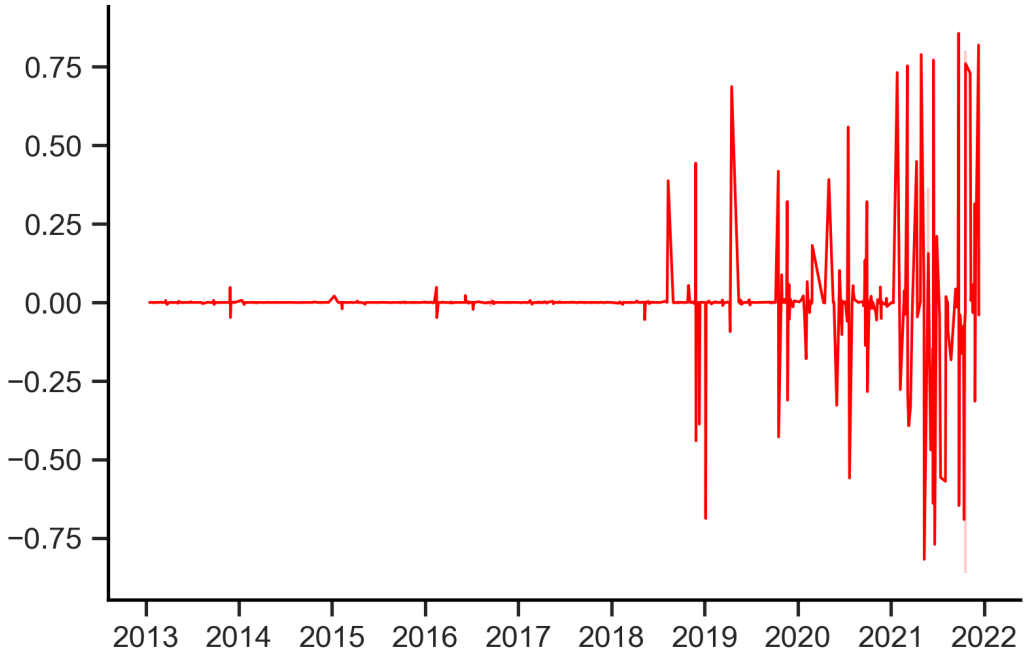


Note: These networks report ECB topic correlations during moderate (panel (a) covering 1997-2012) and intense climate communication (panel (b) covering 2013-2021). Vertices size is the proportion of each topic over the corresponding period. Edges size relates to topic correlation. The climate-related topic is highlighted in yellow while its links with other topics are shown in orange. For clarity, correlations below 0.05 are not reported.

For all these reasons, the subsequent sections of the paper focus on the period of intense ECB climate communication from 2013 to 2021. This choice is driven by several technical and analytical considerations: (i) a significant structural shift in climate change communication, represented by Topic 56, between periods (a) and (b), with 2012 marking a pivotal year; (ii) the relative resilience of period (b) to major economic downturns[8], thereby reinforcing the reliability of credit default spread estimations; and (iii) the substantial growth in the number of firms covered in our CDS database after 2012. In the light of these factors, our model, presented in Section 4, and the empirical results, detailed in Section 5, focus on the period from January 12, 2013, to December 10, 2021, encompassing 740 ECB communications. Topic 56, computed in first differences to mitigate non-stationarity concerns, gauges ECB's climate-related communications for the remainder of this paper (see Figure 6). As highlighted in Figure 4, marked variations in the frequency of Topic 56 become conspicuous toward the latter part of our sample period, specifically from mid-2018 until the end of 2021.

[8]See NBER business cycle dating at `https://www.nber.org/research/business-cycle-dating`.

Figure 6: Climate Change Topic Frequency in ECB Narratives



Note: This figure depicts the temporal frequency of Topic 56—Climate Change, Risk, and Green Bonds—from 2013 to 2021, represented as a time-series of first differences. Positive spikes indicate periods of accelerated growth in the prevalence of this topic within ECB communications, while negative spikes mean substantial declines.

4 Variable selection and empirical framework

In this section, we first present our dependent variable, CDS spreads, and then our independent control variables. Second, we outline our methodological approach based on quantile regression.

4.1 Database and variable selection

To test our hypotheses regarding the influence of ECB climate communication on credit risk, we use daily CDS spreads as our dependent variable. Fundamentally, a transformation of the economic structure toward net-zero targets could significantly impair entities' ability to repay debts, leading to a higher probability of default and increased credit risks (see Kölbel

et al., 2020; Vozian, 2022; Billio & Giacomelli, 2022; and Blasberg et al., 2021). In contrast to other measures (e.g., corporate bonds, ratings, etc.), CDSs are advantageous because they are standardized instruments traded over-the-counter, they are more liquid, and they are available in various maturities. These financial products are consistent with the idea of a forward-looking perspective when addressing climate-related issues, as suggested by Blasberg et al. (2021). Several studies of carbon risk (Ramos-García et al., 2023; Capasso et al., 2020) use Merton's Distance-to-Default as a proxy for credit risk. Unlike them and their use of this accounting-based default probability, we apply a more market-oriented measurements of credit risk (CDS spreads) to complement existing research from the perspective within the credit trade market. Distance-to-Default and CDS spreads are both proxies for default risk, but they are not always strongly consistent. Distance-to-Default relies on strong theoretical assumptions (e.g. asset return is not necessarily normally distributed and default occurs only at maturity), that are not compatible with our forward-looking approach. Moreover, Distance-to-Default is based on historical data, whereas CDS spreads, as a market-based financial derivative insurance product, is better suited for the study of investors' perceptions of climate regulatory risk. Data for Credit Default Swaps of North-American firms are extracted from LSEG Refinitiv Workspace and span the period from January 2007 to December 2021. We have opted to focus on firms located in Canada and the United States, all denominated in U.S. dollars, to have enough observations and maintain our dataset balanced with our communication variable derived from speeches delivered by the ECB. This choice excludes European firms. To mitigate potential biases from turbulent periods, such as the Global Financial Crisis and the Sovereign Debt Crisis, we limit our sample to the period between January 2013 and December 2021. As described in Section 3, this selection aligns with the emergence of the ECB's climate change narrative. Overall, the dataset encompasses CDS spreads for five-, ten-, and thirty-year maturities, covering more than 100 North-American firms (specifically 168, 187, and 137 entities, respectively).

To ensure stationarity, we compute the daily log returns of CDS spreads as[9]

$$s_{i,t}^{m} = \log(CDS_{i,t}^{m}) - \log(CDS_{i,t-1}^{m}) \tag{1}$$

where $CDS_{i,t}^{m}$ is the m-year CDS spread of firm i at day t. $s_{i,t}^{m}$ quantifies the daily relative change in a firm's CDS spread.

Along with our measure of ECB climate change communication, we consider several determinants of CDS spreads as independent daily control variables. In line with the literature, we control for both firm-specific and market-specific factors.[10]

For firm factors, we take into account the stock returns (in log form) for each firm, as well as the annualized log-first difference VIX index, which measures S&P 500 volatility (see Collin-

[9]The Augmented Dickey-Fuller test was conducted and confirmed non-stationarity at the levels of the time series. Detailed results are available upon request from the authors.

[10]See Ericsson et al. (2009), Galil et al. (2014), and Han and Zhou (2015) for firm factors; and Collin-Dufresn et al. (2001); Galil et al. (2014), and Blasberg et al. (2021) for market determinants.

Dufresn et al., 2001; and Blasberg et al., 2021). The rationale for these inclusions is grounded in seminal literature on the subject. For instance, studies by Collin-Dufresn et al. (2001) and Avramov et al. (2007) have emphasized the impact of stock market movements—captured by stock returns—on credit risk and CDS spreads. Likewise, the role of the VIX in our model is similar to Fama and French (1993), which establishes market volatility as a key determinant influencing investor sentiment and risk perceptions, both fundamental elements in credit market dynamics. Thus, the inclusion of these control variables not only adds robustness to our analysis but also provides a comprehensive framework for understanding the factors influencing CDS spreads.

In terms of market factors, we follow the methodologies proposed by Galil et al. (2014) and Blasberg et al. (2021). We assess shifts in business conditions using the Median Rate Index (MRI), which is defined as the median change in spreads across all firms within a given rating group.[11] The MRI serves as a proxy for the business environment, capturing interest rate fluctuations that affect both borrowing costs and the creditworthiness reflected in CDS spreads. Beyond this, the index offers a holistic view of monetary policy, market conditions, and economic sentiment. Given its ease of data availability and interpretability, the MRI proves to be an effective instrument for examining how interest rate shifts influence credit risk within a broader macroeconomic framework, thereby increasing transparency for stakeholders and policymakers.

4.2 Modeling framework

As endogeneity may be a concern in analyzing the role of communications in shaping market expectations, we adopt the intuition and identification strategy detailed in Brunetti et al. (2023). There are two main factors supporting this approach. First, a rich body of both theoretical and empirical literature has conclusively demonstrated that market participants are swayed by central bank announcements.[12] This leads us to reasonably infer that ECB communications play a crucial role as determinants of market risk on the day of these events, and possibly even in the days that follow. Second, our empirical strategy is specifically tailored to the days of ECB announcements. By aligning the dependent variable (as well as control variables) with the day of these announcements, we can accurately discern the effects of climate-related communications on credit risk, thus mitigating the concern of endogeneity.

Unlike other studies that typically use linear regression (Collin-Dufresn et al., 2001), we have opted for a fixed-effect panel quantile regression in accordance with the methodology used by Blasberg et al. (2021) and others. This decision is based on two principal considerations. First, quantile regression enables us to tackle traditional statistical challenges frequently encountered in financial markets and the examination of CDS spreads, such as leptokurtosis, heteroskedas-

[11] Firms are categorized into four rating groups: 'AAA/AAs,' 'As,' 'BBBs,' and 'BB+ and lower.'
[12] See, Blinder et al. (2008) for a review

ticity, and skewness (see Table 5 in Appendix A.2 for descriptive statistics). Second, various research has exposed the heterogeneous effects across the conditional distributions of CDS spreads, a complexity that can be challenging to capture with linear conditional mean regression. Quantile regression facilitates a more intricate analysis, empowering us to scrutinize the entire conditional distribution of CDS spreads, allowing us to pinpoint specific firms that are highly reactive to climate announcements (Giglio et al., 2016; Demir et al., 2022).

To test Hypothesis 1, we define our quantile regression model as follows:

$$Q_{s^m_{i,t}}(\tau|x_{i,t}) = \alpha_{\tau,i} + \beta_{\tau,1}\Delta Climate_t + \beta_{\tau,2}r^m_{i,t} + \beta_{\tau,3}\Delta VIX_t + \beta_{\tau,4}\Delta MRI^m_{i,t} + \varepsilon_{i,t} \quad (2)$$

where $s^m_{i,t}$ denotes the daily change in the m-year CDS spreads for firm i at day t for maturity m, and $\tau \in \{0.1,..., 0.9\}$ symbolizes the fixed decile level. The m-dimensional covariate vector $x_{i,t}$ spans firms $i = 1, ..., N$ and time periods $t = 1, ..., T$. The error term $\varepsilon_{i,t}$ and $\Delta Climate_t$ as our measure of ECB climate-related communication on day t are further elaborated in Section 3. This measure is consistent across all firms since market participants perceive the same announcements. Firm-specific variables are denoted by $r^m_{i,t}$ and ΔVIX_t, such as stock returns and the (log-difference) volatility index, while $MRI^m_{i,t}$ represents market-specific factors for firm i on day t at maturity m. Hypothesis 2 is examined by considering various maturity horizons, specifically 10-year and 30-year terms.

An extensive collection of empirical studies underscores the fact that emissions-intensive industries are the companies most susceptible to climate-related issues (see Dietz et al., 2020; and Blasberg et al., 2021). To investigate our Hypothesis 3 concerning the effectiveness of climate announcements at firms' sector level, we align our approach with Blasberg et al. (2021) and estimate the following equation:

$$\begin{aligned} Q_{s^m_{i,t}}(\tau|x_{i,t}) = \alpha_{\tau,i} + \beta_{\tau,1}\Delta Climate_t + \beta_{\tau,2}r^m_{i,t} + \beta_{\tau,3}\Delta VIX_t + \beta_{\tau,4}\Delta MRI^m_{i,t} \\ + \sum_{j=5}^{15}\beta_{\tau,j}Sector_i + \sum_{j=13}^{23}\beta_{\tau,j}(Sector_i \times \Delta Climate_t) + \varepsilon_{i,t} \end{aligned} \quad (3)$$

where $Sector_i$ refers to a dummy variable indicating classification[13] of firm i based on Thomson Reuters Business Classification (TRBC)[14], with $Sector_i \times \Delta Climate_t$ symbolizing interaction terms between a firm's sector i and climate-related announcements on day t, thus reflecting ECB green communication to sectoral exposure. To illustrate our sectoral classification, Table 1 exhibits the number of firms present in each of our sectoral categories for each of our CDS maturity categories.

[13]See https://www.refinitiv.com/content/dam/marketing/en_us/documents/quick-reference-guides/trbc-business-classification-quick-guide.pdf for more information on the classification.

[14]TRBC classification, as based on the NACE classification, can be related to the CPRS classification presented in the pioneering work of Battiston et al. (2017).

Table 1: Number of Firms by TRBC Sector and by CDS Maturity Category

TRBC Classification	**5Y**	**10Y**	**30Y**	**Examples**
Basic Materials	13	13	13	Dow Chemical Co; United States Steel Corp
Consumer Cyclicals	47	39	21	McDonald's Corp; Levi Strauss & Co
Consumer Non-Cyclicals	8	12	7	Hershey Co; General Mills Inc
Energy	10	10	2	Devon Energy Corp; Valero Energy Corp
Financials	13	37	38	Loews Corp; XLIT Ltd
Healthcare	16	13	8	Johnson & Johnson; HCA Inc
Industrials	23	28	20	Boeing Co; Caterpillar Inc
Real Estate	3	6	4	ERP Operating LP; Site Centers Corp
Technology	17	19	18	Dell Inc; IBM
Utilities	10	10	6	Southern Co; Exelon Corp

Note: This table presents the number of firms classified by sector based on the Thomson Reuters Business Classification (TRBC) for each maturity category. It also shows (in the fourth column) two examples of firms included in our database for each sector.

In overall terms, equations 2 and 3 form the basis for testing our Hypotheses 1, 2 and 3 regarding the role of ECB interventions. It is noteworthy that, while Blasberg et al. (2021) broach a similar theme, our specific hypotheses and implications delve into a regulatory perspective.

The two models are estimated for each decile $\tau \in \{0.1,..., 0.9\}$, aiming to disentangle the impact of ECB announcements and other individual explanatory variables across the entire conditional distribution of CDS spread returns relative to the median. Within this framework, underperforming firms' CDS spreads (where $\tau > 0.5$) signal a decline in creditworthiness, while over-performing firms (where $\tau < 0.5$) are indicative of an enhancement in creditworthiness. The median case, denoted by $\tau = 0.5$, corresponds to situations where the CDS spread remains unchanged.

5 Impact of ECB Communication Greening on Credit Default Swaps

This section looks at the impact of the ECB shift toward climate change communication on CDS spreads. Initially, we present overarching findings that test the validity of Hypotheses 1 and 2, as articulated in Equation 2. We then delve into a sector-specific analysis to address Hypothesis 3, according to Equation 3. Our discussion includes results for both 5-year and 10-year maturities. It should be noted that contracts with a 30-year maturity, which are reported in Appendix C.1 and discussed in Section 6, are inherently more synthetic and should

be interpreted with caution.

5.1 Main Results

We first focus on the global estimation framework set out in Equation 2, summarized in Table 2. Using quantile regression techniques, we assess the estimated coefficients across various deciles for each level of maturity (5 and 10 years). Firstly, it is important to note that all our control variables are statistically significant, corroborating their role as principal determinants of CDS spreads, as per the extant literature. Pivoting to our Hypothesis 1, we find statistically and economically significant coefficients, revealing a positive relationship between CDS spread returns and ECB climate change communications. ECB reveals itself to be a leader in shaping the anticipations of the effects of climate change on firms' default probability. This linkage implies that any intensification in ECB climate-related discourse leads to a corresponding increase in CDS spread returns across our complete sample of firms. Importantly, this influence exceeds mere statistical significance to achieve economic relevance. An elevated frequency in ECB climate-centric messages is associated with a concomitant rise in market perceptions of regulatory risk, consequently amplifying a firm's default risk and, by extension, its CDS spread returns. For practical illustration, in the context of a 5-year maturity, a one standard deviation increment in ECB climate communications (measured as 2.573) correlates with a 0.015 (= 2.573 x 0.006) percentage point augmentation in CDS spread returns among firms in the 9th decile, the most risk-prone segment. This adjustment constitutes 0.28% of the standard deviation in CDS spread returns.

Our results show similarities to those of Blasberg et al. (2021) and Zhang et al. (2023). These two studies take carbon emissions and carbon intensity as proxies to study carbon risk. In our study, we broadened the scope of their strict definition of "carbon risk" by measuring it upstream as the forward-looking regulatory risk of transitioning to a low-carbon economy. Doing so, we find consistent results with Blasberg et al. (2021) and Zhang et al. (2023), finding that investors' perception of this regulatory risk results in an increase in the trade of CDS, increasing their spreads.

Our analysis underscores a decline in the statistical significance of the estimated coefficients as maturity tenors extend, consistent with the predictions of Hypothesis 2. Specifically, coefficients corresponding to a 5-year maturity attain a significance level of 0.1% (in the 7th, 8th, and 9th deciles), while those associated with a 10-year maturity reach significance only at the 5% level.

Lastly, the coefficients demonstrate increasing magnitude at both the lower (1st, 2nd, and 3rd deciles) and upper (7th, 8th, and 9th deciles) tails of the distribution. This result means that firms at both risk extremes are disproportionately affected by climate transition risks, as conveyed through ECB climate-focused communications. The risk profiles of both safe

and risky firms are adversely modified, thus aligning with our primary hypothesis of a positive correlation between climate transition risks and CDS spread returns. This relationship is most pronounced at the tails of the CDS spread returns distribution.

Table 2: Effect of Climate Regulatory Risk on 5- and 10-year CDS Spread (core analysis)

	1	2	3	4	5	6	7	8	9
					5Y				
$\Delta Climate_t$	36.5*	31.9**	13.7*	2.46	-0.73	1.58	18.1***	36.1***	60.5***
	(16.6)	(8.53)	(5.82)	(3.03)	(2.28)	(2.62)	(4.53)	(7.04)	(12.7)
$r^5_{i,t}$	-796***	-659***	-477***	-287***	-189***	-221***	-368***	-571***	-857***
	(113)	(92.9)	(68.5)	(53.1)	(40.6)	(47.6)	(63.2)	(102)	(158)
ΔVIX_t	614***	479***	364***	240***	156***	201***	380***	602***	929***
	(37.8)	(38.2)	(40.1)	(40.2)	(32.9)	(34.4)	(44.1)	(49.1)	(48.1)
$\Delta MRI^5_{i,t}$	2222***	23.1***	22.6***	22.7***	22.8***	22.9***	23.9***	26.2***	28.7***
	(1.38)	(1.54)	(1.61)	(1.75)	(1.84)	(1.84)	(1.78)	(1.81)	(1.69)
					10Y				
$\Delta Climate_t$	26.4*	10.9*	7.48*	-1.01	-1.03	-2.52*	6.16	12.8*	19.2
	(12.5)	(4.24)	(3.82)	(2.58)	(1.20)	(1.78)	(3.56)	(5.47)	(10.2)
$r^{10}_{i,t}$	-644***	-506***	-377***	-203***	-134**	-164**	-293***	-544***	-930***
	(123)	(82.4)	(74.9)	(56.2)	(44.1)	(51.3)	(62.5)	(94.3)	(117)
$\Delta VIX_{i,t}$	639***	486***	367***	228***	133***	163***	335***	529***	818***
	(31.0)	(28.9)	(31.5)	(37.7)	(30.7)	(33.8)	(34.1)	(32.2)	(35.4)
$\Delta MRI^{10}_{i,t}$	2.71***	2.94***	2.65***	2.17***	1.83***	2.19***	3.25***	4.61***	5.98***
	(0.65)	(0.68)	(0.64)	(0.58)	(0.54)	(0.61)	(0.74)	(0.80)	(1.13)

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Note: This table presents coefficient estimates derived from the baseline panel quantile regression model, as specified in Equation 2. The estimates are segmented by CDS spread returns for both 5-year (top panel) and 10-year (bottom panel) maturities. These estimates are reported across all nine deciles, with standard errors in brackets. To facilitate interpretation, all estimates have been scaled by a factor of 1e04.

5.2 Sector level results

The existing literature on transition risks underscores the variable exposure of firms based on their sectoral affiliations. Notably, carbon-intensive industries like energy and basic materials are more susceptible to transition risk and stranded assets compared to low-carbon sectors (Dietz et al., 2016; Dietz et al., 2020).

To empirically validate Hypothesis 3, we use Equation 3 and tabulate the estimated coefficients in Tables 2 and 3 for 5- and 10-year maturities, respectively.[15] Our tables focus on the interaction terms between climate change communication and sectoral classification, while other coefficients are available upon request.

[15]Results for the 30-year maturity are addressed in Section 6 and Appendix C.1.

Table 2 indicates that almost all coefficients are significant and negative for 5-year CDS spread returns. This suggests that investors believe firms across all sectors in our sample are adequately prepared for impending climate change regulations from central banks. These firms are deemed capable of pioneering the innovations and technologies vital for a low-carbon transition in the near term, notably by sourcing or investing in renewable energy or using carbon capture and storage to decrease their emissions. On this aspect, our results contrast with Blasberg et al. (2021) and Zhan et al. (2023). Both these papers find that Scope 1 emissions lead to a positive and significant change in CDS spreads of high-polluting industries, such as the Energy, Industrials and Utilities sectors. In our case, the mechanisms are different. Large emitters are more exposed to regulatory pressure therefore they are more likely to react and engage in the low-carbon transition. Our results reveal the fact that investors anticipate the measures taken by large emitters to align with potential future regulations (expressed here by our dependent variable, as a proxy of transition risk). As a result, the CDS spread of large emitters is significant and negative. Interestingly, the coefficients related to Consumer Cyclicals (CCGS), Healthcare, Technology, and Utilities are largely non-significant, implying greater uncertainty in these sectors regarding transition implementation.

We run the same sector panel quantile regression model for 10-year CDS spread returns (Table 3). No significant coefficients were found. Therefore, the increasing communication of the ECB on the topic of climate change has no impact on investors' expectations of firms' probability of default in the medium term. Here the effect of more stringent and direct carbon regulation (like the extension of carbon pricing) could take the lead. Also, deeper decarbonization using hydrogen will be needed, but from today's perspective this technological solution is uncertain. Finally, Table 12 in Appendix C.1 presents the coefficient estimates of the interaction terms of the sector panel quantile regression model for 30-year CDS spread returns. At this maturity, almost all of our coefficients are strongly significant (at the 1% level) and positive. Therefore, increased central bank communication on the subject of climate change translates into higher probability of default in the long term for firms in our sample, regardless of sector. In the long term, decarbonization is unavoidable. Firms that are not compliant are definitely at risk.

Table 3: Effects of Climate Regulatory Risk on 5-year CDS Spread (sector analysis)

	1	2	3	4	5	6	7	8	9
BM x $\Delta Climate_t$	-183**	-136***	-64.5**	-37.2*	-56.0***	-39.2	-14.5	-134**	16.69
	(73.3)	(37.6)	(24.8)	(17.7)	(14.3)	(21.8)	(42.2)	(41.6)	(115)
CCGS x $\Delta Climate_t$	-84.1	-66.1	-16.4	-22.2	-36.2**	-16.1	-13.0	-92.4***	47.3
	(63.6)	(34.2)	(12.2)	(16.4)	(12.0)	(17.4)	(27.7)	(24.4)	(99.5)
NCGS x $\Delta Climate_t$	-97.6	-122***	-27.1	-35.9	-49.7**	-19.6	-4.61	-119***	73.1
	(70.9)	(34.9)	(18.6)	(18.9)	(17.4)	(22.4)	(33.4)	(28.9)	(112)
Energy x $\Delta Climate_t$	-221**	-161***	-73.2**	-57.4***	-69.0***	-60.6*	-48.2	-191***	-174
	(81.3)	(42.9)	(22.8)	(17.2)	(14.2)	(24.9)	(36.2)	(37.8)	(119)
Finance x $\Delta Climate_t$	-134	-72.0	-48.7*	-43.9**	-52.5***	-34.8	-45.1	-112***	10.8
	(95.0)	(41.1)	(19.7)	(16.5)	(10.8)	(18.7)	(29.0)	(32.0)	(99.1)
Healthcare x $\Delta Climate_t$	-90.7	-42.8	-14.5	-17.9	-34.7**	-22.0	-4.93	-78.6**	68.5
	(70.6)	(34.1)	(13.3)	(18.4)	(12.9)	(19.2)	(27.0)	(27.9)	(107)
Industrials x $\Delta Climate_t$	-204**	-110**	-42.5*	-39.0**	-50.2***	-33.7	-18.2	-82.5*	46.4
	(68.2)	(35.7)	(17.5)	(15.1)	(10.5)	(17.7)	(27.9)	(35.6)	(107)
Real Estate x $\Delta Climate_t$	-324**	-163***	-55.2	-34.1	-49.0***	-34.1	-21.3	-67.8	126
	(115)	(36.0)	(35.5)	(20.8)	(11.7)	(18.2)	(31.4)	(49.6)	(109)
Technology x $\Delta Climate_t$	-58.2	-47.4	19.7	-25.7	-41.3***	-25.1	-9.13	-101**	7.98
	(70.9)	(36.4)	(11.4)	(16.3)	(10.8)	(18.0)	(27.4)	(33.7)	(107)
Utilities x $\Delta Climate_t$	-257*	-103	-38.5	-57.1**	-58.1***	-30.9	-11.6	-56.1	-9.42
	(103)	(53.8)	(23.8)	(19.5)	(10.8)	(19.4)	(27.5)	(32.7)	(114)

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Note: This table presents the coefficient estimates for interaction terms obtained from the sector panel quantile regression model, as detailed in Equation 3, for 5-year CDS spreads. Estimates are reported for all nine deciles, and standard errors are in brackets. For ease of interpretation, all coefficients have been scaled by a factor of 1e04.

Table 4: Effects of Climate Regulatory Risk on 10-year CDS Spread (sector analysis)

	1	2	3	4	5	6	7	8	9
BM x $\Delta Climate_t$	-808	-33.5	-124	-70.3	-40.6	-13.4	40.5	55.9	467
	(541)	(278)	(177)	(73.1)	(39.2)	(49.1)	(107)	(263)	(612)
CCGS x $\Delta Climate_t$	-803	-29.2	-120	-69.4	-40.2	-12.8	42.3	59.6	472
	(541)	(278)	(177)	(73.0)	(39.2)	(49.2)	(107)	(263)	(612)
NCGS x $\Delta Climate_t$	-801	-31.1	-121	-68.6	-40.0	-12.4	44.1	62.3	476
	(541)	(278)	(177)	(73.1)	(39.2)	(49.2)	(107)	(263)	(612)
Energy x $\Delta Climate_t$	-808	-33.7	-125	-70.7	-40.8	-14.2	38.7	52.5	470
	(541)	(278)	(177)	(73.2)	(39.3)	(49.3)	(107)	(263)	(611)
Finance x $\Delta Climate_t$	-808	-31.9	-123	-69.9	-40.1	-13.1	40.9	58.9	476
	(541)	(278)	(177)	(73.1)	(39.2)	(49.2)	(107)	(263)	(612)
Healthcare x $\Delta Climate_t$	-809	-34.6	-122	-70.8	-40.8	-13.4	40.7	56.5	473
	(541)	(278)	(177)	(73.0)	(39.2)	(49.2)	(107)	(263)	(611)
Industrials x $\Delta Climate_t$	-801	-29.7	-121	-69.5	-40.3	-13.1	41.1	60.0	470
	(542)	(278)	(177)	(73.0)	(39.2)	(49.2)	(107)	(263)	(611)
Real Estate x $\Delta Climate_t$	-808	-32.9	-122	-70.0	-40.5	-13.0	42.4	58.2	473
	(541)	(278)	(177)	(73.1)	(39.2)	(49.2)	(107)	(263)	(612)
Technology x $\Delta Climate_t$	-807	-30.9	-119	-69.3	-40.4	-12.9	42.3	59.5	471
	(541)	(278)	(177)	(73.0)	(39.2)	(49.2)	(107)	(263)	(611)
Utilities x $\Delta Climate_t$	-818	-34.1	-123	-70.9	-41.1	-13.3	41.9	61.1	476
	(541)	(278)	(177)	(73.1)	(39.2)	(49.2)	(107)	(263)	(611)

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Note: This table presents the coefficient estimates for interaction terms obtained from the sector panel quantile regression model, as detailed in Equation 3, for 10-year CDS spreads. Estimates are reported for all nine deciles, and standard errors are in brackets. For ease of interpretation, all coefficients have been scaled by a factor of 1e04.

6 Additional results and robustness check

6.1 30-year CDS spread

By design, long-term CDS contracts with maturities exceeding 20 years are inherently more synthetic compared to their shorter-term counterparts. This is primarily attributed to long-term liquidity constraints, which typically result in fewer trades and wider bid-ask spreads.

Tables 11 and 12 in Appendix C.1 present the impact of ECB climate communication on 30-year CDS maturity. Notably, the results exhibit almost no statistical significance. These observations collectively point to increased market sensitivity to climate transition risks in the short-to-medium term, rather than in the long term.

6.2 Event Study

A crucial identification assumption in Equations 2 and 3 is that variations in CDS spreads are attributable to climate regulatory risk, as captured by ECB climate-related announcements, rather than arising from inherent market dynamics specific to CDS.[16] To substantiate the robustness of our methodology, we estimate an event study regression for each considered maturity, formulated as follows:

$$Q_{s^m_{i,t}}(\tau|x_{i,t}) = \alpha_{\tau,i} + \beta_{\tau,1}D_t + \beta_{\tau,2}r^m_{i,t} + \beta_{\tau,3}\Delta VIX_t + \beta_{\tau,4}\Delta MRI^m_{i,t} + \varepsilon_{i,t}$$

In this equation, we replace our measure of climate regulatory risk with a dummy variable, D_t, formulated as:

$$D_t = \begin{cases} 1 & \text{if } \Delta Climate_t \text{ exceeds one standard deviation above its mean,} \\ 0 & \text{otherwise.} \end{cases}$$

This modification allows us to isolate the specific influence of climate-related announcements. We present the results for 5- and 10-year maturities in Table 13, included in Appendix C.2.[17] Our analysis reveals that the dummy variable is both statistically significant and positively associated across all quantile levels, thereby empirically validating the role of climate regulatory risk, as measured by ECB climate-related announcements, in our identification strategy. Sector-specific results, available upon request, corroborate this insight.

6.3 Is the Federal Reserve System green enough?

Our paper positions the ECB as a leading institution in addressing climate-related issues. Although this is not explicitly part of its core mandate, it serves as an important component of forward-looking regulatory policy. This leadership role is evident in how the ECB communicates climate-related information to the market (Arseneau et al., 2022). To validate the rationale of our approach, we apply the same topic extraction methodology to the Federal Reserve System. Statistical criteria support the extraction of 50 distinct topics over the period from January 1997 to December 2021. Tables 14 and 15 in Appendix C.3 list the primary terms extracted from the Federal Reserve's communication narrative through topic modeling. We find that although the Federal Reserve's communications are diverse, none of the topics are climate-oriented. This result finally corroborates our focus on the ECB.

[16] Some studies are using a quasi-natural experiment with the Paris Agreement as an exogenous shock (see Duong et al., 2022; Capasso et al., 2020). We choose not to follow the same empirical strategy, as this event is already taken into account in our dependent variable.

[17] Results pertaining to 30-year maturities, available upon request, are congruent with our primary findings.

7 Conclusions

In recent years, an increasing number of scientific publications (e.g. 6 IPCC Reports published from 1990 to 2023) provide unquestionable evidence that climate change will impact our economic system as a whole. These negative shocks affecting the supply and demand functions of the real economy are vectors of instability in the financial system. Transitioning from a high- to a low-carbon economic system as prescribed by net-zero carbon emissions policies requires a drastic change in our productive system. All actors need to take part in this transformation, and this includes central banks. Even if it is not explicitly part of their mandate, central banks should be aware of climate risk.

In this paper, we investigate how the ECB communicates about climate change. We use a topic modeling approach and extract a topic labeled "Climate Change" from ECB speeches. We show evidence for an increase in ECB communication on the topic of climate change. We then investigate the way it communicates, and find out that ECB talks about climate change in terms of a risk for financial stability. Thus, we conclude that the ECB uses its communication as a signal for financial markets that they may implement a regulation to mitigate climate change impacts on the financial system.

We then use panel quantile regression to isolate the impacts of an increase in ECB communication on the topic of climate change on the expected probability of default for 168 firms (proxied by their CDS spread returns). We investigate 5-, 10- and 30-year contracts. Our findings show an overall positive relationship between lenders' perceived exposure to a regulatory risk from the ECB and the firms' cost of default protection.

In addition, we include sector dummies and interaction terms with our communication variable in our baseline quantile regression and show proof of the existence of nonlinear effects across the short, medium and long term. Our findings show significant and negative coefficients on the short term (5-year maturity), that prove that market actors seem to have integrated a potential implementation of regulation coming from the ECB to mitigate the effects of climate change on financial markets. These results also prove that firms are already seen as capable of transitioning to a low-carbon economy in the short term. In the medium term (10-year maturity), our estimated coefficients are all non-significant, it seems that financial actors are uncertain of how the ECB will act regarding climate risk. Finally, in the long-term (30-year maturity), our estimated coefficients are positive and strongly significant. CDS market participants expect a higher probability of default for firms across all sectors in the very long-term with the increase in ECB communication on climate change.

Overall, we highlight how ECB communication can impact investors' expectation of the probability of different firms defaulting at different time horizons. Our findings are particularly relevant to the regulation of climate risk. Our findings also have important policy implications. They suggest that firms are ready to transition in the short term, and that central

banks should take a more active role to help this transition to a low-carbon system, even by using regulatory tools. Not taking action now will raise uncertainty about climate change impacts on financial markets, leading to a rise in the probability of firms defaulting, which could be the detonator of a new financial crisis.

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Appendix

A Database

A.1 ECB announcements

Table 4: Characteristics of ECB Announcements

Year	# of Speeches	% of Total Speeches	Avg. # of Words per Speech
1997	18	0.98	2705
1998	34	1.86	2897
1999	75	4.10	3583
2000	58	3.17	3230
2001	57	3.12	2862
2002	57	3.12	2980
2003	54	2.95	3033
2004	71	3.88	3281
2005	64	3.50	3569
2006	72	3.94	3444
2007	86	4.70	3441
2008	92	5.03	3366
2009	89	4.87	3270
2010	85	4.65	3171
2011	93	5.08	3229
2012	73	3.99	3019
2013	106	5.80	2778
2014	82	4.48	2950
2015	84	4.59	2830
2016	80	4.37	3003
2017	97	5.30	2903
2018	83	4.54	2848
2019	85	4.65	2459
2020	65	3.55	2497
2021	68	3.72	2547
Total	**1829**	**100**	**3047**

Note: This table offers a detailed overview of the characteristics of our ECB announcements database, covering the period from 1997 to 2021. Specifically, it includes the annual count of speeches, the yearly proportion of speeches relative to the total number of speeches, and the average word count per speech for each year.

A.2 CDS and control variables

Table 5 presents descriptive statistics for all dependent and independent variables used in our study. Average CDS spread returns is the same across our three different maturities (5-, 10- and 30-year contracts) and is situated slightly below zero. Relatively small dispersion can be deduced from the corresponding standard deviation, CDS spread returns varying between 4.1% and 5.2%. Our sample of CDS spread returns comprises sizable outliers with maximum returns from 170% to 192% and minimum returns varying from -119% to -175% across our three different maturities. CDS spread return distributions for our three maturities is right-skewed and very heavy-tailed (relative to a normal distribution), with a kurtosis ranging from 107 to 143.

Table 5: Descriptive Statistics for Dependent and Independent Variables

Variable	Mean	Q25	Median	Q75	SD	Min	Max	Skew	Kurt
Dependant Variables									
$s_{i,t}^{5}$	-0.0004	-0.0104	0.0000	0.0051	0.0529	-1.1933	1.9208	2.9469	107.5042
$s_{i,t}^{10}$	-0.0004	-0.0080	0.0000	0.0047	0.0438	-1.7478	1.7029	2.0167	143.2466
$s_{i,t}^{30}$	-0.0004	-0.0074	0.0000	0.0046	0.0417	-1.6297	1.7189	1.9478	135.4099
Independent Variables									
$\Delta Climate_t$	0.0038	-1.5839	-0.0302	1.5531	2.573	-8.8869	8.8982	0.0556	0.7739
$r_{i,t}^{5}$	0.0009	-0.0102	0.0012	0.0126	0.0374	-1.7167	1.1685	-2.9131	129.1615
$r_{i,t}^{10}$	0.0009	-0.0101	0.0012	0.0125	0.0369	-1.7167	1.1685	-2.8344	126.7275
$r_{i,t}^{30}$	0.0009	-0.0099	0.0012	0.0124	0.0345	-0.9078	0.7411	-2.0183	64.3461
ΔVIX_t	0.0004	-0.0569	-0.0039	0.0480	0.1153	-0.5523	0.9911	1.5168	11.7935
$\Delta MRI_{i,t}^{5}$	-0.0007	-0.0138	0.0000	0.0094	0.0485	-0.2969	1.1036	6.4482	149.5036
$\Delta MRI_{i,t}^{10}$	-0.0006	-0.0106	0.0000	0.0070	0.0345	-0.2759	0.8307	6.1763	156.6420
$\Delta MRI_{i,t}^{30}$	-0.0006	-0.0096	-0.0002	0.0060	0.0291	-0.1794	0.5828	3.7544	74.7234

Note: This table presents descriptive statistics for all dependent and independent variables used in the empirical model.

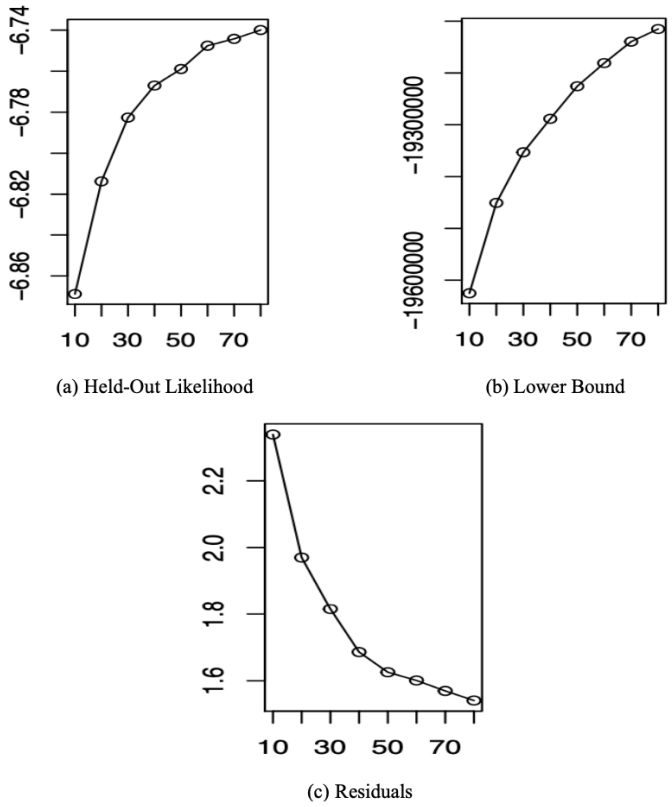
B Latent space and topics meaning

This section discusses the selection of the optimal model as well as the procedure used for topic labeling.

B.1 Model selection

Several statistical methods have been performed to define the optimal latent space of our model. Figure 7 reports our considered metrics for topics 10 to 80, such as the held-out likelihood in panel (a) (Taddy, 2012), the lower bound in panel (b), and the residuals check (Taddy, 2012) in panel (c).[18] As can be seen, both lower bound and held-out are maximized starting at $K = 60$ topics, while residuals reaches the minimum around $K = 70$. To confirm our choice, we follow Roberts et al. (2014) and report in Figure 8 a combination of semantic coherence and exclusivity of words to topics comparing models with $K = 60$, 70, and 80.[19]. The coherence-exclusivity metric confirms that both $K = 70$ and 80 are the best models. As Chang et al. (2009) suggests to increase output's interpretability (i.e., lower K) we consider $K = 70$ topics.

Figure 7: Latent Space Selection over K Topics

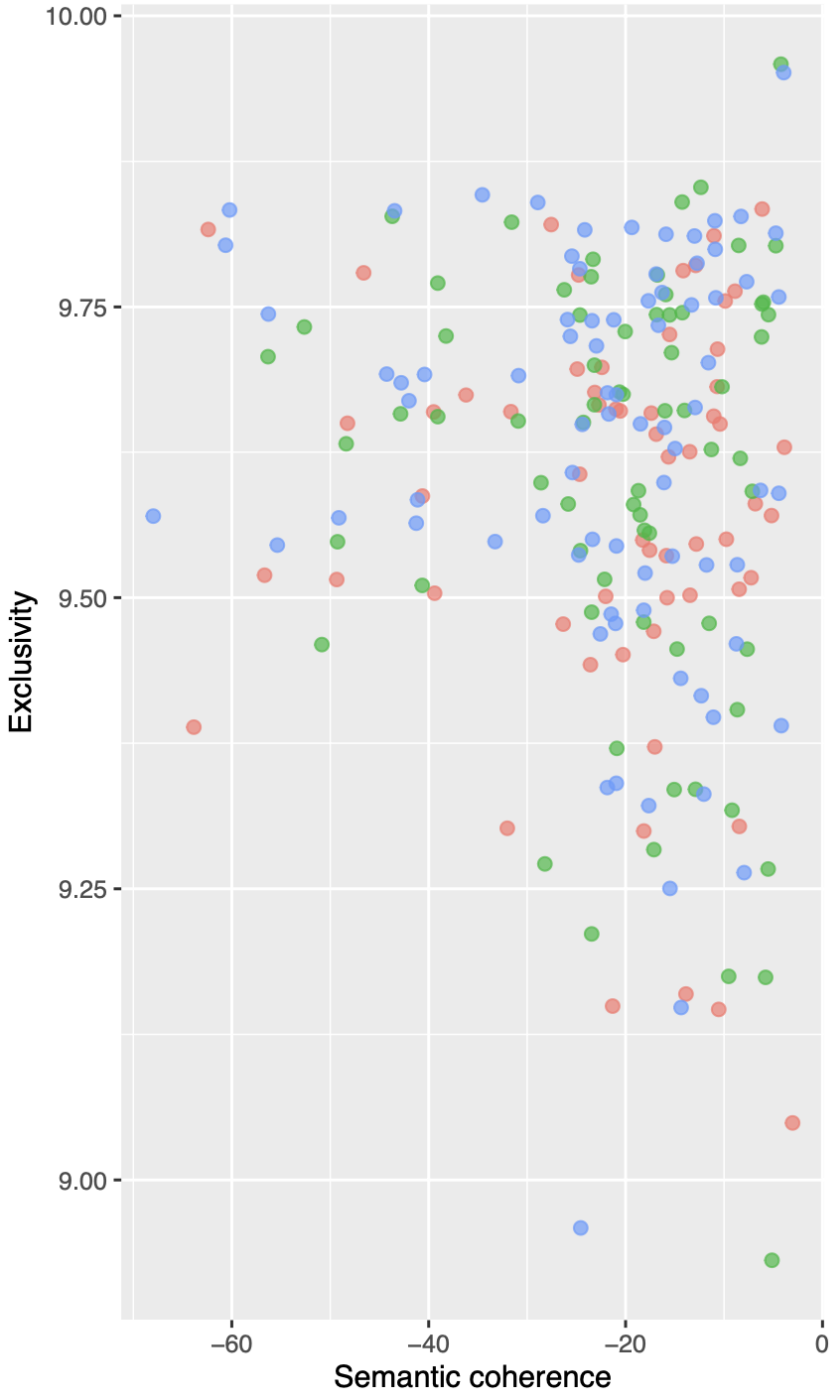


Note: These figures report measures of topic selection for $K = 10$ to 80. Held-out likelihood (panel (a)) and lower bound (panel (b)) criteria are to maximized. Residuals (panel (c)) is to be minimized.

[18] See Roberts et al. (2019) for more details on each metrics.

[19] Exclusivity is measured by FREX metric (see Bischof & Airoldi, 2012)

Figure 8: Exclusivity and Semantic Coherence



Note: This figure shows a combination of semantic coherence and exclusivity (as measured by FREX) of words to topics. The best model is the one that maximized the combination. Red, green and blue denote respectively $K = 60$, 70, and 80 topics.

B.2 Topic labeling

The tables below report labels of each of 70 topics computed using (i) the most probable bigrams in the first column (i.e., most probable two words association); and (ii) top 10 most probable words in the second column. Topic labeling is robust to other metrics such as lift, score and FREX. Additional results are available upon request to authors.

Table 6: ECB's Announcement Topic Labels

Topics	Label	Top 10 terms
Topic 1	Structural Reforms	reform, structur, growth, market, econom, labour, implement, product, will, economi
Topic 2	Monetary Union	european, europ, union, econom, integr, singl, polit, monetari, currenc, will
Topic 3	Payment System	payment, servic, retail, market, provid, instant, eurosystem, european, innov, solut
Topic 4	Member States	europ, year, european, will, peopl, one, countri, world, also, mani
Topic 5	Financial Stability	financi, macroprudenti, sector, fund, risk, bank, polici, system, asset, non-bank
Topic 6	Moneraty Policy	will, monetari, rate, council, polici, oper, area, bank, euro, market
Topic 7	Central Bank	bank, liquid, central, risk, asset monetari, credit, collater, polici, market
Topic 8	Interest Rate & Forward Guidance	inflat, polici, euro, area, monetari, growth, remain, continu, rate, condit
Topic 9	Money Market	market, liquid, bank, oper, money, rate, eurosystem, central, refinanc, polici
Topic 10	Global Economics	globalis, global, trade, economi, domest, increase, financi, import, world, intern
Topic 11	Price Stability	monetari, price, polici, inflat, strategi, stabil, analysi, money, central, develop
Topic 12	European Union	european, one, central, bank, monetari, econom, nation, countri, polici, system
Topic 13	Current Account	growth, economi, area, countri, euro, imbal, global, current, account, adjust
Topic 14	Repo Market	market, repo, securitis, collater, regul, transpar, secur, transact, will, rate
Topic 15	Monetary Analysis	statist, data, area, financi, inform, euro, account, european, nation, econom

Note: This table reports topics' labels from Topic 1 to 15 based on both most probable bigrams (first column) and top 10 most probable stemmed words (second column).

Table 7: ECB's Announcement Topic Labels (con't)

Topics	Label	Top 10 terms
Topic 16	Banks Supervision	bank, risk, need, can, supervisor, will, supervis, rule, busi, european
Topic 17	Labour Market	growth, can, firm, economi, product, crisi, potenti, unemploy, demand, invest
Topic 18	Government Council	independ, central, polici, bank, monetari, govern, account, mandat, treati, institut
Topic 19	Financial Supervision	supervisori, supervis, bank, institut, nation, author, supervisor, level, frameworld, europea
Topic 20	Euro Banknotes	digit, payment, euro, cash, bank, money, use, central, will, mean
Topic 21	Financial (Bond) Markets	market, euro, area, develop, financi, bond, integr, increas, introduct, currenc
Topic 22	Exchange Rate	polici, monetari, stabil, price, econom object, growth, will, rate, can
Topic 23	Inflation Expectations	euro, area, price, inflat, year stabil, rate, monetari, market, expect
Topic 24	Payment Instrument	card, payment, scheme, european, market, bank, will, area, retail, nation
Topic 25	Market Infrastructure & Cyber Resilience	cyber, financi, resili, will, risk, bank, trust, market, infrastructur, system
Topic 26	Financial Crisis	financi, crisi, measur, bank, polici, economi, market, credit, rate, will
Topic 27	Fiscal Policy	save, invest, pension, tax, increas, current, rate, age, may, will
Topic 28	Interest Rate	price, euro, growth, area, econom, develop, remain, stabil, rate, expect
Topic 29	Exchange Rate	euro, banknot, europ, area, exhibit, european, currenc, will, design, featur
Topic 30	Monetary Union	fiscal, govern, area, euro, polici, econom, countri, debt, framework, deficit

Note: This table reports topics' labels from Topic 16 to 30 based on both most probable bigrams (first column) and top 10 most probable stemmed words (second column).

Table 8: ECB's Announcement Topic Labels (con't)

Topics	Label	Top 10 terms
Topic 31	European Union	market, legal, one, law, chang, rule, regul, can, case, competit
Topic 32	Retail Payment	bank, payment, will, direct, nation, servic, custom, debit, need, scheme
Topic 33	Price Stability	euro, area, polici, currenc, econom, monetari, singl, new, european, eurosystem
Topic 34	Bank Money	money, bank, currenc, central, valu, trust, system, time, price, public
Topic 35	Asset & House Prices	household, incom, polici, monetari, hous, asset, price, distribut, effect, wealth
Topic 36	Financial Integration	financi, integr, market, european, euro, area, system, also, bank, cross-bord
Topic 37	Asset Purchase & Forward Guidance	rate, purchas, polici, asset, bond yield, market, expect, effect, forward
Topic 38	Systemic Risk	model, research, econom, use, system polici, risk, role, financi, uncertainti
Topic 39	Exchange Rate	countri, converg, member, euro, access, state, rate, new, process, polici
Topic 40	Risk Management	clear, risk, financi, market, deriv, central, need, will, system, manag
Topic 41	Sovereign Debt	euro, area, monetari, crisi, sovereign, polici, countri, market, bank, govern
Topic 42	Capital Flows	exchange, rate, polici, currenc, countri, capit, monetari, reserv, domest, economi
Topic 43	Payment Service	payment, will, bank, market, servic, european, also, euro, project, industri
Topic 44	Policy Strategy	price, monetari, euro, polici, stabil, area, rate, govern, eurosystem, council
Topic 45	Balance Sheet	polici, bank, monetari, area, euro, also, measur, will, credit, recoveri

Note: This table reports topics' labels from Topic 31 to 45 based on both most probable bigrams (first column) and top 10 most probable stemmed words (second column).

Table 9: ECB's Announcement Topic Labels (con't)

Topics	Label	Top 10 terms
Topic 46	Instant Payment System	technolog, financi, innov, bank, new, servic, payment, global, challeng, digit
Topic 47	Euro Banknote Coin	banknot, euro, coin, cash, will, changeov, circul, public, bank, countri
Topic 48	Euro Role	euro, currenc, intern, area, exchang, use, role, market, countri, dollar
Topic 49	Stress Test	bank, capit, risk, stress, assess, test, framework, account, requir, model
Topic 50	Product Growth	growth, product, labour, area, euro, market, increas, employ, rate, economi
Topic 51	Financial System	financi, market, risk, credit, institut, system, manag, fund, asset, investor
Topic 52	Central Bank Forward mission	bank, will, central, european, year financi, work, let, also, today
Topic 53	Market Infrastructure	market, secur, settlement, infrastruct, will system, integr, effici, clear, eurosystem
Topic 54	Macro-prudential Risk	financi, system, risk, crisi, macro-prudenti, polici, stabil, can, will, institut
Topic 55	Policy Low Rate	rate, interest, polici, monetari, low, lower, negat, real, effect, inflat
Topic 56	Climate Change, Risk & Green Bond	climat, risk, chang, bank, green will, transit, financi, need, can
Topic 57	Financial Stability	bank, financi, central, system, stabil, polici, supervis, institut, role, function
Topic 58	Euro Area	area, euro, countri, differ, shock, across, econom, region, differenti, competit
Topic 59	Public Debt	countri, crisi, debt, market, financi, public, may, problem, system, euro
Topic 60	Inflation Rate	inflat, price, expect, polici, shock, measur, may, year, monetari, demand

Note: This table reports topics' labels from Topic 46 to 60 based on both most probable bigrams (first column) and top 10 most probable stemmed words (second column).

Table 10: ECB's Announcement Topic Labels (con't)

Topics	Label	Top 10 terms
Topic 61	Bank Union	bank, resolut, union, will, singl, european, nation, mechan, supervisori, fund
Topic 62	Global Financial Crisis	global, financi, intern, crisi, economi, system, market, countri, institut, cooper
Topic 63	Euro Banknote	euro, will, banknot, inform, campaign, coin, area, public, nation, bank
Topic 64	Monetary Policy & Price	polici, central, monetari, bank, price, inflat, economi, expect, stabil, can
Topic 65	Banking Sector	bank, area, euro, credit, loan, sector, capit, lend, financ, profit
Topic 66	Assets Purchases	polici, pandem, monetari, measur, crisi, support, condit, will, fiscal, respons
Topic 67	Policy Decision	central, communic, bank, polici, public market, decis, transpar, inform, expect
Topic 68	Single Market	european, econom, union, need, nation area, polici, euro, polit, can
Topic 69	Financial Sector	bank, market, new, activ, competit, servic, financi, product, develop, can
Topic 70	Growth Rate	financi, polici, market, econom, growth, monetari, challeng, also, recent, time

Note: This table reports topics' labels from Topic 61 to 70 based on both most probable bigrams (first column) and top 10 most probable stemmed words (second column).

C Additional results and robustness

C.1 30-years CDS maturity

Table 11: Effects of Climate Regulatory Risk on 30-year CDS Spread (core analysis)

	1	2	3	4	5	6	7	8	9
					30Y				
$\Delta Climate_t$	13.9	11.5	6.08	-0.19	-0.26	4.92	11.2**	12.2*	38.4*
	(14.7)	(7.81)	(5.29)	(2.97)	(1.67)	(3.01)	(4.28)	(6.19)	(11.7)
$r_{i,t}^{30}$	-438**	-358***	-282***	-175***	-124**	-139**	-225***	-377***	-607***
	(137)	(83.7)	(66.5)	(50.1)	(39.8)	(45.8)	(67.3)	(100)	(130)
$\Delta VIX_{i,t}$	371***	306***	232***	157***	106***	136***	249***	356***	528***
	(36.5)	(29.6)	(28.0)	(27.1)	(21.5)	(21.7)	(28.8)	(30.9)	(34.6)
$\Delta MRI_{i,t}^{30}$	15.8***	14.8***	14.0***	13.4***	13.3***	13.6***	14.8***	16.9***	19.2***
	(1.47)	(1.51)	(1.73)	(1.77)	(1.84)	(1.82)	(1.80)	(1.58)	(1.65)

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Note: This table presents coefficient estimates derived from the baseline panel quantile regression model, as specified in Equation 2. The estimates are segmented by CDS spread returns for 30-year maturity. These estimates are reported across all nine deciles, with standard errors in brackets. To facilitate interpretation, all estimates have been scaled by a factor of 1e04.

Table 12: Effect of climate regulatory risk on 30-year CDS spread (sector analysis)

	1	2	3	4	5	6	7	8	9
BM x $\Delta Climate_t$	178***	58.6**	57.6**	63.7***	61.3***	50.0***	62.2**	54.6*	131**
	(46.1)	(21.5)	(17.7)	(10.8)	(8.75)	(12.3)	(23.9)	(26.7)	(49.0)
CCGS x $\Delta Climate_t$	294***	115***	112***	83.8***	77.1***	67.2***	70.3***	73.5***	134***
	(36.3)	(19.7)	(15.9)	(11.0)	(7.16)	(9.21)	(14.3)	(17.9)	(36.6)
NCGS x $\Delta Climate_t$	272***	122***	118***	95.2***	82.1***	63.9***	96.9***	118***	229***
	(35.9)	(26.3)	(12.4)	(14.2)	(13.5)	(14.3)	(24.0)	(22.5)	(37.8)
Energy x $\Delta Climate_t$	-14.2	94.3*	138***	80.4***	64.6***	46.5***	59.7***	52.9**	226***
	(80.9)	(39.6)	(35.4)	(9.84)	(4.10)	(4.69)	(5.05)	(18.3)	(39.8)
Finance x $\Delta Climate_t$	108***	53.9**	77.3***	72.3***	60.8***	47.4***	58.3***	54.0	119***
	(28.4)	(18.1)	(15.7)	(10.3)	(8.98)	(10.1)	(12.7)	(31.6)	(35.7)
Healthcare x $\Delta Climate_t$	88.2*	26.6*	64.2***	53.6***	56.3***	35.2***	35.8***	28.3	95.7***
	(40.3)	(13.2)	(13.5)	(6.88)	(4.08)	(6.34)	(9.68)	(18.2)	(24.6)
Industrials x $\Delta Climate_t$	202***	111***	118***	86.1***	77.4***	65.4***	70.5***	76.3*	119**
	(57.5)	(11.8)	(11.7)	(9.68)	(8.16)	(8.14)	(10.6)	(30.7)	(43.7)
Real Estate x $\Delta Climate_t$	171***	45.8*	92.8***	67.4***	62.7***	49.2***	64.6***	67.4***	120.1**
	(50.5)	(18.4)	(12.9)	(7.25)	(4.46)	(7.56)	(7.70)	(18.6)	(45.7)
Technology x $\Delta Climate_t$	175***	109***	107***	81.4***	68.5***	62.8***	64.0***	66.5**	88.4***
	(30.5)	(9.86)	(17.1)	(8.80)	(6.81)	(5.29)	(8.43)	(23.2)	(25.5)
Utilities x $\Delta Climate_t$	74.7	60.2***	70.7***	61.7***	58.1***	47.5***	54.7***	50.6*	149*
	(58.8)	(15.9)	(13.2)	(8.55)	(4.93)	(6.67)	(12.5)	(21.5)	(62.4)

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Note: This table presents the coefficient estimates for interaction terms obtained from the sector panel quantile regression model, as detailed in Equation 3, for 30-year CDS spreads. Estimates are reported for all nine deciles, and standard errors are in brackets. For ease of interpretation, all coefficients have been scaled by a factor of 1e04.

C.2 Event study

Table 13: Event Study Analysis for 5- and 10-year CDS

	1	2	3	4	5	6	7	8	9
					5Y				
D_t	28.5*	12.3	-8.21*	-1.77	5.13**	11.0***	32.8***	76.0***	114***
$r^5_{i,t}$	-810***	-662***	-475***	-287***	-190***	-221***	-368***	-588***	-894***
ΔVIX_t	608***	475***	365***	240***	156***	201***	377***	593***	917***
$\Delta MRI^5_{i,t}$	22.8***	23.0***	22.6***	22.7***	22.8***	22.9***	23.8***	26.2***	28.6***
					10Y				
D_t	32.8***	-2.39	-11.7**	-3.72*	1.84*	6.14***	29.4***	58.6***	93.2***
$r^{10}_{i,t}$	-655***	-507***	-372***	-202**	-135***	-165***	-292***	-551***	-937***
ΔVIX_t	627***	488***	365***	228***	133***	162***	334***	521***	800***
$\Delta MRI^{10}_{i,t}$	2.68***	2.93***	2.65***	2.18***	1.83***	2.18***	3.23***	4.49***	5.82***

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Note: This table presents the coefficient estimates from our event study for both 5- (top panel) and 10-year (bottom) maturities. Estimates are reported for all nine deciles, and standard errors are in brackets. For ease of interpretation, all coefficients have been scaled by a factor of 1e04.

C.3 The greening of the FED narratives

Table 14: Federal Reserve System's Narratives

Topics	Top 10 terms
Topic 1	facil, window, discount, liquid, collater, panic, treasuri, lend, reserv, fund
Topic 2	rule, simpl, prescript, gap, output, equilibrium, optim, variabl, money, policymak
Topic 3	macroprudenti, vulner, countercycl, leverag, resili, buffer, buildup, tool, time-vari, lean
Topic 4	euro, currenc, union, circul, e-money, dollar, euro-denomin, transit, benchmark, submiss
Topic 5	consolid, affili, merger, insur, subsidiari, umbrella, safeti, charter, compani, thrift
Topic 6	model, analysi, research, data, benefit-cost, empir, analys, staff, literatur, assumpt
Topic 7	communic, transpar, minut, releas, statement, project, decis, index, forecast, public
Topic 8	subordin, supervisor, disciplin, host, techniqu, supervisori, pillar, supervis, capit, subsidiari
Topic 9	citi, neighborhood, partnership, rural, moderate-incom, communiti, local, nativ, lower-incom, resid
Topic 10	recoveri, spend, weak, quarter, inventori, pace, outlook, sale, slow, construct
Topic 11	resolut, reform, fail, oversight, crisi, nonbank, jurisdict, failur, coordin, big-fail
Topic 12	neutral, interest, rate, equilibrium, low, lower, bound, zero, yield, real
Topic 13	market, financi, liquid, risk, investor, credit, fund, mortgag, bank, secur
Topic 14	core, inflat, food, energi, slack, labor, wage, headlin, commod, compens
Topic 15	basel, comment, propos, implement, supervisor, agenc, pillar, framework, guidanc, minimum
Topic 16	budget, social, tax, retir, fiscal, age, revenu, health-car, surplus, retire
Topic 17	independ, central, deflat, zero, polit, credibl, monetari, money, stimul, mandat
Topic 18	small, estat, busi, loan, owner, commerci, creditworthi, lend, credit, lender
Topic 19	debt, household, ratio, home, profit, refinanc, homeown, mortgag, cash, extract
Topic 20	sharehold, disclosur, corpor, fair, audit, auditor, pension, mutual, disclosuri, account
Topic 21	gas, oil, barrel, crude, energi, hurrican, gasolin, spot, petroleum, drill
Topic 22	forecast, util, trend, shock, suppli, stori, acceler, favor, growth, disinflationari
Topic 23	complianc, audit, control, director, auditor, reput, manag, enterprise-wid, senior, organ
Topic 24	premium, yield, bond, treasuri, curv, ten-year, volatil, long-term, slope, matur
Topic 25	deficit, surplus, save, imbal, trade, gdp, foreign, export, domest, claim
Topic 26	macroeconom, policymak, action, volatil, monetari, instabl, polici, advers, econom, stanc
Topic 27	electron, check, payment, digit, fintech, stablecoin, network, debit, card, ledger
Topic 28	shadow, prudenti, repo, wholesal, broker-deal, surcharg, intermediari, fire, system, liabil
Topic 29	subprim, predatori, higher-pr, lender, abus, mortgag, lend, decept, loan, penalti
Topic 30	job, women, worker, labor, unemploy, wage, hire, workforc, employ, men

Note: This Table reports the top 10 most probable stemmed words for topics 1 to 30.

Table 15: Federal Reserve System's Narratives (con't)

Topics	Top 10 terms
Topic 31	readi, conting, prepar, council, prepared, millennium, site, date, rollov, backup
Topic 32	foreclosur, rental, vacant, hous, properti, delinqu, homeown, mortgag, modif, home
Topic 33	doubtless, endeavor, engend, presum, paradigm, arguabl, civil, perceiv, free, readili
Topic 34	pandem, covid, support, virus, reopen, vaccin, pre-pandem, bottleneck, pre-covid, economi
Topic 35	inflation-target, target, inflat, anchor, explicit, regim, nomin, object, dual, numer
Topic 36	stress, test, scenario, buffer, supervisori, surcharg, capit, firm, loss, exercis
Topic 37	communiti, banker, tailor, examin, burden, custom, local, rural, branch, feedback
Topic 38	purchas, accommod, sheet, committe, guidanc, longer-term, normal, longer-run, outlook, path
Topic 39	high-tech, equip, product, hour, comput, per, technolog, invest, softwar, growth
Topic 40	gold, emerging-market, crise, countri, peg, exchang, float, liber, flow, poor
Topic 41	deriv, dealer, hedg, counterparti, clearinghous, default, swap, trade, collater, settlement
Topic 42	inequ, black, famili, white, wealth, racial, minor, dispar, middle-incom, incom
Topic 43	skill, physic, patent, farm, intellectu, human, high-school, technolog, agricultur, scientif
Topic 44	listen, review, dual-mand, makeup, strategi, neutral, maximum, price-st, goal, statement
Topic 45	financi, risk, market, system, bank, institut, can, manag, inform, will
Topic 46	lot, dont, happi, get, feel, thing, peopl, got, road, think
Topic 47	global, spillov, export, foreign, exchang, domest, emerg, depreci, inflow, transmiss
Topic 48	bubbl, asset-pric, burst, stock, bust, recess, episod, collaps, boom, specul
Topic 49	presid, chairman, governor, vote, member, chair, board, staff, divers, fed
Topic 50	literaci, educ, student, consum, teach, person, knowledg, teacher, young, save

Note: This Table reports the top 10 most probable stemmed words for topics 31 to 50.

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