Bocconi

WORKING PAPER SERIES

WORKING PAPER
N. 181
JUNE 2022

Central Banks and Climate Policy: Unpleasant Trade–Offs? A Principal–Agent Approach

By Donato Masciandaro and Riccardo Russo

Università Bocconi
BAFFI CAREFIN
Centre for Applied Research
on International Markets, Banking,
Finance, and Regulation

Central Banks and Climate Policy: Unpleasant Trade–Offs? A Principal–Agent Approach

Donato Masciandaro* and Riccardo Russo**

June 2022

Abstract

This paper focuses on the trade–offs that central banks would face if they were to start tackling climate change. Disruptive natural events can hamper growth and capital accumulation, thereby affecting price and financial stability – elements for which central banks are responsible. Yet, the array of instruments they could use to mitigate climate–related risks overlap with those already used in relation to their monetary and macroprudential mandates. By leveraging a principal–agent setting, we consider the conditions under which the central bank architecture would be fit to take on this objective without jeopardising the attainment of central banks' core mandates. We also examine the corresponding effects in terms of climate risks. Our results show that central banks' effectiveness in this regard depends on the degree of their independence from governments' climate preferences and on their ability to calibrate their "green" easing, either monetary and/or regulatory, on the realised level of abatement and emissions.

JEL Classification: D02, E52, E58, E61, E63
Keywords: monetary policy, macroprudential policy, fiscal policy, climate change, delegation, independence.

* *Department of Economics and Baffi Carefin Centre, Bocconi University, Via Guglielmo Röntgen 1, Milan 20136, Italy. Email:* donato.masciandaro@unibocconi.it

** *Economics Group, King's Business School, King's College London. Bush House, 30 Aldwych, London WC2B4BG, UK. Email:* riccardo.russo@kcl.ac.uk

---

This paper is based on a solo–authored chapter that will be submitted as part of the PhD thesis of Riccardo Russo in partial fulfilment of the requirements for the title of Doctor of Philosophy at King's Business School, King's College London.

1. Introduction

Since the beginning of the 2000s, CO_2 emissions have increased by 60.98% worldwide (IEA, 2021). This trend is expected to lead to severe climate–related economic disruptions, such as a decline in agricultural productivity (Schauberger et al., 2017) and lower economic growth (Kotz et al., 2021). According to Stern (2007), these disruptions could translate into a permanent GDP loss ranging from 5% to 20% per year over a time span of 20 years unless concrete action is taken. More specifically, to avoid the most severe effects of climate change, global emissions should be reduced by at least 30% by 2050.

Amid growing concerns and public demonstrations, 196 national governments signed the Paris Agreement in 2015. The agreement aims to limit global warming to less than 2 (preferably 1.5) degrees Celsius relative to pre–industrial levels. This ambitious objective requires the signatories to foster systemic transformations of their economies (Schoenmaker, 2021), set carbon–neutrality targets, and provide support to those countries in need of financial, technical, or capacity–building assistance.

Central banks have started wondering whether the effects of climate change will call for their intervention. In the past few years, this topic has become increasingly common in their speeches and declarations (Carney, 2015; Dikau et al., 2019; Schnabel, 2021). In most cases, however, this focus has not yet translated into actual policymaking (Masciandaro and Tarsia, 2021). Rather, central banks in developed countries have launched cautious investigations into whether, how and to what extent they should intervene in climate policy. The European Central Bank's strategy review is an example in this regard.

This cautious stance stems not only from the different sensibilities of central bankers around this matter but also from their interpretations of the different mandates they must respect. Historically, such mandates have not entailed direct references to climate change, although there have recently been some exceptions in developing countries (Masciandaro and Tarsia, 2021). Instead, central bankers generally focus on price and, since the Great Financial Crisis, financial stability, to which it is often added a corollary on sustaining or not jeopardising economic growth.

Whether the scope of these mandates could be stretched to allow central banks to take climate–related actions is an open debate from both a policy–oriented and an academic point of view. On the one hand, some claim that the effects of climate change on economic performance may jeopardise financial stability and that central banks should account for these effects. On the other hand, many suggest that letting central banks take on responsibilities beyond their monetary and macroprudential obligations would make their overall action ineffective. These actors suggest that climate policy should be left to fiscal authorities (see Batten et al., 2016, for a general overview).

This paper proposes a theoretical framework for assessing the effectiveness of central banks' potential interventions in climate policy relative to those of national governments. To date, research around central banks' "green" policies has mostly been oriented towards empirical investigations of specific sectors or qualitative analyses of central banks' potential tools. It has not focused on justifying policy recommendations based on a theoretical background that accounts for the interactions and incentives of the two institutions. The framework we present can serve as a useful instrument for justifying the kind of policy mix that would be the best–suited for tackling climate change while not jeopardising price and financial stability.

We proceed by analysing different settings in which a central bank can undertake climate action through its monetary and/or macroprudential instruments. By comparing the outcomes of these architectures with one in which the fiscal authority acts alone, we assess whether central banks' participation in climate policy would be beneficial, detrimental or neutral in terms of "greening" the economy, and if this outcome would come at the cost of missing central banks' monetary and macroprudential targets.

Overall, we present four cases. The first, which only envisions the government as intervening in climate policy, represents the benchmark case. Thereafter, we consider three other settings in which, along with the fiscal tools set by the government, the central bank pursues its price and financial stability mandates under certain climate–related constraints. In so doing, we consider such constraints to be binding, initially on monetary policy, then on macroprudential policy, and finally on both monetary and macroprudential policy.

The remainder of this paper is organised as follows. In section 2, we review the literature related to the economic and financial effects of climate change as well as the possible pros and cons of different kinds of intervention. In section 3, we present the baseline economy and its properties. The benchmark setting with the government alone is discussed in section 4, while sections 5 and 6 introduce and analyse the central bank's role. We present our conclusions in section 7.

2. Background and Motivation

Climate change is likely to affect the macroeconomy (Tol, 2009; McGlade and Ekins, 2015; Hsiang et al., 2017; Nordhaus, 2017; McKibbin et al., 2017, 2020) and may lead to economic disruptions through two main channels (Bolton et al., 2020): physical risks and transition risks. Physical risks may arise due to the destruction of capital and the associated decline in firms' profitability following more severe and frequent weather events, such as floods, storms and heat waves. Transition risks stem from the possibility of a sudden reduction in fossil–fuel consumption and emissions, which would disrupt the current economic system by not providing it with enough time to adapt (Allen et al., 2020; Semieniuk et al., 2020).

The effects of these two channels can, in turn, propagate to the financial system (Battiston et al., 2017). Specifically, the devaluation of assets and collateral due to climate-related events may hinder banks' abilities to recover their credit, resulting in a higher probability of default and loss given default as well as an increased credit risk (Monnin, 2018b). Moreover, an abrupt transition to lower emissions could make some assets unexploitable. Investors' perceptions of such stranded assets would change, possibly resulting in "fire sales" and, thus, higher market risk (Dietz et al., 2016). In turn, higher credit and market risk would negatively affect the balance sheets of the most exposed financial institutions (Pagliari, 2021), hinder their refinancing capacity and increase liquidity risk (Kling et al., 2021). In addition, increased operational risk would result from any climate-induced damage to banks' infrastructure, such as data centres and offices, while higher insurance risk would result from higher claims due to the adverse events (Cleary et al., 2019). Finally, a possible spread to sovereigns could make them riskier (Volz et al., 2020).

The evidence found in the literature is not univocal in suggesting whether these risks are adequately priced in by different markets. An important strand of this research focuses on housing, for which a negative link between exposure to extreme climate events and valuations is easier to establish (Bernstein et al., 2019; Baldauf et al., 2020; Giglio et al., 2021). However, studies of other markets provide ambiguous results. For instance, while Bansal et al. (2016) find timely pricing of climate-induced risks through the devaluation of assets, Hong et al. (2019) claim this occurs with a delay when it comes to stock prices. The implication is that the market may not be able to produce the right incentives to tackle climate change on its own and that, therefore, additional policy interventions are needed (Monasterolo et al., 2017; Chenet et al., 2021). Numerous tools of a fiscal, monetary or macroprudential nature have been proposed.

In general, one can distinguish between those tools requiring governments' action (fiscal) and those that have to be put in place by central banks (monetary and macroprudential). On the fiscal side, the main instrument that has been proposed and introduced is the carbon tax (or carbon pricing), which is levied on firms in proportion to their CO_2 emissions (Stiglitz and Stern, 2017; Blanchard and Tirole, 2021; BIS, 2021; OECD, 2021). On the monetary and macroprudential side, possible interventions relate to the inclusion of climate-related risks in capital requirements, climate stress testing and the integration of ESG criteria into asset-purchase programmes (Campiglio et al., 2018; Dafermos et al., 2018; Monnin, 2018a; De Grauwe, 2019; Dikau and Volz, 2019; Dikau et al., 2020; Bremus et al., 2021).

The policies or policy mix that would be the most effective option for reducing pollution is subject to debate (Krogstrup and Oman, 2019). The partial effectiveness of carbon pricing seems to have been established, but there is still disagreement about whether it is enough on its own (Tvinnereim and Mehling, 2018). While some point out that such a policy is subject to market failures and, thus, call for central banks' interventions (Campiglio, 2016), others, including those who first proposed the tax, claim that any role played by central banks could be detrimental (Tirole, 2021) or insufficient if not properly coupled with governmental action (Bolton et al., 2020; McConnell et al., 2022; Dafermos and Nikolaidi, 2021; Hansen, 2022).

Since the publication of Kydland and Prescott's (1977) well–known work, interactions among society, governments and central banks have successfully been modelled through principal–agent theory. This strand of literature provides a useful and tested toolkit that has not been widely applied to climate policy despite its relevance. Notably, as central bankers are unelected officials, their potential interventions in climate policy can only stem from the mandates that elected governments hand over to them (Bartholomew and Diggle, 2021). This envisions a twofold relationship – on the one hand, the government takes climate concerns into account due to the sensibility of the electorate or genuine social–welfare concerns. On the other hand, the government delegates the task to the central bank, which acts as its agent.

Since the signing of the Paris Agreement, several central banks in both developed and developing countries have started to stress their commitment to intervening in climate policy. D'Orazio and Popoyan (2019, 2020) propose an index allowing for the categorisation of countries around the world according to their stance on climate–related regulations. Their results show that most developed economies are now in the discussion stage. Masciandaro and Tarsia (2021) propose an index of "green sensibility" that accounts not only for actual implementations but also for different kinds of commitments. In line with previous results, they find an increasingly pressing discourse about climate–related interventions.

The possibility that words may translate into actions calls for a thorough examination of what intervention in climate policy would mean in terms of: (i) the attainment of the central banks' "core" objectives (price and financial stability) and (ii) central banks' potential efficacy in reducing pollution. Most of the recent literature has focused either on empirical investigations of the possible effects of such climate interventions on specific markets or on descriptive analyses of the tools that can be deployed to support governments in the fight against climate change. In other words, it seems to be assumed that central banks can effectively complement governments' policies with respect to climate policy, and that the possible trade–offs between this goal and central banks' core objectives would favour the former. Otherwise, central banks would have no reason to intervene.

However, given the early stage of the discussion, we cannot assume that the support central banks may provide would be effective in reducing CO_2 or other kinds of emissions. On the other hand, this may be enough to jeopardise their ability to properly conduct monetary and macroprudential policies. Whether this is the case should be determined through analyses of the potential (and limits) of central banks' institutional design with respect to the other main player – governments. Would the current institutional design of central banks allow them to withstand and contribute to governments' climate policies without detrimental effects on the targets of monetary and macroprudential policies? Alternatively, would governments be better left alone?

Leveraging on different principal–agent settings, this paper contributes to the extant literature by providing background theoretical models addressing the expected efficacy of central banks' potential interventions in climate policy. In so doing, we distinguish among cases in which the instruments used by the central bank would be of a monetary, macroprudential, or both monetary and macroprudential nature. Taking emissions as a reference variable for measuring climate change, we then compare each of these settings with one in which the government acts alone. The setting resulting in lower emissions and smaller deviations from monetary and macroprudential targets is then deemed best suited for achieving the social optimum.

3. The Economy

Both governments and central banks have tools that could be used to intervene in climate policy. In line with the major analyses (Stiglitz and Stern, 2017; Blanchard and Tirole, 2021; BIS, 2021; OECD, 2021), the governmental instrument considered here is a carbon tax. Central banks' potential interventions include the reformulation of asset–purchase programmes in favour of environmentally friendly securities, the integration of climate–related criteria into stress testing, collateral requirements and credit ratings; and climate–specific regulation (Campiglio et al., 2018; Dafermos et al., 2018; Monnin, 2018a; De Grauwe, 2019; Dikau and Volz, 2019; Dikau et al., 2020; Bremus et al., 2021).

Basically, these interventions envision the introduction of climate risks into the existing framework central banks use to carry out monetary and macroprudential policies, and the subsequent recalibration of the current instruments without an explicit need for new mandates or tools (Krogstrup and Oman, 2019). In addition to the weight always assigned to central banks' core missions, this also reflects the fact that, at least in major monetary jurisdictions, the introduction of an additional, explicit mandate would require the amendment of international treaties (e.g., the TFUE for the ECB) or complicated institutional procedures that would make this option hardly feasible. As such, the way forward is to make central banks' policymaking subject to climate constraints.

Therefore, in our subsequent analyses, central banks' climate action, where present, is assumed to stem from the inclusion of climate risks within the scope of price and financial stability. The variables to stabilise for achieving these two objectives are respectively assumed to be inflation (Walsh 1995; Chortareas and Miller, 2003, 2004) and credit, whose relevance in determining the financial cycle is well established in the literature (Schularick and Taylor, 2009; Jordà et al., 2010;

Gourinchas and Obstfeld, 2011; Claessens et al., 2012; Drehmann et al., 2012; Borio, 2012; Caruana and Shim, 2016).

Henceforth, emissions represent the measure of climate risk (Stiglitz and Stern, 2017; Blanchard and Tirole, 2021; BIS, 2021; OECD, 2021) and are determined as:

$$e = y - a, \tag{1}$$

where y and a, respectively, represent the productive sector's output and abatement in real terms. The decision to keep these variables in real terms reflects the fact that carbon taxes are usually levied "per tonne" of CO_2. In this case, the government levies the tax "per unit" of emissions, comparable to CO_2.

The general definition of inflation, accounting for climate risks, is:

$$\pi = m + \alpha_1(c - c^e) + \alpha_2 y - \alpha_3 e, \tag{2}$$

where m is a measure of monetary accommodation, c and c^e stand for actual and expected credit, respectively, and y and e have the same meaning as in (1). A level of credit above expectations boosts output and, thus, inflation (Balke, 2000; Calza and Sousa, 2005). Higher emissions result in a slowdown of economic activity and inflation through the realisation of climate risks (Stern, 2007). The instrument of the central bank is m (Walsh, 1995; Chortareas and Miller, 2003, 2004), which resembles the case of a "green" asset–purchase programme. The parameters α_1, α_2 and α_3 are the weights that unexpected credit, output and emissions, respectively, are assigned with respect to m in determining π, with $\alpha_1 > 0$, $\alpha_2 > 0$ and $\alpha_3 \geq 0$.

Similarly, the climate–dependent definition of credit is given by:

$$c = \rho + \beta_1(\pi - \pi^e) + \beta_2 y - \beta_3 e, \tag{3}$$

where ρ is a regulatory accommodation and represents the central bank's macroprudential instrument (Smets, 2014). It may, for instance, be considered as the inverse of a countercyclical capital buffer. The factor π^e is expected inflation and y has the same meaning as before. Higher unexpected inflation reduces real debt burdens, greater output boosts economic activity, and both create more favourable lending conditions, thereby increasing credit. The opposite applies to higher emissions due to the translation of physical risks into financial risks (Battiston et al., 2017). The parameters β_1, β_2 and β_3 are the weights that unexpected inflation, output and emissions, respectively, have in determining credit relative to ρ, with $\beta_1 > 0$, $\beta_2 > 0$ and $\beta_3 \geq 0$.

In the following analyses, the central bank sequentially incorporates climate risks into its modelling of the two target variables, so that the resulting monetary and/or macroprudential instruments account for them. Of course, both instruments must be set each time, but they do not necessarily result from climate–constrained modelling. We devote one model to each case. In the first, the central bank does not account for climate risks at all ($\alpha_3 = 0, \beta_3 = 0$). In the others, the central bank accounts for climate risks through monetary tools ($\alpha_3 > 0, \beta_3 = 0$), macroprudential tools ($\alpha_3 = 0, \beta_3 > 0$) or both ($\alpha_3 > 0, \beta_3 > 0$). This allows us to define four climate–constraints sets:

- *Constraint set S1: the government is alone.* Inflation and credit are respectively defined as in (2) and (3), with $\alpha_3 = 0$ and $\beta_3 = 0$.
- *Constraint set S2: climate risks in monetary policy.* Inflation and credit are respectively defined as in (2) and (3), with $\alpha_3 > 0$ and $\beta_3 = 0$.
- *Constraint set S3: climate risks in macroprudential policy.* Inflation and credit are respectively defined as in (2) and (3), with $\alpha_3 = 0$ and $\beta_3 > 0$.
- *Constraint set S4: climate risks in monetary and macroprudential policies.* Inflation and credit are respectively defined as in (2) and (3), with $\alpha_3 > 0$ and $\beta_3 > 0$.

4. Governments and Climate Policy

The benchmark analysis presented in this section focuses on a government's climate policy and envisions three players: a representative, profit–maximising firm with a production process that entails polluting emissions that can be neutralised through abatement, a central bank that conducts monetary and macroprudential policies without regard to climate risks, and a fiscal authority that levies a carbon tax on the firm's emissions.

The authority to tax emissions is given to the government by voters through an electoral delegation process, according to which the government already in office is re–elected provided that it maximises the voters' welfare function. Voters' preferences are assumed to be homogenous and concave with respect to the government's carbon tax. On the one hand, voters benefit from the firm's profits, which are assumed to be equally distributed among them.[1] On the other hand, voters have a climate sensibility and would like emissions to be reduced. These are two conflicting objectives, as the carbon tax is expected to negatively affect profits while

[1] The aim of this feature is to create a link between the state of the economy and voters' behaviour, which is referred to as the "economic voting hypothesis" (e.g., Downs, 1957; Key, 1966) in the literature. According to this theory, voters will not re–elect the incumbent government if they are unsatisfied with the state of the economy (Lewis–Beck, 1988). Here, this is summarised by the representative firm's profits. While this theory may be deemed simplistic, it serves the aim of justifying delegation in a context in which voting is not the key aspect to consider.

pushing the firm to reduce emissions. Furthermore, voters' welfare depends on the ability of policymakers to keep inflation and credit in line with the expected targets.[2]

With regard to which voters the politician would like to please, two cases can be analysed: the *helping–hand view* (Pigou, 1938) assumes that the policymaker wishes to please citizens, rather than a particular constituency or lobby, which is referred to as the *grabbing–hand view* (Shleifer and Vishny, 1998). According to the latter view of the political actor (Frye and Shleifer, 1996; Friedman et al., 2000; Brown et al., 2009), policymakers are motivated by a desire to please specific, well–defined voters in order to win elections (Masciandaro and Quintyn, 2008).

We assume that the policymaker is benevolent. Moreover, it is worth noting that the two views do not automatically produce different outcomes. For example, in countries where policymakers are more likely to be grabbing–hand politicians, they can still implement delegation choices that are consistent with welfare and efficient criteria (Becker et al., 2016) in order to signal their competence and skills (Gratton et al., 2020).

In serving as the voters' agent, the government's aim is to balance voters' conflicting preferences in terms of the carbon tax rate, while delegating monetary and macroprudential policies to the central bank. In this setting, the government does not delegate climate responsibilities to the central bank. This may be due to strict mandates, highly independent central bankers or other institutional features. This approach allows us to respectively interpret the weights α_3 and β_3 from section 3 as measures of monetary and macroprudential policies' independence from the government's climate preferences. The more independent the central bank (i.e., the lower these parameters), the tougher it is for the government to force it to account for climate in its modelling of the economy.

The degree of the central bank's independence is determined in the first step of a two–stage process, with two events subsequently taking place: a "constitutional" event and a "business–cycle" event (Masciandaro, 2021). In the first stage, society operates with a long–run perspective and the lawmakers determine the relevant features of the central bank's institutional design.[3] In this perspective, the delegation

[2] This is in line with the economic–voting hypothesis.

[3] In this two–tier framework (Buchanan, 1962; Romer and Romer, 1997; Herrendorf and Lockwood, 1997; Drazen, 2002; Hughes et al., 2005, 2007; Hefeker and Zimmer, 2011; Miller, 2019), lawmakers simultaneously decide on two monetary institutions (Besley and Case, 2003) in the "constitutional" stage (Persson and Tabellini, 2004; Aghion et al., 2004; Alesina and Tabellini, 2007): how to design the monetary policy task (i.e., the monetary policy regime) and who has control over that policy (i.e., the monetary policymaker). The lawmakers are long–sighted players and the legislature decides on monetary policy issues through a supermajority vote (Dal Bó, 2006; Battaglini and Coate, 2007). Moreover, the lawmakers work under a veil of ignorance (Romer and Rosenthal, 1983; Aghion and Bolton, 2003; Aghion et al., 2004), completely ignoring not only the possible structure of the government in the business–cycle stage but also the fact that some of the incumbent lawmakers may be part of such a government.

of monetary policy to non–elected central bankers has been motivated, showing that bureaucrats are preferable to politicians in technical policy (Alesina and Tabellini, 2007). The same perspective can be used to define the central bank's involvement as a prudential policy actor (Masciandaro and Volpicella, 2016; Masciandaro, 2022). Given the institutional setting, citizens and policy makers interact in the second stage, which is characterised by a shorter horizon, and the focus is on defining policy actions to address the business cycle.

In this section, the outcome of the "constitutional" stage is assumed to result in an institutional framework in which the central bank is responsible for monetary and macroprudential policies, but not for climate policy. Therefore, it does not set its instruments after taking climate–related concerns into consideration. Inflation and credit are, thus, defined according to S1.

4.1 Climate Risks and Carbon Tax

The preferences of voters and, thus, of the government can be summarised by the welfare function:

$$W = t - \omega_1 \frac{t^2}{2} - \omega_2 (\pi - \hat{\pi})^2 - \omega_3 (c - \hat{c})^2, \tag{4}$$

where t is the tax rate, and the first two terms represent its expected positive effect in reducing emissions (*emission effect*) and its negative effect on profits (*profit effect*), respectively. The parameter $\omega_1 > 0$ represents the weight the latter is assigned relative to the former. The emission effect is assumed to be linear, while the profit effect is assumed to be quadratic[4], so that the first effect outweighs the second for low–enough values of t and is outweighed by it for too high tax rates. In other words, voters are unwilling to give up an excessively high amount of profits to reduce emissions (Hamel et al., 2019).

Voters' welfare is also negatively related to deviations in inflation and credit from the respective targets, $\hat{\pi}$ and $\hat{c}$. The parameters $\omega_2 > 0$ and $\omega_3 > 0$ are their weights in determining W with respect to t. The minimisation of these deviations would ensure that price and financial stability are achieved as per voters' preferences. The government, which aims is to please voters, delegates responsibility for monetary and macroprudential policies to the central bank. Therefore, the central bank's targets can be summarised by a simplified version of the loss functions in Ueda and Valencia (2012) and Smets (2014):

[4] Hamel et al. (2019) find that most people are unwilling to bear the direct costs of finance policies aimed at mitigating climate change and that this preference is stronger for higher costs. This leads to the quadratic form of the profit effect.

$$L = (\pi - \hat{\pi})^2 + \lambda(c - \hat{c})^2, \tag{5}$$

where all of the variables have the same meaning as before. The central bank is penalised for any deviation in realised inflation and credit from $\hat{\pi}$ and $\hat{c}$. The parameter $\lambda > 0$ is the weight assigned to the latter objective relative to the former.

The profit function of the representative firm must account for policymakers' interventions. In this case, only the government's intervention – the carbon tax – takes climate concerns into consideration. The tax is levied directly on firms' emissions. The central bank sets its monetary and macroprudential instruments without accounting for climate risks. Nevertheless, the central bank still affects profits: a higher degree of monetary and/or regulatory accommodation would allow the financial sector to lend more, thereby increasing aggregate demand and the firm's profits (Hartwig and Lieberknecht, 2020).

The firm's real profits are given by:

$$p = y - \delta_1 \frac{y^2}{2} - \delta_2 \frac{e^2}{2} t + \delta_3 (1 - \vartheta)(m + \rho - a). \tag{6}$$

The decision to consider profits in real terms aims to keep (6) consistent with (1). For a given price, higher real output translates into higher revenues (y) and production costs ($y^2/2$). Higher emissions hamper the firm's performance through the realisation of physical risks, the effects ($e^2/2$) of which are likely to be non–linear (Stern, 2007). Abatement (a) is a cost for the firm. Monetary and regulatory accommodations favour investment and, thereby, profits, while the government taxes emissions through t. In order to keep the focus on climate policy, we do not consider other kinds of taxes. The parameters $\delta_1 > 0$, $\delta_2 > 0$ and $\delta_3 > 0$, respectively, represent the weights of these effects relative to y's.

Finally, the parameter $0 \leq \vartheta \leq 1$ indicates the extent to which the central bank manages to make monetary and regulatory accommodation contingent on the level of abatement and, thus, emissions (calibration power). This parameter, which we assume is determined in the "constitutional" stage, will be null if the central bank does not manage (or is unable) to exert any kind of control[5] or simply does not account for climate risks (as in this section). It will be equal to unity if the central bank manages to do so fully. In the latter case, this implies that monetary and regulatory accommodations will fully cover the cost of abatement, and the fourth term will disappear from the profit function. In the former case, the firm will benefit from m and ρ to increase profits rather than increasing abatement.

The two policymakers play first and their optimisation problems are independent from one another. The order in which they set their respective instruments is

[5] By, for instance, imposing certain climate–related lending conditions on banks.

therefore irrelevant.[6] The government maximises (4) with respect to t. It does so subject to S1, but this makes no difference, as in no case do the definitions of inflation and credit depend on the carbon tax. This yields the optimal tax rate:

$$t = \frac{1}{\omega_1}, \tag{7}$$

which depends negatively on the weight assigned to the profits effect. The central bank then minimises (5) with respect to m and ρ, subject to S1. This yields the following response functions in terms of the monetary and macroprudential instruments, respectively:

$$m = \hat{\pi} + \alpha_1(c^e - \hat{c}) - \alpha_2 y \tag{8}$$

and

$$\rho = \hat{c} + \beta_1(\pi^e - \hat{\pi}) - \beta_2 y. \tag{9}$$

As the central bank does not account for climate risks in its modelling of the economy, its instruments do not depend on emissions. Furthermore, after plugging (8) and (9) back into the definitions of inflation and credit in S1, their expected and realised levels can be determined for any amount of emissions as $\pi = \pi^e = \hat{\pi}$ and $c = c^e = \hat{c}$. The central bank thus manages to achieve its targets.

The representative firm then sets the values of output and abatement to maximise (6) subject to (1), (8), (9) and the expectations that have been formed. The parameter ϑ is null. This yields the optimal values of output and abatement, respectively, as:

$$y = \frac{1 - \delta_3(1 + \alpha_2 + \beta_2)}{\delta_1} \tag{10}$$

and

$$a = \frac{1 - \delta_3(1 + \alpha_2 + \beta_2)}{\delta_1} - \omega_1 \frac{\delta_3}{\delta_2}, \tag{11}$$

where all of the parameters have the same meaning as before. Plugging these optimal values back into (1) determines emissions as:

---

[6] Making the two problems dependent on the instruments set by the other policymaker (rather than on exogenous parameters) would imply bringing into the analysis considerations about fiscal and monetary dominance that go beyond the delegation process considered in this paper.

$$e = \omega_1 \frac{\delta_3}{\delta_2}. \tag{12}$$

Henceforth, we refer to this model as M1. In terms of the central bank's efficiency with respect to the policy it is assigned in this framework, these results can be summarised as:

- *Proposition 1: central bank's targets.* Assume that the central bank does not account for climate risks while the government levies a carbon tax. Then, expectations and the realised values of inflation and credit are anchored to the central bank's targets.
- *Proof 1.* By plugging (8) and (9) back into the definitions of inflation and credit in S1, taking expectations and then accounting for them in the definitions of the target variables yields $\pi = \pi^e = \hat{\pi}$ and $c = c^e = \hat{c}$, respectively.

5. Central Banks, Governments and Climate Policy

As governments have already introduced measures to tackle climate change, central banks' interventions would serve as a complement to pre–existing policies. For instance, the first carbon tax was introduced in Finland in 1990 (UNCSD, 2010). Other countries have since followed, and nearly every government has established or renewed its commitment to the Paris Agreement. On the other hand, the discussion concerning whether and how central banks should try to mitigate climate change continues.

In this section, we analyse central banks' potential interventions in climate policy along with those of governments. Such interventions stem from an institutional setting that makes monetary and/or macroprudential policies subject to government's climate preferences (the parameters α_3 and β_3 will be as in the constraint sets S2 to S4). As the government serves as the agent of voters with a climate sensibility, it leverages on the central bank's own sensibility to its preferences to ensure that it accounts for climate risks within its price and financial stability mandates. As in the previous section, the other player is a polluting firm with an abatement capacity.

5.1 Climate Risks, Carbon Tax and Monetary Policy

Let us start with the case in which the central bank views climate constraints as binding its monetary policy (i.e., S2 applies). This would, for instance, resemble a situation in which the central bank promotes a "green" asset–purchase programme while the government levies a carbon tax. The government's preferences are still summarised by the welfare function in (4). The preferences of the central bank and the representative firm are summarised by (5) and (6), respectively. As the central bank accounts for climate risks in this case, the parameter ϑ is allowed to be non-null.

As before, the two policymakers move first. The government sets t to maximise (4). As its optimisation problem is the same as in M1 and independent from that of the central bank, it sets the same tax rate as in (7). The central bank then sets m and ρ to minimise (5), subject to S2. This yields the response function in terms of the monetary instrument as:

$$m = \hat{\pi} + \alpha_1(c^e - \hat{c}) - \alpha_2 y + \alpha_3(y - a), \tag{13}$$

and the one for the macroprudential instrument shown in (9). As shown by (13), the inclusion of climate constraints in the definition of the monetary target variable affects the central bank's policy setting and allows for emissions $(y - a)$ be taken into account. Furthermore, after plugging (9) and (13) back into the definitions of inflation and credit, as per S2, their expectations can be determined as $\pi^e = \hat{\pi}$ and $c^e = \hat{c}$. The central bank still manages to anchor expectations to its monetary and macroprudential targets. Realised inflation and credit are then on target as well.

Finally, the representative firm maximises (6) with respect to y and a, subject to (1), (7), (9), (13) and the expectations that have been formed. This yields the optimal values of output and abatement as:

$$y = \frac{1 - \delta_3(1 - \vartheta)(1 + \alpha_2 + \beta_2)}{\delta_1} \tag{14}$$

and

$$a = \frac{1 - \delta_3(1 - \vartheta)(1 + \alpha_2 + \beta_2)}{\delta_1} - \omega_1 \frac{\delta_3(1 - \vartheta)(1 + \alpha_3)}{\delta_2}, \tag{15}$$

respectively. Finally, after plugging (14) and (15) back into (1), emissions are given by:

$$e = \omega_1 \frac{\delta_3(1 - \vartheta)(1 + \alpha_3)}{\delta_2}. \tag{16}$$

Whether (16) is smaller than, larger than or equal to (12) depends on the parameters ϑ and α_3. We can distinguish three cases: if $\vartheta = 1$, emissions will be null and, thus, lower than in M1. If $\vartheta = 0$, emissions will be higher than in M1. For $0 < \vartheta < 1$, the results depend on α_3 as well – emissions will be lower than if the government acted alone provided that ϑ is sufficiently large and α_3 is sufficiently small. Henceforth, we refer to this model as M2.

- *Proposition 2–a: central bank's targets.* Assume that the central bank accounts for climate risks as per S2, while the government levies a carbon tax. Then, expectations and the realised values of inflation and credit are anchored to the central bank's targets.
- *Proof 2–a.* By plugging (13) and (9) back into the definitions of inflation and credit in S2, taking expectations and then accounting for them in the definitions of the target variables yields $\pi = \pi^e = \hat{\pi}$ and $c = c^e = \hat{c}$, respectively.
- *Proposition 2–b: emissions.* Assume that the central bank accounts for climate risks as per S2, while the government levies a carbon tax. Then, resulting emissions will not necessarily be lower than if the government acted alone as long as $\vartheta < 1$.
- *Proof 2–b.* It is enough to compare (16) and (12), knowing that the parameter α_3 is positive.

5.2 Climate Risks, Carbon Tax and Macroprudential Policy

In this model, we move to the case of a central bank accounting for climate issues through macroprudential policy (the conditions of S3 apply). This would, for instance, be equivalent to the introduction of stricter regulations accounting for climate risks or the inclusion of ESG criteria in stress testing. If the central bank was to do so, it would still consider the same loss function as in (5), but subject to the constraints imposed by S3. Voters' welfare and the profits of the representative firm are still as in (4) and (6), respectively, with ϑ not necessarily null.

The sequence of events does not change. The government sets the same tax rate as in (7), while the central bank sets its monetary and macroprudential instruments to minimise (5), subject to S2. This yields the response function in terms of m as in (8) and the one in terms of ρ as:

$$\rho = \hat{c} + \beta_1(\pi^e - \hat{\pi}) - \beta_2 y + \beta_3(y - a). \tag{17}$$

As was the case for m in M2, the macroprudential instrument ρ now depends on emissions, $(y - a)$. By plugging (8) and (17) back into the definitions of inflation and credit in S3, we can further verify that their expected levels are anchored to the central bank's targets of $\hat{\pi}$ and $\hat{c}$, respectively. After expectations are accounted for, the realised levels will also be on target.

The representative firm then sets output and abatement to maximise (6) subject to (1), (7), (8), (17), and the expected levels of inflation and credit. This results in the same optimal level of output as in (14) and the one of abatement as:

$$a = \frac{1 - \delta_3(1 - \vartheta)(1 + \alpha_2 + \beta_2)}{\delta_1} - \omega_1 \frac{\delta_3(1 - \vartheta)(1 + \beta_3)}{\delta_2}. \tag{18}$$

Finally, plugging (14) and (18) back into (1) yields:

$$e = \omega_1 \frac{\delta_3(1 - \vartheta)(1 + \beta_3)}{\delta_2}. \tag{19}$$

As was the case for (16), the relation between this level of emissions and the one from M1 depends on ϑ and the policy–specific independence parameter, now β_3. As before, we can distinguish three cases. For $\vartheta = 1$, emissions will be null and lower than in M1. For $\vartheta = 0$, emissions will be higher than in M1. For $0 < \vartheta < 1$, emissions will be lower than in M1 for sufficiently large ϑ and sufficiently small β_3. Henceforth, we refer to this model as M3.

- o *Proposition 3–a: central bank's targets.* Assume that the central bank accounts for climate risks as per S3, while the government levies a carbon tax. Then, expectations and the realised values of inflation and credit are anchored to the central bank's targets.
- o *Proof 3–a.* By plugging (8) and (17) back into the definitions of inflation and credit in S3, taking expectations and then accounting for them in the definitions of the target variables yields $\pi = \pi^e = \hat{\pi}$ and $c = c^e = \hat{c}$, respectively.
- o *Proposition 3–b: emissions.* Assume that the central bank accounts for climate risks as per S3, while the government levies a carbon tax. Then, resulting emissions will not necessarily be lower than if the government acted alone as long as $\vartheta < 1$.
- o *Proof 3–b.* It is enough to compare (19) and (12), knowing that the parameter β_3 is positive.

5.3 Climate Risks, Carbon Tax, Monetary and Macroprudential Policies

In the last case, we envision the deployment of all three instruments considered in this paper. The government levies its carbon tax, while the central bank considers all climate constraints that may be applied. This would correspond to a central bank setting encompassing, for instance, both an asset–purchase programme and the level of macroprudential regulation based on the state of the climate, among other factors.

In terms of the framework analysed here, the preferences of the central bank are still represented by the loss function in (5), now considering inflation and credit as in S4. The government still targets social welfare as in (4) and the representative firm's profits are given by (6).The parameter ϑ is not necessarily null.

The government maximises (4) and sets t as in (7). The central bank minimises (5) subject to the economy constraints in S4, setting monetary and macroprudential accommodation as in (13) and (17), respectively. The responses in terms of both instruments depend on emissions. Again, plugging these values back into the definitions of inflation and credit in S4, and taking expectations, yields $\pi^e = \hat{\pi}$ and $c^e = \hat{c}$. This implies that $\pi = \hat{\pi}$ and $c = \hat{c}$. Then, the representative firm maximises (6) subject to (1), (7), (13), (17), and the expected levels of inflation and credit. It sets production to (14) and abatement to:

$$a = \frac{1 - \delta_3(1-\vartheta)(1+\alpha_2+\beta_2)}{\delta_1} - \omega_1 \frac{\delta_3(1-\vartheta)(1+\alpha_3+\beta_3)}{\delta_2}. \tag{20}$$

Emissions are therefore given by:

$$e = \omega_1 \frac{\delta_3(1-\vartheta)(1+\alpha_3+\beta_3)}{\delta_2}. \tag{21}$$

As climate risks are now accounted for in both monetary and macroprudential policies, emissions depend on the two independence parameters α_3 and β_3 in addition to ϑ. The three–case scenario from M2 and M3 still applies. For $\vartheta = 1$, emissions will be null and lower than in M1. For $\vartheta = 0$, emissions will be higher than in M1. For $0 < \vartheta < 1$, emissions will be lower than in M1 for sufficiently large ϑ and sufficiently small α_3 and β_3. Furthermore, for a given $\vartheta < 1$, (21) will be larger than (16) and (19). Henceforth, we refer to this model as M4.

- *Proposition 4–a: central bank's targets.* Assume that the central bank accounts for climate risks as per S4, while the government levies a carbon tax. Then expectations and the realised values of inflation and credit are anchored to the central bank's targets.
- *Proof 4–a.* By plugging (13) and (17) back into the definitions of inflation and credit in S4, taking expectations and then accounting for them in the definitions of the target variables yields $\pi = \pi^e = \hat{\pi}$ and $c = c^e = \hat{c}$, respectively.
- *Proposition 4–b: emissions.* Assume that the central bank accounts for climate risks as per S4, while the government levies a carbon tax. Then, as long as $\vartheta < 1$, resulting

emissions will not necessarily be lower than if the government acted alone but higher than if S2 or S3 applied.

- *Proof 4–b*. It is enough to compare (12), (16), (19) and (21), knowing that α_3 and β_3 are positive.

6. Discussion

Our results show that expected inflation and credit are anchored to the central bank's targets in all cases, even though the instruments that are set under climate constraints depend on emissions. Therefore, concerns about the capability of central banks to achieve their core objectives and simultaneously account for climate risks do not seem justified.

Nevertheless, we highlight two caveats. First, in each case, the central bank has perfect information about the determinants of inflation and credit. Second, it sets its instruments based on these definitions. In other words, as it is independent in setting its instruments after the "constitutional" stage, it is not subject to external pressures – politicians and/or private lobbies – that could force it to pursue a biased level of the target variables.

Indeed, even if the central bank accounts for climate risks as a form of delegation by the government, such delegation is only made possible by the sensibility of the central bank to government's climate preferences. This is summarised by the "independence" parameters α_3 and β_3, which refer to the institutional features that the legislators set in the "constitutional" moment and that the incumbent government cannot directly influence.

Potential extensions of this setting may consider interdependence. Nevertheless, as long as the delegation process is effective and the government's objectives remain in line with those of the central bank, this case would reasonably lead to results similar in meaning but greater in size, as the effect of an active government's influence would add to the effect stemming from the "institutional" parameters.[7]

With regards to emissions, our results indicate that central banks' inclusion of climate risks in their policymaking would not necessarily be beneficial in the fight against climate change. Their potential efficacy crucially depends on the degree of independence from government's climate preferences set in the "constitutional" stage and on their ability to make their "green" easing, either monetary and/or regulatory, dependent on the realised level of abatement and emissions. Otherwise, firms would simply devote these resources to increasing profits.

[7] A more interesting case would be the introduction of an interest group with conflicting preferences. This could push the central bank to deviate from the delegated targets (Chortareas and Miller, 2003, 2004), mimicking a "grabbing–hand" framework.

More specifically, low degrees of independence (large α_3 and/or β_3) coupled with a low ability to bind the ex–post behaviour of firms (low ϑ) would result in a higher level of emissions than if the government acted alone. Furthermore, if the central bank is completely unable to monitor the use of its instruments ($\vartheta = 0$), this would be the case regardless of its independence status. This is evident in propositions 2–b to 4–b, and can be seen by comparing model M1 to models M2, M3 and M4.

The only case in which the central bank's interventions would undoubtedly be beneficial is the one in which it could ensure the full channelling of its resources to the reduction of abatement costs ($\vartheta = 1$). However, this is unlikely to hold in reality, as central banks' "green" easing could affect firms' profits in two ways: indirectly, through the financial sector, or directly, through special programs like the ECB's CSPP. Central banks only have the mandate (and, probably, the capability) to monitor financial institutions. In the first case, then, the central bank could monitor the intermediary but not the final recipient. In the second case, monitoring necessities would probably fall beyond the central banks' authority. We cannot, for instance, envision central banks monitoring the emissions of non–financial corporations.

7. Conclusion

The extant literature on potential central–bank interventions in climate policy mostly focuses on empirical or descriptive evaluations of the tools central banks could deploy to support governments. As such, it implies that the two policymakers could cooperate optimally. Nevertheless, questions remain about the scope of central banks' mandates as well as the negative effects that climate responsibilities may entail for their independence and the achievement of their targets, suggesting that cooperation around this matter may not necessarily be the best way forward. This has translated into a cautious attitude among central banks towards taking concrete actions in climate policy.

This paper proposes a principal–agent framework for analysing whether central banks' interventions in climate policy would be beneficial, and how such interventions would affect their ability to pursue price and financial stability. In modelling central banks' actions through monetary, macroprudential, or both instruments, our benchmark case is one in which the government implements a climate policy on its own in the form of a carbon tax. By comparing the resulting levels of emissions produced by the representative firm as well as expected inflation and credit, we deduce which policy framework would be best suited for keeping emissions under control while not jeopardising the attainment of the central bank's monetary and macroprudential objectives.

Our results suggest that, on the one hand, central banks would still be able to achieve their core price and financial stability objectives when accounting for climate risks. On the other hand, their ability to induce a reduction in emissions is only verified for sufficiently independent central banks with adequate monitoring capacity. This latter point is the most controversial, as central banks are unelected institutions that lack the authority and, most likely, the capability to directly monitor productive and polluting sectors. In the absence of these two conditions, central banks' interventions in climate policy may actually *increase* emissions, thereby working against governments' actions. Only clearly independent central banks with at least a moderate supervisory authority should consider intervening in climate policy.

References

Aghion, P., Alesina, A., Trebbi, F. (2004). "Endogenous political institutions", *Quarterly Journal of Economics*, 119(2), 565–611.

Aghion, P., Bolton, P. (2003). "Incomplete social contracts", *Journal of the European Economic Association*, 1(1), 38–67.

Alesina, A., Tabellini, G. (2007). "Bureaucrat or politician? Part I: A single policy task", *American Economic Review*, 97(1), 169–179.

Allen, T., Dees, S., Boissinot, J., Caceido Graciano, C. M., Chouard, V., Clerc, L., De Gaye, A., Devulder, A., Diot, S., Lisack, N., Pegoraro, F., Rabaté, M., Svartzman, R., Vernet, L. (2020). "Climate–related scenarios for financial stability assessment: An application to France", *Banque de France Working Paper No. WP774*.

Baldauf, M., Garlappi, L., Yannelis, C. (2020). "Does climate change affect real estate prices? Only if you believe in it", *The Review of Financial Studies*, 33(3), 1256–1295.

Balke, N. S. (2000). "Credit and economic activity: Credit regimes and nonlinear propagation of shocks", *Review of Economics and Statistics*, 82(2), 344–349.

Bansal, R., Kiku, D., Ochoa, M. (2016). "Price of long–run temperature shifts in capital markets", *NBER Working Paper 22529*.

Bartholomew, L., Diggle, P. (2021). "Climate change and central banks: The case for violating neutrality", *Vox Article*.

Battaglini, M., Coate, S. (2007). "Inefficiency in legislative policymaking: A dynamic analysis", *American Economic Review*, 97, 118–149.

Batten, S., Sowerbutts, R., Tanaka, M. (2016). "Let's talk about weather: The impact of climate change on central banks", *Staff Working Paper No. 603*, Bank of England.

Battiston, S., Mandel, A., Monasterolo, I., Schütze, F., Visentin, G. (2017). "A climate stress–test of the financial system", *Nature Climate Change*, 7, 283–288.

Bernstein, A., Gustafson, M. T., Lewis, R. (2019). "Disaster on the horizon: The price effect of sea level rise", *Journal of Financial Economics*, 134(2), 253–272.

Besley, T., Case, A. (2003). "Political institutions and policy choices: Evidence from the United States", *Journal of Economic Literature*, 41(1), 7–73.

BIS (2021). "Climate–related financial risks: Measurement methodologies", *Basel Committee on Baking Supervision*.

Blanchard, O., Tirole, J. (2021). "Major future economic challenges", *France Stratégie*.

Bolton, P., Despres, M., Pereira da Silva, L. A., Samama, F., Svartzman, R. (2020). "The Green Swan: Central banking and financial stability in the age of climate change", *Report*, Banque de France and Bank of International Settlements.

Borio, C. (2012). "The financial cycle and macroeconomics: What have we learnt?", *BIS Working Paper No. 395*.

Bremus, F., Schütze, F., Zaklan, A. (2021). "The impact of ECB corporate sector purchases on European green bonds", *DIW Discussion Paper No. 1938*.

Brown, D. J., Earle, J. S., Gehlbach, S. (2009). "Helping hand or grabbing hand? State bureaucracy and privatization effectiveness", *American Political Science Review*, 103(2), 264–283.

Buchanan, J., (1962). "Predictability: The criterion of monetary constitutions", in Yeager, L., (ed.), *In search of a monetary constitution*. Cambridge Massachusetts, Harvard University Press, 155–183.

Calza, A., Sousa, J. (2005). "Output and inflation responses to credit shocks: Are there threshold effects in the Euro Area?", *ECB Working Paper No. 481*.

Campiglio, E., Dafermos, Y., Monnin, P., Ryan–Collins, J., Schotten, G., Tanaka, M. (2018). "Climate change challenges for central banks and financial regulators", *Nature Climate Change*, 8, 462–468.

Campiglio, E. (2016). "Beyond carbon pricing: The role of banking and monetary policy in financing the transition to a low–carbon economy", *Ecological Economics*, 121, 220–230.

Carney, M. (2015). "Breaking the tragedy of the horizon – climate change and financial stability", *Speech*, Lloyd's of London.

Caruana, J., Shim, I. (2016). "La politique macroprudentielle: Un ouvrage en cours pour les banques centrales", *Revue d'Économie Financière*, 1(121), 111–130.

Chenet, H., Ryan–Collins, J., Van Lerven, F. (2021). "Finance, climate change and radical uncertainty: Towards a precautionary approach to financial policy", *Ecological Economics*, 183, 1–14.

Chortareas, E. G., Miller, S. M. (2003). "Monetary policy delegation, contract costs and contract targets", *Bulletin of Economic Research*, 55(1), 101–112.

Chortareas, E. G., Miller, S. M. (2004). "Optimal central banker contracts and common agency", *Public Choice*, 121(1), 131–155.

Claessens, S., Kose, M., Terrones, M. E. (2012). "How do business and financial cycles interact?", *Journal of International Economics*, 87(1), 178–190.

Cleary, P., Harding, W., McDaniels, J., Svoronos, J. P., Yong, J. (2019). "Turning up the heat – climate risk assessment in the insurance sector", *FSI Insight No. 20*.

Dafermos, Y., Nikolaidi, M., Galanis, G. (2018). "Climate change, financial stability and monetary policy", *Ecological Economics*, 152, 219–234.

Dafermos, Y., Nikolaidi, M. (2021). "How can green differentiated capital requirements affect climate risks?", *FMM Working Paper No. 63–2021*.

Dal Bó, E. (2006). "Committees with supermajority voting yield commitment with flexibility", *Journal of Public Economics*, 90(4–5), 573–599.

Drazen, A. (2002). "Central bank independence, democracy, and dollarization", *Journal of Applied Economics*, 5(1), 1–17.

De Grauwe, P. (2019). "Green money without inflation", *Vierteljahrshefte zur Wirtschaftsforschung*, 88(2), 51–54.

Dietz, S., Bowen, A., Dixon, C., Gradwell, P. (2016). "Climate value at risk of global financial assets", *Nature Climate Change*, 6, 676–679.

Dikau, S., Robins, N., Täger, M. (2019). "Building a sustainable financial system: The state of practice and future priorities", *Financial Stability Review*, 37, Bank of Spain.

Dikau, S., Volz, U. (2019). "Central banking, climate change and green finance", *Handbook of Green Finance*, 81–102.

Dikau, S., Robins, N., Volz, U. (2020). "A toolbox of sustainable crisis response measures for central banks and supervisors", *INSPIRE Working Paper*, London School of Economics and SOAS University of London.

D'Orazio, P., Popoyan, L. (2019). "Fostering green investment and tackling climate–related financial risks: Which role for macroprudential policies?", *Ecological Economics*, 160, 25–37.

D'Orazio, P., Popoyan, L. (2020). "Taking up the climate change challenge: A new perspective on central banking", *LEM Paper No. 2020/19*, Sant'Anna School of Advanced Studies.

Downs, A. (1957). "An economic theory of political action in a democracy", *Journal of Political Economy*, 65(2), 135–150.

Drehmann, M., Borio, C., Tsatsaronis, K. (2012). "Characterising the financial cycle: Don't lose sight of the medium term!", *BIS Working Paper No. 380*.

Friedman, E., Johnson, S., Kaufmann, D., Zoido–Lobaton, P. (2000). "Dodging the grabbing hand: The determinants of unofficial activity in 69 Countries", *Journal of Public Economics*, 76(3), 459–493.

Frye, T., Shleifer, A. (1996). "*The invisible hand and the grabbing hand*", NBER Working Paper Series, n. 5856.

Giglio, S., Kelly, B., Stroebel, J. (2021). "Climate finance", *Annual Review of Financial Economics*, 13, 15–36.

Gourinchas, P. O., Obstfeld, M. (2011). "Stories of the twentieth century for the twenty–first", *NBER Working Paper No. w17252*.

Hamel, L., Lopes, L., Muñana, C., Brodie, M. (2019). "The Kaiser Family Foundation Post Climate Change Survey", *The Kaiser Family Foundation*.

Hansen, L. P. (2022). "Central banking challenges posed by uncertain climate change and natural disasters", *Journal of Monetary Economics*, 125, 1–15.

Hartwig, B., Lieberknecht, P. (2020). "Monetary policy, firm exit and productivity", *Deutsche Bundesbank Discussion Paper No. 61/2020*.

Hefeker, C., Zimmer, B. (2011). "The optimal choice of central bank independence and conservatism under uncertainty", *Journal of Macroeconomics*, 33(4), 595–606.

Herrendorf, B., Lockwood, B. (1997). "Rogoff's "conservative" central banker restored", *Journal of Money, Credit and Banking*, 29(4), 476–495.

Hong, H., Weikai, Li F., Xu, J. (2019). "Climate risks and market efficiency", *Journal of Econometrics*, 208, 265–281.

Hsiang, S., Kopp, R., Jina, A., Rising, J., Delgado, M., Mohan, S., Rasmussen, D. J., Muir–Wood, R., Wilson, P., Oppenheimer, M., Larsen, K., Houser, T. (2017). "Estimating economic damage from climate change in the United States", *Science*. 356(6345), 1362–1369.

Hughes Hallet, A., Weymark, D. N. (2005). "Independence before conservatism: Transparency, politics and central bank design", *German Economic Review*, 6, 1–21.

Hughes Hallett, A., Weymark, D.N. (2007). "Fiscal leadership and central bank design", *Canadian Journal of Economics*, 40(2), 607–627.

IEA (2021). "Global energy review 2021".

Jordà, Ò., Schularick, M., Taylor, A. M. (2010). "Financial crises, credit booms and external imbalances: 140 years of lessons", *IMF Economic Review*, 59(2), 340–378.

Key Jr., V. O. (1966). "The responsible electorate: Rationality in presidential voting, 1936–1960", *Harvard University Press*.

Kling, G., C Lo, Y., Murinde, V., Volz, U. (2021). "Climate vulnerability and the cost of debt", *World Development*, 137, 1–11.

Kotz, M., Wenz, L., Stechenmesser, A., Kalkuhl, M., Levermann, A. (2021). "Day to day temperature variability reduces economic growth", *Nature Climate Change*, 11(4), 319–325.

Krogstrup, S., Oman, W. (2019). "Macroeconomic and financial policies for climate change mitigation: A review of the literature", *IMF Working Paper No. 19/185*.

Kydland F., Prescott E. (1977). "Rules rather than discretion: The inconsistency of optimal plans", *Journal of Political Economy*, 85(3), 473–492.

Lewis–Beck, M. S. (1988). "Economics and the American voter: Past, present, future", *Political Behavior*, 10, 5–21.

Masciandaro, D. (2022). "Politicians, central banks and macroprudential supervision", in R. Holzmann and F. Restoy (eds), Central banks and *supervisory architecture in Europe. Lessons from crises in the 21st century*, Edward Elgar, forthcoming.

Masciandaro, D. (2021). "Independence, conservatism, and beyond: Monetary policy, central bank governance and central bank preferences (1981–2021)", *Journal of International Money and Finance*.

Masciandaro, D., Quintyn, M. (2008). "Helping hand or grabbing hand? Politicians, supervisory Regime, financial structure and market View", *North American Journal of Economics and Finance*, 19(2), pp. 153–174.

Masciandaro, D., Volpicella, A. (2016). "Macro prudential governance and central banks: facts and drivers", *Journal of International Money and Finance*, 61, 101–119.

Masciandaro, D., Tarsia, R. (2021). "Society, politicians, climate change and central banks: An index of green activism", *Baffi CAREFIN Centre Research Paper No. 2021–167*.

McConnell, A., Yanovski, B., Lessman, K. (2022). "Central bank collateral as a green monetary policy instrument", *Climate Policy*, 22(3), 339–355.

McGlade, C., Ekins, P. (2015). "The geographical distribution of fossil fuels unused when limiting global warming to 2°C", *Nature*, 517, 187–190.

McKibbin, W. J., Morris, A. C., Panton, A., Wilcoxen, P. (2017). "Climate change and monetary policy: Dealing with disruption", *CAMA Working Paper77/2017*.

McKibbin, W. J., Morris, A. C., Panton, A., Wilcoxen, P. (2020). "Climate change and monetary policy: issues for policy design and modelling", *Oxford Review of Economic Policy*, 36(3), 579–603.

Miller, D.S. (2019). "Optimal structure of fiscal and monetary authorities", *Journal of Money, Credit and Banking*, 51(2–3), 289–312.

Monasterolo, I., Battiston, S., Janetos, A. C., Zheng, Z. (2017). "Vulnerable yet relevant: The two dimensions of climate–related financial disclosure", *Climate Change*, 145, 495–507.

Monnin, P. (2018a). "Central banks and the transition to a low–carbon economy", *Council on Economic Policies Discussion Note 2018/1*.

Monnin, P. (2018b). "Integrating climate risks into credit risk assessment – Current methodologies and the case of central banks corporate bond purchases", *Council on Economic Policies Discussion Note 2018/4*.

Nordhaus, W. (2017). "Evolution of assessments of the economics of global warming: Changes in the DICE model, 1992–2017", *NBER w23319*.

OECD (2021). "Effective carbon rates 2021: Pricing carbon emissions through taxes and emissions trading".

Pagliari, M. S. (2021). "LSIs' exposures to climate change related risks: An approach to assess physical risks", *ECB Working Paper No. 2517*.

Persson, T., Tabellini, G. (2004). "Constitution and economic policy", *Journal of Economic Perspectives*, 18(1), 75–98.

Pigou, A. (1938). "*The economics of welfare*", London, Macmillan & Co.

Romer, C.D., Romer, D.H. (1997). Institutions for monetary stability, in C.D. Romer and D.H. Romer (eds.), "*Reducing inflation: Motivation and strategy*", NBER, Chicago, Chicago University Press.

Romer, T., Rosenthal, H. (1983). "A constitution for solving asymmetric externality games", *American Journal of Political Science*, 27, 1–26.

Schauberger, B., Archontoulis, S., Arneth, A., Balkovic, J., Ciais, P., Deryng, D., Elliott, J., Folberth, C., Khabarov, N., Müller, C., Pugh, T. A. M., Rolinski, S., Schaphoff, S., Schmid, E., Wang, X., Schlenker, W., Frieler, K. (2017). "Consistent negative response of US crops to high temperatures in observations and crop models", *Nature Communications*. 8(1), 1–9.

Schnabel, I. (2021). "From green neglect to green dominance?", *Speech*, European Central Bank.

Schoenmaker, D. (2021). "Greening monetary policy", *Climate Policy*, 21(4), 581–592.

Schularick, M., Taylor, A. M. (2009). "Credit booms gone bust: Monetary policy, leverage cycles and financial crises, 1870–2008", *NBER Working Paper No. w11512*.

Semieniuk, G., Campiglio, E., Mercure, J. F., Volz, U., Edwards, N. R. (2020). "Low–carbon transition risks for finance", *Wires Climate Change*, 12(1), 1–24.

Shleifer, A., Vishny, R. (1998). "*The grabbing hand*", Cambridge, Harvard University Press.

Smets, F. (2014). "Financial stability and monetary policy: How closely interlinked?", *International Journal of Central Banking*, 10(2), 263–300.

Stern, N. (2007). "Stern review: The economics of climate change", *Cambridge University Press*.

Stiglitz, J. E., Stern, N. (2017). "Report of the High–Level Commission on carbon pricing", *CPLC*, World Bank.

Tirole, J. (2021). "The political economy of climate change", *Speech*, UBS Center.

Tol, R. S. J. (2009). "The economic effects of climate change", *Journal of Economic Perspectives*, 23(2), 29–51.

Tvinnereim, E., Mehling, M. (2018). "Carbon pricing and deep decarbonisation", *Energy Policy*, 121, 185–189.

Ueda, K., Valencia, F. (2012). "Central bank independence and macroprudential regulation", *IMF Working Paper No. 12/101*.

UNCSD (2010). "Questionnaire for the Member States on experiences, success factors, risks and challenges with regard to objective and themes of UN Conference on Sustainable Development".

Volz, U., Beirne, J., Preudhomme, N. A., Fenton, A., Mazzacurati, E., Renzhi, N., Stampe, J. (2020). "Climate change and sovereign risk", *Working Paper*, SOAS University of London.

Walsh, C. E. (1995). "Optimal contracts for central bankers", *The American Economic Review*. 85(1), 150–167.