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Society, Politicians, Climate Change and Central Banks: An Index of Green Activism♠

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This paper proposes an index for evaluating central bank activism in addressing climate-change issues. Consistent with a principal-agent approach, this metric assumes that the central bank's sensibility on climate change depends on both economic and political drivers. The index has been created to include not only actual policies but also participation in green networks and initiatives that signal central bank activism on climate change.

Keywords: Climate change, central banking, principal-agent, political pressure, monetary policy, financial stability.

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1. Introduction

According to the Intergovernmental Panel on Climate Change IPCC (2014), the average global temperature will increase by 0.5 to 2 degrees by 2050 with a predicted maximum increase of 5 degrees by 2100. In his seminal paper, Stern (2007) points out that this will result in an overall economic cost of climate change equivalent to losing at least 5% of global GDP each year, from now onwards. If a wider range of risks and impacts are considered, the estimate of damage could rise to 20% of GDP or more. Among the various ways in which climate change can affect economic growth, Schaunberger et al. (2017) show that high temperatures lead to a decline in crop yields and Kotz et al. (2020) show that day-to-day temperature variability has a negative linear effect on regional economic growth rates.

To avoid these effects, global emissions should be cut by at least 30% and preferably by 50% by 2050, bearing a cost of almost 1% of global GDP each year (Stern, 2008). This will involve many radical changes, not only in society but also in the economy. On 12 December 2015, 196 countries signed the Paris Agreement with the goal of limiting global warming to below two degrees (preferably 1.5) Celsius, compared to pre-industrial levels (UNFCCC, 2016). Attempts to limit the risks from global warming will require system transitions, which can be enabled through an increase in adaptation and mitigation investments, policy instruments, the acceleration of technological innovation, and behavioural changes (Schoenmaker, 2021). Additional resources could come from efforts to direct finance towards investments in infrastructure for mitigation and adaptation (IPCC, 2018).

Central banks have begun to consider the economic and financial effects of climate change. The initial step in this regard was taken by Carney (2015), who highlighted the impact that climate change will have on financial stability. In addition, Carney (2015) highlighted the temporal mismatch between climate change and central bank policies. Finally, as climate change will also affect monetary policy by slowing productivity growth and heightening uncertainty and inflation volatility, central banks should integrate sustainability considerations into their investment decisions (IMF, 2019).

As Carney (2015) suggests, there are three broad channels through which climate change can affect financial stability: 1) physical risks, 2) transition risks and 3) liability risks. Physical risks are likely to directly harm firms' finances, and affect their ability to access credit and invest, eventually leading to bankruptcy (Dietz et al., 2016). Transition risks may increase the risks of economic dislocation and stranded assets" which will lose their value, thereby leading to unemployment, economic losses (McGlade and Ekins, 2015) and, eventually, to financial imbalances. Each central bank's activities will be highly affected by climate change in terms of both their balance sheets exposure and the policy tools available to them.

The aim of this paper is two-fold. After a review of the extant literature on climate change and central banking (Section 2), we propose a metric for evaluating central bank activism in addressing climate-change issues. Consistent with a principal-agent approach, the metric assumes that central bank sensibility on climate change depends on economic and political drivers (Section 3). It includes not only actual policies but also participation in green networks and initiatives (Section 4). Proposed steps for future research are discussed in the conclusion (Section 5).

2. Literature Review

This section aims to review the extant literature on climate change and central banking. The main limitation of this stream of literature is the relatively low number of articles on the subject. Although the topic is becoming increasingly relevant, policymakers and academics have only focused their attention on it in the past few years. Although are a few peer-reviewed articles, the literature is mainly based on reports. In addition, most articles and reports lack empirical analyses, although this is not surprising given the absence of robust methodologies and comprehensive data (Campiglio et al., 2018). However, research in the field has been increasing substantially.

2.1 Climate Change and Financial Risk

Today, climate-related financial risks are highly debated because of the possible effects on the financial system and financial stability in general. Dietz et al. (2016) find that the expected "climate value at risk" (climate VaR) of global financial assets today is 1.8% given a business-as-usual emissions path. A representative estimate of global financial assets amounts to USD 2.5 trillion. Monnin (2018b) claims that climate risks are not adequately reflected in credit-risk analyses and shows that accounting for them can alter the ratings of firms and, thus, their credit eligibility under current risk-management frameworks. Therefore, integrating climate risks into credit risk analysis is essential for enforcing risk standards.

Kling et al. (2018) investigate the impact of the climate vulnerability on bond yields. They provide early evidence that measures of climate vulnerability have a positive impact on the cost of sovereign debt (e.g. an increase in interest rates). They estimate that the debt cost due to higher climate vulnerability has exceeded USD 62 billion over the last ten years. Volz et al. (2020) present new empirical evidence on the relationships among climate vulnerability, resilience and the sovereign cost of capital. Using a sample of 40 developed and emerging economies, their econometric analysis confirms that climate vulnerability has significant implications for sovereign borrowing costs and that the magnitude of the effect is larger for countries vulnerable to climate change.

2.2 Market-based Solutions

Given the increasing awareness on climate-based financial risk, some researchers have tried to highlight the potential role of markets in mitigating the risks associated with climate change. The evidence produced so far is not unanimous regarding the ability of markets to fully and efficiently incorporate the costs of the environmental transition. Hong et al. (2019) investigate whether the prices of food stocks efficiently discount these risks and show that climate risk information is incorporated into stock prices with a significant delay. In contrast, Bansal et al. (2016) find that climate-change risk has a negative impact on asset valuations, which implies that markets price in climate-change risk. In the real-estate market, Giglio et al. (2021) show that housing markets provide information about the appropriate discount rates for valuing investments in climate-change abatement. However, the extent to which this result extends to other situations is highly uncertain and beliefs regarding future cash flows are highly heterogeneous.

In terms of the real economy, Bernstein et al. (2019) examine how markets price long-run uncertain cash flows in relation to one of the most salient, long-run risks facing today's society: sea level rise (SLR). Homes exposed to sea level rise (SLR) sell for approximately 7% less than equivalent, unexposed properties equidistant from the beach. Interestingly, these effects may, in part, be triggered by psychological factors. In this regard, Baldauf et al. (2020) assess how much beliefs about the future impact of climate change affect home prices, and find that homes located in climate-change "denier" neighbourhoods sell for about 7% more than homes in climate-change "believer" neighbourhoods.

Various authors have tried to identify viable ways to pursue a smooth environmental transition by using well-known market-based instruments. Most of this literature has focused on carbon pricing and its feasibility (Stieglitz et al., 2017; Klennert et al., 2018). However, as these instruments are insufficient for adequately addressing the challenges of climate-change mitigation (Tvinnereim and Mehling, 2018), macroeconomic- and financial-policy instruments should be included in policy efforts focused on climate mitigation (Campiglio, 2016; Krogstrup and Oman, 2019) to complement the market-based solutions mentioned above. To the best of our knowledge, the most recent analysis in this regard is offered by Chenet et al. (2021), who claim that the emerging policy framework for dealing with climate-related financial risks has largely focused on market-based solutions that seek to reduce perceived information gaps that prevent the accurate pricing of climate-related financial risk (CRFR). This approach has a limited impact because CRFR is characterised by radical uncertainty, making "efficient" price discovery impossible. Therefore, Chenet et al. (2021) propose an alternative "precautionary" financial policy approach that draws upon two existing concepts — the 'precautionary principle' and modern macroprudential policy — and justifies the full integration of CRFR into financial policy, including prudential, macroprudential, and monetary policy frameworks.

2.3 From Climate Change to Financial Stability

The impact of climate risk on financial assets will affect the financial system in terms of losses for individual institutions and the financial system as a whole. Climate change will likely have important adverse effects on firm defaults, bank leverage and the prices of financial assets based on these institutions' relative exposure to climate disasters (Dafermos et al., 2018; Dietz et al., 2016). This will likely lead to financial instability and, to the extent that central banks are responsible for financial stability, eventually lead central banks to adopt new measures.

Several papers assess the transmission of climate risk to the financial system. Monasterolo et al. (2017) assess greenhouse gas (GHG) exposure in different sectors. After manufacturing, the financial and banking sectors are the most exposed. The most GHG-intense sectors are electricity, gas, steam and air-conditioning supply. The actors most exposed to these sectors are governments owing to their ownership or participation in utility and extraction companies. The latest ECB Financial Stability Review (Alogoskoufis et al., 2021) points out that banks and non-bank financial institutions alike are faced with the task of managing the implications of climate change over the medium to long term. The ECB analysis suggests that such risks appear to be particularly concentrated in certain sectors, geographical regions and individual banks, which exacerbates the related implications for financial stability. At the same time, data and methodological gaps still need to be addressed to comprehensively evaluate climate-related risks.

Battiston et al. (2017) look at how climate-policy risk might spread through the financial system, and find that direct and indirect exposure to climate-policy-relevant sectors represents a large portion of investors' equity portfolios, especially for investment and pension funds. An early and stable policy framework would allow for smooth asset-value adjustments, and lead to potential net winners and losers. In contrast, a late and abruptly introduced policy framework could have adverse systemic consequences. Similarly, the ESRB Advisory Scientific Committee (2018) distinguishes between a benign scenario and an adverse scenario. In an adverse scenario, the transition to a low-carbon economy occurs late and abruptly. This adverse scenario could affect systemic risk through three main channels: (i) the macroeconomic impact of sudden changes in energy use; (ii) the revaluation of carbon-intensive assets; and (iii) a rise in the occurrence of natural catastrophes.

Dafermos et al. (2018) analyse: (i) the effects of climate change on financial stability, and (ii) the financial and global warming implications of a green quantitative easing (QE) programme. First, by destroying the capital of firms and reducing their profitability, climate change is likely to gradually deteriorate firms' liquidity, leading to a higher rate of default that could harm both the financial and the non-financial corporate sectors. Second, climate-change damages can lead to portfolio reallocations that cause a gradual decline in the price of corporate bonds. Third, climate-induced financial instability might adversely affect credit expansion, exacerbating the negative impact of climate change on economic activity. Semieniuk et al. (2020) contribute to the conceptual understanding of transition risks by developing a consistent theoretical framework of the drivers, transmission channels and impacts of the phase-out of carbon-intensive industries on the financial system. In this regard, Battiston et al. (2021) discuss the key research challenges related to the analysis of the relation between climate risks and financial stability. They point out that embedding climate change in macroeconomic and financial analysis using innovative perspectives is fundamental for developing a comprehensive understanding of risks and opportunities in the era of the climate crisis.

One of the most recent analyses on this topic is found in Bosetti et al. (2021), who study the interactions among climate change, credit and economic dynamics, and test a mix of policy interventions. They show that climate damages to firms make the banking sector more prone to crises, and they test a set of "green" finance policies to address these risks: i) green Basel-type capital requirements, ii) green public guarantees for credit and iii) carbon-risk adjustments in credit ratings. These three policies moderately reduce carbon emissions and the resulting climate impacts. Although their effects on financial and real dynamics is not entirely positive, the combination of all three policies leads to a virtuous cycle of (mild) emission reductions, stability in the financial sector and high economic growth. Bosetti et al.'s (2021) results highlight the importance of complementing financial policies addressing climate-related risks with mitigation policies aimed at curbing emissions from real economic activities.

2.4 Climate Change, Financial Stability and Central Banking

Although different in some ways, all of the previous papers highlight the risks of climate change for the stability of the financial system and push for public intervention, especially from central banks.

The Carney (2015) speech was key for steering central bankers' attention to the climate-change problem, especially as the relevance of the issue for central banks' strategies and policies became clear. Although most central banks have focused on the link between climate change and financial stability, the immediacy and gravity of the situation demonstrate that these steps are merely

preliminary and much still needs to be done. In addition, there is variation among central banks in their focus on this issue – East Asian countries have already implemented active environmental policies, while Western countries are falling behind. Especially in recent years, more academics have tried to assess the risks of climate change for financial stability and examined the role of central banks in this regard.

2.4.1 Climate Change and Central Bank Involvement

Several papers have investigated whether central banks should play an active role in mitigating climate change from both economic and legal perspectives. For instance, Volz (2017) examine the extent to which environmental factors affect central banks' conventional goals. The author provides a theoretical analysis for and against central banks' efforts to respond to environmental and sustainability challenges. The paper explores the ways in which central banks (and financial regulatory authorities) influence investment decisions as well as the creation and allocation of credit. While arguing that central banks should play a proactive, "sustainable-development role", the paper also discusses the risks of overstretching central banks' mandates and vesting too much power in unaccountable institutions.

Batten at al. (2016) identify different ways in which climate change and policies on carbon emissions could affect central banks' objectives. They highlight the potential to generate significant balance-sheet losses and financial instability, which could affect central banks' abilities to maintain inflation close to their targets. Similarly, Economides and Xepapadeas (2018) suggest that climate change and the use of instruments to mitigate its detrimental effects affect the design of monetary policies. They conclude that monetary policies should be adjusted when climate change is taken into account and energy or carbon taxes are present.

McKibbin et al. (2017, 2020) claim that climate disruptions will increase the frequency and severity of negative supply shocks, making it more difficult for central banks to forecast output gaps and, therefore, to forecast inflation. Furthermore, the interaction between climate policy and monetary policy suggests that considering each regime separately can easily lead to policies that seem acceptable in isolation but perform poorly in practice. They conclude that these policy spheres should be explicitly brought together and that more appropriate macroeconomic modelling frameworks should be developed.

Monnin (2018a) explores the policy options central banks can use to contribute to the transition to a low-carbon economy. The studies presented in that paper suggest that as climate change represents a potential risk for the stability of the financial system, central banks should develop a comprehensive evaluation of climate-related systemic risks in the financial sector. They should also consider regulatory measures to mitigate those risks by implementing higher capital requirements for loans related to carbon-intensive economic activities and increasing capital levels, thereby strengthening the financial system's stability.

Dikau and Volz (2018) claim that responsibility for financial and macroeconomic stability implicitly or explicitly lies with the central bank, which should address climate-related and other environmental risks on a systemic level. In addition, central banks are in a powerful position to support the development of green finance models, and to enforce the adequate pricing of environmental and carbon risk by financial institutions. They discuss the reasons why central banks should be concerned with aligning finance with sustainable development. However, Volz (2017)

claims that central banks should only focus on fixing capital misallocation in the green economy and that using tools to address negative environmental externalities should be a secondary policy.

2.4.2 Climate Change and Central Bank Goals

Academics have extensively discussed whether direct involvement in tackling climate change lies within central banks' mandates. These studies have highlighted the benefits of having the environmental transition backed by central banks as well as the risks of having central banks overloaded with tasks related to the transition. Campiglio et al. (2018) point out that a smooth, low-carbon transition will require the implementation of a comprehensive set of policies, some of which might require the collaboration of central banks and financial regulators. This cooperation will not require a modification of the central banks' mandate. In fact, supporting the development of more comprehensive measures of financial risk to include climate physical and transition risks is well within central banks' present mandate to ensure the effective functioning of financial markets. Similarly, Bolton et al. (2020) explore how central banks can, within their mandate, promote unprecedented collective action and coordination efforts among various actors to tackle climate change. They point out that although central banks can help prevent environmental risks and mitigate their consequences by, for instance, developing scenario analyses, these initiatives will not be sufficient on their own.

Similarly, Schellhorn (2020) suggests that as timely and effective climate action is a precondition for the stability of the global financial system, and as the Federal Reserve and other central banks share responsibility with legislative and regulatory authorities for maintaining financial-system stability, the Fed shares responsibility for effective climate action. The new low-interest-rate monetary policy environment favours sustainable long-term but high-risk investments. Market participants need timely guidance and support from regulatory and supervisory authorities, including the Federal Reserve to expedite global fund allocations to low-carbon assets.

D'Orazio and Popoian (2020) evaluates the determinants of each central bank's involvement in the green transition. They point out that a decision to implement green regulations is not exclusively related to the central bank's mandate, but to the central bank's independence and to the structure of the interaction between monetary policy and prudential policy. Moreover, higher exposure to climate-related adverse events plays a crucial role in the adoption of green prudential regulations. To avoid potential conflicts between monetary policy and green prudential regulations caused by intertwined transmission mechanisms, the analysis highlights the importance of having a central bank that hosts the green prudential regulations under its governance roof. This paper has the greatest number of similarities to our analysis in terms of data and methodology. However, while its focus is on macroprudential policies, we are interested in the central banks' overall green sensibility. We provide more details on this difference in the data section.

Dikau and Volz (2021) point out that the extent to which central banks adopt a more active approach to support a government's sustainability objectives is ultimately a political decision. Nevertheless, climate change and mitigation policies will have profound impacts on economies with potentially significant implications for macroeconomic and financial stability. These aspects need to be addressed by central banks within their core responsibilities. According to these authors, a central bank that does not address climate risks is failing to do its job.

2.4.3 Climate Change and Central Bank Tools

The past few years have brought a rapid increase in the amount of attention central banks pay to climate change. This may have been triggered by the worsening of the impact of climate change on economic growth, or by the increase in attention paid to the issue by citizens and Institutions. Dikau et al. (2019) chart the rise of central banks' and supervisors' actions on climate change and sustainability issues. They highlight that a clear evolution in central banks' market signalling on climate and sustainability issues can be identified in the speeches of central bank governors since 2015. These speeches have progressively become more active and have transitioned from mere acknowledgments of climate change to calls for binding decisions.

As the need for central bank involvement in climate policies has become more obvious, Dikau et al. (2021) assess which policies are the best options given available toolkits. Central banks and supervisors need to adopt a systemic perspective, and address both micro- and macroprudential risks over a much longer time horizon. Monetary and financial authorities must play a pivotal role in shaping the tools, methodologies and data systems required for the net-zero economy. Dikau and Volz (2018) review the tools and instruments central banks and financial regulatory agencies use to address environmental risk and promote green finance and sustainable development. They also provide a brief review of green public financial governance initiatives.

D'Orazio and Popoyan (2019) analyse green financial policies as well as the conditions under which they could help tackle climate change and promote green lending while limiting climate-related financial risks. They suggest policy instruments similar to those proposed in previous papers, but also point out that existing tools in the framework of Basel III can be destabilising for the financial system. They therefore ultimately suggest alternative strategies. In addition, according to these authors, financial risks related to physical, liability and transition risks do not seem to be adequately considered by financial institutions, regulators or markets in the current financial framework. Similarly, Dafermos and Nikolaidi (2021) identify the transmission channels through which the green differentiated capital requirements (GDCRs) can affect credit provision and loan spreads. They show that GDCRs can reduce the pace of global warming and, thereby, decrease the physical financial risks. This reduction is quantitatively small but is enhanced when implemented in combination with green fiscal policies. McConnell et al. (2020) discuss potential green monetary-policy instruments to identify those most appropriate for supporting the transition process. They identify adding collateral "haircuts" based on assets' carbon intensity to the central bank's collateralised lending framework as the most promising conduit of green monetary policy. In addition, adjusting the collateral framework and introducing a carbon tax reduces the burden of the transition.

Finally, we note that the research agenda on climate change and central banking has been affected by the Covid-19 pandemic, as is true for most other policy areas. In this regard, Dikau et al. (2020) find a divergence between current crisis-response measures and wider efforts to promote sustainable finance. Authorities in Europe and East Asia are the most active in terms of these sustainability efforts. This highlights the potential for convergence in the next phase. Importantly, many of the instruments that are being applied by central banks and financial supervisors during the pandemic could be calibrated to better account for climate- and other sustainability-related risks and objectives.

2.4.4 Climate Change and Central Bank Policies

In the previous sections, we have discussed in mostly general terms the policies central banks can adapt and use to smooth the environmental transition. In this section, we consider research exploring green policies implemented by central banks worldwide. However, most of these policies have been implemented in East Asian and developing countries. Although the number of central banks that have implemented green policies is limited, an analysis of those policies can help to shed lights onto which policies can best help prevent the climate crisis.

Dikau and Ryan-Collins (2017) provide a detailed list of central banks that have begun addressing the risks of climate change, presumably owing to their higher climate risk and their shallower financial markets. In addition, the central banks that are more active on green initiatives have a less binding focus on price stability. These central banks use three categories of intervention: i) green credit-allocation instruments; ii) green regulatory instruments and iii) other green central banking activities, such as the development of green finance guidelines or the establishment of green bond markets. Dikau and Ryan-Collins (2017) highlight that as global private markets are not sufficiently financing the transition to the green economy, the experiments conducted in these countries may provide valuable lessons for developed economies, especially in the aftermath of the financial crisis that led central banks to be more active and to adopt unconventional policies. Campiglio (2016) highlights that the use of these policies requires moving beyond current central banking practices in high-income countries, which have previously used reference interest rates as their sole policy tool. Hence, the adoption of measures aimed at controlling credit allocation is likely to prove challenging and controversial.

Among the papers reviewing existing central banks' green financial policies, Dikau and Volz (2021) make an important contribution to the literature by collecting information on all of the green activities central banks around the world have carried out or planned. This study is particularly important, as it provides up-to-date information on existing green policies. In addition, these authors claim that as climate risks can directly affect central banks' traditional core responsibilities, all institutions should incorporate climate-related physical and transition risks into their policy frameworks in order to safeguard macro-financial stability. However, the ways in which central banks will address the climate emergency will inevitably differ.

Recently, the ECB (2021) pointed out that policy actions may be required to ensure the resilience of the financial system to climate-related risks. Enhanced climate-related disclosure requirements, including companies' forward-looking emission targets, and deeper, more effective green financing are essential steps in a smooth transition towards a sustainable economy and a general reduction in climate-related vulnerabilities. At the same time, possible market failures can stem from data gaps, which would raise the risk of greenwashing. The upcoming ECB climate stress test will analyse trade-offs in a forward-looking manner, thereby providing an additional basis for future policy discussions. Ultimately, given the systemic dimension, considerations about how to mitigate climate-related risks in the financial system require a macroprudential perspective to be effective and to ensure cross-sector consistency.

Moreover, it is worth mentioning an interesting analysis by Hansen (2021), who compares the effect of green fiscal and monetary policies, and points out that monetary policy is a weak substitute for fiscal policy. Central banks that overstate their ability run the risk of losing their distance from the political arena and providing false hope to public actors trying to effectively tackle climate change.

Finally, in investigating the effects of existing policies, several authors have tried to assess the effects of current purchase programmes on green bonds issues. As green bonds are not usually explicitly required in purchase programmes, some authors discuss steps that can be taken to align monetary policies with environmental policies.

Matikainen et al. (2017) show that the corporate-bond purchase programmes of the Bank of England and the European Central Bank have been skewed towards carbon-intensive industries, while renewable-energy companies are not represented at all. This has prompted calls for the greening of quantitative easing. Dafermos (2018) claims that the implementation of a green corporate purchase programme can reduce climate-induced financial instability and limit global warming, although such a programme is not sufficient in itself. The effectiveness of this programme depends on the responsiveness of green investment to changes in bond yields. Monnin (2018a) also investigates the imbalance in central banks' purchase programmes towards carbon-intensive sectors, and points out that central banks should further assess these biases and ensure that climate-related risks are adequately reflected in their own balance sheets as well as their collateral frameworks. For these reasons, De Grauwe et al. (2019) suggest that when bonds bought during the ECB's quantitative easing programme come to maturity, the ECB should replace traditional bonds with "environmental bonds" while not creating new money.

Bremus et al. (2021) analyse the effect of the ECB's Corporate Sector Purchase Programme (CSPP) and the recent Pandemic Emergency Purchase Programme (PEPP) on the yields of eligible green bonds. They find that both programmes significantly improve financing conditions for eligible green bonds, thereby increasing the attractiveness of these instruments to issuers, although the effects of the CSPP and PEPP are heterogeneous. In this regard, Solana (2019) discusses whether aligning the ECB's CSPP with EU environmental commitments may be legally binding. The author claims that Article 11 of the TFEU integrates environmental objectives into the mandate of the Eurosystem, and requires that those objectives be taken into account when designing and implementing monetary policy. The author concludes that, other than a distinctive source of legal obligations, Article 11 of the TFEU represents an opportunity for the Eurosystem to contribute to improving the understanding of the relationship between climate change and financial stability.

Macaire and Naef (2021) carry out one of the first empirical analyses on the effect of central banks' green policies on the yield spread between green and non-green bonds. Specifically, they use a policy by the People's Bank of China (PBoC) that includes green financial bonds in the pool of assets eligible as collateral for the medium-term lending facility. Using a difference-in-differences technique to compare pairs of green and non-green bonds issued by the same institutions, they show that the policy lowered the spread between the pairs of instruments by 46 basis points.

Finally, Schoenmaker (2021) focuses on evidence highlighting the market bias towards carbon-intensive companies. This paper develops a method to tilt the ECB's asset and collateral framework towards low-carbon assets. The author finds that a medium tilting approach reduces carbon emissions in the ECB's corporate and bank bond portfolio by more than 50%, and shows that a low carbon allocation can be achieved without undue interference with the transmission mechanism of monetary policy.

With regard to the effects of central banks' policies on the effects of climate change, the adoption of environmental-related policy tools might provide a framework for natural experiments aimed at

assessing whether there is an impact on firm profitability and green investments. To the extent that some central banks are starting to adopt such measures, researchers may be able to estimate the effects of these policies by analysing the differences between these countries and those that have yet to adopt such measures. As pointed out by Campiglio et al. (2018) and D'Orazio and Popoyan (2018), many low-income and developing countries are adopting instruments to channel credit towards the green sector, while developed countries seem to be falling behind in this regard. This is particularly important for the design of future analyses.

3. Society Preferences, Political Pressure and Central Banks' Green Sensibility

Our review of the economic literature highlights a key fact – in the past few years, central banks have progressively increased their focus on including environmental sustainability considerations in their actions for economic reasons that correlate climate change with macroeconomic outcomes. Consequently, a research question naturally arises: Is this motivation sufficient? Our answer is negative. We start from a general assumption that central bankers' choices have endogenous outcomes given the rules of the game that govern their interactions with other relevant players (i.e. citizens and politicians). Therefore, political incentives can also play a role.

In investigating potential economic and political drivers of a central bank's "green" sensibility, it seems effective to utilize a principal-agent setting. In the last thirty years, the economic literature has systematically analysed interactions between central bankers and politicians using principal-agent settings. More specifically, we draw inspiration from two-tier theoretical settings in which two different and subsequent events occur: a "political" event and an "economic" event (Herrendorf and Lockwood, 1997; Drazen, 2002; Aghion et al., 2004; Hughes Hallet and Weymark, 2005, 2007; Alesina and Tabellini, 2007; Hefeker and Zimmer, 2011; Miller 2019). In the first event, the citizens first delegate to the politicians a political task, which in our case is to build up a "political green voice" that can influence the central bank's decisions. In the second event, the central bank defines its own "economic green voice", which incorporates climate change considerations into its policy framework as well as the possibility that citizens and politicians can exert pressure to include or discard such considerations. In other words, given that any green policy affects welfare, we assume that citizens – both households and firms – are the "ultimate" principal agents (Ferrari and Pagliari, 2021) to whom politicians and central bankers respond. This is described in more detail in the following.

3.1 Economy, Climate Change and Central Banks' Green Sensibility

The potential relevance of the relationships among society preferences, political pressure and green central banking can be discussed in a systematic way using, on the one hand, a standard-stylized macroeconomic model that includes climate-change effects and, on the other hand, a two-tiered setting that governs central banking, where incumbent politicians can influence central bankers' decisions .

Our starting assumption is that climate change can influence growth, employment and inflation through three main channels. First, climate change can be considered as a supply shock that leads to a change in productive capacity, which in turn produces higher inflation and lower output growth (McKibbin et al., 2017; Economides and Xepapadeas, 2018). More specifically, temperature shocks due to increased emissions can lead to inflationary pressure (Mukeerjeel and Ouattara, 2021). Second, the use of taxation to deal with the effect of climate change can trigger further fluctuations in prices and output (McKibbin et al., 2017; Economides and Xepapadeas, 2018; IMF, 2019; NGFS,

2020). Third, as discussed in our literature review, climate change can be associated with financial instability (McKibbin et al., 2017; Shoenmaker, 2021). All in all, climate change is likely to affect the real economy (Tol, 2009; Hsiang et al., 2017; Nordhaus 2017) and the financial sector (Allen et al., 2020; Pagliari, 2021).

In order to capture these three channels in the most simple and general way, we assume that: 1) output growth is determined by a simplified supply curve with nominal and wage rigidities,[1] where $\sigma > 0$ represents the sacrifice ratio when the aim of central bank policy is to influence output growth, which can also be a proxy of the trade-off between flexibility and credibility in the central bank's action;[2] 2) aggregate demand depends crucially on central bank choices via the expectations channel[3] without frictions and lags;[4] and 3) financial instability shocks can influence both aggregate demand and aggregate supply.

Our key assumption is that central banks have a medium-to-long term perspective and are fully mindful of their impact on climate change, including their influence on financial stability (Shoenmaker 2021). At the same time, how central banks should respond to climate change is subject to opposing views. On the one hand, the doves support green monetary policies while, on the other side, the hawks strongly reject such as perspective (Financial Times, 2019). In the middle if price stability continues to be a primary goal of a central bank, climate-related considerations should be taken into account (Schnabel, 2021). In other words, we can assume that, when defining their decisions, central bankers can have heterogeneous green preferences.

We use inflation targeting, which is a goal-based rule, as a metric to summarize the central bank's decisions. The same decisions can be described using interest-rate rules, which are instrument rules, in line with Taylor,[5] or money rules, in line with McCallum.[6] These two specifications – goal-based rules and instrument rules – can be used alternatively without any loss of generality provided that the inflation-expectations channel results in changes in the real interest rate.[7] In other words, the model used for business-cycle analysis consists of three equations that include financial frictions:[8] aggregate supply and aggregate demand curves together with a central bank rule. The descriptions of the aggregate supply and aggregate demand curves are as follows:

$$y = \sigma_E(\pi - \pi^e) \quad (1)$$

and $y = \pi^e$. (2)

All else equal, we assume that σ_E represents the climate-change sacrifice ratio (i.e. the inflationary costs of any central bank policy that accommodates climate-change needs). Given these assumptions, two subsequent events occur: a political event and an economic event. In the first

[1] Barro and Gordon (1983), Backus and Driffill (1985). For the sake of simplicity, here the natural rate is zero, as in Rogoff (1985).
[2] Rogoff (1985).
[3] Clarida et al. (1999).
[4] Schellekens (2002). On monetary policy uncertainty, see the seminal works by Friedman (1968), Poole (1970), and Cukierman and Meltzer (1986).
[5] Taylor (1993).
[6] McCallum (1987) and (1993).
[7] Clarida et al. (1999), Tillmann (2012). More generally, the effects of monetary policy actions can be transmitted either through changes in the nominal interest rate or variations in the quantity of money. See McCallum (1997), Ireland (2004), Nelson (2005), Favara and Giordani (2009), Caraiani (2016), and Belongia and Ireland (2019) for more detailed discussions.
[8] See, for example, Sims and Wu (2019), where a four-equation model with financial intermediation collapses to the above-mentioned standard three-equation model using simple parameter restrictions.

event, the politicians decide the relevant features of their climate-change voice, considering their own political cost and benefit analysis, which in turn depends on citizens' preferences. In the second event, the central banker defines her green sensibility given the political attitude, which is summarized by the green political voice.

3.2 Society's Preferences and the Green Political Voice

Starting from the political event, let us describe the delegation framework between citizens and politicians (Alesina and Tabellini, 2007). The green voice is captured through a parameter $\Omega > 0$. The intuition is that the higher Ω is, the higher the political pressure on the central banker will be.

Citizens care about the green voice's effectiveness according to a classic well-behaved concave function $U = U(\Omega)$ in which social welfare increases with the optimal voice level. The green voice is a proxy for the country's environmental policy, which depends on institutional, political and economic factors (Hahn 1990, Congleton 1992, Joskov and Schmalesee 1998, Neumayer 2002, Pearce 2005, Fredricksson and Millimet 2007, Bernauer and Koubi 2009, Del Rio and Labanderia 2009, Bailer and Weiler 2010, Marques et al. 2010, Chang and Berdiev 2011, Holzinger and Sommerer 2011, Jenkins 2014, Dolphin et al. 2020). Finding the optimal voice level is not a trivial task, given that both social benefits and costs are present. Moreover, any climate policy creates winners and losers, and distributive climate conflicts may arise (Vogel 1997, Daugbjerg and Svendsen 2001, Battig and Bernauer 2009, Meckling 2011, Bailey et al. 2012, Aklin and Urpelainen 2013, Cheon and Urpelainen 2013, Stokes 2015, Hughes and Urpelainen 2015, Lachapelle and Paterson 2013, Lachapelle et al. 2017, Genovese and Tvinnereim 2018, Genovese 2019, Mildenberger 2020, Aklin and Mildenberger 2020, Kennard 2020).

Linear preferences are used:

$$U(\Omega) = \Omega . \qquad (3)$$

The politician's reward is based on how she carries out her job. We assume that our politician wishes to please the citizens. Alternatively, we could assume that the politician aims to please specific constituencies (e.g. the lobbies). Nevertheless, we adopt the *helping hand view* of the politician's type – she wishes to please citizens rather than a particular constituency or lobby (the *grabbing-hand view*) (Shleifer and Vishny 2002). This assumption allows us to show the conditions under which the final political decision - the actual level of Ω – can differ from the socially optimal one despite the politician's desire to please the citizens.

The level of Ω is determined by the politician's ability, Φ, and by her effort, *a*:

$$\Omega = a + \phi . \qquad (4)$$

In the first political moment, the sequence of events is as follows: a) society chooses to delegate the task of expressing its green voice on the central bank's policy stance to the politician; b) the politician chooses her effort, *a*, before knowing her ability, Φ, with regard to implementing this particular task (developing a green voice on the central bank's stance is not a typical task); c) the politician defines her voice, thereby revealing her ability, Φ; and d) citizens listen to the voice but not consider the relationship between effort and ability, as they cannot distinguish innate talent from contingent effort. They then reward the politician.

The politician's utility function, denoted by $L = L(R, C)$, is defined as:

$$L = R(U) - C(a) \,, \tag{5}$$

where $R(U)$ is the reward function and $C(a)$ is the cost function. The political reward is a function of the social utility, while the political costs are a function of the effort needed to implement the task. The politician evaluates every task assignment while considering the political rewards and costs of each task. Let us describe the three crucial features of the politician:

i) Ability: The ability of the politician is a random variable with a normal distribution, where we denote the mean with Φ_{AV}, and

ii) Political reward: The incumbent politician wishes to be re-elected. The politician therefore needs to provide the majority of voters with enough utility. As such, her utility function is associated with the social welfare function $U = U(\Omega)$.

In general, the politician wishes to please voters and her goals are aligned with those of the citizens. Each delegated task (i.e. each specific alignment) can be more or less convenient in terms of political gains from the politician's point of view. We denote the political value she assigns to fulfil the specific task of offering a green voice on central bank policy by β_L, with $0 \leq \beta_L \leq 1$. Therefore:

$$R(U) = \beta_L U \,. \tag{6}$$

The alignment of incentives between the politician and the citizens is a necessary and sufficient condition for finding the politician's optimal behaviour. The political reward differs from the social reward so long as $\beta_L \neq 1$. From the politician's point of view, the political gains of a green voice are associated with the expected benefits in terms of consensus. Moreover, the reward will be useful if the citizens' utility exceeds the minimum threshold of utility, W, that they expect from an incumbent politician. The political competition condition can be defined as follows:

$$R_L = \beta_L \Pr(U \geq W) \,. \tag{7}$$

The usefulness of the political reward will depend on this condition.

iii) Political costs: The politician knows that expressing a green voice on a central bank's choices has an implicit cost, as it is likely to occur when a policy position is taken. The politician's cost function can assume the following specification:

$$C(a) = c_L a^2 \,, \tag{8}$$

It follows that the politician maximizes social welfare net of the costs of executing the task and taking into accounting the political reward:

$$\max L = R(U) - C(a) = \beta_L U - c_L(a_L) = \beta_L(a_L + \Phi) - c_L a_L^2 \,. \tag{9}$$

From the first-order condition, the optimal effort will be:

$$\frac{\partial L}{\partial a_L} = \beta_L - 2ca_L = 0,$$

which implies that:

$$a_L = \frac{\beta_L}{2c_L}. \qquad (10)$$

Given a_L, the politician's effective political reward will depend on the condition of political competition:

$$R_L = \beta_L \Pr(U \geq W). \qquad (11)$$

Citizens are rational. They realise that the alternative to the existing policymaker is another politician with average ability. Given their expectations, a^e, for effort, it follows that:

$$W = a^e + \Phi_{AV}. \qquad (12)$$

Then:

$$R_L = \beta_L \Pr(\Phi + a_L \geq \Phi_{AV} + a^e) = \beta_L \Pr(\Phi - \Phi_{AV} > a^e - a_L. \qquad (13)$$

Nature determines the ability of the incumbent Φ_L. It follows that:

$$R_L = \beta \Pr(\Phi_L - \Phi_{AV} > a^e - a_L). \qquad (14)$$

When rational expectations are matched (i.e. $a^e = a_L$), the effective political reward will be positive if the ability of the incumbent politician is above average:

$$\Phi_L > \Phi_{AV}. \qquad (15)$$

Given condition (15), the equilibrium level of voice will be determined by the politician's ability and effort:

$$\Omega_L = a_L + \Phi_L = \frac{\beta_L}{2c_L} + \Phi_L. \qquad (16)$$

Given the exogenous politician's ability, the level of voice will depend on the political preferences, which can differ from the socially optimal preferences.

Exploring the politician's preferences is essential for understanding how and when the green voice is implemented. Voice is an endogenous variable. Various hypotheses can be advanced to explain the genesis of the political preferences. In our framework, the endogeneity of the preferences can easily be captured if we assume that the political parameters β_L, c_L, Φ_L depend on well-identified

drivers. In the empirical section, we explore the possible relevance of a political green sacrifice ratio. In other words, we assume that:

$$\Omega_{L=f(}\sigma_{P)}. \tag{17}$$

3.3 Central Bank Preferences and Green Sensibility

The definition of the political voice realizes the setting that can influence the central banker decisions. With the aim of highlighting the relationship between central bank policy and political voice, let $V_{cb}(t_{cb},\pi)$ be a standard utility function of an independent central banker:[9]

$$V_{cb}(t_{cb},\pi) = B(t_{cb},\pi) - C(t_{cb},\pi) = \frac{2\pi^{0.5}}{t_{cb}} - \frac{1}{2}\sigma\Omega_L t_{cb}\pi^2, \tag{18}$$

where $B(t_{cb},\pi)$ and $C(t_{cb},\pi)$ are the individual benefits and costs, respectively, and $\sigma\Omega_L$ is the effect of the political voice. We can assume that the central banker's individual perception of the convenient green sacrifice ratio depends on the political voice. Therefore, this relationship can be either positive or negative. Finally, $t_{cb} > 0$ is the degree of central bank conservatism.

Why can the green political voice influence an independent central banker? The reasoning is as follows: political pressures on the central bank may be relevant for shaping the actual monetary policy decisions if the government in charge can threaten the central banker's role. For example, if the institutional setting is such that any incumbent government in extraordinary times can retain the option to override the central banker's decision, the central banker can be tempted to accommodate the political wishes to avoid being overridden (Lohman 1992).

On the one hand, we assume that the individual benefits are increasing and concave in the inflation rate:

$$\frac{\partial B(t_{cb},\pi)}{\partial\pi} = \frac{1}{\sqrt{\pi}t_{cb}} > 0;\ \frac{\partial B^2(t_{cb},\pi)}{\partial\pi} = -\frac{1}{2\pi^{3/2}t_{cb}} < 0. \tag{19}$$

As we already know, inflation can be a beneficial tool for macro stabilization from the central bank's point of view. Moreover, central bankers are bureaucrats who may consider inflation (i.e. seignorage) as a financial source for their organisations.

On the other hand, we assume that individual costs are increasing and convex in the inflation rate, given that the central banker cares about her personal reputation:

$$\frac{\partial C(t_{cb},\pi)}{\partial\pi} = \sigma\Omega_L t_{cb}\pi > 0;\ \frac{\partial C^2(t_{cb},\pi)}{\partial\pi} = \sigma\Omega_L t_{cb} > 0. \tag{20}$$

Finally, for the sake of completeness, we assume that the central bankers are heterogeneous with respect to their degree of conservatism, which is common knowledge.[10] Notably, as we stressed above, the degree of conservatism – hawkishness versus dovishness – can influence the

[9] Here we use the utility function proposed by Favaretto and Masciandaro (2016), and assume that the central banker's independence is constant and normalized to one.

[10] For more information on uncertainty and central banker's preferences, see Beetsma and Jensen (1998), Muscatelli (1998), Lossani et al. (1998), Tillman (2008), Sorge (2013), and Morimoto (2018).

central bank's attitude towards climate change. Then, central bankers can be indexed, such that more conservative central bankers bear higher marginal costs and/or enjoy lower marginal benefits from any given policy, given that the implementation of an overly inflationary policy is costly for a conservative central banker:

$$\frac{\partial B(t_{cb},\pi)}{\partial \pi} = -\frac{2\sqrt{\pi}}{{t_{cb}}^2} < 0\,;\ \frac{\partial C(t_{cb},\pi)}{\partial \pi} = \frac{\sigma \Omega_L \pi^2}{2} > 0\,. \tag{21}$$

The central banker's preferred inflation rate, π_{cb}, is such that the marginal benefits match the marginal costs:

$$\frac{\partial B(t_{cb},\pi)}{\partial \pi} = \frac{\partial C(t_{cb},\pi)}{\partial \pi};\ \frac{1}{\sqrt{\pi} t_{cb}} = \sigma \Omega_L t_{cb} \pi\,. \tag{22}$$

Then:

$$\pi_{cb} = \frac{1}{{t_{cb}}^{4/3} \sigma {\Omega_L}^{2/3}}\,. \tag{23}$$

Finally, we can explicitly consider the third channel between climate change and macroeconomic performances – the role of climate change as a source of financial stability uncertainty in the decisions of central bankers. The question then becomes: How do central bankers make their choices when there is a source of financial stability uncertainty that can affect their overall decisions?

The simplest way to sketch out such a situation is to consider a central bank's policy choice when a source of financial stability uncertainty can change the overall expected outcomes. Monetary policy and financial stability are associated with one another, but their true relationship is unknown. On the one hand, for any level of the inflation rate, π, the benefits depend on a random variable, Ψ (i.e. the gains from central bank involvement in financial stability issues). On the other hand, losses from the central banker's involvement in financial stability can occur. The size and likelihood of such as losses are captured through another random variable, Δ. The central bankers know the distributions of both benefits and costs. We assume that financial stability uncertainty influences only the central banker's benefits. However, uncertainty can affect both benefits and costs with different weights without any changes in our results.

Focusing on the role of financial stability uncertainty, the central bank function becomes:

$$B(t_i,\pi,\Psi,\Delta) = B(t,\pi,\Psi,\Delta)\ . \tag{27}$$

The utility of the central banker becomes:

$$V_j(t_j,\pi,\Psi,\Delta) = \frac{2\pi^{0.5}\Psi}{t_j \Delta} - \frac{1}{2} t_j \pi^2\,. \tag{28}$$

From the optimality conditions, the preferred inflation rate will be:

$$\pi_j = \frac{\Psi^{2/3}}{t^{4/3}\Delta^{2/3}}\,. \tag{29}$$

Therefore, in defining an optimal policy stance, the central banker must address the unpleasant and uncertain trade-off between expected costs and benefits, so that the sensibility toward

climate-change issues is implied. Again, such sensibility can be a function of the political green voice.

All in all, a central bank's green sensibility can be associated with political voice, and more active politicians can influence the central bank's attitude on climate-change issues. The political voice can increase or decrease the central bank's perception of the optimal green sacrifice ratio. In other words, the nature of the association between a central bank's green attitude and the political voice depends on the direction of the politician's activism. In turn, the political green voice depends on the political sacrifice ratio. Moreover, each central bank's attitude toward the relevance of climate change can matter.

In conclusion, the role of central bank sensibility in influencing its decision as well as the exploration of the relevant drivers of such a sensibility becomes a genuinely empirical issue. Therefore, the development of a relevant metric is needed.

4. The Central Bank Green Activism Index

As we highlighted in the literature review, although several central banks have started to adopt green policies, adoption is not homogeneous. Therefore, rather than focusing only on actual policies, we decided to assess the central banks' more general "green sensibility", which includes green policies as well as participation in green networks, involvement in green initiatives, and research and announcements on future initiatives. We made this decision because, as we mentioned above, and only a fraction of all central banks have sincerely adopted green policies, while many others have only started to assess the effects of climate change on their operations.

As we are interested in what drives central banks to account for climate change and the environmental transition, we decided to focus on sensibility rather than actual policies. This allows us to include central banks that are in different stages of this transition. In addition, as central banks that are more active on this topic are, on average, from developing or Eastern countries, considering sensibility rather than policies allows us to have a broader and more heterogeneous sample. This is particularly important for the econometric analysis, as it allows us to have more variability in our data.

4.1 The Central Bank Green Activism index

As we are interested in what determines central banks' involvement in environmental policies, we first need to design a quantitative measure to capture this effect. We therefore created the Central Bank Green Sensibility Index (CBGSI) – a metric of how much central banks signal being concerned with the effects of climate change on both the real economy and the financial system.

We built the index based on Dikau and Volz (2021), who provided a comprehensive and up-to-date list of all green policies and initiatives adopted by central banks. D'orazio and Popoyan (2020), the paper most similar to ours, uses a similar metric, but their variable differs in two aspects. First, D'Orazio and Popoyan (2020) focuses on actual green prudential regulation policies. We instead account for the broader "green sensibility", which includes a wider variety of actions that are planned or implemented. Second, D'Orazio and Popoyan (2020) use a dummy variable equal to 1 if

the central bank has adopted green prudential regulation policies (0 if under discussion), while we built an index as an interval variable.

The D'orazio and Popoyan (2020) dummy is based on the Green Prudential Instrument Index by D'Orazio and Popoyan (2019a), which can be found in a dataset made available by the authors. The D'Orazio and Popoyan (2019a) dataset includes two indexes: the "Green Macroprudential Index" [0;…;2] and the "Green Prudential Instrument Index" [0;…;10]. Both indexes are built as nominal variables – the order does not have any quantitative meaning and, therefore, they cannot be used in our analysis. Apart from the mentioned aspects, we choose to use Dikau and Volz (2021) as a source for our data, because they have a larger sample of both proper policies and other initiatives (e.g. reports, networks), which creates more variability in the index.

After collecting the information contained in Dikau and Volz (2021), we built a dataset of all central banks that had adopted or announced green initiatives, and then classified them according to the authors' classification:

1. Green Network participation;
2. Incorporation of ESG criteria in central banks portfolio management/TCFD supporter;
3. Integration of climate risk into macroprudential policy (implemented or under development);
4. Guidelines on environmental risk management, disclosure requirements or stress tests for financial institutions;
5. Green bond support programmes; and
6. Green lending guidelines/guidance or "promotional/directed" credit policies for financial institutions.

To these, we added three categories:

7. Green reports or announcements (involvement in green research or initiatives);
8. Mandate updated to incorporate green activities; and
9. Incorporation of sustainable practices into their functioning as a corporation and efforts to reduce their ecological footprint (also "leading by example").

For each central bank in our dataset, we assigned a value of 1 for each category for which it had designed, or planned to design, a relevant policy or initiative. Equation 1 reports the mathematical formula of the CBGSI. As we have nine categories, the CBGSI can take values in the interval [0;…;9]. Dikau and Volz (2021) considered a total of 135 central banks. Of these, 70 had an explicit or implicit environmental mandates,[11] while 65 did not have any environmental requirement in their mandate. We make this distinction because some central banks have a mandate that explicitly includes the promotion of sustainable growth or development as an objective, while others are tasked with supporting their governments' national policy objectives. Thus, by "implicit environmental mandate", Dikau and Volz (2021) referred to the implications that most central banks will have to incorporate climate and mitigation risks into their core policy implementation frameworks to efficiently and successfully safeguard prices and financial stability, even if their mandates make no

[11] Of these 70 central banks, 16 had an explicit environmental mandate (i.e. included an explicit objective for the promotion or support of "sustainable" economic growth or development) and 54 have support for government policies in their mandate (mandated with the objective of supporting the government's policy priorities).

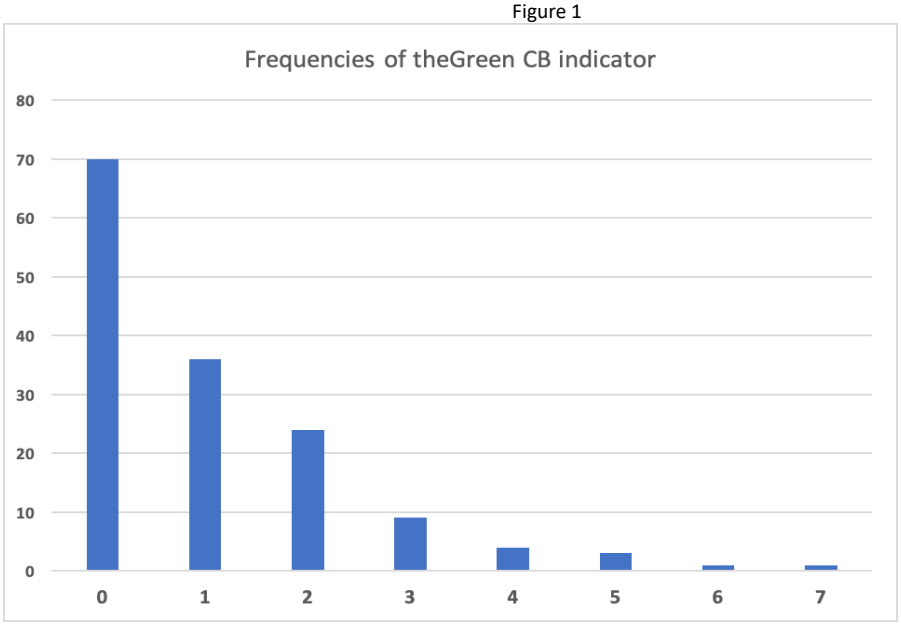
explicit reference to sustainability:

$$CBGSI = \sum_{i=1}^{9} D_i \qquad (30)$$

Importantly, Dikau and Volz (2021) show that environmental "sensibility" does not strictly depend on the mandate. Although 48% of the central banks in the sample had no explicit or implicit sustainability objectives, many of them had begun to engage in various green activities.

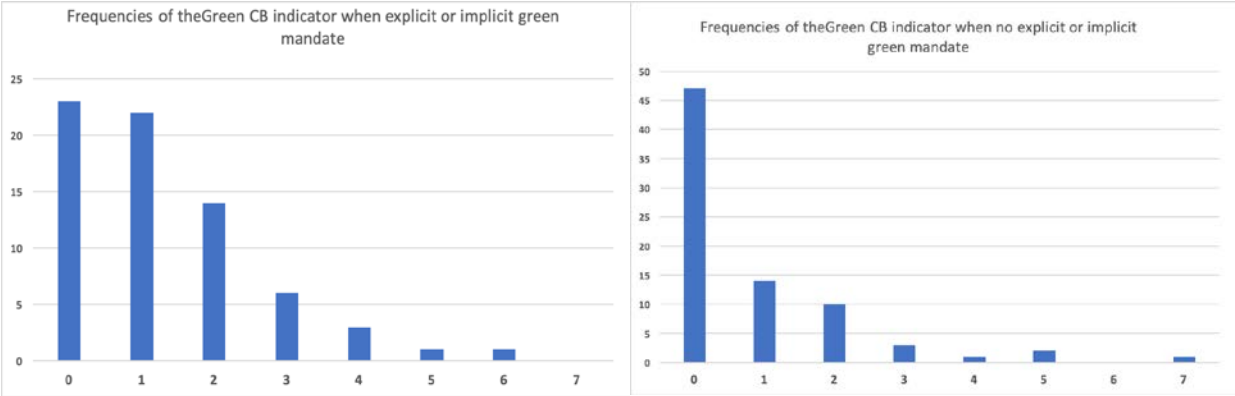
Our sample differs from Dikau and Volz (2021). Whereas central banks that have adopted or planned to adopt environmental policies are the same in both samples, central banks that lag in this regard (i.e. those with a CBGSI equal to 0) are those found in Masciandaro and Romelli (2018). We decided to use their sample in order to have a larger number of central banks not engaging in green initiatives for the sake of ensuring more variability in the data. Figure 1 reports the frequencies of the CBGSI. As we can see, the distribution is right skewed with the majority of central banks characterized by low values of the index, a few with high values, and none with the maximum value (i.e. the maximum value of the index is 7/9).

Figure 1



One of Dikau and Volz's (2021) main findings is that although 48% of the investigated central banks have no direct or indirect mandate demanding the central bank's engagement with climate change-related topics, numerous central banks – 33 according to their count (31 in our sample, likely because Iceland and New Zealand are repeated) – without mandates on sustainability or support for government policy had begun to address climate-change-related risks and sustainability challenges. Figure 2 shows the frequencies of the CBGSI divided between central banks with and without a "green mandate". Notably, in both samples most central banks have a value of 0 for the CBGSI, meaning that no green initiatives had been planned or implemented, although in the "no mandate" sample this value is twice as big. This confirms that the central bank's sensibility to the climate-change crisis does not completely depend on the mandate.

Figure 2



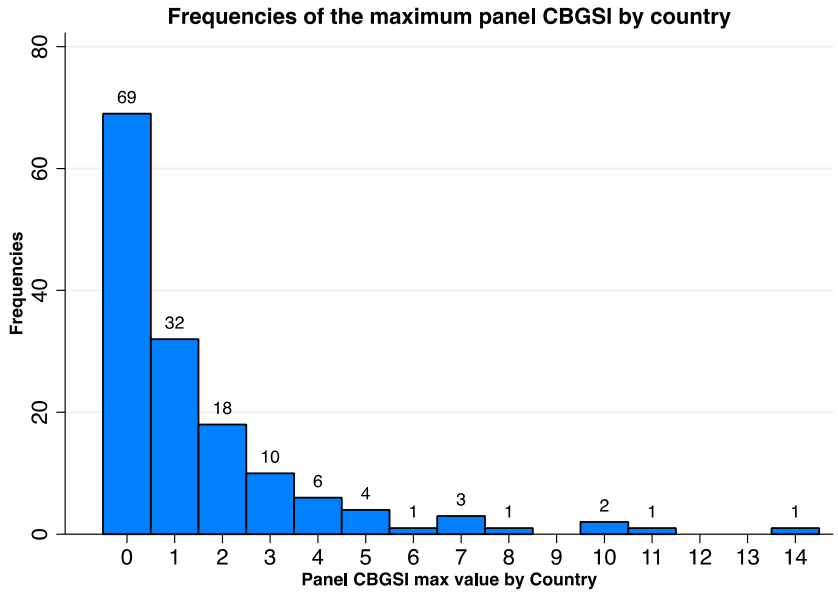
Given that the decision to adopt green monetary policies does not depend totally on the mandate, there may be drivers for green policies not related to legal aspects. This paper aims to explore which of these drivers may affect central banks' decisions to adopt such policies.

To extend our analysis, we design and build the panel index for central banks' green sensibility, which is once again based on the data provided by Dikau and Volz (2021). However, in contrast to the cross-country version of the index, we do not aggregate policies or initiatives according to authors' classification. Instead, we sum them up over the years they have been enacted or announced. Hence, the formula for the panel CBGSI is:

$$PCBGS_t = \sum_{t=0}^{t} D_{t,} \qquad (31)$$

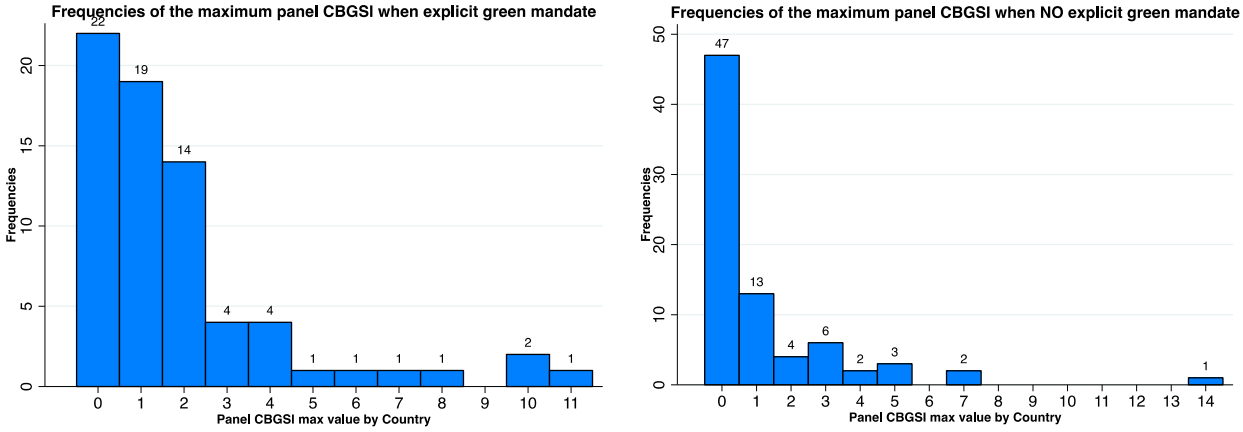
where D_t is equal to the total number of policies or activities designed or planned in each year regardless of their classification. Figure 3 shows the distribution of the maximum (over the considered timespan) for the panel CBGSI at the country level. We plot the maximum to harmonize the panel CBGSI with its cross-country version, making the comparison more reliable. Figure 3 is mostly in line with Figure 1, which implies that the two indexes follow a similar right-skewed distribution. However, by construction, the panel index has a longer tail and is more dispersed.

Figure 3



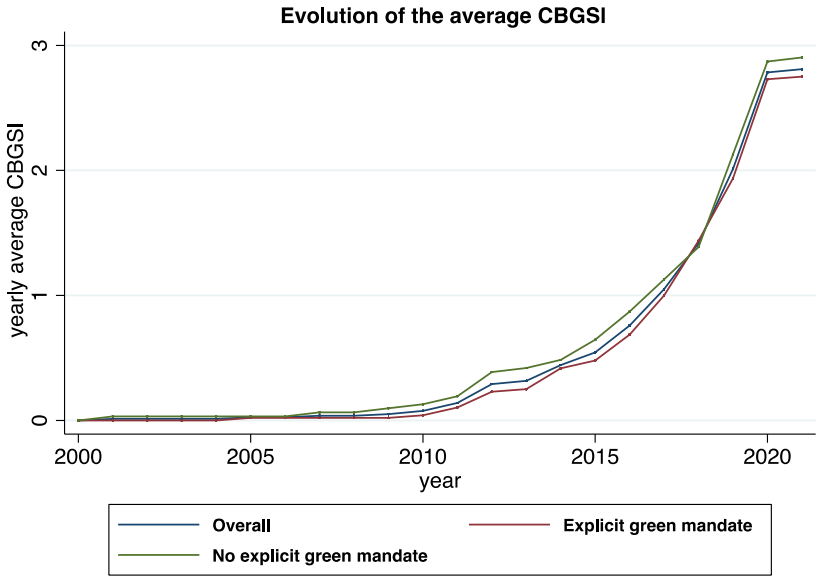
Similarly, in Figure 4, we plot the frequencies of the index divided by whether the central bank had an explicit or potentially implicit green mandate. The figure confirms that the presence of an explicit or potentially implicit green mandate is not a determinant of the adoption of green policies or initiatives by central banks.

Figure 4



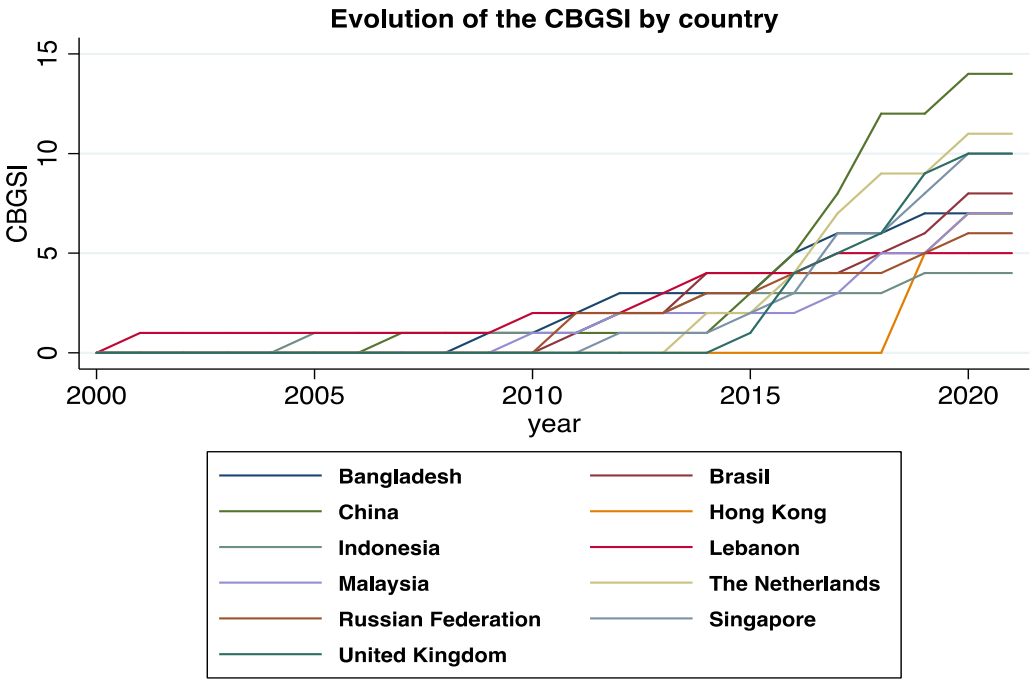
Thus far, we have only shown the cross-country dimension of the index. We now assess the panel dimension. Figure 5 plots the yearly average evolution of the panel CBGSI. As shown in the previous figures and mentioned in the previous section, most central banks have null or low indexes. For this reason, we chose not to include these countries when calculating the average; otherwise, the values would be underestimated by the presence of these countries (i.e. biased towards 0).

Figure 5



As expected, Figures 5 and 6 show that even the central banks leading the environmental transition only started being active in this regard in 2010. The most important increase in central banks green sensibility is visible in 2015, the same year as the Carney (2015) speech. This trend is confirmed when dividing the sample according to the presence of a central bank with an explicit or potentially implicit green mandate. In addition, the Figure below shows an unexpected result: the average CBGSI is slightly higher for central banks without an explicit or potentially implicit green mandate than for central banks with a green mandate. This result is mainly driven by the presence of countries whose central banks are leading the environmental transition in the "no mandate" sample, including Bangladesh, China, Lebanon and Hong Kong. Given that central banks have been heterogeneous in the face of the environmental transition, we plot the evolution of the index for the most active countries from this perspective. To do so, we classified central banks with the maximum value of the panel index equal or higher than 5 as highly sensible. As shown in Figure 6, these central banks follow the overall path shown in Figure 3.

Figure 6



5. Conclusion

Central banks around the world seem to be increasingly committed to further incorporating climate-change considerations into their policy design. Additional questions arise: How are aspects, such as commitment, measured? Which factors are its drivers? This paper represents a first step in exploring these research questions. We reviewed the extant literature on climate change and central banking, and we developed a metric to evaluate central banks' sensibility in addressing climate-change issues. Further steps are needed, and we are convinced that as central banks are public agents, the metric will be useful in analysing their relationships with their principals (citizens and politicians) to uncover which economic and political drivers influence central bank activism on climate change and environmental sustainability.

Future research could assess which, if any, variables lead central banks to adopt green-focused policies using our Central Bank Green Activism Index as the dependent variable. As regressors, such studies could use a set of climate change data (Kling et al. 2020, Kotz et al. 2020, Volz et al. 2020, Eckstein et al. 2021) as well as political variables (Volkens et al. 2020).

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