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THE GEOGRAPHY OF CLIMATE CHANGE RISK ANALYSIS AT CENTRAL BANKS IN EUROPE

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The geography of climate change risk analysis at central banks in Europe

(A központi bankok klímakockázat-elemzésének földrajza Európában)

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Contents

Abstract

Incorporating climate change considerations in central bank decisions has been fraught with legal and technical controversies. Legal, because interpretations of central bank mandates in relation to sustainability has been widely cited as hurdles to the discussion of climate change; and technical, because no methodology used to exist to assess and to measure the impact of climate risks on financial stability.

This paper first analyses the spatial and temporal process climate change-related risk analysis spread among central banks by text mining - counting relevant bigrams - in 941 European financial stability reports of 39 central banks in Europe. It then maps climate risk relevant references of these reports.

The study argues that geographical proximity played a significant role in the spread of the climate friendly central bank mandate interpretations. It also shows that the ECB, together with representatives of EU national central banks and their technical know-how, played a pivotal role in turning an innovation from being a novel research method into an accepted analytical framework. At the beginning of 2023, it now paves the way a towards a Basel-conform banking regulation within the EU, which reflects climate change risks too.

JEL: E58, Q54, G17, G21, L38

Keywords: financial geography, central bank mandates, climate change, financial stability, text mining, bigram search, fiduciary duty

Összefoglaló

Az éghajlatváltozással kapcsolatos megfontolások jegybanki döntésekbe való beépítése előtt sokáig jogi és technikai akadályok álltak. Jogi, mert korábban a jegybanki mandátumokra a fenntarthatósági vizsgálatok akadályaként tekintettek; és technikai, mert nem létezett módszertan az éghajlati kockázatok pénzügyi stabilitásra gyakorolt hatásának mérésére.

Írásunk a központi bankok éghajlatváltozással összefüggő kockázatok elemzésének térbeli és időbeli terjedését vizsgálja. Ezt szövegbányászattal teszi – a releváns bigramokat számolva, amelynek fókusza 39 európai központi bank összesen 941 európai pénzügyi stabilitási jelentése. A cikk ezt követően a stabilitási jelentések irodalmi hivatkozásait is feltérképezi.

Elemzésünk azt mutatja, hogy a földrajzi közelség jelentős szerepet játszott a klímabarát jegybanki mandátum-értelmezés elterjedésében, majd az EKB egyre inkább kulcsszerepet kezdett játszani a folyamatban. Mire az innováció újszerű kutatási módszerből elfogadott elemzési keretté változik, előbb-utóbb adaptálhatóvá válik egy klímakockázatokat tükröző Bázel-konform szabályozásra.

1 Introduction

In his famous speech at Lloyds, Mark Carney, governor of the Bank of Canada from 2008 to 2013, and governor of the Bank of England from 2013 to 2020, pointed out the tragedy of the horizon when incorporating climate change-related considerations in institutional decisions. He said that the implications of climate change are beyond the planning horizon of most actors, which means, *"beyond the business cycle, the political cycle, and the horizon of technocratic authorities, like central banks, who are bound by their mandates"* (Carney, 2015). While it is the temporal aspect of his statement which is most often cited, his point with central bank mandates is equally important.

There has been considerable heterogeneity in the way central bank mandates relate to climate change and in their interpretations both in space and over time. For instance, Asian central banks generally seemed to be open towards incorporating the fight against climate change in their policies. In particular, the Reserve Bank of India (RBI) addressed environmental aspects in a note to its supervised entities in 2007, followed by the Bangladesh Bank to issue regulations to banks to incorporate environmental aspects in lending in 2011 (Durrani et al. 2020). In Europe, however, most central banks had initially been hesitant to consider climate change in their policies, given their missing or ambiguous legal mandates (Dikau and Volz, 2021). Parallels can be drawn with the asset management industry, where fiduciary duty, a legal obligation to consider only financially relevant factors in investment decisions, was interpreted as a need to focus on short-term returns (Clark and Hebb, 2005). Trustees only gradually started to incorporate longer term considerations such as climate change, and only did so if they saw others doing it (Woods, 2011).

Besides social and geographical proximity, the local presence of complementary skills seems to be an important determinant for an initiative to be successful, as the example carbon markets shows (Knox-Hayes, 2009). Such a complementarity set of skills and the parallel representation of nation states and technical skills is present at the European Central Bank (Clark, 2015), which is not only a prime candidate to be a forerunner in the development of climate risk analytical methodologies, but can legitimately develop a mutually accepted set of methodologies (and possibly regulation) within the EU. This development may be similar to the process the Basel risk framework became a globally accepted standard (Bieri, 2009).

The main aim of this paper is to understand the temporal process various central banks in Europe gradually started reporting on climate risks in their financial stability reports (FSRs). For that, we analyze 941 FSRs of 39 central banks in Europe, published between 2003 and 2022, by counting the number of climate change relevant bigrams, followed by a graph-analysis of references within the FSRs.

It is shown that central bank mandate interpretations have been gradually opening towards climate change-related topics since the Paris Agreement of late 2015 (EP, 2018, MNB, 2022). This included the systematic measurement and tracking of climate risk exposures (BIS, 2021, EBA, 2022). Initially, however, the methodologies and the necessary data on climate risks were almost nonexistent, and their development required research and data gathering. Then, similarly to other innovations, the discussion of climate risks in financial stability reports started in a geographically bounded location, led by the Central Bank of the Netherlands (De Nederlandsche Bank, DNB) and the National Bank of Belgium (NBB). It subsequently spread across space and time, whereby proximity (in the wider sense human geographers interpret it (Rutten, 2016), Simandan, 2016)) played a significant role. Fairly quickly, however, the onus of the innovation moved to the European Central Bank (ECB), which has not only been working on the ways to measure the financial stability impact of climate change in a coordinated manner, but has also been drafting Eurozone-wide analyses. In the future, climate change related financial risk analysis may form a part of the standard set of FSRs, at least within the Eurozone (ECB/ESRB, 2022).

The paper serves as evidence that financial analytical methods spread across space and time in a geographically bounded way, and become norm only once a higher order legal framework says so. These results also underpin the importance of top-down regulation in climate change-related matters in an institutional setting.

One should not read this paper as an assessment of central bank climate activism, as it offers a glimpse into the understanding of climate risks as seen in FSRs. Moreover, no climate risk analysis can reduce our carbon footprint; it is active mitigation and adaptation measures which are the real and urgently needed actions to prevent a full-scale climate disaster.

This paper is structured as follows. The next section discusses the literature on the geography of financial institutions, and its regulations and central bank mandates. This is followed by a section on climate risk representation, followed by analysis of FSRs. The fifth section discusses the manifestation of climate risks within FSRs, and the last section concludes.

2 The geography of central bank mandate interpretations

Despite the fact that the United Nations Environment Programme Finance Initiative (UNEP FI) drew attention to the global warming problem in 1992, financial institutions in general used to face grave legal difficulties with incorporating climate change considerations in their business, including central banks. According to the fiduciary duty rule of the Anglo-Saxon world, corporate managers must act in the best interest of their beneficiaries. This used to mean maximizing financial returns, which often meant quarterly returns. Fiduciaries had a difficult time explaining that sustainability goals are in the long-term financial interest of their beneficiaries and not some distant ideologist goal (Clark and Hebb, 2004).

In 2005, the UN has entrusted the Freshfields Bruckhaus Deringer law firm to conduct research into the possibilities of incorporating Environmental, Social and Governance (ESG) Issues into the investment decision making process of asset managers (Freshfields Report, 2005). This report delivered legal arguments stating that doing so is "*clearly permissible and is arguably required in all jurisdictions"*. Given that institutions such as pension funds and endowments have the longest investment horizons, which may stretch to full working life or to perpetuity, incorporating climate change in investment decision making directly belongs to the trustees' legal obligations (Clark and Hebb, 2005).

Despite the Freshfields report, which was an opinion expressed by an expert company, Woods (2011) found that, in practice, fiduciary duty had still been interpreted by pension fund trustees as the need to act in a similar way as most other investors do. Her research confirmed that the collective inaction of pension funds was related to the uncertainty surrounding the interpretation of fiduciary duty and to behavioral inertia. Her paper highlights that in Anglo-Saxon legal framework, the concept of 'peer' is highly important, and decision makers must act as someone '*in a like capacity and familiar with such matters would use in the conduct of an enterprise of a like character and with like aims'* (ERISA, 29 USC §18.1104). It is not easy to break with conventional investment processes and to consider climate change in investment decisions when no other institution does so. One implication of Woods's research is that geography, the (social) proximity of actors influences the adoption patterns of innovations, including institutional behavior too. An example for social proximity[1] in central banking context in Europe is offered by the Eurozone. Eurozone members dominate the numerous committees and forums of the ECB (there are members from countries with national currencies too), one could expect that the spread of climate change-related policy interpretations spreads quicker among them.

To illustrate the significance of geography in this respect, the 'Report of the Climate-Related Market Risk Subcommittee, Market Risk Advisory Committee of the U.S. Commodity Futures Trading Commission' is cited (Behnam and Litterman, 2020). Its topics are fairly similar to the points discussed by the ECB and other European financial stability reports. Its list of references, however, never made over the pond, meaning that we could not identify a single citation of a central bank publication in Europe.

There are further parallels between the interpretation of fiduciary duty and central bank mandates in relation to climate change. The typical core central bank mandate is to maintain price stability, a dominant task since the inflationary times of the 1970s and 1980s. The mission to foster financial stability was elevated to a similar significance in the years following the financial crisis of 2008 (Issing et al., 2008). The comprehensive analysis on central bank mandates of Dikau and Volz (2021) shows that during the 2010s, most EU central banks only indirectly referred to sustainability in their mandates, by citing Article 3 of the Treaty on European Union. It says that the Union "[…] *shall work for the sustainable development of Europe based on balanced economic growth and price stability, a highly competitive social market economy, aiming at*

[1] One should emphasize the way human geographers interpret proximity. Rutten (2016) provides an overview of the socio-spatial dynamics in proximity interpretations, implying that the purely physical interpretation of the „near-far" dichotomy hides the social interdependencies in interactions during the knowledge creation process.

full employment and social progress, and a high level of protection and ***improvement of the quality of the environment***" (emphasis added). Hence, among most EU central banks, environment was only an indirect matter, codified at the end of a banal sentence in a distant legal text. There has been considerable room for interpretation how far central banks may reach, particularly during the first half of 2010s.

The literature holds hints on the patterns such an innovation spreads in space and time, once the interpretation tilts in the direction of permissive attitudes towards climate change-related central bank policies. Knox-Hayes (2009) found that successful carbon markets were created where service providers with complementary skills and offerings were present, notably, in London and New York, and knowledge transfer was made easier by their frequent interactions. Again, the ECB, in which both the representation of nation states and the representation of expertise is present (Clark, 2015), offers such an institutional avenue for exchanging ideas and mandate interpretations. To start with, all EU nationals are eligible to work for the ECB, including short term exchange programs for national central bank staff. Another example is the dialogue on various topics run by the European System of Central Banks (ESCB), which often takes place at the ECB. Specifically on climate change, the ECB set up a Climate Change Centre in 2021, reporting directly to the ECB's President, with initially ten individuals (ECB, 2021c), including a renowned climate scientist with a PhD in agrometeorology and climatology (Responsible Investor, 2022).

Subsequently, the ECB provides opportunity to identify complementary skills and for an exchange of best practices in climate risk analysis (see one outcome of such a collaboration at ECB, 2023). Once a jointly determined methodology is created and agreed upon, such an analytical framework may turn into a widely accepted standard, in a similar way Bieri (2009) describes the success of the Basel-process and the spread of a globally accepted regulation. This means, climate risk analysis may lose its novelty status and turn to be a part of the wider risk framework.

To summarize the expected geographical evolution of central bank climate risk analysis: it started as an innovation, which first spread in a geographically bounded way. It is expected that Eurozone central banks were earlier adopters than central banks with national currencies, and finally, climate risk analysis is expected to join the standard risk analysis framework and lose its special status in financial stability publications.

3 Climate change and financial stability

There are broad options for European national central banks to interpret their mandates related to sustainability (Dikau and Volz, 2021). The DNB engaged with it as early as in 2011. After the financial crisis of 2008, they reasoned, "*we* [the members of the Governing Board] *realised it was essential to link prosperity with sustainability*" (Knot, 2015, Elderson, 2018). Other central banker thinkers were not turning towards climate change directly, but were trying to establish a link with financial stability. As Mark Carney of the Bank of England stated in his famous speech at Lloyds in 2015, the planning horizon for most economic actors, including central bankers, was considerably shorter, given the length of a typical credit cycle of ten years at most. This opinion was in 2019 reinforced by the ECB Banking Supervision: "*[c]limate-related risks do not pose a threat to the financial stability in the euro area in the short term*" (ECB Banking Supervision, 2019). Hence climate change could not be a defining issue for financial stability during the 2010s.

The Paris Agreement, signed on 12 December 2015 and entered into force on 4 November 2016, in which signatories agreed on country-level legally binding targets on CO_2 emissions, led to a tipping point in central bank mandate interpretations. For the avoidance of doubt, the European Parliament (EP) underscored in its 2016 annual report on the ECB that *"the ECB as an EU institution is bound by the Paris Agreement"* (EP, 2018).

The EP statement was not just a "Freshfields report moment" for central banks, but significantly more. As Thomas Steiner, a director of the Austrian National Bank (ÖNB) stated, *"we are policy takers, not policy makers"* (Steiner, 2022), which means that central banks execute orders, and the statement of the EP was just that. The ECB Strategy Review, published in 2021, is the manifestation of the revised mandate interpretation in favor of fighting climate change. The Strategy Review laid out an action plan to include climate change considerations in the Bank's monetary policy strategy, including regular climate stress testing of the Eurosystem balance sheet from 2023 onwards (ECB, 2021b).

There were further factors in play besides the Paris Agreement and the EP decision to push central banks towards an environmentally friendly mandate interpretation. For one, the consequences of climate change have been gradually arriving at the doorstep of the ECB. During the summer of 2018, drought led to low waters, and cargo ships were not able to travel on the Rhein, leading to fuel shortages in southern Germany (e.g. Süddeutsche Zeitung, 2018). Another, less tangible factor was the criticism that the quantitative easing programme (QE) of the ECB has been overwhelmingly skewed towards high emitters (Matikainen et al. 2017), and researchers demanded that it should explicitly include the climate agenda its strategic focus.

While such events, including messages of elected politicians, litigation threats and weather phenomena, drew climate change to the ECB's attention, other central banks may have not followed so close. For instance, the deputy governor of the Czech National Bank, which is not Eurozone member, stated that environmental policies should be left to elected leaders (Bloomberg, 2021), and its FSRs have not touched upon the topic until 2022. Therefore, the next section discusses the methodology to map the geography of climate change analysis in European financial stability reports to systematically uncover the spatial and temporal spread of climate risk analysis at central banks.

4 Data and methodology

4.1 FINANCIAL STABILITY REPORTS

To understand the geography of climate change risk analysis, we looked at the FSRs of central banks in Europe. One may debate if FSRs are the right kind of publications to study the ways central banks discuss climate change risk. Admittedly, climate risks can be analyzed in a macroeconomic setting, which are not necessarily central to FSRs. Sovereigns are at risk of default as a result of climate change (Volz et al., 2020); and macro models with sectoral breakdowns can be powerful tools for macroeconomic analysis, examining the impact of climate change on GDP, inflation and other macroeconomic variables (CamEcon, 2021). The rising significance of financial stability in central bank mandates and modelling efforts after the crisis of 2008, however, tilted climate change analysis towards a financial stability perspective.

Financial stability, the ability of the state in which the "*financial system […] is capable of withstanding shocks and the unravelling of financial imbalances"* (ECB, 2016)[2], is assessed in FSRs[3] by most central banks. An FSR is a "*vehicle to allow stakeholders to form a view about how effectively the central bank is undertaking its broader financial stability responsibilities*" (Allen et al., 2004). It usually consists of "core" and "non-core" parts, whereby core-sections cover the same topics from issue to issue, and non-core parts include results from special and occasional studies (Cihák, 2006). While one can and should openly discuss if a special topic should be part of an FSR or published separately, it is hardly questionable that issues directly impacting financial stability should be parts of it.

The Task Force on Climate-related Financial Disclosures categorizes climate risks into physical risks, the damage or complete destruction of physical assets stemming from climate change induced weather events, and into transition risks which accompany the transition to a low- or zero carbon economy. Both acute physical risks, which are event driven, and chronic risks, which result from long-term shifts in climate patterns, such as sea level rise (TCFD, 2017), may diminish or destroy a borrower firm or individual's ability to repay its loan obligation on time (increase their 'probability of default' values), and increase the 'loss given default' values, both of which are core concepts in a typical analysis in FSRs within the Basel Risk Regulatory Framework (Aspachs et al., 2006). Similarly, transition risks, such as investments in low- or zero emission production techniques, house insulations, or even climate-related litigation costs affect future credit quality.

To underscore the relevance of FSRs further: Pointner et a. (2019) summarize the relationship between further Basel III-risk types, typical concepts in financial stability reports, and physical risks. They concede that market risk (increased price volatility due to disasters), liquidity risk (sudden withdrawals, high demand for emergency loans), operational risk (destruction of banking infrastructure), reputational risk and systemic risk (rising correlation of defaults, underestimation of natural disasters) may all be results of sudden, acute physical disasters. All these arguments underpin the tenet that financial stability reports are the right documents to look at when looking for climate risk analysis in central bank publications.

[2] The World Bank, the Bank of England, the De Nederlandsche Bank and the Magyar Nemzeti Bank all define financial stability in a similar spirit.

[3] Some central banks use a different name for FSRs but report on similar topics. The Banque de France, for instance, produces a journal-like Financial Stability Review, whereby each issue is dedicated to a special topic, and its chapters are basically academic research papers. Its 2019 issue focused on climate change and greening of the financial system with an impressive set of analyses and papers. In contrast, the French report on financial stability is referred to as the 'Assessment of Risks to the French Financial System', which we denote as FSR in this paper. Similarly, the Banco de España has a Financial Stability Review (the more journal-like publication) and a Financial Stability Report on the state of the financial system. We refer to this latter as FSR.

4.2 THE DATA

The underlying data was obtained using 941 FSRs of 39 central banks from Europe, as reflected by **Table 1**. We collected the FSRs from the earliest date we found them online, until the end of 2022. From the central banks included, 26[4] are within the European Union, and the European Central Bank. In addition, we also looked at further national banks of Europe, including the UK, national banks of Iceland, of the countries in the Balkans, Moldova and the Ukraine. While most of FSRs are available in English, there are exceptions. The Banque Centrale du Luxembourg writes in French only (we translated the bigrams in French, with possibly less than optimal results); The Vatican and Andorra do not have such reports. This way, we had FSRs of 39 institutions in total. Each of these publish one or two FSRs every year, or none[5], and their length varies between a few and up to 200 pages.

Table 1
Countries included in the analysis

Countries	Number of national banks
All EU-member countries, apart from Bulgaria, for which we did not find FSRs in English	26
ECB	1
Non-EU European countries with central banks: Albania, Bosnia-Herzegovina, Iceland, Kosovo, Montenegro, North Macedonia, Norway, Serbia, Switzerland, UK, Ukraine	11
Total	**39**

We carried out two types of analysis: counting bigrams and mapping the references of FSRs. First, we scanned the FSRs for climate change related expressions by counting them. Such expressions are best captured as bigrams, or two consecutive words, such as 'physical risks', 'hot house' (a scenario defined by NGFS), 'green bonds' or 'climate stress'. The use of its monogram versions, or single words, can appear in other contexts, such as 'physical money' or 'economic climate', and would distort the analysis.

Bigram search is a widely accepted way of analyzing cultural tendencies in books (Michel et al. 2010) or in bibliographic databases and journal archives (Chumtong and Kaldewey, 2017). Financial geographers have also used bigram frequencies to underpin their analysis (Clark et al. 2015).

Relevant bigrams were identified using two sources: (1) from the journal papers and central bank documents most often cited by FSRs' climate change sections, which specifically focus on the modelling questions and financial implications of climate change[6]. These documents were selected either because they are the most often cited documents by FSRs or we found them relevant during the literature review. From these documents, we selected the top two thousand most frequent bigrams[7], after removing stop words[8], and expression stemming[9] (removal of endings). Then we manually flagged climate change relevant items from the most frequent bigrams. The second (2) source is represented by the most relevant bigrams from the journal *Nature Climate Change* between 1990 and 2014, as identified and listed by Hamed et al. (2015). The reason for the use of a second source is to counter any criticism of a potential bias in the papers we used to learn relevant bigrams. Admittedly, there is *some* overlap between the authors of the climate-relevant FSR sections

[4] We could not identify FSRs for the Bulgarian National Bank in English.
[5] For instance, the Bundesbank did not publish a financial stability report in the crisis year of 2008, or the Croatian National Bank FSR is not available on their website in English for 2020. Another peculiarity is Greece, where their Central Bank did not publish a traditional FSR during the recovery phase from the crisis during most of the 2010s. The Central Bank of Ireland started publishing an FSR in 2019 only. The links to the FSRs prior to 2019 of Central Bank of the Republic of Kosovo were broken on their website. Moreover, we were not able to find a map (shapefile) that recognizes the country.
[6] DNB (2017), Vermeulen et al (2018), Batten et al. (2016), Battiston et al (2017), BIS (2021), Behnam and Litterman (2020), Chenet et al (2019), Dikau and Volz (2021), Durrani et al. (2020), ECB (2021), Kemp (2021), Kemp et al (2022), Keenan (2019), Keenan and Bradt (2020), Hudson et al (2019), Gray (2021), Alogoskoufis et al (2021)
[7] The term frequency – inverse term frequency approach (tf-idf), widely used to identify the most important words (or bigrams) in a document, delivered considerably less climate change relevant top candidates than the method described above.
[8] Stop words are words such as 'the', 'or', 'and', taken from the *tidytext* library, which combines three distinct lexicons, and lists altogether 1149 stop words (Silge and Robinson, 2016).
[9] Using Dr. Martin Porter's stemming algorithm, implemented by the SnowballC R package (Bouchet-Valat, 2020).

and the authors of these papers, who may use their own vocabulary. We counterbalance this potential effect by including bigrams from *Nature Climate Change*. The final bigram list is included as a footnote. [10]

Before the last step, we classified each bigram in the learner set manually if they are rather related to physical risks (P), transition risks (T) or both (B). Finally, we counted the number bigram appearances within the FSRs, and aggregated the results for each year.

The second part of the analysis involved the opening of all relevant FSRs, and manually collecting the references from the parts discussing climate change. This way, a table was constructed with the FSR's year, publication's name, year and institution, containing in total 587 references. We also added an additional variable to record if the publication is available at a central bank (not just FSRs but working papers and other publications[11]), at a scientific journal or at any other institution.

[10] The stemmed bigrams (i.e. two consecutive words after the removal of stopwords ('the', 'a', etc.) and word endings) are listed in the followings. We classified each bigram manually, whereby T stands for transition risk related, P for physical risk related and B for both risk type-related bigram: *climat chang (B), climat risk (B), climat relat (B), physic risk (P), transit risk (T), climat polici (B), carbon price (T), green bond (B), fossil fuel (T), carbon tax (T), flood risk (P), low carbon (B), sea level (P), orderli transit (B), climat scenario (B), energi transit (T), hot hous (B), carbon intens (T), hous world (B), sustain financ (B), transit scenario (T), green financ (B), extrem weather (P), level rise (P), climat stress (P), flood insur (P), weather event (P), global warm (B), disorderli transit (B), ghg emiss (T), pari agreement (B), natur disast (P), renew energi (B), greenhous ga (B), carbon emiss (T), carbon economi (T), risk cascad (P), cat model (P), climat impact (P), transit polici (T), vulner factor (P), transit vulner (T), address climat (B), sustain invest (T), carbon footprint (T), carbon neutral (T), chang risk (B), emiss reduct (T), energi mix (T), climat action (B), energi effici (T), incorpor climat (B), climat model (P), environment risk (P), climat data (P), clim chang (B), ga emiss (T), ngf scenario (B), environment protect (B), natur climat (P), degre celsiu (B), iipp wp (B), integr climat (B), green transit (B), strand asset (T), environment sustain (B), includ climat (B), physic climat (P), intergovernment panel (B), wide climat (B), emiss intens (T), damag function (B), energi intens (T), futur climat (B), global temperatur (P), system ngf (B), emiss trade (T), reduc emiss (T), assess climat (B), carbon border (T), climat target (B), eu taxonomi (T), green technologi (B), nat clim (P), flood damag (P), mitig climat (P), chang mitig (P), durrani volz (B), green bank (B), rise sea (P), temperatur rise (P), catastroph climat (P), climat system (P), coastal flood (P), environment polici (B), fiduciari duti (B), greenhous gase (B), hot summer (B), natur hazard (P), chang climat (B), climat mitig (B), intern energi (B), natur catastroph (P), orderli scenario (B), disclosur tcfd (T), materi climat (P), physic capit (P), surfac temperatur (P), catastroph model (P), catastroph risk (P), emit firm (T), ga ghg (T), specif climat (B), volz ecolog (B), coal mine (T), delai transit (B), earth system (P), energi consumpt (T), energi sector (T), green activ (B), greener economi (B), energi label (T), hurrican activ (P), ngf climat (B), agreement target (B), climat crisi (B), climat financ (B), climat scienc (B), disrupt energi (T), energi sourc (T), environment chang (P), extrem climat (P), global climat (B), green invest (B), hazard simul (P), physic damag (P), transit cost (T), climat specif (B), environment object (B), extrem heat (P), green asset (B), green growth (B), green loan (B), issu green (B), physic collater (P), price climat (B), sustain insur (P), transit disorderli (B), carbon financ (T), climat event (P), effect carbon (T), geograph locat (P), global emiss (T), heat stress (P), mitig measur (B), nation flood (P), cascad climat (P), climat damag (P), climat neutral (B), emiss data (T), environment harm (B), environment tax (T), explicit carbon (T), flood protect (P), global catastroph (P), grai hazard (B), optim carbon (T), carbon dioxid (T), climat hazard (P), disast risk (P), emiss target (T), energi cost (T), environ agenc (B), european environ (B), ibach urgentem (B), natur ga (T), tropic cyclon (P), atmospher carbon (B), carbon concentr (B), carbon cycl (T), chronic physic (P), climat shock (B), coastal lender (P), combat climat (B), emiss pathwai (T), eu emiss (T), european green (B), financ green (B), fuel sector (T), ghg concentr (B), green credit (B), hurrican andrew (P), north atlant (P), promot green (B), quantifi climat (B), temperatur anomali (P), temperatur increas (P), action climat (B), baselin orderli (B), carbon transit (T), climat catastroph (P), energi system (T), energi technologi (T), environment qualiti (B), financ emiss (T), fl ga (B), hhw scenario (B), hurrican risk (P), incentivis risk (B), rel emiss (T), sea surfac (P), carbon risk (T), carbon taxat (T), climat servic (B), climat variabl (B), energi demand (T), energi product (T), flood hazard (P), hurrican season (P), indirect emiss (B), monetari green (B), natur capit (B), transit hot (B), water suppli (P), atlant hurrican (P), averag emiss (T), coastal properti (P), energi tax (T), environ re (P), extrem temperatur (P), flood scenario (P), fr ngf (B), green qe (B), green support (B), http www.ipcc.ch (B), u. environment (B), world hot (B), www.nature.com natureclimatechang (B), carbon sink (T), catastroph event (P), cdr technologi (T), dt hhw (B), environ chang (B), extrem physic (P), flood loss (P), gradual warm (B), increas climat (B), increas flood (P), irrevers natur (P), mass extinct (P), nat hazard (P), object green (B), petroleum agricultur (T), pollut bond (B), risk hot (B), sri strategi (B), u. energi (B), urgentem data (B), weather deriv (P), absolut emiss (T), anthropogen emiss (T), carbon premium (T), cata stroph (P), climat attribut (B), climat respons (B), deep ocean (P), embed climat (B), environment extern (B), estim climat (B), flood prone (P), fluvial flood (P), futur flood (P), green deal (B), green firm (T), green index (T), green innov (T), green univers (T), hhw ot (B), implicit carbon (T), intern carbon (T), nawm model (P), public www.nature.com (B), water infrastructur (P), aerosol impact (B), biomass burn (B), blind spot (B), burn black (T), carbon balanc (T), carbon budget (T), carbon feedback (B), challeng climat (B), challeng polit (), chang commun (B), citi resili (P), climat justic (B), climateg inquiri (B), cloudi pictur (B), consensu predict (B), conserv measur (B), cool polar (P), dry southern (P), emiss gap (T), fight climat (B), forest carbon (B), global forest (B), global ocean (P), marin invad (P), ocean acidif (P), ocean warm (P), past reveal (B), polit climat (B), power plant (T), sea ic (P), snow albedo (B), solar power (T), summer extrem (P), summer heat (B), sustain futur (B), target power (T)*

[11] For instance, Vermeulen et al (2018) is attributed to the DNB.

4.3. LIMITATIONS

Some may count the narrow focus on FSRs as a limitation of this study. Our goal here is, however, to understand the spatial and temporal changes of FSRs, which represent changes to the traditional topic spectrum of FSRs. It is not our goal to analyze broader capabilities of central bank research related to climate change; and it is not our goal to assess all pathways climate change risks may impact financial stability. We would like to comprehend the way the current analytical framework spread across space and time, and to gauge any potential path dependence within that.

As a result, the analysis of FSRs measures central bank climate risk awareness only to some extent. While some central banks may dedicate an entire chapter to climate change-related topics in their FSRs, others only summarize a climate stress test in a small text box. Despite that, climate change-relevant attention is present above an arbitrary occurrence threshold, and we may measure the attention dedicated towards climate issue in FSRs with the bigram occurrences.

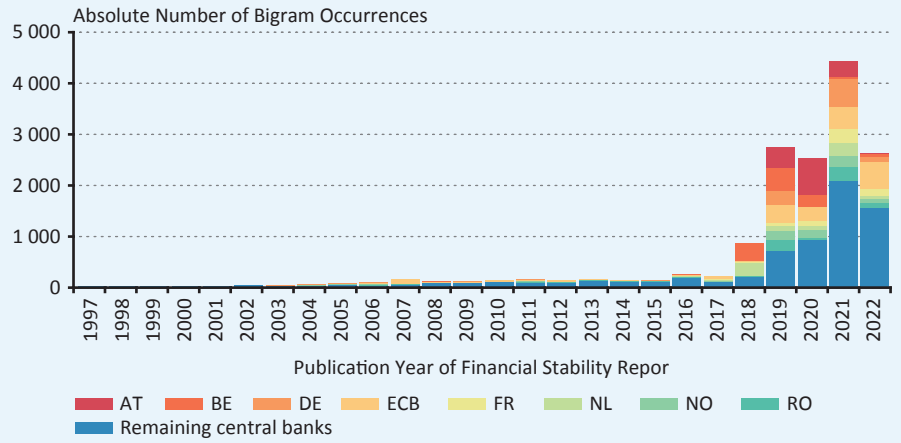
Moreover, references reflect when an innovation or an analytical approach is borrowed, or influence is acknowledged. Similarly, cross-references between central banks may reflect adaptation of innovations too. After a while, however, references to the ECB gradually turn into recognitions of an institutional hierarchy, let it be legal duty or a coordinated effort to harmonize analytical procedures. In any case, the spatial and temporal processes of both the bigram analysis and of the references help to understand the geography of climate change analysis in financial stability reviews.

5 Analysis

5.1 THE FIRST DISCUSSIONS ON CLIMATE RISKS

The results of the geography- and climate change related bigram search are reflected by **Figure 1**. It shows low occurrences up until 2018, which was mostly noise stemming from the analytical method used. The first wave was started in 2018 by the Dutch and the Belgian National Banks, followed by a strengthening flow of climate-related mentions in other central banks' FSRs.

Figure 1
Absolute number of climate change-related keyword occurrences in FSRs of selected central banks of Europe



Looking at individual publications, until the mid-2010s, FSRs discussed natural disasters as deplorable events which are regrettably parts of life. The first larger keyword clustering is observable in the FSR of the Österreichische Nationalbank, Austria (ÖNB), in 2002. Their second FSR in that year discussed the financial consequences of the devastating floods of that year. In a stark contrast to the way today's FSRs capture climate change physical risks, they discuss the flood's implications as a macroeconomic shock: "*the flood is a typical example of a negative supply shock, as it damaged important infrastructural facilities, caused crop failures, destroyed production sites or forced temporary interruptions in production"* (ÖNB FSR, 2002/2, p. 29). They note that negative supply shocks caused by natural disasters are often followed by positive demand shocks, triggered by the reconstruction. *"Economic growth in Austria is going to decline by 0.12% in 2002 vis-a'-vis the baseline scenario, but is expected to be 0.2% to 0.3% higher in 2003 owing to investments"*, without any reference to Basel-type concepts such as financial stability or default probabilities.

ECB FSRs mention climate related concepts - hurricanes in the Caribbean and the Atlantic coast of the US - since 2004, the first year an FSR is available on their website. The reason for that is the fact that at that time, five of the ten largest reinsurers globally were European companies with considerable exposures to that region. Then the cause for the first larger bump on the graph in 2007 was driven by a longer text box on the relationship between insurance sector and climate change (ECB FSR, June 2007, p. 127). It talks about increased expected losses due to "extreme weather events", and states that *"[i]nsurers and in particular reinsurers can transfer part of the risk associated with natural disasters to the capital markets using instruments such as weather derivatives and catastrophe bonds".* This seemed to solve the concerns related to financial stability, since "[*t]he euro area insurance sector, and in particular the reinsurance segment, is increasingly prepared to handle possible future high-impact, albeit low-probability, events, or several closely spaced events affecting parts of the sector and individual insurers".*

These quotes underpin the initial tenet of climate change being an insurable risk in the sense Ewald (1992) refers to modernity. As such, the financial system is capable of fending off temporary imbalances without interruptions in crucial services to households and businesses. Even the December 2011 FSR stated that the *„occurrence of natural catastrophes also enables insurers and reinsurers to increase their prices"*. Beyond that point, mentions of "*massive tornados that hit the South and Midwest of the United States in April and May, and Australian floods in January 2011 [ ] and the expected impact of La Niña*[12]" (ECB FSR, Dec. 2011, pp 109) represented the business-as-usual, since its effects were expected to be solved within the financial system.

The sustainability-focus of the DNB surfaced in the form of the DNB's cautious "exploratory study" on the exposure of the Netherlands to climate transition risks only in 2016 (Schotten et al, 2016), and as an explanatory summary document on transition and flood risks (DNB, 2017), without any consideration of further physical risk types. This was followed by a real climate stress test one year later (Vermeulen et al., 2018), and parts of it were cited in the following FSR too (DNB FSR, autumn of 2018). Their focus on transition risks and the sole focus on flood risk as physical climate risk is particularly interesting. The explanation for that probably lies in the data and methodology problem. This relates to the considerable difficulties to gather data on real estates used as loan collaterals, including their exact location and the degree of damages in case of a weather-related calamity. The notable exception of flood risk relies on the experience Netherlands has in pushing back the sea, which effort was first recorded by the ancient Greek geographer Pytheas of Massalia.

The National Bank of Belgium (NBB) was also among the first to discuss climate change in length too. Its openness towards the fight against climate change was there: it published a study on the macroeconomic impact of the fight against climate change already in 2011 (Bruggeman, 2011). This was followed by a long climate risk-related discussion in the FSR of 2018. The main difference to the approach of DNB was the NBB's limited contribution to methodological innovations. The NBB FSR of 2018 focused on general economic implications, including a literature review and a brief discussion of financial stability related topics. In contrast, the DNB presented novel results using a new stress testing method, which was a significant a contribution to the climate risk assessment methodology (Vermeulen et al., 2018).

In contrast to the examples before, the FSR of the Bundesbank, Germany, referred to the rising trend in the number of natural catastrophes in 2005, but did not discuss the topic further until 2019. Surprisingly, its FSR of 2005 indicated the limited ability of the insurance sector to distribute natural catastrophe risks on their own. Instead, it highlighted the need to use catastrophe bonds more intensively, in order to involve other financial participants in physical risk sharing: *"Hurricane Katrina recently highlighted the limits of insurability […] Catastrophe risks [...]are transferred to the capital markets through the issuance of bonds. If the loss event occurs, the bondholders' principal and interest, as a rule, pass to the issuer. However, the market is growing only slowly (see the chart above)"*. Despite this brief section, the FSRs of the Bundesbank remained relatively quiet about climate change until 2019. The 2019 issue subsequently described the analytical framework found in other publications, which could be used to measure the financial stability impact of climate change, but stopped short of providing figures or proposing novel approaches.

To analyze spatiotemporal patterns in a more granular manner, **Table 2** contains the first year a bigram is mentioned three times or more in a country's FSR. The top row contains the total number of climate-related bigram mentions for a particular country (without the three-mentions limit), which is the same absolute occurrence number that was shown before. The first figure column represents the frequency a specific bigram appears in all FSRs (again, without the three-mentions limit). Due to size limitations, only the top countries and top bigrams are displayed. We have determined the column order arbitrarily, to reflect total bigram mentions and temporal patterns.

[12] La Niña is an oceanic and atmospheric phenomenon, which includes lower than average sea surface temperatures in the Southern parts of the Pacific Ocean, and usually lasts up to five months. A consequence of the La Niña is an increased hurricane activity in the Atlantic basin, with reduced tropical cyclone activity in the Pacific Ocean.

Table 2

The total number of (stemmed) bigram mentions by country (top row), bigram mentions for the top bigrams (first column) and the first year an FSR mentions a bigram more than three times. Cnt stands for the total number of bigram occurrences.

		NL	BE	ECB	FR	AT	UK	DE	SE	RS	RO	NO	MT	SI	PT	CZ	LV	EE	ES	FI	IT	LT	IE	CH	XK	HR	PL	SK	IS	BA	MK	AL	UA	HU	ME
		733	1179	1926	603	1478	268	892	494	311	609	657	497	538	352	483	309	354	317	196	231	223	243	135	133	140	170	155	147	115	80	46	85	108	86
bigram	cnt	NL	BE	ECB	FR	AT	UK	DE	SE	RS	RO	NO	MT	SI	PT	CZ	LV	EE	ES	FI	IT	LT	IE	CH	XK	HR	PL	SK	IS	BA	MK	AL	UA	HU	ME
climat chang	1617	2017	2018	2007	2019	2019	2019	2019	2019	2018	2019	2017	2021	2019	2019	2008	2020	2020	2019	2016	2020	2020	2021	2020	2022	2021	2021	2021	2021		2018			2019	
climat relat	951	2018	2018	2019	2019	2019	2019	2019	2018	2020	2019	2019	2021		2021	2022			2019		2020		2021	2020		2021		2021							
climat risk	812	2021	2018	2019	2017	2019	2022	2019	2021	2018	2019	2019	2021	2019		2020	2020	2020	2021		2022	2021	2021	2020	2022	2021			2021		2018				
transit risk	743	2018	2018	2019	2019	2019	2019	2019	2019	2021	2019	2019	2021	2019	2019	2020	2021	2020	2019	2022	2020	2021	2021	2021	2022	2021			2021						
physic risk	491	2018	2018	2019	2019	2019	2019	2019	2019	2021	2019	2019	2021	2019	2019	2020	2020	2020	2019		2020	2021	2021	2020	2022	2021	2021	2021	2021						
water suppli	426		2020	2021		2021				2011		2005	2013	2007				2022	2005						2020	2009	2004	2015		2011				2020	2010
natur ga	393	2022	2020	2006	2021		2002		2021		2014	2006			2022	2022			2022	2022		2022	2022				2006	2021		2010			2016	2007	
natur disast	326	2021	2019	2005	2017	2002				2010		2021		2008		2008		2020				2021					2006			2013					
mitig measur	322		2015	2004		2020				2014			2019	2021	2020		2018		2021			2008			2021				2009					2014	
energi intens	303	2018	2018	2020	2022	2020		2022	2022		2016		2021				2022	2020	2022		2022					2021		2021	2012					2022	
energi effici	268		2019			2020		2021			2021	2022	2021	2009			2020	2016				2014	2022		2022			2022						2022	
energi sector	265			2016	2016		2003	2020			2007	2004	2013			2015	2022	2016	2021	2016	2022	2022			2022			2022				2012	2017		
green bond	244		2018	2019		2020				2021				2019	2019	2021					2021	2022						2021							
climat polici	234	2018		2019	2021	2020		2019			2019		2021		2021			2020		2016				2021											
sustain financ	212		2018	2019		2019					2019	2021	2020	2019	2011	2020	2020	2020																	
fossil fuel	200	2016	2018	2020	2021	2019		2019	2021		2021		2021		2022	2022		2020	2022	2022		2022				2021									
carbon intens	199	2016	2018	2019		2019		2021			2019		2021	2022	2022		2020	2022			2021		2021				2021								
low carbon	194		2018	2019	2019	2019	2019	2019			2019		2021	2019	2019	2021		2020					2021			2021	2021				2018				
carbon price	193	2018		2021		2020		2021				2020									2022														
energi cost	181	2022	2020	2006				2021						2022	2022		2022	2022	2022		2022		2022					2021				2022		2022	

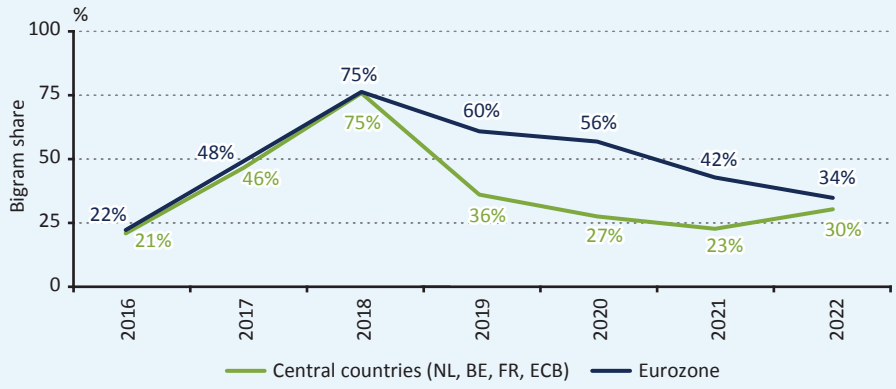
Note: stemmed bigrams are not the original expressions but word stems (hence 'energi')

As **Figure 1** and **Table 2** show, the ECB was the next to embrace the climate change topic in its FSR in depth, along with a set of centrally located European countries (France, Austria and the UK). In the ECB FSR, a special chapter addresses the data-related problem outright in the May 2019 issue. While on the transition risk side the uniform classification of sustainable assets was missing (the EU Taxonomy Regulation came into force in 2020, and its delegated acts in 2022 only), the report recognizes the existence of "*measurement gaps"* in *"understanding of exposures of financial institutions to climate change-related risks*" (ECB FSR May 2019 p 121). Despite the obstacles, the authors of the ECB FSR pivoted back to *some* kind of data: instead of using data on the location of bank exposures (e.g. where the buildings financed by mortgages are), and how they are exposed to risks (how much will burn), the report reaches out to aggregated catastrophe loss figures from reinsurers (Munich Re is mentioned several times) and the NatCatService.

Climate change has remained an IT- and data problem ever since (as recognized by NGFS, 2022). The ECB first climate stress test relied on (still approximated) data provided by the startup *Four Twenty Seven*[13] (ECB, 2021: 30), modelled corporate exposures to physical climate risks in a simplified fashion (just think of the problem of using headquarters vs. actual production sites), and omitted residential mortgages entirely. Despite all these problems, the ECB not only joined the innovatory process of financial climate risk research, but could also use its central position within Europe to transfer knowledge to other central banks, and to reach out to experts from across the European Union.

To underscore the temporal advantage of the Dutch, Belgian, French Central Banks and the ECB, the green line in **Figure 2** shows the share of these central banks' climate change-related bigram mentions in their FSRs out of all bigram mentions. It demonstrates that in 2017 and 2018, these were the dominant central banks discussing climate change in their FSRs, the year in which the number of the total bigrams first exploded. Once the diffusion process reached other European countries, in 2019, other Eurozone central banks caught up the pace and joined the exchange (blue line). Subsequently, their relative share diminished as other non-Eurozone countries' national banks started writing on the issue in their FSRs.

Figure 2
The climate change-related bigram-share of the central banks of the Netherlands, Belgium, France and the ECB in their FSRs out of all European FSRs (green line) and of the central banks of the Eurozone

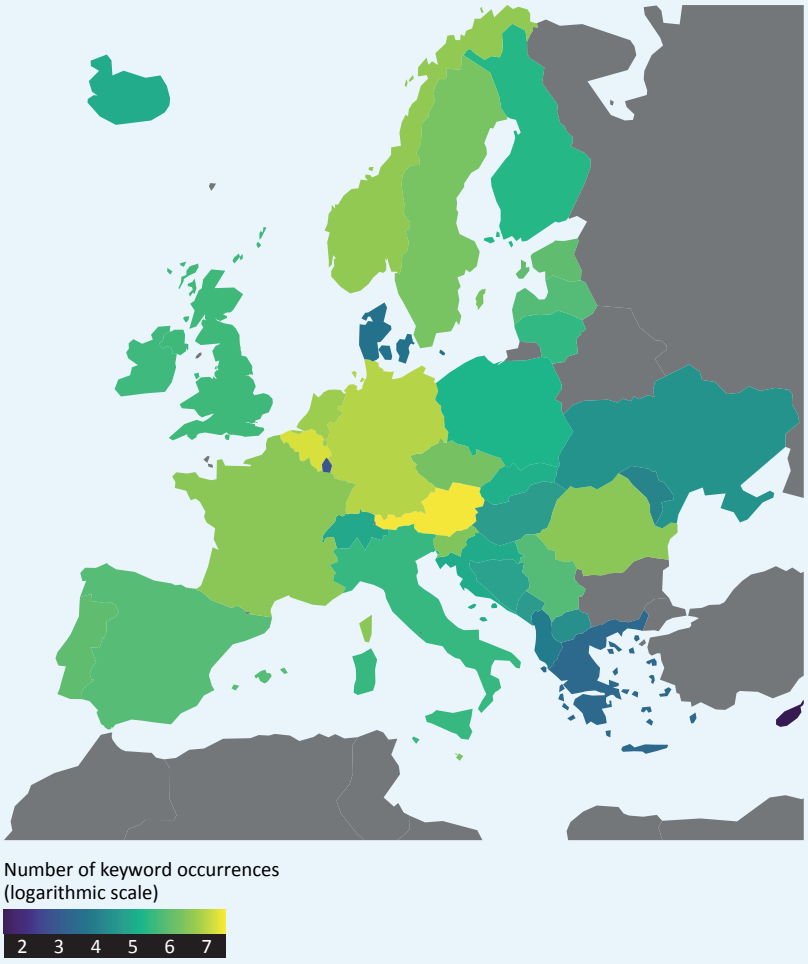


5.2 LATER DEVELOPMENTS

Up until 2022, climate change related bigram mentions followed a peculiar geography (**Figure 3**). The brightest colored country on the map is Austria, where the Österreichische Nationalbank (ÖNB) follows a special structure in its FSRs. The non-core parts of the FSR are basically research papers, and as such, represent significantly longer writings than the text boxes of the ECB or MNB FSRs. This does not downplay ÖNB's research related to climate change, quite the opposite. In 2019, they published a methodological overview of a Basel-conform climate change modelling (Pointner et al., 2019, in ÖNB FSR Dec. 2019), followed by a report on a climate transition stress test in November 2020 (Battiston et al., 2020, in ÖNB FSR, Nov. 2020), and by another on a carbon price shock in 2021 (Guth et al., 2021 in ÖNB FSR Nov 2021).

[13] Later acquired by Moody's.

Figure 3
Countries colored according to the number of keyword mentions in their FSRs published between 2000 (or earliest available) and 2022, logarithmic scale



Notes: the map excludes ECB FSRs; Luxembourg FSRs are published in French only, and bigram search was based on a manual translation; Bulgaria does not publish FSRs, Greece started publishing them only recently. Unfortunately, we could not find a shapefile which accounts for Kosovo.

The second brightest country on the map is Belgium, where the NBB continued to discuss climate change in its FSRs. However, similarly to their restrained attitude in 2018, their 2019 FSR is again limited to the discussion of a survey carried out among commercial banks in Belgium. It first reports on a slightly climate-related scenario analysis of a "*potential introduction of a minimum energy performance standard for residential real estate on the banking sector's mortgage portfolio*" in its FSR of 2020, which resembles to a kind of climate stress test on transition risks.

It seems that in 2021 the DNB brought real innovation to the table again. It reported on granular level physical risk analysis, unsurprisingly for the Netherlands, on flood risk. The following long citation illustrates the data-related pain points in such a modelling: *"we have drawn together granular data from a range of individual sources to create a dataset representing over €700 billion in domestic real estate exposures. This includes both regular data that we gather as well as data from a special survey of insurers and pension funds. The picture that emerges is that the majority of real estate is located in parts of the Netherlands that may be affected by flooding. These include both areas which are not protected by flood defence systems (outside the dikes) and parts of the Netherlands that are protected against floods"* (DNB FSR, Autumn 2021).

The tendency to discuss transition risks first and leave the analysis of physical risks second is not limited to the DNB: all central banks face the earlier mentioned data- and methodology-related difficulties when assessing the impact of physical risks on bank balance sheets. In fact, only 18 percent of all bigrams are directly related to physical risks, whereas 33 percent cover transition risks (the rest covers general concepts related to both). On country level[14], most first mover central banks (of NL, BE, ECB and FR) first wrote on transition risks, followed by discussions of physical risks (see Appendix for selected countries).

Another bright country on Figure 3, represented by the Central Bank of Norway, which first discussed climate change in its FSR of 2019. While the report states that "*Norway's exposure to direct physical climate change is limited"*, and remains analyzed in a shallow manner only, a lengthy chapter is dedicated to the consequences of a potential drying in oil demand on the country's financial stability (Norges Bank FSR, 2019. pp. 47). This late joining seems to be surprising in the 9th largest oil-exporter country globally, where the Norges Bank itself runs an investment management fund to invest oil- and gas-related revenues for future generations. However, even the Norwegian Government first produced a risk assessment on climate change in 2018 only (NOU 2018: 17), which discussed the transition's implications on the Norwegian economy.

A similar surprise is delivered by the limited space dedicated to climate change in the FSRs of the Bank of England (BoE), with a total of bigram mentions of around 240 (**Figure 3** and **Table 2**). While the BoE had contributed several innovations to climate risk analysis in the early years of the 2010s, its FSRs focused on other, seemingly more urgent matters such as the Brexit. The absence of top-down climate analyses is somewhat alleviated by the fact that the bottom-up stress test results, carried out using inputs from supervised banks and insurers, were published in May 2022 (Bank of England, 2022).

There are further surprises in Eastern Europe too. The FSRs of the Romanian Central Bank first referred to measures aiming at reducing greenhouse gas emissions already in 2011. This was a description of a jointly financed programme by the Romanian Government, the EU, IMF and the World Bank to improve the country's energy efficiency, without mentioning climate change (in the FSR). Fast forward to 2019, when Romania's FSR wrote again on climate change. The special section of the FSR on climate starts with discussing the sums the EU had been spending on tackling climate change, followed by a high-level analysis showing the financial system's vulnerability to climate risks in the country. Similarly surprising is the case of Serbia, which addresses climate change in the FSR of 2018 and of 2020. Besides the description of basic ideas and indicators, the text of both years contains mentions of credit lines provided by the European Bank for Reconstruction and Development (EBRD). In comparison, Slovenia, a Eurozone member, also dedicated considerable space to the transition risk of its financial sector in its FSR of 2019, admitting that the country had already met the 2030 emissions target in that year.

5.3 ANALYSIS OF REFERENCES

The citations in FSRs most often refer to journal papers (12 percent of all citations), followed by references to ECB publications (11 percent, see **Table 3**). We found little concentration in paper references with one exception: the paper of Battiston et al (2017), titled 'A climate stress-test of the financial system', published in the Nature Climate Change, is referenced 11 times out of the total 68 journal paper citations.

The ranking development shows the gradual disappearance of national central banks from the top slots over time. References to papers and talks published the DNB and the Bank of England dominated FSRs in 2018, including DNB (2017), Schotten et al. (2016) and Vermeulen et al. (2018) for DNB, and the famous speech of Carney (2015), Batten et al (2016) for the Bank of England. Citations on these central banks slid back gradually, and disappeared from 2021 onwards. Once the community of central banks digested their innovations, approaches and methods are being coordinated, international bodies grew to dominate rankings, led by the ECB, Network of Central Banks and Supervisors for Greening the Financial System (NGFS), Intergovernmental Panel on Climate Change (IPCC) and others.

[14] Looking at the totals for Europe would be distorted by late joiner central banks, which started discussing transition risks first.

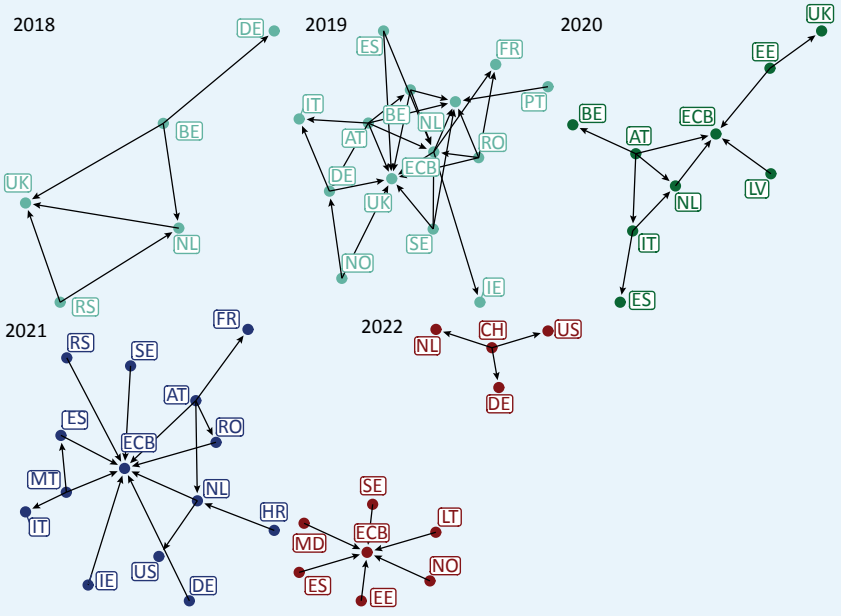
Table 3
Top cited institutions by their rank and citation year

Top five cited institutions (2018 - 2022)				Top five cited institutions in 2018		Top five cited institutions in 2019		Top five cited institutions in 2020		Top five cited institutions in 2021		Top five cited institutions in 2022	
rank	name	count	share	name	count	name	count	name	count	name	count	name	count
1	ECB	68	12%	DNB	11	journal paper	18	ECB, journal paper	14	ECB	21	ECB	24
2	journal paper	68	12%	journal paper	8	Bank of England, NGFS	16	EC	9	journal paper	20	journal paper	8
3	NGFS	45	8%	Bank of England	5	EC	13	NGFS	6	NGFS	17	Banca d'Italia	5
4	EC	35	6%	NGFS	3	DNB, ECB	9	Banca d'Italia, DNB, EIOPA, ESRB, UN	4	IPCC	10	IPCC	4
5	DNB	29	5%	EC, TCFD	2	UN	8	Bank of England, BIS	3	EC	8	BIS, EBA, EC	3

Note: *institutions with the same number of citations are separated with a comma*

The directed graph of references (**Figure 4**) contains the citations central bank related publications only. The arrows point from central bank FSRs towards other central banks which are referenced. The years represent the publication year of the FSRs. The graph visualizes the centrality of the DNB and the Bank of England in 2018, which only grew stronger for the year of 2019. The pandemic year of 2020 generated a lower number of citations compared to the preceding year. In any case, the ECB was already been the most often cited central bank, and its dominance only grew by the year of 2021. It is notable though that in 2022 the absolute number of references dropped, but the ECB's central location remained unchallenged.

Figure 4
The directed graph of FSR references with central bank publications only (arrows point towards the cited institution. The graph does not reflect the number of citations)



The drop in the number of climate risk related bigrams in 2022 is not just a result of the war in the Ukraine, rise in inflation and central bank rates, which arguably keep central bankers preoccupied, just like the COVID-19 pandemic did in 2020 and 2021. But also there seem to be a settlement in methodological questions: "*a growing body of empirical evidence on climate-related risks to financial stability has now provided a robust analytical foundation for macroprudential policy considerations*" (ECB/ESRB, 2022: 3). Instead, the focus shifted from discussing research to a gradual and dynamic refinement of risk assessments, and to talking about regulation. Both ECB/ESRB (2022) and the EBA (2022) papers focus on the ways climate risks can be incorporated into a macroprudential risk framework, meaning in other words that the regulators are pondering about the options how higher or lower climate risks in bank portfolios should appear in bank capital allocation processes. More specifically, the EBA (2022: 12) states, "*[t]he analysis demonstrates that the Pillar 1 framework already includes mechanisms that allow the inclusion of new types of risk drivers such as those related to environmental risks*". Such a regulation on climate risks and capital requirements would finish the process of climate risk analysis being an interesting piece of financial research, which turns into a EU-wide accepted piece of standard.

6 Conclusion

This paper looked into the process climate change risk analysis became from being neglected by central banks in Europe into being a dynamically canonized research framework ready to be incorporated in the banking risk regulatory framework from a geographical perspective. It was shown that measuring and mitigating climate change was not fundamental in central bank policies up until the early 2010s in Europe. Central banks mandates, which are fairly similar within the EU, were interpreted as permissive or strict, but some central banks, notably of the Netherlands and of Belgium were early starters in climate risk analysis. The tipping point was the Paris Agreement of 2015, which was followed by the decisions of elected politicians, such as of the European Parliament on the European Central Bank (EP, 2018), or the Parliament of Hungary (MNB, 2021) to explicitly instruct central banks to consider climate change in their policies.

Once a geographically and socially close central banks got involved in developing novel ways to look at the financial stability implications of climate risks, a central venue, the ECB was used to exchange ideas, combine skills and to borrow legitimacy to develop a uniformly accepted methodology. These methods cascaded from the first innovators to the ECB and then to the Eurozone, while others joined looking at the financial stability implications of climate risks later, with notable exceptions. Finally, as of writing this paper, EU-wide institutions are publishing discussion papers how to implement the new, 'robust' analytical methods into the regulatory capital framework.

The evidence presented to underpin the statements above was an analysis of climate risk-related discussions and references of the 941 financial stability reports of 39 central banks in Europe, using text mining – bigram counting - and network analysis. The data shows that DNB and the Bank of England were most often cited by other FSRs, only to be crowded out by the ECB and intergovernmental bodies such as the European Commission, IPCC or the NGFS in later years. This process illustrates that the first central banks to develop methodologies in climate risk analysis were rewarded by citations; and the DNB's success meant that their work is now published in concert with the ECB.

The findings contribute to the broader literature of financial geography. Similarly to other institutions, physical and social proximity is as important in explaining central bank behavior and mandate interpretations as institutional proximity. Second, the paper not only underscored the importance of regulation in fighting climate change, but also highlighted a successful and technocratic way to provide legitimacy to a regulation in a geographically diverse continent.

A final note on climate risk analysis: writing financial stability reports will not save us from the climate disaster. The findings made by the FSRs and other climate change-related analytical studies should be implemented, to speed up the transition process to a zero-carbon economy and to adaptation measures. Central banks are in a particularly fortunate position through their ability to require transparent reporting from their supervised entities, prefer the securities of low-carbon corporations in their asset purchase programs, or to require lower capital from commercial banks when financing green projects, such as the example of the MNB shows (Scope Ratings, 2021, MNB, 2022). In short, it is not the number of keywords and analytical frameworks that matter but actual policies.

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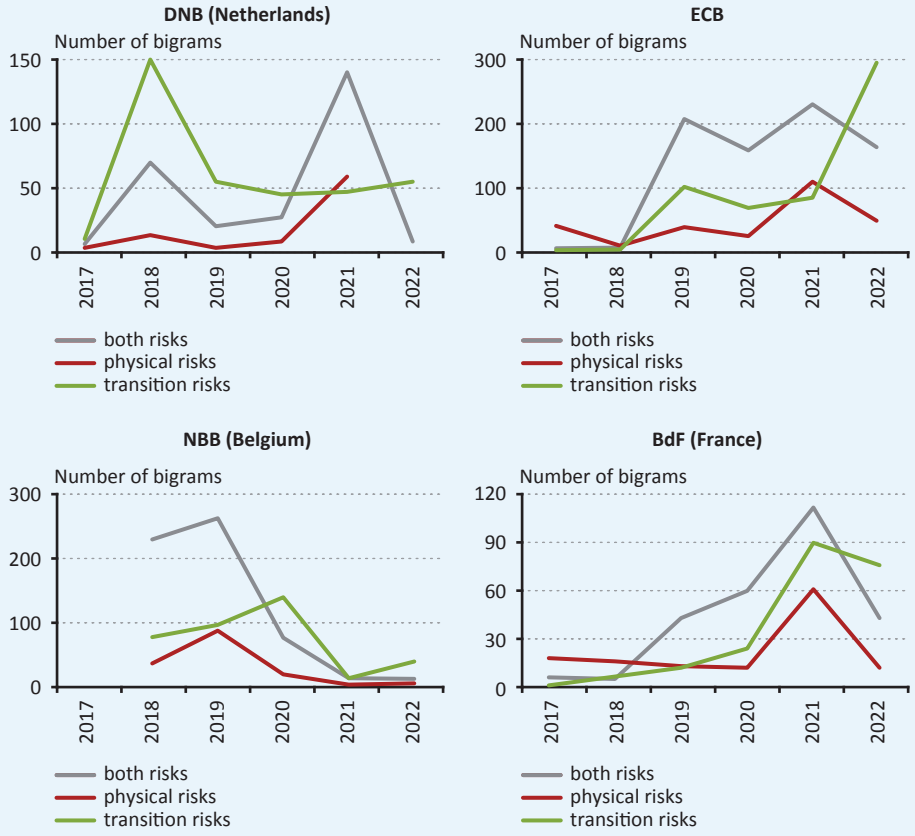
Appendix

Figure 5
The number of bigrams by the risk type they are related to, in selected central bank FSRs



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