The impact of climate change on monetary policy

Andreas Breitenfellner, Wolfgang Pointner¹ Refereed by: Francesco Drudi, ECB

The challenges of climate change will affect all areas of economic policy, including monetary policy. Rising temperatures, extreme weather events and the political, social and technological responses to climate change may have significant effects on prices, output, productivity or credit markets. Central banks need to reflect these effects in their assessment of risks to price stability, their projections of economic developments and their analyses of financial markets. The mandate of the Eurosystem defines price stability as the primary objective of monetary policy, but it also mentions the support of general EU economic policies, including those aiming at environmental protection. In this contribution, we describe the implications of climate change for price stability, for the future conduct of monetary policy and for central banks' balance sheets. While monetary policy may play a role among the possible economic policy reactions to climate change, we contrast this role with more effective policy responses. Monetary policy has several instruments at its disposal: changes in the collateral framework, asset purchases and disclosure of climate-related information. Monetary policy implementation is subject to operational constraints, e.g. the principle of market neutrality, which need, however, to be balanced against central bank objectives and must take market inefficiencies into account. Our considerations square well with the ECB's recently presented action plan to include climate change considerations in its monetary policy strategy.

JEL classification: E52, Q54

Keywords: Climate change, carbon transition, monetary policy, central banks, Eurosystem

Climate change is one of the fundamental challenges to the economy that can affect prices, aggregate demand, and the balance sheet of both financial intermediaries and central banks. Many central bankers have identified climate change as a source of risks to financial stability and price stability. Already in 2015, Mark Carney, then Governor of the Bank of England, addressed the "tragedy of the horizon" in a seminal speech, referring to the problems financial markets face in correctly pricing climate-related risks. Since she became President of the European Central Bank (ECB), Christine Lagarde has stressed the importance of climate change for economic policymakers. Her fellow ECB Executive Board member Isabel Schnabel (2021a) explained what central banks could do to contribute to the global fight against climate change, and Frank Elderson (2021) emphasized the effects of climate change on credit markets and bank supervisors. Other members of the Governing Council of the ECB^2 have also contributed to the debate on whether central banks should take climate change into account and, if so, on how best to incorporate climate-related risks or climate change-mitigating efforts into their policy framework. As a result of the ECB's recent monetary policy strategy review, the Governing Council emphasized its commitment to ensuring that the Euro-

¹ Oesterreichische Nationalbank, Foreign Research Division, andreas.breitenfellner@oenb.at; Economic Analysis Division, wolfgang.pointner@oenb.at. Opinions expressed by the authors of studies do not necessarily reflect the official viewpoint of the OeNB or the Eurosystem. The authors would like to thank Peter Backé for valuable comments.

² See, for example, Holzmann (2021), Villeroy de Galhau (2021), Visco (2021) or Weidmann (2021).

system fully takes into account, in line with the EU's climate goals and objectives, the implications of climate change and carbon transition for monetary policy and central banking.

This paper presents the possible consequences of climate change for monetary policy in general and for the euro area in particular as well as its effects on the Eurosystem's monetary policy objectives and instruments and its future policy space. We will only deal with financial stability aspects of climate change if they affect monetary policy transmission; climate-related financial stability risks have been addressed in previous OeNB publications (e.g. Pointner and Ritzberger-Grünwald, 2019). However, we will try to assess the scope for action central banks may take in coordination with other policymakers, who bear the principal responsibility for tackling climate change and its consequences. This question is of particular importance for the Eurosystem, which has a clear mandate to maintain price stability in the euro area, but is also obliged to support the general economic policies in the European Union without prejudice to this primary objective. In this respect, the Governing Council of the ECB recently announced an action plan, including a road map, to further incorporate climate change considerations into its policy framework (ECB, 2021).

Some effects of climate change might even reduce central banks' policy space as climate change impacts the natural rate of interest by reducing productivity and driving up savings, although countervailing effects that are related to technological progress spurred by transition polices must be taken into account. Rising uncertainty about future economic outcomes makes it more difficult for monetary policymakers to identify temporary and structural changes in the economy.

This article is structured as follows: Section 1 explains why climate change and its economic consequences are a concern for central banks and how the Eurosystem's mandate addresses environmental issues. In section 2, we discuss economic policy options available to tackle climate change and identify the appropriate role monetary policy might play in this context. Section 3 briefly addresses the risk management of climate-related financial risks by central banks and financial intermediaries. Section 4 presents some monetary policy instruments that could be used to tackle climate change and section 5 concludes.

1 The relevance of climate change for central banks

Climate change can affect price stability, the transmission mechanism of monetary policy and the balance sheet of central banks. A comprehensive overview of climate-related risks to price stability is given by Batten et al. (2020) or by the Network for Greening the Financial System (NGFS) (2020). Most obviously, rising global temperatures and more frequent extreme weather events will probably impact the production structure of economies and therefore have effects on prices. Climate change will affect agriculture, as crops and livestock are sensitive to temperatures and weather conditions. Agricultural prices have already been notoriously volatile in the past and have therefore also been of concern in inflation forecasts. If the physical risks of climate change, i.e. the risks of direct damage to physical assets (e.g. buildings and roads), materialize, they not only reduce output in a particular period, as Dietz and Stern (2015) emphasize, but can also lower production capacity in the economy at least temporarily, if e.g. firms must be rebuilt, and in the long run, if corporations must channel their available funds to

repair investment instead of promoting productivity-enhancing R&D. Heat waves can diminish labor productivity via negative health effects, too. Storms that destroy railroads or droughts that reduce the water levels of rivers have a negative effect on trade. While negative effects on productivity are expected to dampen the longterm equilibrium interest rate, increasing capital demand for green investments might counterbalance the downward pressure on interest rates.

The transition to a climate-neutral economy will most likely affect the price of energy and transport and have indirect effects on the prices of other goods. Central banks with an inflation target will closely monitor developments like the introduction of a carbon tax and integrate them into their analyses of inflation dynamics. Climate change and the side effects of climate policies could also disrupt financial markets and thus disturb the transmission channel of monetary policy, which relies on functioning bond markets and banks' ability to pass on monetary policy decisions to the real economy.

Finally, central banks hold assets for different purposes (e.g. reserve management, collateral, nonstandard monetary policy measures) and these assets are prone to revaluation due to climate change or climate policies; therefore, central banks should include an assessment of climate change risks in their own risk management.

The consequences of climate change might alter the structural parameters in central banks' economic models. Most central banks rely on macroeconomic models which incorporate the long-term relations between demand, supply and prices. Climate change and the reactions of policymakers and markets to global warming can alter the supply side of an economy, and shifts in consumers' preferences can cause secular changes to the deep parameters, such as intertemporal preferences or risk aversion, on which these macroeconomic models are built (as can other secular trends like demographic changes). Currently, not many central banks integrate climate change in their economic models. Models used by climate economists, such as integrated assessment models (IAMs), often lack a representation of monetary transmissions channels, whereas macroeconomic models do not incorporate economic damage resulting from climate change so far.

The radical uncertainty triggered by climate change might also alter the economic modeling framework. Traditionally, macroeconomic models employed by central banks assume a maximization rule applied by social planners, firms or households that strive to maximize the expected value of their future output, profits or utility while being subject to certain constraints. Krogstrup and Oman (2019) emphasize that climate change rises uncertainty about the expected outcomes of economic activities to new levels where the probabilities for catastrophic events become nonnegligible. Such catastrophic and often irreversible events include the thawing of permafrost, which could release huge amounts of greenhouse gases (GHGs) or cause ocean streams to change course. Bearing this in mind, policymakers dealing with climate change should adopt a risk management approach inspired by value-at-risk (VaR) models, which means maximizing future outcomes under the constraint that the risk of catastrophic and irreversible climate change remains below an agreed percentile. Broeders and Schlooz (2021) discuss the effects of climate change as a driver of fundamental uncertainty on central bank policy and propose to apply the precautionary principle to cope with potentially irreversible outcomes that cannot be estimated ex ante with meaningful

precision. The precautionary principle states that under radical uncertainty, additional mitigating policies are justified to lower the likelihood of, and the damage resulting from negative shocks to central banks' balance sheets and their policy objectives. Concluding their analysis, Broeders and Schlooz (2021) present practical examples in the field of central bank risk assessment, risk mitigation and the disclosure of climate-related information.

1.1 Conducting monetary policy in view of climate change

Not only will monetary policymakers take climate change into account when assessing risks to price stability, but also when choosing the appropriate monetary policy instruments. Both the assessment of risks and the choice of policies must reflect economic developments in the euro area, leaving out idiosyncratic shocks at the national or regional level. Given the size of the euro area, the economic effects of climate change may differ significantly from region to region. The European Environment Agency (2017) presented climate change impacts for the main biogeographical regions in Europe, pointing out that while in the Mediterranean region (Greece, Italy, Portugal and Spain) rising temperatures might lead to droughts and wildfires, the Atlantic region (Ireland, western France, Belgium, the Netherlands and northern Germany) might suffer from heavy precipitation and an increasing risk of coastal and river flooding; some regions might even benefit from higher average temperatures as heating costs would go down and harvests would improve. The regional impact of climate change could boost or reduce economic outcomes, which means that economic heterogeneity might possibly make the conduct of monetary policy more complicated. The diversity of the economic effects of climate change and the concomitant risks to price stability will challenge monetary policy in large countries like the USA or China, too. But these countries have established functioning risk-sharing mechanisms (e.g. fiscal federalism) which allow them to better absorb idiosyncratic regional shocks.

The effects of climate change could also reduce central banks' future room for policy maneuver. The impact of global warming on economic output is not limited to acute damage by storms, floods or droughts. Climate change may also reduce productivity growth. Economides and Xepapadeas (2018) describe climate change as a new propagation mechanism for total factor productivity (TFP) shocks, with GHG emissions lowering productivity in the long run given repeated climaterelated damage. In their model, carbon taxes could dampen growth in the short run, but in the long run output would be higher as negative TFP shocks from climate change would be absent.

The increasing uncertainty about the effects of climate change could increase precautionary savings and thus lower effective demand and drive up risk premia in financial markets. The stranding (i.e. devaluation) of assets due to climate change or climate policies might trigger financial losses for banks and hamper monetary policy transmission. Dafermos et al. (2018) model the effects of unmitigated climate change over a period of 100 years, including not only the stronger depreciation of capital and lower growth rates due to climate-related damage but also the rebalancing of households' portfolios from corporate bonds toward deposits and governments securities that is triggered by higher economic uncertainty. According to their simulations, this climate-induced asset price deflation would cause corporate bond yields to rise strongly after 2080³. Bylund and Jonnson (2020) show that such an increase in uncertainty has a dampening impact on the equilibrium interest rate because it strengthens precautionary saving. If climate change depresses the interest rate level, negative shocks to the economy (some of which may be triggered by climate change itself) bear a higher risk of bringing policy rates close to the effective lower bound. Under these circumstances, it seems likely that monetary policy must rely on nonstandard instruments more often. Unfortunately, such effects would be reinforced if fiscal policy was also constrained in its capacity to stabilize the economy due to high debt levels, which in turn might also be caused by additional public expenditure for climate change adaptation or mitigation measures.

Climate change can also affect the transmission of monetary policy to the real economy. When central bankers change their monetary policy stance, they rely on financial intermediaries to pass on their policy impulse to firms and households. Since banks are a major source of funding in the euro area, the credit channel is of utmost importance for monetary policy transmission. Banks are exposed to climate-related risks via their assets. The impact of climate change may destabilize credit markets by driving up default probabilities, reducing liquidity or causing reputational damage. Damage caused by climate change can erode the value of collateral and reduce borrowers' debt servicing capability, which in turn increases the probability of default and the numbers of nonperforming loans (NPLs). Climate policies like the introduction of carbon taxes may reduce debtors' revenues or depress the value of their investments, creating stranded assets.⁴ Battiston et al. (2020) provide an assessment of the exposure of Austrian banks to transition risks based on the classification of climate policy-relevant sectors, but as the European Systemic Risk Board (ESRB, 2021) concludes, the quality and comparability of data is still wanting, especially with respect to the disclosure of firm-level data or forward-looking scenario analyses.

1.2 Strategic implications of climate change for central banks

Climate change can affect both the demand and the supply side of an economy. Positive demand shocks accelerate both inflation and GDP growth at the same time; hence an inflation-targeting central bank would react by raising interest rates to curb inflationary pressures and prevent an overheating of the economy. Supply shocks trigger price increases and dampen GDP growth; therefore, a restrictive monetary policy response which aims to maintain price stability would lead to a widening of the output gap. The Eurosystem's objective is to keep prices stable in the medium term, inter alia, because a medium-term focus allows monetary policy to react flexibly to different shocks and it takes into account the effective lags with which monetary policy decisions affect prices.

A climate-related demand shock could happen if consumer preferences changed, e.g. if consumers seriously reduced their demand for fossil-fueled vehicles. In such a case, workers in the automotive industry would become unemployed and

³ In contrast to the financial effects of transition policies like the introduction of carbon taxes, the effects of unmitigated climate change would occur later but are assumed to be irreversible.

⁴ Combined with an initial green investment push, steadily rising carbon prices could shift the economy to a higher equilibrium by reducing uncertainty. Additional positive economic effects of carbon pricing come, for instance, from increased energy efficiency (see e.g. IMF, 2020).

domestic demand would decline, as would consumer prices. An accommodative monetary policy reaction would stimulate growth and employment and furthermore facilitate investment in the necessary structural changes in the manufacturing sector.

The introduction of a carbon tax would rather act as a negative supply shock, depending on its pass-through and the use of revenues (see section 2.3). Energy prices would go up immediately and follow the pass-through to other production sectors, driving up inflation more broadly. Simultaneously, output would be reduced. Output losses are difficult to estimate in this scenario, however, as they crucially depend on the redistribution of carbon tax revenues. Euro area monetary policy would – given its medium-term orientation, which was only recently confirmed by the Eurosystem – be concerned by these price increases only if there were second-round effects from carbon taxes or if a carbon tax was introduced over an extended period. Many policy proposals suggest such an extended introduction phase for carbon taxes to give firms more time to adjust to new prices. In accordance with its secondary objective, namely to support the general economic policies in the EU, the Eurosystem could decide to let singular carbon tax-induced price increases happen without changing its monetary policy stance as long as there is no indication that these price increases would fuel a broader-based acceleration of inflation over the medium term. Such a strategy would rely crucially on the Eurosystem's capability to identify the sources of price increases correctly.

In an analysis of different monetary policy strategies, McKibbin et al. (2020) run simulations of the effects of climate change on inflation and output, based on a multi-sector multi-region model. They compare pure inflation targeting with flexible inflation targeting and nominal GDP targeting strategies with respect to their effects on prices, output and carbon emissions. Whereas a purely inflationtargeting central bank would change its monetary policy if, and only if, inflation deviated from its inflation target, a flexible inflation-targeting central bank follows a Taylor rule with non-zero weight on the output gap⁵. Under nominal GDP targeting (or nominal income targeting), the central bank attempts to stabilize nominal GDP growth; this means that negative supply shocks that reduce economic output and stimulate prices at the same time would induce less vigorous monetary policy reactions than under inflation targeting. McKibbin et al. (2020) find that among the three monetary policy regimes, purely inflation targeting central banks react more strongly to the introduction of carbon taxes, causing a more substantial reduction in output while keeping inflation close to target, while flexible inflation targeting would allow for a modest temporary increase in inflation that would significantly reduce output losses, and nominal GDP-targeting results in the highest tax-induced inflation spike and the smallest output loss. But interestingly, carbon emissions would be reduced most effectively under pure inflation targeting, whereas flexible inflation targeting and nominal GDP targeting would result in a lower reduction of carbon emissions because they allow for output stabilization.

⁵ A purely inflation-targeting central bank would change its policy rate at time t it according to the rule $i_t = i_{t-1} + a(\pi^e - \pi^*)$ with π^e being the expected inflation rate and π^* the inflation target. Under flexible inflation targeting, the reaction function looks more like $i_t = i_{t-1} + a(\pi^e - \pi^*) + \beta(y^e - y^*)$ with $y^e - y^*$ denoting the output gap and $\beta > 0$.

Moving the focus from the primary objective of price stability to the secondary objective of supporting the EU's general economic policies, it is clear that policymakers other than central banks are more directly in charge of fighting climate change. Governments have more effective instruments at their disposal, e.g. environmental regulations, taxation or industrial policies (see following section). Coordinating these different policies properly will improve the outcomes. There is the political risk that the burden of climate action is shifted to central banks, which are less exposed to the electoral process, when democratically elected politicians try to avoid passing unpopular laws, e.g. laws introducing carbon taxes. Nevertheless, independent central bankers should refrain from transgressing the boundaries of their competence, as the public might see this as an unwarranted "mission creep." Villeroy de Galhau (2021) explicitly rejects such allegations, emphasizing the relevance of climate change for price stability and for the smooth implementation of monetary policy. However, monetary policy cannot compensate for delayed or insufficient policy reactions by national policymakers. Therefore, it is important to discuss transparently about who can contribute what and whose actions and policies are most effective.

1.3 Climate change and the mandate of the Eurosystem

In the Treaty on the Functioning of the European Union (TFEU), the European System of Central Banks (ESCB) is tasked with pursuing the primary objective of maintaining price stability. Article 127 TFEU specifies that "without prejudice to the objective of price stability, the ESCB shall support the general economic policies in the Union with a view to contributing to the achievement of the objectives of the Union as laid down in Article 3 of the Treaty on European Union (TEU)." We described above how climate change may affect prices and inflation and, thus, the primary objective of the ESCB. In addition, it is paramount for any central bank to protect its balance sheet from the financial risks caused by climate change. In the current interest rate environment, with policy rates close to the effective lower bound, the central bank's balance sheet has become a more relevant monetary policy instrument than before. Asset purchase programs have led to unprecedented expansions of central banks' balance sheets, and the acquired assets face different degrees of climate risks. Managing these risks cautiously and efficiently is also a form of complying with the primary objective as it contributes to maintaining the full operability of the monetary policy instruments the ESCB needs to fulfill its mandate.

According to Article 3 Treaty on European Union (TEU), the EU "shall work for the sustainable development of Europe based on balanced economic growth and price stability, a highly competitive social market economy, aiming at full employment and social progress, and a high level of protection and improvement of the quality of the environment. It shall promote scientific and technological advance." Evidently, the mandate of the ESCB proposes a clear hierarchy insofar as price stability is its primary objective. This means that, from any set of policy options, monetary policymakers should choose the option that contributes most to price stability, no matter how much this affects other objectives stated in Article 3 TEU. If two or more policy alternatives contribute equally to price stability, they can be prioritized according to their support of the secondary objectives.

However, the Treaty does not rank the objectives identified in Article 3 TEU. Prioritizing these objectives is an inherently political choice for which the ESCB has neither a democratic mandate nor the necessary competence. Such political choices are reserved for institutions that are directly accountable to the electorate, which can democratically express their approval or rejection of the choices made. It should be noted in this context that among the reasons why central banks have been granted independence is that they have one primary objective and do not engage in political deliberations that would necessitate more democratic accountability than is currently exercised. Therefore, any prioritization among the secondary objectives should closely follow the guidance provided by the political organs of the EU, i.e. the Council of the European Union and the European Parliament. It is in the interest of these political organs to express unequivocally any priorities they have agreed upon. However, the Eurosystem itself will independently decide how to support prioritized objectives and assess whether such support is feasible without prejudice to price stability.

Monetary policy is not capable of equally supporting all the objectives enumerated in Article 3 TEU. Some of them might come closer to the original field of expertise of central bankers than others. As for the "protection and improvement of the quality of the environment," central banks have recently gained expertise in analyzing the economic and financial risks of climate change because of their function as financial supervisors⁶; hence, it could be argued that this objective is closer to their practical experience than others.

The mandate obliges the Eurosystem to support the general economic policies in the EU and not to design its own policies in these areas. Before central banks can decide on how to best support these general economic policies, they must be defined and implemented. Therefore, with respect to climate change, central banks are not policymakers but policytakers. The sooner the competent authorities decide upon the appropriate policies to fight climate change, and the more detailed these policies are, the better the Eurosystem can support them within the limits of its mandate. Arguably, the EU has already outlined its priority with the European Green Deal⁷. Finally, the fight against climate change is singled out against all other objectives listed in Article 3 TEU given the irreversibility and potentially catastrophic impact of climate change. Some of the arguments listed here tend to support the view that the Eurosystem should prioritize action against climate change.

2 Economic policies to support climate change mitigation

The main objective in fighting climate change is to limit global warming to well below 2 degrees Celsius, preferably to 1.5 degrees Celsius, compared to preindustrial levels, as agreed in the Paris Agreement. The EU has announced ambitious measures to achieve this target. Most important among them is the reduction of GHG emissions, which should be halved by the year 2030 and allow the EU to

⁶ See, for example, the activities by the Central Banks and Supervisors Network for Greening the Financial System (NGFS).

⁷ Whether the European Green Deal itself, or its gradual implementation, are precise enough to give unequivocal guidance for Eurosystem monetary policy is a political issue we must leave open here. Filling the "democratic authorization gap," however, is a balancing act (Jourdan and Beckmann, 2021). If the EU institutions followed the British example in explicitly specifying the secondary mandate (HM Treasury, 2021), they might encounter a problem with central bank independence.

become carbon neutral by 2050. This carbon transition must be financed by both private and public investments.

2.1 Setting a carbon price

Markets are unable to price efficiently the effects of GHG emissions on our climate due to negative externalities and other market failures. Changing market prices by introducing a Pigouvian tax that internalizes the external costs of GHG emissions may support their required reduction in a technologically neutral and cost-effective manner as well as in accordance with the polluter pays principle. In practice, this effect could be achieved by either introducing a carbon tax or an emissions trading system. Both policies could raise the price of emissions up to a level where it covers the full social costs of its negative externality, thereby correcting market failures. While a tax determines higher prices (e.g. of oil) and allows the market to decide upon the demanded volumes, a trading scheme defines a limited volume of goods per period and allows the market to determine their prices. European energy producers and large manufacturing firms are already subject to the EU's Emissions Trading Scheme (ETS), which was introduced in 2005. The responsibility for carbon taxes rests with the national fiscal authorities; to avoid market turmoil, a harmonized introduction across the EU would be reasonable. In addition, and to avoid "carbon leakage,"8 these measures should be complemented by a carbon border adjustment mechanism, which defines charges on imports and rebates on exports that account for the carbon content of imported goods and carbon price differences. The obvious aim of these policies is to change the relative prices between different modes of production according to their emission intensity. The same effect can also be achieved by reducing subsidies for emission-intensive energy generation.

However, it should be noted that pricing externalities is not a magic bullet that solves all the economic and social challenges of climate change. As Stern and Stiglitz (2021) put it, "it is a fundamental mistake to begin the analysis of climate change under the premise that, but for the mispricing of emissions, the economy is efficient." They refer to several problems, such as moral hazard, which becomes an issue when economic agents expect that large climate-related losses might be covered by the government, or imperfect capital markets where credit rationing prevails, which leads to underinvestment in climate-neutral technologies as these only offer uncertain returns. Initiatives by financial market regulators and supervisors, including central banks, address some of these issues by increasing transparency, setting standards and preventing green washing. A prominent example is the European Commission's Action Plan on Financing Sustainable Growth with the EU taxonomy for sustainable activities at its core. The EU taxonomy is a classification system defining environmentally sustainable economic activities (European Commission, 2021). With the above caveats in mind, carbon pricing policies will be an important component of public policies supporting carbon transition, even though they will be accompanied by other tools.

⁸ Carbon leakage occurs when emission-intensive production is outsourced to countries under other jurisdictions and the respective products are imported as a way to avoid having to comply with the regulatory treatment of emissions.

2.2 Energy efficiency-enhancing regulations

Policymakers could also choose regulatory approaches to reduce emissions. These so-called "command and control" measures include e.g. the implementation of strict energy standards for goods and processes or an outright ban of certain technologies with negative climate impacts. From an economist's viewpoint, such regulatory approaches are inferior to a Pigouvian tax because they limit the choice of consumers and producers, which means that outcomes will deviate from those achieved by a more efficient market solution. On the other hand, if time is of the essence, these measures might be more effective since taxation and the subsequent market process might take a while to establish a new efficient equilibrium; a banned technology will cease emitting any carbon as soon as the ban enters into force. Clearly defined energy standards also have the advantage that they help shape the market, an effect which may go beyond the initial legal applicability of the imposed standards. The EU is a large market and if its consumers will only buy products that comply with certain energy standards, even foreign producers might adjust their goods to these standards to stay in the market.

2.3 Political economy aspects of climate-related economic policies

Carbon taxes, the reduction of subsidies and regulatory limitations of emissions will have income and wealth effects for households and firms. As we have seen from the yellow vest protests in France, the introduction of carbon taxes can have significant political and social repercussions. Therefore, climate policies should be designed in a forward-looking manner and take into account redistributive effects. In 2019, an initiative by US economists⁹ proposed introducing a carbon tax the revenues of which should be returned directly to US citizens so they would benefit from a "carbon dividend," which would, in turn, improve public acceptance of the new tax. With regard to material regulations of GHG emissions, it should be borne in mind that their effects and their acceptance strongly depend on whether carbon-free alternative technologies are available and at what price. Many sustainable modes of energy generation, such as photovoltaics or wind power, have become highly efficient over the past few years and could easily substitute emissionintensive technologies (IRENA, 2021), provided that sufficient energy storage capacity is created to balance supply fluctuations. On the other hand, banning (new) combustion engine cars might hit less wealthy people disproportionally hard as long as low-cost public transport alternatives are not available.

2.4 Green industrial policy

Expanding the production-possibility frontier toward more carbon-neutral technologies should be one of the aims of industrial policy. The policy options mentioned above (e.g. carbon tax, regulations) are likely to induce changes in demand, which in turn will trigger investments in new technologies. Recalibrating a country's innovation system is an intricate process and a risky business. Mission-oriented industrial policies as proposed by Mazzucato and McPherson (2018) could support the economy in carbon transition by funding basic research, subsidizing innovators or offering public guarantees for the development of carbon-neutral prototypes. In

⁹ Information on this initiative was published by the Climate Leadership Council; its signatories comprise all living former chairs of the Federal Reserve and 27 Nobel laureate economists.

contrast to current policies aimed at strengthening the innovative capacities of all economic sectors, this approach would explicitly give preference to technologies that foster climate change mitigation and adaptation. More targeted R&D funding should enable the corporate sector to supply climate-neutral products earlier and more cheaply, thus making the transition process more palatable to the public.

Stern and Stiglitz (2021) also stress the interdependence of tax policies and green industrial policy. They show that introducing higher carbon prices earlier would have the benefit of prompting earlier innovations. Both innovation and the diffusion of innovative technologies are path dependent; therefore, incentivizing firms to focus their R&D expenditure on emission-saving technologies and to adopt new energy systems early on would yield a double dividend.

Comparing all the discussed policies in terms of efficacy generates a hierarchy of instruments. The objective of fighting climate change is achieved most effectively by curbing the demand for emission-intensive goods. If the prices of these goods actually reflect their negative externalities, households and firms will reduce their demand for emission-intensive goods. Complementing positive price signals by active innovation policies that foster climate-neutral innovation augments the climate policy mix. Regulatory limits or bans on particular goods or technologies can curb GHG emissions very swiftly, but entail higher social costs, especially if emission-free substitutes are not available or only available at high prices.

3 Tackling climate-related financial risks

An important element of carbon transition is transforming the energy-related capital stock in the economy. This will require much higher investments in energy efficiency and new technologies. According to estimates by the European Commission¹⁰, the EU will need to invest an additional EUR 350 billion annually until 2030.

If financial institutions include the risks of climate change when calculating their risk-adjusted returns, the relative prices of climate-neutral and polluting assets would change in favor of climate-neutral assets. In response to these challenges, the Network for Greening the Financial System (NGFS), an association of central banks and financial supervisors, was launched in 2017, aiming to help accelerate the scaling-up of green finance and to develop recommendations regarding central banks' role in the fight against climate change.

Accounting for climate-related financial risks requires the disclosure of climate-related information such as data on the carbon intensity of production or the location of assets, which is often still unavailable. One of the main objectives of the NGFS and of private sector initiatives like the Task Force on Climate-related Financial Disclosures (TCFD)¹¹ is the integration of climate risks into the customary risk management procedures of financial institutions. This requires the dissemination of available monitoring and assessment methods and the disclosure of the relevant data. Whereas the methods for monitoring climate risk exposures are already well established and scientific progress is ongoing, the availability of the relevant data is lagging behind. Although financial institutions emit compara-

¹⁰ See European Commission (2020).

¹¹ The TCFD was established by the Financial Stability Board in 2015 and tasked with developing voluntary and consistent climate-related financial risk disclosures for well-informed investment, lending and insurance decisions.

tively little GHGs in their own operations, their exposure to climate-related risks can be significant due to loans to emission-intensive firms.

Integrating climate risks into risk management standards for banks and other financial institutions has a double benefit. It would make potential credit losses and market liquidity changes more predictable. And by prompting changes in relative asset prices of climate-neutral and GHG-emitting companies, it could also contribute to improving the funding costs for green firms and thus act as a catalyst for economic transformation. Nevertheless, this approach would have a rather limited effect on the overall transition to a climate-neutral economy compared to that of introducing effective carbon taxes, implementing regulatory changes that limit GHG emission or pursuing mission-oriented technology policies. The effect would be comparatively small because it would affect only the marginal funding conditions to the extent that banks and other financial intermediaries are able to price climate-related risks appropriately. Carbon taxes, by contrast, can change the retail prices of goods and, thus, effective demand for these goods. Still, green financial regulatory policies are an important measure in addition to green fiscal and industrial policies, as they might correct present market failures.

Financial regulation can only change the marginal cost of funding for firms and households. However, clear rules and guidance on climate risk management can prevent the financial sector from mispricing emission-intensive assets. Whereas the contribution of financial regulation to fighting climate change might be small, such rules can significantly improve the resilience of financial institutions. In any case, although the various policy levels may be complementary, the positive effects of introducing a carbon tax cannot be substituted by financial regulation, whose purpose is altogether different.

Box 1

Market neutrality and climate change

According to the Treaty on the Functioning of the European Union (TFEU), the ESCB shall act in accordance with the principle of an open market economy with free competition, favoring an efficient allocation of resources. This is a general rule the Eurosystem must also comply with when implementing monetary policy. In practice, exercising market neutrality has been considered an appropriate approach for the Eurosystem when it comes to respecting the principle of an open market economy. Market neutrality is understood to minimize the impact of monetary policy on relative prices and to curtail unintended side effects on market functioning. The objectives of exercising market neutrality are to preserve the price discovery mechanism (see below) and to limit distortions in market liquidity. If there is a conflict between monetary policy objectives and the principle of an open market economy, monetary policy interference must be justified and proportional. This means that the intended measures are required to achieve monetary policy objectives and may not go beyond what is necessary.

Price discovery is the process of incorporating all information relevant to the valuation of an asset in its market price. Central bankers do not pretend to have better information than market participants and therefore try to avoid causing a change in relative asset prices. These must remain the outcome of the free play of market forces. This restraint, on behalf of central banks, is difficult to justify in the presence of market failures. The risks that arise to future cash flows from climate change should be incorporated in asset prices. The European Systemic Risk Board (ESRB, 2020) finds that the exposure of assets to climate-related risks is not reflected in their prices and that financial intermediaries do not consider climate change sufficiently in their market risk assessment. The price discovery mechanism is also disturbed because issuers of financial assets fail to appropriately disclose their exposure to climaterelated risks. Despite the efforts of the Task Force on Climate-related Financial Disclosures (TCFD) to compile and publish methods for the disclosure of these risk exposures, only a small minority of firms are willing to apply them.¹² Risk exposures that are not disclosed properly cannot inform the price discovery process. Policies that incentivize firms to assess and disclose their exposures would therefore improve the functioning of the price discovery mechanism. Eligibility under the expanded asset purchase programme (APP) requires having at least one credit rating provided by an external credit assessment institution that is accepted under the Eurosystem credit assessment framework. But most of these credit ratings do not take climate-related risks into account.

If central banks departed from market neutrality, however, they may encounter difficulties in the implementation of monetary policy. A lack of market liquidity increases transaction costs and reduces the efficiency of an open market economy. If Eurosystem asset purchases were biased toward assets that contribute to the mitigation of climate change (e.g. green bonds), the markets for these assets might suffer from excess demand because the supply of green bonds is rather small compared to the volumes required for monetary policy implementation. Moreover, a special focus on rather small market segments would limit the effectiveness of monetary policy operations.

The Eurosystem has already decided to moderate its practice of market neutrality in compliance with the principle of proportionality. The eligibility criteria for asset purchases result in bond holdings that do not reproduce the market allocation exactly. For example, under the public sector purchase programme (PSPP), sovereign bonds were purchased according to the ECB capital key and not according to their market share as would have been suggested when exercising market neutrality. Schnabl (2021b) argues that "in the presence of market failures, adhering to the market neutrality principle may reinforce pre-existing inefficiencies that give rise to a suboptimal allocation of resources." Therefore, she recommends replacing the market neutrality principle by a market efficiency principle that actively acknowledges the existence of welfare-reducing market failures.

4 Monetary policy instruments and climate change

While monetary policy is impacted by climate change and climate action, it might need to react to this impact. Subject to individual central banks' mandates, monetary policy could even actively contribute to climate policies. The various instruments in the monetary policy toolkit differ with regard to the effectiveness of their risk-oriented (protective) and climate-policy-oriented (proactive) approaches. In practice, however, the distinction between protective and proactive approaches is blurred. Considering both types of approaches, the NGFS (2021) reviewed several options available to central banks to factor climate-related risks into their operating framework.¹³ Following their review, table 1 presents 12 options of how central banks could adjust their main operational functions when implementing monetary policy in four fields: credit operations, collateral policies, asset purchases, and risk assessment and disclosure. We added this last field although the measures listed here are not monetary policy instruments on their own, but rather tools to make monetary policy instruments more effective.

¹² Due to the lack of reliable disclosures, credit ratings cannot reflect these risks appropriately.

¹³ For a less comprehensive comparison of options, see Krogstrup and Oman (2019) or Breitenfellner et al. (2019).

Options for monetary policy instruments in dealing with climate change

Instruments / criteria	Monetary policy effectiveness	Climate mitigation	Effectiveness in risk protection	Operational feasibility
Credit operations				
Adjust counterparties' eligibility		+	+	?
Adjust pricing to reflect collateral composition	-	+	?	-
Adjust pricing to reflect counterparties'				
climate-related lending (green funding support)	?	++	?	-
Collateral policies		'		
Adjust haircuts to climate-related risks	?	+	+	-
Negative screening (e.g. exclude coal mining)	-	+	+	?
Positive screening (e.g. favor green bonds)	+	++	-	?
Align collateral pools with climate-				
related objective	?	++	+	-
Asset purchases				
Tilt purchases				
(climate risk at issuer or asset level)	?	++	+	-
Negative screening (e.g. exclude nondisclosers)	-	+	+	?
Risk assessment and disclosure				
Adapting climate-related credit ratings	?	+	+	+
Climate stress test of balance sheets	+	+	++	+
Disclose climate-related information on				
central bank assets and collateral	?	+	++	+
Incorporate climate-related risks into				
macroeconomic models	+	?	+	+

Source: NGFS, OeNB

Note: Potential impact: ++ strongly positive; + positive; ? minimal; - negative; - - strongly negative.

The options presented in table 1 are evaluated with regard to four criteria: their monetary policy effectiveness, their contribution to climate mitigation, their effectiveness in risk protection and their operational feasibility. This evaluation is based on qualitative expert judgment and should not be interpreted as a recommendation of any of the listed measures.

4.1 Targeted credit operations

As one way to include climate considerations in monetary policy, banks' loan portfolios could be assessed with respect to their environmental impact, and incentives could be provided to encourage the extension of loans to low-carbon activities. Central banks have already experimented with various schemes of targeted credit easing programs to revive banks' lending to households and firms.¹⁴ Similarly, by conducting targeted green refinancing operations, central banks could provide liquidity at preferential terms if banks extended credit for lowcarbon activities or for projects that sustain carbon transition.¹⁵

Table 1

¹⁴ Starting in 2014, the ECB, for instance, issued various rounds of targeted longer-term refinancing operations (TLTROs) in which interest rates on the borrowing of participating banks became more attractive the more loans (except mortgages) these banks issued to nonfinancial corporations and households.

¹⁵ A concrete example is the preferential capital requirement program for green housing loans in place in Hungary (MNB, 2019).

There are three specific options in this field:

- *Adjusting counterparties' eligibility:* Central banks could make access to lending facilities conditional on counterparties' disclosure of climate-related information or on the carbon intensity of their investments.
- Adjusting pricing to reflect the composition of pledged collateral: Central banks could charge a relatively lower interest rate to counterparties that pledge a higher proportion of low-carbon assets as collateral or set up a credit facility (potentially at concessional rates) accessible only against low-carbon assets.
- Adjusting pricing to reflect counterparties' climate-related lending: Central banks could make the interest rate for central bank lending facilities conditional on the contribution of counterparties' lending (relative to an appropriate benchmark) to

climate change mitigation and/or the decarbonization of their business models. Research suggests that conventional green policies in the form of emission-based interest rates set by the central bank provide effective incentives for decarbonizing the economy and reducing climate-related damage. Böser and Colesanti Senni (2020) conduct a simulation exercise showing that monetary policy instruments can induce the adoption of cleaner technologies across the entire economy and reduce the economy's expected emission intensity. Nevertheless, we should not underestimate the problems related to the operational complexity of such measures, as these might pose risks to the effectiveness of monetary policy. For instance, central banks would need to apply a catalog of clear definitions of what constitutes sustainable finance, such as the EU taxonomy for sustainable activities currently developed by the European Commission. Another option would be to use ratings related to firm's climate or, more broadly, environmental, social, and corporate governance (ESG) performance. The low correlation of various rating scores, however, reflects the wide discretion in constructing such indicators on the one hand and data gaps on the other (Berg et al., 2020).¹⁶

4.2 Collateral policies

Collateral protects central bank borrowing in case of counterparty default. Collateral frameworks define the set of eligible collateral that financial institutions can use in operations with central banks as well as the haircuts imposed. Eligibility in central bank operations affects the rate of repurchase agreements (repos), liquidity and the price of an asset in the secondary market. Central banks use several eligibility criteria for collateral, with credit ratings determining the credit quality and haircuts applied. Eligible assets can be pledged to borrow liquidity from central banks, which creates incentives to issue larger quantities of those assets. Therefore, it is useful although ressource-intensive to thoroughly assess potential biases favoring high-carbon assets within central banks' collateral framework. The individual options in this context are:

• Adjusting haircuts to better account for climate-related risks: Haircuts could be calibrated beyond what might be required from a traditional risk mitigation perspective in order to promote the market for sustainable assets. Central banks could increase the haircuts of carbon-intensive issuers or assets. Conversely, they could lower haircuts for more climate-aligned issuers or assets.

¹⁶ The same reasoning, however, applies to traditional ratings as well, and these are used for collateral purposes nevertheless.

- *Negative screening:* Central banks could exclude collateral assets that are otherwise eligible on the basis of their issuer-level climate-related risk profile for debt securities or on an analysis of the carbon performance of their underlying assets for pledged pools of loans or securitized products.
- *Positive screening:* Central banks could accept sustainable collateral that would otherwise not be eligible to incentivize banks to fund projects that support environmentally friendly activities (e.g. green bonds or sustainability-linked assets).
- Aligning collateral pools with a climate-related objective: Central banks could require counterparties to pledge collateral in a way that it complies with climate-related objectives at an aggregate pool level.

The example of China shows the potential that greening a central bank's collateral framework offers. Since mid-2018, the People's Bank of China (PBoC) has included green financial bonds in the pool of assets eligible as collateral for its medium-term lending facility. Macaire and Naef (2021) show that this policy move increased the "greenium," i.e. the yield spread between green and nongreen bonds, by 46 basis points. Dafermos et al. (2021) view the Eurosystem collateral framework as biased toward carbon-intensive sectors (see also box 2). To help realign the implementation of monetary policy with the European Green Deal, they propose to reduce the weighted average carbon intensity of the collateral framework. Their results show that even an aggressive calibration of haircuts will not significantly reduce the carbon intensity of the ECB's collateral list, unless the eligibility criteria are rebalanced toward greener bonds.

However, since haircuts deal with liquidity risk, they might not be ideal tools for providing climate policy incentives while keeping monetary policy effective. Moreover, screening strategies could have different impacts on issuers depending on their size, or they could create distortions across asset classes.

4.3 Asset purchases

The environmental implications of quantitative easing (QE) programs have sparked a debate about the choice of assets purchased under such programs, which resulted in two reform proposals:

- *Tilting purchases:* Central banks could rebalance their asset purchases according to climate-related risks and/or criteria applied at the issuer or asset level.
- *Negative screening:* Central banks could exclude some assets or issuers from their purchases if these fail to meet climate-related criteria.

The effectiveness of both types of measures could be questioned on the following grounds: In theory, asset purchases not only reduce the yields of assets directly purchased by the central bank, but also the yields of all other assets since investors rebalance their portfolios by purchasing other assets to replace the QE securities they sell to the central bank. If this portfolio-rebalancing channel works efficiently, the choice of particular assets purchased by the central bank should be irrelevant for any price effect (assuming perfect substitutability). So, even if corporate bond purchases pose higher climate risk to a central bank's balance sheet, they may not significantly skew overall investment toward high-carbon sector assets in the economies concerned. Insufficient empirical evidence of such portfolio rebalancing effects undermines doubts about the economic relevance of the choice of assets and their carbon content, however.

Ferrari and Nispi Landi (2020) study the effects of "green QE," which temporarily tilts a central bank's balance sheet toward bonds issued by firms in nonpolluting sectors. They find that for green QE to be effective, there must be imperfect substitutability between green and brown bonds. While a temporary green QE helps mitigate emissions, it has only limited effects on reducing the stock of pollution. Battiston and Monasterolo (2019) show that weights the ECB introduced for carbon-intensive companies that diversify their portfolio toward low-carbon investments would support the transition to green finance in line with market neutrality and decrease the ECB's exposure to potentially carbon-stranded assets. However, this would imply that the ECB considers to negatively discriminate carbon-intensive economic activities in line with the European Commission's EU taxonomy, whose legal implementation is still pending.

While the carbon intensity of central bank's corporate bond portfolios has attracted a lot of attention, QE asset purchases are typically dominated by sovereign bonds. Their environmental impact can be assessed on the basis of governments' decarbonization commitments. Sveriges Riksbank (2020) has divested municipal bonds issued by high-emitting provinces in Canada and Australia. On a positive note, several European governments have started issuing sovereign green bonds. The environmental effectiveness of such bonds is questioned, however, especially by countries with high emission intensity (Hardy, 2020). In contrast, Monasterolo and Raberto (2017) find that large-scale purchases of green sovereign bonds help develop a green bond market, accelerate transition by green investment and reduce the risk of stranded assets for the financial system.¹⁷ The environmental materiality of bonds issued by supranational institutions such as the European Investment Bank (EIB) is less controversial. Labeled "the EU climate bank," the EIB (2020) announced that it would increase its support to climate and environmental action to levels that exceed 50% of its overall lending activity by 2025 while ensuring that the remainder of its lending is in line with the Paris Agreement.

4.4 Risk assessment and disclosure

The final group of measures should be seen as preconditions to sustainable monetary policy rather than as monetary policy instruments themselves. They are usually less controversial because their aim is to protect monetary policy and central banks from the intrinsic risks of climate change. These measures are:¹⁸

- Adapting climate-related credit ratings: Central banks could contribute to the transparent and consistent incorporation of climate-related financial risks in credit ratings. This includes a careful choice of credit rating agencies considering their sustainability assessment capabilities and the development of minimum standards in internal ratings.
- Climate stress test of central bank balance sheets: Central banks could assess their risk exposure to climate change and enhance their climate risk assessment capabilities.
- Disclosing climate-related information on central bank assets and collateral: Central banks could comply with TCFD recommendations and the respective policies

¹⁷ However, if such moves are not matched by ambitious decarbonization policies in the real economy, the development of green asset bubbles cannot be excluded.

¹⁸ See also the need to incorporate climate-related risks into macroeconomic models described in section 1.

such as the EU legal framework which is currently being developed (e.g. the Corporate Sustainability Reporting Directive – CSRD). Beyond that, central banks could also require climate-related disclosure for assets to qualify as eligible collateral and for asset purchases.

Without exhausting the list of advantages and disadvantages of the individual measures presented above, this section concludes with three general observations:

- 1. Central banks may first need to take steps with regard to the assessment and disclosure of climate-related risks. These steps should improve understanding for additional actions taken at a later stage.
- 2. Moving further to core monetary policy instruments, it should be kept in mind that corporate bonds and in general exposure to the private sector are more often used as collateral while the purchase programs are heavily dominated by sovereign bonds. Thus, despite public debates being focused on purchasing programs, any preferential treatment within the collateral framework may be more effective in the long run, particularly in times when nonstandard measure may not be active.
- 3. All measures listed have in common that, apart from having a direct impact on climate and carbon risks in the central bank's balance sheet, they also send a powerful signal encouraging private financial markets to adapt to carbon transition.

Box 2

How carbon biased is the Eurosystem's monetary policy?

Sustainability-concerned NGOs, think tanks and researchers have sparked a lively debate on an alleged carbon bias of the Eurosystem's monetary policy instruments, in particular in relation to the corporate sector purchase programme (CSPP).¹⁹ Dafermos et al. (2020) find that the four most carbon-intensive economic sectors account for roughly 62.7% of the outstanding amount of bonds purchased by the Eurosystem. However, their share in all euro area nonbank corporate bonds is just 45.5% and their contribution to gross value added (GVA) is only 29.1%. Jourdan and Kalinowski (2019) calculate that 63% of assets bought through the CSPP were issued by firms operating within the most strongly carbon-emitting sectors: extraction and distribution of fossil energy sources, car manufacturing and equipment, other energy-intensive sectors, and utilities. Battiston and Monasterolo (2019) develop a benchmark of the euro area corporate bond market that mimics the CSPP eligibility criteria. They show that the CSPP closely follows the benchmark dominated by fossil fuel and carbon-intensive companies. Regarding Austria, Hanzl et al. (2020) estimate that 62% of the corporate bonds available for the ECB's purchase program in October 2020 were issued by the oil, gas and plastic industries. Interestingly, more than a year earlier, the comparable share of these industries was only 42%. Matikainen et al. (2017) provide a sectoral analysis of the CSPP that also suggests a skew toward high-carbon sectors. Using publicly available information, they calculate that 62.1% of ECB corporate bond purchases take place in the sectors of manufacturing and electricity and gas production, which alone are responsible for 58.5% of euro area greenhouse gas emissions. Renewable energy companies are not represented at all in ECB corporate bond purchases, while oil and gas companies make up an estimated 8.4% of its CSPP portfolio.

At the other end of the scale, sectors and activities aligned with climate objectives represent a tiny fraction of the CSPP. Across all sectors, the share of green bonds according to Jourdan and Kalinowski (2019) accounts for some 7% of the CSPP portfolio. De Santis et al. (2018),

¹⁹ See e.g. Barkawi (2017), Monnin (2018) and Schoenmaker (2019).

however, note that the Eurosystem holds close to 20% of the CSPP-eligible green corporate bond universe and even 24% of the green PSPP²⁰-eligible universe (sovereigns, agencies and supranational institutions). They also state that purchase programs have diminished the spreads for eligible green bonds at a steady pace while driving up their net issuance. Green bonds have grown tenfold in five years, despite their small share of just 1% in the overall bond supply denominated in euro. Following these market dynamics would call for stepping up purchases of low-carbon bonds in line with the growing share of green bonds in eligible bonds in general.

Analyzing the Eurosystem's collateral framework, Dafermos et al. (2021) suggest that its current form favors bonds issued by carbon-intensive sectors. They verify a carbon bias in the collateral rules for corporate bonds, given that these favor carbon-intensive companies disproportionately. These firms issue 59% of the corporate bonds the ECB accepts as collateral, while their overall contribution to EU employment and GVA is less than 24% and 29%, respectively. Four large fossil fuel companies rely on bonds subsidized by the ECB collateral framework for more than half of their overall financing.

The observed bias toward carbon-intensive sectors in the ECB's asset purchases may reflect the current capital intensity of these sectors and the size of firms operating in these sectors. In that case, the bias could conform to the market neutrality principle, which, however, would confirm serious doubts about the allocative efficiency of financial markets regarding externalities that are usually not priced. Thus, the question arises whether the Eurosystem should consider other criteria besides the supposedly "neutral" market allocation in the eligibility rules and the determination of weights for its asset purchases and collateral framework (Schnabel, 2021b).

5 Concluding remarks

Climate change is a fundamental challenge to macroeconomic stability. As such, it also affects the objectives and instruments of monetary policy. The Eurosystem's mandate defines maintaining price stability as the Eurosystem's primary objective. This implies that it must monitor the climate-related risks to price stability and assess their impact on the monetary policy transmission mechanism and on central banks' balance sheets. To do so, monetary policymakers inter alia rely on scenario techniques, given that the macroeconomic impact of climate change is still mostly uncharted territory. In addition to pursuing its primary objective, the Treaties also commit the Eurosystem to support the European Union's general economic policies that aim, inter alia, at environmental protection without prejudice to price stability. However, "central bankers do not sit in the driver's seat of climate policy" (Holzmann, 2021). This seat is occupied by governments, which can and should introduce carbon prices and other policies that directly correct the market failure causing climate change.

Carbon taxes, emissions trading schemes, direct regulations or green industrial policies can support the transition to a carbon-neutral economy more effectively and efficiently than monetary policy. In turn, a well-managed transition would reduce the risks to financial market stability and thus help central banks achieve their objectives in line with their mandate. Whatever approach central banks choose, financial market supervision and monetary policy will complement but never replace governments' decarbonization efforts.

²⁰ Public sector purchase programme.

Different monetary policy strategies have different implications for climate change. Even for inflation-targeting regimes, simulations indicate significant differences in outcomes with respect to inflation, output stabilization and the reduction of GHG emissions. A similar variance in climate outcomes also applies to different monetary policy instruments. The framework for credit operations, collateral policies, asset purchases or asset quality assessment and disclosure could be adjusted to reflect the risks of climate change and to contribute to the greening of the financial system. A risk-oriented (or protective) approach on central bank climate action seems to be a good starting point and basis for pragmatic consensus. In this spirit, the ECB's new monetary policy strategy statement states that climate factors will be incorporated in future monetary policy assessments. According to the statement, the design of the ECB's monetary policy operational framework will be adapted in relation to climate-related disclosures, risk assessment, corporate sector asset purchases and the collateral framework (ECB, 2021). Sveriges Riksbank (2020) has shown that risk-orientation can go very far by implementing a rigorous sustainability strategy for its asset purchases and foreign exchange reserve management. The Bank of England (2021), in turn, is now moving ahead with an ambitious proactive strategy to explicitly support an orderly economy-wide transition to net zero GHG emissions by 2050 through its quantitative easing measures. While the direction of the path is clear, the speed of actions toward "net zero central banking" will continue to be matter of discussion (Robins et al., 2021). Eventually, all public and private economic actors will have to contribute according to their capabilities to achieving a climate-neutral economy by the mid-21st century.

References

- **Barkawi, A. 2017.** Why monetary policy should go green. Retrieved March 21, 2019 from the Financial Times.
- **Bank of England. 2021.** Options for greening the Bank of England's Corporate Bond Purchase Scheme. Discussion Paper. May.
- Batten, S., R. Sowerbutts and M. Tanaka. 2020. Climate Change: Macroeconomic Impact and Implications for Monetary Policy. In: Walker T. et al. (eds.). Ecological, Societal, and Technological Risks and the Financial Sector. Palgrave MacMillan. 13–38.
- Battiston, S., M. Guth, I. Monasterolo, B. Neudorfer and W. Pointner. 2020. Austrian banks' exposure to climate-related transition risk. In: Financial Stability Report 40. OeNB. 31–44.
- **Battiston, S. and I. Monasterolo. 2019.** How could the ECB's monetary policy support the sustainable finance transition?" FINEXUS Working Paper. University Zurich.
- Breitenfellner, A., W. Pointner and H. Schuberth. 2019. The potential contribution of central banks to green finance. In: Vierteljahrshefte zur Wirtschaftsforschung. 88(2):55–71
- **Böser, F. and C. Colesanti Senni. 2020.** Emission-based Interest Rates and the Transition to a Low-carbon Economy. CER-ETH Economics working paper series 20/337.
- Broeders, D. and M. Schlooz. 2021. Climate change uncertainty and central bank risk management. In: Journal of Risk Management in Financial Institutions. Vol. 14, 2. 121–130
- **Bylund E. and M. Jonnson. 2020.** How does climate change affect the long-run real interest rate? Economic Commentaries No 11. Sveriges Riksbank.
- **Carney, M. 2015.** Breaking the tragedy of the horizon climate change and financial stability. Speech at Lloyd's of London on September 29.

- **Climate Bonds Initiative. 2019.** Greening the Financial System: Tilting the playing field The role of central banks. Report in conjunction with the SOAS Centre for Sustainable Finance and WWF.
- **Dafermos, Y. D. Gabor, M. Nikolaidi, A. Pawloff and F. van Lerven. 2021.** Greening the Eurosystem collateral framework How to decarbonize ECB's monetary policy.
- **Dafermos, Y. D. Gabor, M. Nikolaidi, A. Pawloff and F. van Lerven. 2020.** Decarbonising is easy Beyond market neutrality in the ECB's corporate QE. New Economics Foundation, October.
- Dafermos, Y., M. Nikolaidi, G. Galanis. 2018. Climate Change, Financial Stability and Monetary Policy. Ecological Economics 152. 219–234.
- **De Santis, R. A., K. Hettler, M. Roos and F. Tamburrini. 2018.** Purchases of green bonds under the Eurosystem's asset purchase programme. ECB Economic Bulletin 7/18. November.
- Dietz S. and N. Stern. 2015. Endogenous Growth, Convexity of Damage and Climate Risk: How Nordhaus' Framework Supports Deep Cuts in Carbon Emissions. Economic Journal. 125(583). 574–620.
- **ECB. 2021.** ECB presents action plan to include climate change considerations in its monetary policy strategy. Press release. July 8.
- Economides, G. and A. Xepapadeas. 2018. Monetary Policy under Climate Change. CESifo Working Paper 7021.
- **EIB. 2020.** EIB group climate bank roadmap 2021–2025. November 2020. European Investment Bank.
- **Elderson, F. 2021.** Patchy data is a good start: from Kuznets and Clark to supervisors and climate. Keynote speech at the ECB-EBRD joint conference on "Emerging climate-related risk supervision and implications for financial institutions."
- **European Commission. 2021.** Sustainable finance. https://ec.europa.eu/info/business-economyeuro/banking-and-finance/sustainable-finance_en
- **European Commission. 2020.** Stepping up Europe's 2030 climate ambition. Investing in a climate-neutral future for the benefit of our people. Brussels. COM(2020) 562 final.
- **European Environment Agency. 2017.** Climate change, impacts and vulnerability in Europe. An indicator-based report. EEA Report No 1/2017. Luxembourg.
- ESRB. 2020. Positively green: Measuring climate change risks to financial stability. June 2020.
- **ESRB. 2021.** Climate-related risk and financial stability. ECB/ESRB Project Team on climate risk monitoring. Frankfurt.
- Ferrari, A. and Nispi Landi, V. 2020. Whatever it takes to save the planet? Central banks and unconventional green policy. ECB Working Paper 2500.
- Hanzl, L., O. Picek and J. Tölgyes. 2020. Wie "grün" sind die EZB-Käufe österreichischer Unternehmensanleihen? Policy Brief 23. Momentum Institut.
- Hardy, D. C. 2021. European Sovereign Green Bonds and Long-term Policy Commitment. European Political Economy Project, St Antony's College, Oxford. slides presented on 24 May 2021.
- **HM Treasury. 2021.** Remit for the monetary policy committee (MPC). Publishing service of the UK Government.
- **Holzmann, R. 2021.** CESEE's second transition challenges on the road to low carbon economies. Welcome Remarks to the 87th East Jour Fixe of the Oesterreichische Nationalbank. June 17.
- IMF. 2020. World Economic Outlook.
- **IRENA. 2021.** Renewable Power Generation Costs in 2020. International Renewable Energy Agency.

- Jourdan, S. and M. Beckmann. 2021. Why green monetary policy is legal and legitimate. Blog comment. Positive Money Europe. https://www.positivemoney.eu/2021/03/green-monetary-policy-legal-legitimate/
- Jourdan, S. and W. Kalinowski. 2019. Aligning Monetary Policy with the EU's Climate Targets. Policy Note. Veblen Institute for Economic Reforms and Positive Money Europe.
- **Krogstrup, S. and W. Oman. 2019.** Macroeconomic and financial policies for climate change mitigation: A review of the literature. IMF Working Paper 19/185.
- Lagarde, C. 2021. Climate change and central banking. Keynote speech at the ILF conference on Green Banking and Green Central Banking
- Macaire, C. and A. Naef. 2021. Impact of Green Central Bank Collateral Policy: Evidence from the People's Bank of China. SocArXix. Open Archive of the Social Sciences. https://osf.io/ preprints/socarxiv/cmwpn/
- **Matikainen, S., Campiglio, E. and Zenghelis, D. 2017.** The climate impact of quantitative easing. Policy Paper, Grantham Research Institute at LSE.
- Mazzucato, M. and M. McPherson. 2018 The Green New Deal: A bold, mission-oriented approach. UCL Institute for Innovation and Public Purpose Policy Brief 04
- McKibbin, W., A. Morris, P. Wilcoxen and A. Panton. 2020. Climate change and monetary policy: issues for policy design and modelling. Oxford Review of Economic Policy. Volume 36. Number 3. 579–603
- **MNB. 2019.** MNB introduces a Green Preferential Capital Requirement Programme. Press release Magyar Nemzeti Bank. 18 December 2019.
- Monasterolo, I. and M. Raberto. 2017. Is There a Role for Central Banks in the Low-Carbon Transition? A Stock-Flow Consistent Modelling Approach (November 21).
- **Monnin, P. 2018.** Central Banks and the Transition to a Low-Carbon Economy. CEP Discussion Note.
- **NGFS. 2020.** Climate Change and Monetary Policy. Initial takeaways. Technical document prepared by the "Scaling up Green Finance" workstream. June.
- **NGFS. 2021.** Adapting central bank operations to a hotter world: Reviewing some options. Report of the Network of Central Banks and Supervisors for Greening the Financial System.
- **Pointner, W. and D. Ritzberger-Grünwald. 2019.** Climate change as a risk to financial stability. In: Financial Stability Report 38. OeNB. 30–45.
- Riksbank. 2020. Sustainability strategy for the Riksbank. Decided on 16 December.
- **Robins, N., S. Dikau and U. Volz. 2021.** Net-zero central banking: A new phase in greening the financial system Policy report. LSE. Grantham Research Institute and SOAS. March.
- Schnabel, I. 2021a. From green neglect to green dominance? Intervention at the "Greening Monetary Policy Central Banking and Climate Change" online seminar. Organised as part of the "Cleveland Fed Conversations on Central Banking."
- **Schnabel, I. 2021b.** From market neutrality to market efficiency. Welcoming address at the ECB DG-Research Symposium "Climate change, financial markets and green growth".

Schoenmaker, D. 2019. Greening monetary policy. CEPR working paper.

- Stern, N. and J. Stiglitz. 2021. The Social Cost of Carbon, Risk, Distribution, Market Failures: An Alternative Approach. NBER Working Paper No. 28472.
- Villeroy de Galhau, F. 2021. The role of central banks in the greening of the economy. Speech 11 February. Paris.
- Visco, I. 2021. Financing carbon neutrality. Remarks at the roundtable on financing carbon neutrality, BOAO Forum for Asia Annual Conference. 20 April 2021
- Weidmann, J. 2021. Climate risks, financial markets and central banks' risk management. Speech at the Green Swan 2021 Global Virtual Conference. 2 June.