

Climate Change and Monetary Policy in the Euro Area



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Abstract

Climate considerations have entered the agenda of the ECB in recent years. The ECB has intensified its analyses of the macroeconomic impact of climate change and started to evaluate and implement more active approaches and best practices to support the green transition. In this paper we discuss how climate change could affect monetary policy, other policies available to the ECB to support the green transition, and potential trade-offs with its primary objective of price stability.

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AUTHORS

Joscha BECKMANN, Kiel Institute for the World Economy and FernUniversität Hagen
Klaus-Jürgen GERN, Kiel Institute for the World Economy
Nils JANNSEN, Kiel Institute for the World Economy
Nils SONNENBERG, Kiel Institute for the World Economy

ADMINISTRATOR RESPONSIBLE

Giacomo LOI
Drazen RAKIC
Maja SABOL

EDITORIAL ASSISTANT

Adriana HECSER

LINGUISTIC VERSIONS

Original: EN

ABOUT THE EDITOR

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To contact Economic Governance and EMU Scrutiny Unit or to subscribe to its newsletter please write to:

Economic Governance and EMU Scrutiny Unit
European Parliament
B-1047 Brussels
E-mail: egov@ep.europa.eu

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LIST OF ABBREVIATIONS

APP	Asset purchase programme
ECB	European Central Bank
ESG	Environmental, Social, and Governance (ESG)
GDP	Gross domestic product
GTLRTO	Green targeted longer-term refinancing operations
PEPP	Pandemic emergency purchase programme
TLTRO	Targeted longer-term refinancing operations

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EXECUTIVE SUMMARY

- **Climate change can have considerable economic effects that are relevant for central banks.** Physical risks (e.g. temperature increases or a higher frequency of extreme weather events) and transition risks of climate change (e.g. due to carbon pricing or regulatory measures of governments) can impact inflation or output, increase macroeconomic volatility, and affect financial markets. Some of these effects will have only a temporary impact on inflation and are, thus, less of a concern of central banks. However, they can lead to higher inflation volatility and increase overall uncertainty, making it more difficult to identify the appropriate stance of monetary policy. Other effects could lead to more persistent upward pressure on inflation, but central banks have effective tools to stabilise inflation so that these effects should mainly result in relative price adjustments.
- **Governments are responsible for reducing carbon emissions to address climate change.** Policies to mitigate climate change can have large distributional effects. Therefore, it is important that such policies are backed by the democratic legitimation of governments. The mandate of the ECB leaves room to support as a secondary objective the general economic policies of the European Union, which include protecting and improving the environment. However, secondary objectives shall be supported without prejudice to the primary objective of price stability. Against this backdrop, the ECB can only have a supportive role in mitigating climate change.
- **The ECB has taken several measures to account for climate considerations.** Some of these measures are general reactions to climate change, such as improving the analytical toolkit with regard to the macroeconomic impact of climate change or conducting climate stress tests to assess the impact of climate change on financial markets. But the ECB has also introduced monetary policy measures to support the green transition, in particular the tilting of its corporate bond holdings towards issuers with a better climate score. Moreover, the ECB plans to adjust eligibility criteria for its market operations with regard to better climate-related disclosures and climate scores of issuers.
- **Achieving price stability is the most important contribution of monetary policy to the green transition.** Price stability contributes to sustained growth and high employment and stimulates investment. Moreover, it helps to firmly anchor inflation expectations, which will support achieving price stability in the future when the impact of climate change on inflation may increase. The impact of other measures of the ECB on mitigating climate change is probably small. The extent to which the ECB will be supportive will vary over time, given that the ECB aligns policies, including the volume of bond holdings, to its primary objective.
- **The ECB has to consider unwarranted side effects when supporting the green transition.** The instruments of the ECB are efficient in targeting price stability, but may not be in targeting other objectives. Moreover, there is lack of market standards for green investments and forward-looking indicators with regard to the green transition. Therefore, it is difficult to assess the impact of the measures of the ECB and how they interact with other measures from governments. The more the ECB would try to support the green transition the stronger potential conflicts with its mandate and the higher the risks for its credibility with regard to its primary objective would be.

1. INTRODUCTION

Climate change has moved to the centre of the policy debate. Climate considerations did not play an important role for central banks for a long time. While it was widely acknowledged that weather fluctuations, and extreme weather events in particular, can have significant macroeconomic effects, these effects were perceived to be largely transitory and thus less of a concern for central banks that seek to maintain price stability in the medium term. However, by increasing the magnitude and the frequency of weather fluctuations and extreme weather events, climate change can also have more persistent macroeconomic effects due to physical risks associated with events, such as heat waves, prolonged draughts, or flooding, and transition risks that arise in the process of the transition towards a carbon-free economy. In the meantime, climate change is more in the focus of many governments. For example, the mitigation of climate change is an important political goal in the European Union.

Climate considerations have also entered the agenda of the ECB in recent years. The implications of climate change for the conduct of monetary policy in the euro area have been analysed in the context of the ECB's comprehensive monetary strategy review (ECB, 2021a). The ECB has not only intensified its analysis of the impact of climate change on inflation, financial stability and the related consequences for monetary policy. It has also started to evaluate and implement active approaches and best practices to support the green transition, for example by tilting its corporate bond holdings guided by climate considerations. When evaluating more active approaches, the ECB has to consider its mandate with the primary objective being to maintain price stability. In this regard, the instruments of monetary policy aim to efficiently achieve such primary objective but might not be efficient to support other goals. Therefore, the ECB has to carefully check which incentives it provides when it tries to support the green transition and how its actions interact with measures taken by governments. In an international perspective, the Federal Reserve Board in the United States, while also monitoring the potential impact of climate change on output and inflation, is reluctant at this stage to actively take into account climate considerations in its monetary policy operations (Powell, 2023). One reason might be concerns on whether central banks could efficiently and should try to support actively the green transition. Moreover, the general political agenda with regard to mitigate climate change deviates across countries (DiLeo et al., 2023).

In this paper, we discuss the role of climate considerations for central banks. We start by providing a selected overview of the rich literature on the potential impact of climate change on the economy (Section 2). Given the primary objective of the ECB, we focus on the potential impact on inflation, but also on other areas, such as financial stability or the natural rate of interest. Next, we review to what extent the institutional framework gives the ECB room to take climate considerations into account and discuss potential trade-offs (Section 3). Finally, we discuss policy instruments of the ECB to take climate considerations into account, including instruments the ECB has already implemented, instruments it plans to implement, and instruments it may consider in the future (Section 4).

2. MACROECONOMIC EFFECTS OF CLIMATE CHANGE

2.1 Overview and theoretical considerations

Climate change can affect macroeconomic outcomes via physical risks and transition risks. Physical risks stem from both gradual warming, which requires adjustment to challenges such as rising sea levels or changes in precipitation patterns, and an increase in the frequency of extreme weather events with potentially large effects on economic activity. Transition risks arise from policies to reduce CO₂ emissions in the transition towards a green economy. This includes carbon pricing, which can reinforce shifts in consumer preferences and technological change and result in higher energy prices, increased uncertainty, and stranded assets of firms, especially in carbon-intensive industries (ECB, 2021a,b).

Physical risks and transition risks affect inflation, output, and financial markets. Climate change can affect both the level of output and inflation and their volatility. Physical risks can have an impact on headline inflation through energy and food prices, expectations, or other supply and demand factors. Effects of transition risks on energy prices and inflation are difficult to assess since they also depend on future policies, which may be adopted to foster the energy transition. Moreover, climate change could impair financial stability if extreme weather events cause large damages, or the transition is not appropriately priced in capital markets. Finally, climate change could affect the natural rate of interest, which is a reference for central banks for a neutral monetary policy stance (ECB, 2021a,b).¹ All of these channels are relevant for central banks. For the ECB, the impact of climate change on inflation is particularly important given its primary objective to maintain price stability. This includes not only persistent but also transitory effects of climate change (e.g., due to stronger weather fluctuations or a higher frequency of extreme weather events) as an increase in volatility makes it more difficult to identify the main drivers of macroeconomic developments and to assess the appropriate monetary policy stance.

Extreme weather events and increasing temperatures tend to increase food prices. The main transmission channels are negative effects on supply via a reduction of production capacities and natural resources as well as disruptions in supply chains (Kotz et al., 2023; Faccia et al., 2021). Extreme weather events, such as droughts, can lead to a decline in food supply (Ciccarelli et al., 2023). Effects on demand are not clear. After hot summers, lower economic activity might result in lower food demand, especially in less developed countries. Such negative demand effects could even lead to a decline in food prices in the medium run (Faccia et al., 2021). However, the consensus in the literature is that extreme weather events and higher temperatures tend to increase food prices in the short run, and potentially in the medium term, and increase volatility (Kotz et al., 2023; Faccia et al., 2021; Mukherjee and Ouattara, 2021).

Physical risks can affect energy supply and demand, thus inflation. Physical risks can directly affect headline inflation via energy prices and indirectly as energy is an input factor for the production of other goods (Lucidi et al., 2022) or due to a disruption of supply chains (Ciccarelli et al., 2023). Temperature increases have two opposing effects on energy demand: Warmer winters reduce energy demand for heating while warmer summers raise demand for cooling. Overall, the evidence suggests that the negative effect of warmer winters is stronger, resulting in lower energy demand if global temperatures are increasing (Lucidi et al., 2022). Negative effects of temperature increases on energy

¹The natural rate of interest reflects the equilibrium real interest rate that would prevail in an economy without nominal rigidities in wages and prices under full employment (Mongelli et al., 2021).

consumption have been documented in various studies for the United States and the euro area (Considine, 2000; Dowling, 2013; Spinoni et al., 2018). A negative effect on energy demand can also result from the negative impact of higher temperature and extreme events on economic activity. Similar to food prices, extreme weather events tend to increase energy price volatility and uncertainty (Wen et al., 2021).

Also, the transition towards a carbon free economy can affect energy prices. This implies the need to reduce the consumption of carbon-intensive energy, such as fossil fuels. Given that a full substitution of such energy forms with green energy is not possible in the short run, one important instrument to lower carbon emissions is to increase carbon prices, which could lead to persistent upward pressure on energy prices. The resulting impact on headline inflation also depends on the roll-out of the energy transition. Scenario-based projections of transition risks on inflation usually consider two different scenarios related to energy prices: An orderly transition to carbon neutrality characterised by immediate but gradual increases in energy prices, which are anticipated, and an unorderly transition, in which energy price increases are higher, occur later and are not anticipated. An unorderly transition leads to higher upward pressure on inflation (ECB, 2021a; Allen, 2020).

Climate risks may also affect inflation expectations. Persistent inflation rates above the 2% level increase the risk that long-run expectations are de-anchoring from the inflation target of the ECB. This risk is particularly high when prices of goods that are frequently purchased, such as energy and food, are increasing (Carvallo et al., 2017). A recent ECB survey among 90 large and mostly multinational companies shows that two thirds of respondents expect physical climate risks and the energy transition to have no net effect on their business activity (Kuik et al., 2022). However, half of them pointed towards risks stemming from climate change and more than 75% expect to increase their prices, mentioning higher prices of raw materials, energy inputs, and carbon prices as major reasons. However, given that inflation expectations have been fairly stable after the recent period of prolonged inflation, a de-anchoring would probably require substantial price increases, including significant second-round effects. Inflation expectations are also unlikely to increase solely as a result of higher inflation volatility. Overall, climate change can affect inflation expectations, but such effects reflect a propagation mechanism rather than an original source and they will be probably small if the credibility of central banks to maintain price stability is high.

Climate change can also affect headline inflation via changes in productivity and output. Physical risks can reduce total productivity due to lower labour productivity as a result of heatwaves or due to lower capital productivity as a result of capital and infrastructure destruction (ECB, 2021a,b). Lower productivity would lead to upward pressure on inflation. Empirical analyses find such effects, for example in international trade and in the tourism industry (Deryugina and Hsiang 2014; Ciccarelli et al., 2023). The effects of transition risks on productivity are unclear given that they depend on technological and structural changes (ECB, 2021a).

2.2 Quantitative impact of climate change on the economy and implications for monetary policy

Different approaches have been applied to assess the impact of transition risks and physical risks on the economy. The impact of weather fluctuations or extreme weather events, which could provide information about the physical risks, is usually analysed via empirical models based on historical data. In some cases, such estimates rely on climate projections to forecast future effects on inflation. The macroeconomic impact of climate change in the future, including transition risks, depends on several factors, such as the impact of climate change on weather, climate policy measures, or technological change, which are only partially covered by historical data. Therefore, the economic

impact of transition risks is usually gauged via climate models, which account for different scenarios and can also be adopted to analyse the impact of extreme events. A workhorse model in this regard is provided by the Network for Greening the Financial System (NGFS).² Table 1 in the Annex provides a selective overview of the literature on the effects of climate change on inflation.

Scenario-based analysis of transition and physical risks indicate that climate change can have persistent effects on inflation, but that such effects are unlikely to raise inflation above the 2% target in the medium term. The ability of the central bank to affect output and inflation in these scenarios depends on the natural rate of interest, which can restrict the monetary policy space due to the zero lower bound (ECB, 2021a). Results for transition risks suggest that in an orderly transition scenario (with an immediate expected rise of energy prices by around 3.5% per annum) effects on headline inflation are negligible, while in the case of an unorderly transition (with an unexpected and later increase in energy prices by 13.5% per annum) headline inflation increases by 0.5 percentage points (p.p.) after four years (ECB, 2021a). Further simulations analyse different frequencies of disasters as physical risks which are modelled via a combination of both demand and supply shocks. In a baseline scenario, in which the current distribution of such shocks is used and the natural rate of interest is 2%, consumer price inflation (CPI) averages at 2%. In a second scenario, in which more frequent major disasters occur, average CPI drops to 0.9% for a natural rate of interest of 2%. In case of more frequent disasters, inflation increases only in the short-run while negative effects on output reduce inflation in the medium term. (ECB, 2021a).

Several studies have identified a positive effect of both extreme weather events and higher temperature on food price inflation, but estimated medium-term effects for advanced economies on headline inflation tend to be small. The empirical evidence suggests that positive short-run effects on food price inflation are not propagated into headline inflation in advanced economies over the medium term (Faccia et al. 2021; Mukherjee and Ouattara, 2021). For both natural disasters (including droughts and storms) and temperature increases, a cross-country analysis finds substantial effects on food and headline inflation in emerging and developing countries and a rather limited effect in advanced economies (Parker, 2016; Faccia et al., 2021). Kotz et al. (2023) estimate the effects of global warming on inflation for 121 countries based on both historical estimates and climate projections. According to their findings, future warming will increase annual food and headline inflation by a range of 0.9-3.2 and 0.3-1.2 percentage points per year, respectively, depending on the scenario and the empirical specification. They find that the impact of a one degree Celsius increase in temperature on inflation in one month persists for one year. Moreover, climate effects on food prices increase the volatility of headline inflation. Peersman (2023) finds that shocks to food prices contribute up to 30% to euro area inflation volatility in the medium term. Empirical evidence of physical climate risks on energy prices is scarce. Lucidi et al. (2022) analyse the impact of temperature shocks on inflation for six euro area countries (Belgium, France, Germany, Italy, Greece, Spain) from 2000 to 2019. They find that warm spells lead to a moderate downward pressure on headline inflation, which can be attributed to a decline in energy prices.

Further evidence points to nonlinear effects of physical risks on inflation. Several studies find that temperature increases have larger inflationary impacts in hotter months and regions and that hot summers have particularly strong effects on inflation. (Kotz et al., 2023; Ciccarelli et al., 2023; Faccia et al., 2021; Mukherjee and Ouattara, 2021). Such nonlinearities increase uncertainty surrounding future inflation since the effects on inflation and its volatility are more difficult to predict.

² The NGFS is a group of central banks and supervisors with the aim to analyse and enhance the role of the financial system to manage risks and stimulate low-carbon investments for environmentally sustainable development.

Climate change can also affect economic growth and trade. Both temperature changes and extreme weather events reduce output as they impair production and lower productivity. The effects of transition risks on output depend on a variety of factors, such as policies implemented to mitigate climate change and resulting uncertainty. Table 2 in the Annex presents selected empirical evidence on the effects of physical risks on economic growth and international trade. The negative effect on economic growth has been confirmed for many countries and across various samples by several studies (Dell et. al., 2012; Felbermayr and Gröschel, 2014).

Climate change can result in higher volatility in financial markets and increased systematic risks. Both physical and transition risks could materialise in financial distress due to stranded assets or sudden adjustments in financial markets (ECB, 2021a; Carney, 2015; Lane, 2019). Firms with high carbon emissions are for example particularly exposed to future carbon prices and regulatory measures while countries in hot regions are more exposed to temperature increases. There is also the risk that the transition towards a green economy leads to boom and bust cycles of green assets. Whether climate risks of firms are correctly priced by financial markets is an open question. One reason why climate risks might not be correctly reflected in asset prices could be that carbon prices do not fully reflect the external effects of CO₂ emissions. There is some evidence that financial markets already take climate risks into account. Banks in the euro area already charge higher (lower) interest rates to companies with higher (lower) carbon emissions (Altavilla et al, 2023). Moreover, there is evidence that financial markets demand a risk premium for firms with high carbon emissions (Bolton and Kacperczyk, 2021). However, there is also evidence that stock prices of food companies do not completely reflect the risks of climate change (Hong et al. 2019). Financial distress can have large effects on output and inflation and is therefore relevant for central banks, also because it can hamper the monetary policy transmission. Central banks have instruments to mitigate financial distress, as has been shown during the global financial crisis or the sovereign debt crisis in the euro area. The ECB tries to assess financial risks by climate stress tests (ECB, 2021a,b; ECB, 2023c). The latest results show that a faster transition, despite higher energy and investments costs, significantly reduces financial risks in the medium term (ECB, 2023c). This aligns with previous scenario-based estimates by the ECB, which showed that an orderly transition would reduce the probability of asset and capital losses for financial institutions and investors (ECB, 2021a).

Climate change could also affect the natural interest rate. The natural rate of interest is a reference to assess whether monetary policy is tight or loose and is therefore relevant for central banks. A recent survey by Mongelli et al. (2021) suggests that the natural rate of interest is likely to decrease due to climate change. Several transmission mechanisms could lead to a decline in the natural rate, such as precautionary savings in response to uncertainty with regard to physical and transition risks, or negative effects on potential output growth. The impacts of other effects stemming from demographic trends and labour productivity are not clear. A negative impact on the natural rate could be dampened if the green transitions leads to a higher demand for investment. A lower natural rate would imply that monetary policy will hit the zero lower bound more frequently so that central banks will more often have to rely on non-standard policy tools, such as asset purchase. However, estimates of the natural rate of interest come with a high degree of uncertainty, which is likely to increase when the impact of climate change is considered.³

All in all, climate change can have a considerable impact on inflation. Most directly, climate change will have effects on food prices mainly via physical risks and on energy prices mainly via transition risks. Of course, climate change can also have effects on a variety of prices, for example, because it can also

³ For a review on the estimation of natural rate of interest and its role for monetary policy, see Fiedler et al. (2018).

affect output, productivity, or trade and thereby in turn influence inflation, or because of second-round effects of energy price fluctuations. Against this backdrop, climate change will probably lead to more transitory increases in inflation, to a higher volatility in inflation and other macroeconomic variables, and higher uncertainty. Climate change could also lead to persistent upward pressure on inflation, for example, if energy prices are increasing strongly in the transition period towards a carbon-free economy. However, the available evidence suggests that persistent upward price pressure will likely be moderate in magnitude.

Climate change can be challenging for central banks, but does not necessarily compromise price stability. For central banks, it is important to distinguish between transitory and persistent effects of climate change. Transitory effects, e.g. due to weather fluctuations or extreme weather events, on inflation would be less of a concern of central banks because they will fade out anyway and monetary policy measures usually need some time to realise its full effect on inflation. However, in practice it is often difficult to differentiate between transitory and persistent drivers of inflation. Consequently, an increase in volatility and uncertainty will make it more difficult for central banks to identify the main drivers of inflation and, in turn, the appropriate stance of monetary policy. If climate change leads to more persistent upward pressure on inflation, central banks can maintain price stability in the medium term with existing instruments so that the impact of climate change will materialise in relative price changes. High credibility will help central banks anchor inflation expectations and stabilise inflation over the medium term at the desired level. Climate change can also lead to challenges for central banks in other areas. There is the risk that the zero lower bound will be hit more often amid a lower natural interest rate with implications for monetary policy. Moreover, climate change can increase financial market volatility and systemic risks making it more challenging for the ECB to assess financial stability. Finally, climate change could also influence monetary policy transmission although conclusive evidence concerning the effects of climate change on monetary policy transmission is still missing (ECB, 2021a).

3. INSTITUTIONAL FRAMEWORK AND TRADE-OFFS

The primary objective of the ECB is to maintain price stability. The Treaty on the Functioning of the European Union states that the primary objective of the European System of Central Banks is to maintain price stability in the euro area. Secondary objectives shall be only supported without prejudice to the primary objective. The ECB defines this mandate to keep inflation low, stable, and predictable and more concretely by keeping inflation at 2% over the medium term. The mandate of the ECB is in line with the Tinbergen rule that states that one policy instrument is needed to achieve one policy goal because otherwise trade-offs could emerge (Tinbergen, 1952).

Climate change can affect inflation, but measures to foster the green transition are hardly in the scope of the primary objective. To the extent that the consequences of climate change will impact inflation or the effectiveness of monetary policy to maintain price stability, measures that contribute to mitigate climate change could help the ECB to meet its primary objective of price stability in the future (ECB, 2021a). However, while monetary policy tries to maintain stability in the short to medium-run, climate change is a long-run phenomenon and measures to mitigate climate change likely unfold their effects largely beyond the medium term. If trade-offs between stabilising current prices and implementing measures to foster the green transition exist, it is mandatory for central banks to prioritise price stability. If the ECB would tolerate larger deviations from its inflation target this could undermine credibility with respect to its primary objective and in turn de-anchor inflation expectations. However, well-anchored inflation expectations are an important precondition for effective monetary policy and thereby will help the ECB to maintain price stability in the future (Beckmann et al., 2022), in particular if the impact of climate change on inflation will increase. Moreover, it is uncertain to what extent the ECB could contribute to mitigate climate change and how large the impact of climate change on inflation in the future will be. Reasons include that inflation is driven by a variety of factors, which are difficult to disentangle, and that the impact of climate change on inflation depends on different factors, such as technological change. In this regard, successfully mitigating climate change depends crucially on whether governments make efficiently use of their policy tools and how quickly international coordination can be improved.

The secondary objective of the ECB gives some room to consider climate change in monetary policy. According to the Treaty on the Functioning of the European Union, the secondary objective of the ECB is to support the general economic policies of the European Union. These general economic policy aims include balanced economic growth, full employment, and protecting and improving the environment (ECB et al., 2021b). The second objective of the ECB does not comprise a hierarchy between policies of the European Union. Therefore, the ECB has some discretion to prioritise between the policies it supports (ECB, 2021c). In doing so, however, the ECB has to meet several general provisions and principles, such as proportionality, institutional balance, the principles of an open market economy, and equal treatment (ECB, 2021a). This implies that the ECB supports institutions that are responsible to mitigate climate change but does not autonomously address climate change or other policy goals of the European Union and that its prioritisation of policies is not in conflict with the prioritisation of the European Union. These provisions, therefore, limit the extent to which the ECB can engage in the green transition or other policies.

Governments are responsible for reducing carbon emissions to address climate change, leaving only a limited role for monetary policy. Policies to mitigate climate change can have large distributional effects on private households, firms, or regions, for example by increasing the price for or by supporting technologies to reduce carbon emissions (Eurofound, 2021). For social acceptance, it is important that such policies are backed by the democratic legitimisation of governments. The more

the ECB engages in such policies, for which it has no explicit mandate, the more its independence might be called into question. Given that mitigating climate change by a green transition is an important objective, governments have effective tools at hand to reach this goal, including carbon pricing and regulatory measures. Governments have to implement these tools in a way that ensures that the goals with regard to the green transition can be reached largely independently of monetary policy given that central banks follow their main objective of price stability. One reason is, that the contribution of monetary policy is hardly plannable. The ECB stabilises output and prices usually at business cycles frequency around a long-run trend (Woodford, 2003). This implies that the stance of monetary policy on average will be neutral, with expansionary and restrictive stances varying largely symmetrically over time according to the macroeconomic circumstances. This also implies that the ECB will unwind bond holdings after some time when it is warranted to maintain price stability. Against this backdrop, monetary policy can contribute to mitigate climate change within its mandate but will probably only have a limited role.

Monetary policy can make an important contribution to the green transition by efficiently achieving its primary objective. It is widely acknowledged that price stability contributes to sustained growth and to high employment (Bernanke, 2006). For example, price stability helps to allocate resources to the most productive use, as large fluctuation in prices could distort price signals. Price stability also makes future costs of firms better plannable and reduces uncertainty. Therefore, it helps to stimulate investment, including those to facilitate the green transition, which usually have a long investment horizon. By maintaining price stability, the ECB could also contribute to increase its credibility with regard to its primary objective and to anchor inflation expectations at its inflation target, thereby mitigating the impact of climate-related economic shocks on inflation. Moreover, credible monetary policy also supports well-functioning financial markets, which are an important condition for effective monetary policy transmission and, at the same time, will support the green transition.

When supporting the green transition, the ECB has to carefully check for unwanted side-effects. The market for green bonds (bonds that are used to finance green investments) is — while increasing — still relatively small. In 2022, the share of green bonds in total bond issuance in the European Union was below 10% (European Environment Agency, 2023). Therefore, large asset purchase programmes of the ECB tilted towards green bonds could have a disproportionally large impact on this market and potentially distortionary effects (ECB et al., 2021b). If the ECB conducts asset purchases to maintain price stability, at some point it has to unwind its assets holdings when the macroeconomic conditions have changed. As a result, volatility of green assets could increase. Higher volatility could in turn increase uncertainty, which is usually a drag on investment (Bloom, 2009). In “low for long” interest rate environments, the ECB can conduct asset purchase programmes as an additional tool to ease financing conditions. If inflation undershoots persistently the target of the ECB, such as in the euro area in the period between the sovereign debt crisis and the pandemic, there might be room to further increase asset purchases focused on green assets, as inflation is too low anyway and the optimal amount of asset holdings is uncertain.⁴ However, expansionary monetary policy can have negative side-effects. For example, there is evidence that low interest rates can foster a misallocation of resources that in turn dampens productivity (Acharya et al., 2023; Cetto et al., 2016; Monacelli et al., 2023). Moreover, prolonged expansionary monetary policy can result in financial imbalances and increase the risk of financial crises (Grimm et al., 2023). Such side effects would counteract objectives of economic policies of the European Union, such as sustained growth and high employment, that are a secondary objective

⁴ Of course, there are several additional relevant aspects with regard to the appropriate size of asset purchase programmes. For a detailed discussion of quantitative easing programmes see e.g., Fiedler et al. (2016).

of the ECB similarly to the protection of the environment. In turn, such side effects could lower the fiscal space and thereby make it for governments potentially more difficult to foster the green transition.

4. MONETARY POLICY INSTRUMENTS TO ADDRESS CLIMATE CHANGE

The ECB has different measures available to take climate considerations into account. The ECB has already implemented several of these measures or has concrete plans to implement them (ECB, 2021d; ECB, 2022). Some of them are general reactions to the consequences of climate change and are not directly related to market operations. For example, the ECB is expanding its analytical toolkit to better understand the impact of climate change and of policies to mitigate climate change on inflation or financial stability. The ECB also tries to improve statistical data useful for such analyses and has started to tilt its non-monetary holdings (e.g., holdings in the pension fund), which are not subject to the policy mandate, towards lower carbon emissions (ECB, 2023a).

Some of the implemented measures aim to directly support the green transition. The main instrument of monetary policy — adjusting interest rates — leaves little room to take other considerations than price stability into account. However, other instruments of the ECB are somewhat more flexible with regard to secondary objectives. For example, the ECB has implemented asset purchase programmes, which have become an additional tool when interest rates hit the zero lower bound. Moreover, the ECB can adjust regulatory measures, such as eligibility criteria for collateral in their market operations. For example, the ECB will introduce compliance with disclosures for corporate assets under the Corporate Sustainability Reporting Directive (CSRD) as a requirement for eligibility as collateral in their market operations beginning in 2026. As a large part of assets that are generally eligible are not covered by the CSRD (e.g., asset-backed securities), the ECB wants to foster better climate-related disclosures for such assets. In doing so, the ECB will improve information available for markets to reduce and prevent a systematic mispricing of climate-related risks. The ECB has implemented or is preparing measures that have a more direct impact on financial markets. First, it has started to tilt its corporate bond holdings towards green assets. Second, it will adjust the collateral framework with the aim to limit the share of assets from issuers with a high carbon footprint beginning during the year 2024.

The ECB has started to deviate from the market neutrality principle in its corporate bond holdings to take the climate performance of issuers into account. When the ECB is implementing its monetary policy, it usually only aims to affect general market conditions but not relative prices of assets, which could have unintended consequences and may conflict with the mandate of the ECB (Cœuré, 2015). Therefore, the ECB used to purchase corporate bonds in proportion to their market capitalisation relative to all eligible bonds. With regard to the institutional requirements, this concept of market neutrality complies with the provision of the Treaty on the Functioning of the European Union to “act in accordance with the principle of an open market economy with free competition, favouring an efficient allocation of resources”. From a general perspective, monetary policy interventions will never be completely neutral, for example because firms or industries are differently affected by changes in the interest rate or because only firms active in the capital market are directly affected by asset purchase programmes. However, these effects are accepted because price stability is seen as an overarching objective and because monetary policy is expected to be conducted largely symmetrically around a neutral stance so that its long-run impact might be small. With regard to carbon emissions it turns out that the corporate bond purchases of the ECB were biased towards firms with relatively high carbon emissions (Liebich et al., 2021). One important reason is that firms with high carbon emissions are usually relatively capital-intensive and therefore are issuing more bonds than other firms. In 2022, the ECB started to tilt its corporate bond holdings from the corporate sector purchase programme (CSPP) and the corporate bonds bought in the pandemic emergency purchase

programme (PEPP) towards issuers with a better climate performance. To do so, the ECB redirected its reinvestments within the purchase programmes based on a climate score.

It is not easy to be green.⁵ When taking climate considerations into account in its market operations, the ECB has to consider several aspects. For example, simply underweighting bonds of high carbon emitters could distort incentives to lower carbon emissions for firms that have the highest emissions. Therefore, the ECB uses several indicators — in addition to past carbon emissions also plans to reduce emissions and the quality of disclosures with regard to emissions — to build a score that guides the weight within their bond holdings (ECB, 2023b). However, there is lack of market standards for green investments and forward-looking indicators with regard to the green transition of firms complying with climate goals. Also, there is no general consensus concerning the techniques and industries to be qualified as green, for instance in the case of nuclear power generation or natural gas plants. Therefore, it is difficult to assess the impact and the efficiency of the criteria applied by the ECB (ECB, 2021a). In this regard, it is also uncertain how the tilting of bond holdings of the ECB interacts with other measures to foster the green transition implemented by governments. By tilting its bond holdings towards issuers with a better climate performance, the ECB sets its priority on one specific secondary goal as it is difficult to assess whether its bond holdings are biased with regard to other secondary objectives, such as sustainable growth, full employment or, more recently, defence.

Financial market considerations may also play a role for the ECB. The ECB may also improve capital allocation on financial markets (Schnabel, 2021) and reduce risks in their bond holding related to climate change (ECB, 2023b). The efficient allocation of capital might be hampered to the extent that externalities of carbon emissions are not correctly priced on capital markets, for example if current carbon prices do not fully reflect externalities. If externalities are fully priced in, there is the risk that assets of firms with high carbon emissions suffer severely. However, it is difficult to assess to what extent risks related to carbon emission are appropriately priced on capital markets — respective evidence is mixed — and whether the ECB can contribute to a more appropriate pricing. Moreover, also green assets could be subject to boom-and-bust cycles, for example due to technological change, regulatory risks or herding, and thereby create risks for portfolios.

The impact of the ECB's measures on the green transition is difficult to assess, but probably small. Corporate bond holdings account only for a small share in the asset purchase programmes of the ECB. Since the beginning of 2022, the share of corporate bond holdings in total bond holdings of the Asset Purchase Programme (APP) is relatively stable at about 10% with a volume of about 300 billion euros. The share of corporate bond holdings in the Pandemic Emergency Purchase Programme (PEPP), which overall size is roughly half of that of the APP, is below 10%. The share of corporate bond holdings in the total volume of eligible bonds is about 20%. However, the impact on total corporate finance conditions is lower than this relatively large share suggests. First, not all corporate bonds are eligible for the asset purchase programmes, because several eligibility criteria apply. In particular, only bonds of non-financial corporations are eligible for these programmes, while a large share of bonds are issued by financial corporations. Second, corporations finance themselves also by means of equity capital and bank loans. In particular, bank loans are relatively important for the financing of corporations compared to bonds in euro area. In 2022, the liabilities of non-financial corporations in bank loans was about three times as large as liabilities in bonds. Empirical evidence suggests that the corporate bond purchases have improved financing conditions for non-financial corporations. However, yields of non-eligible bonds have declined due to portfolio rebalancing of investors (Mäkinen et al., 2020; Todorov, 2020; Zaghini, 2019). The adjustment of asset purchases based on climate scores

⁵ Hauser (2021).

implies that the relative effect on financing conditions of corporations with a good climate score will be reduced to the extent that portfolio rebalancing effects will also lower yields for bonds of corporations with a bad climate score. The ECB implemented its tilting approach to its bond holdings in a period when it did not increase its bond holdings anymore, but only reinvested redemptions. Available data indicate that the reinvestments made in the fourth quarter — the ECB started titling its bond holdings towards issuers with a better climate score in October 2022 — were considerably less carbon-intensive than the reinvestments made before (Elderson and Schnabel, 2023). However, in its efforts to tighten monetary policy in accordance with its primary objective, the ECB stopped to reinvest redemptions within the APP in July 2023 and thereby slowed the tilting. As the ECB apparently has no plans to actively rebalance its portfolio towards bonds issuers with a better climate score, the strategy of the ECB to guide its corporate bond purchases by climate considerations, therefore, will only become fully visible in its bond holdings when the ECB at some point will loosen its monetary policy again and considers purchases of corporate bonds necessary to maintain price stability. Finally, it is not obvious whether a lack of finance is a major impediment for the green transition compared to earnings prospects, regulatory burdens, or pricing of external effects.

The collateral framework of the ECB is another instrument to address climate change considerations. Commercial banks pledge assets as a collateral for the refinancing operations of the ECB. Depending on the rating, a different discount/haircut is applied to these assets. From a historical perspective, the collateral framework is closely related to the lender of last resort function of a central bank. Today it is also known as the “Bagehot rule”, which argues that in a financial panic a central bank should lend fast and forcefully against good collateral (Bagehot, 1873). The refinancing operations of the ECB fulfilled this crisis character during the Great Financial Crisis, the Euro Crisis and the early stages of the pandemic (Schnabl and Sonnenberg 2020). The collateral framework was changed several times during these crisis periods. For example, one of the first measures during the early stages of the pandemic was the easing of the risk tolerance of the Eurosystem and hence the reduction of haircuts applied to bonds of a lower rating and the inclusion of Greek sovereign bonds (ECB 2020). Another variant of refinancing operations are targeted longer term refinancing operations (TLTROs), which were instrumental in the pursuit of the ECB to easing the monetary stance at the zero lower bound (Sonnenberg 2023). These refinancing operations are targeted to increase the credit supply of commercial banks. During the early phase of the pandemic these operations were remunerated negatively, thus commercial banks could earn extra interest income, when they engaged in the issuance of new loans or at least held their credit supply constant. Also, for these operations commercial banks have to pledge a collateral.

In principle the universe of eligible collateral could be tilted towards “green” assets by the ECB in order to consider climate change risks. This tilting would, however, be facing several caveats. In response to the crisis the ECB enlarged the universe of eligible collateral in order to prevent a financial panic from developing. During the pandemic, the collateral framework was also eased to “fallen angles”, i.e. bonds which were downgraded during the pandemic. It is doubtful how credible an exclusion of “non-green” assets would be in a crisis period, when a financial panic is looming. Therefore, the impact in the first place could be limited if the announcement is not credible. Another caveat is that a non-controversial rating for green and non-green assets is required, otherwise window dressing and green washing activities could undermine the approach.

Financing conditions of low-emission firms could benefit, from tilting the collateral framework towards green assets, but the overall effect on green investments will be small. Giovanardi et al. (2023) find that financing conditions of greener (lower emissions) companies would improve as banks would prefer lending towards these sectors in an adjusted collateral framework. The authors report

that a possible wedge between the yields of green and non-green sectors might emerge, while the yields on green bonds fall and the yields of conventional bonds rise. This per se could create incentives for more green investments. However, the authors report that the effects on green investments are low. Additionally, the change in the collateral framework has an impact on the leverage ratio of green companies, which increase their debt financing. The authors conclude that the effect on green investments would probably be small and that this policy is an inferior substitute for an explicit carbon taxation.

In the spirit of TLTROs, green targeted longer-term refinancing operations (GTLTROs) have been suggested as an additional policy tool. GTLTROs are based on the idea to adopt the objective and modalities of standard TLTROs, while including incentives for banks to issue credits towards companies investing in green activities (ECB, 2021a).

It has been argued that common TLTROs support unsustainable lending practices via cheap refinancing options. The correction of such market failures and improving financial stability via a reduction of environmental and climate-related financial risk are arguments brought forward for green TLTROs (van 't Klooster and van Tilburg, 2020). There are two different ways of green longer-term refinancing operations, which have been proposed (van 't Klooster and van Tilburg, 2020). Either the interest rates banks pay would be adjusted according to the volume of green loans issued by the bank or the volume of GTLTRO credits depends on the percentage of new green loans issued by the bank. The potential implementation of GTLTROs raises several key questions and the resulting challenges make an implementation in the near future unlikely.

The concrete implementation of GTLTROs would further increase the reporting effort and require an uncontroversial classification of green and non-green projects. While the ECB is sympathetic to the idea of GTLTROs, it has been pointed out that acquiring the adequate information, ensuring banks are able to collect relevant data and defining a verification process represent serious challenges which need to be overcome first (ECB, 2021a). The distinction between green and non-green companies raises several questions. The ongoing discussion regarding Environmental, Social, and Governance (ESG) ratings reflects these issues. Such ratings are designed to grade companies and countries based on the idea that ESG investments are of key relevance for meeting emission targets (Wang et al., 2023). As a result, such ratings have been considered as an important instrument for green finance policies (Zhang, 2023). However, ratings can differ significantly depending on the provider, possibly reflecting ambivalent or different methodologies. Different ESG ratings can display correlation below 50% (Billio et al., 2021). Divergent ESG ratings make it therefore difficult for banking supervision or lenders to achieve relevant information (Zhang, 2023). Given these shortcomings, the implementation of green targeted longer-term refinancing operations is not straightforward and the benefits with regard to financial stability or a green transition are not obvious. In June 2023, the European Commission has published, as part of its [sustainable finance package](#), a legislative proposal to introduce rules for ESG ratings providers to improve transparency and reliability.

5. CONCLUSION

Climate change can have considerable macroeconomic effects that are relevant for central banks. Physical risks include implications of gradually rising temperatures and a higher incidence of extreme weather events. Transition risks arise from initiatives of governments to decarbonise the economy such as carbon pricing or regulatory measures. Both can directly impact inflation, in particular by leading to upward pressure on food or energy prices and higher volatility. They can also affect output, productivity, or trade and thereby indirectly affect inflation. Climate change tends to increase macroeconomic volatility and can lead to financial market instabilities, for example because some firms are particularly exposed to the impact of climate change. Some of the effects of climate change will have only a temporary impact on inflation and are, thus, less of a concern of central banks. However, they lead to a higher inflation volatility and increase overall uncertainty, making it more difficult to identify the main drivers of inflation and the appropriate stance of monetary policy. Increasing carbon prices could lead to more persistent upward pressure on inflation. However, central banks have effective tools to stabilise inflation so that these effects should mainly result in relative price adjustments. Overall, climate change could make it more challenging for central banks to achieve their primary objective, but they have the instruments to maintain price stability amid climate change.

Governments are responsible for addressing climate change, leaving only a limited role for the ECB. Policies to mitigate climate change can have large distributional effects. Therefore, it is important that such policies are backed by the democratic legitimisation of governments. Governments have effective instruments to achieve this goal, including carbon pricing and regulatory measures. Governments have to implement these tools in a way that ensures that a green transition can be achieved independently of monetary policy support. The mandate of the ECB leaves some room to take climate considerations into account as part of its secondary objective, which is to support the general economic policies of the European Union, includes protecting and improving the environment. However, secondary objectives shall be supported without prejudice to the primary objective of price stability. Against this backdrop, the ECB will only have a supportive role in mitigating climate change.

The ECB has taken several measures to account for climate considerations. Some of these measures are general reactions to the potential consequences of climate change, such as improving the analytical toolkit with regard to the macroeconomic impact of climate change or conducting climate stress tests to assess the impact of climate change on financial markets. Yet, the ECB has also adjusted its monetary policy operations to support the green transition, in particular the tilting of its corporate bond holdings towards issuers with a better climate score. Moreover, the ECB plans to adjust eligibility criteria for its market operations with regard to better climate-related disclosures and climate scores of issuers. Achieving price stability is the most important contribution of monetary policy to the green transition. Price stability contributes to sustained growth and high employment and stimulates investment. Moreover, it helps to firmly anchor inflation expectations which will support achieving price stability in the future when the impact of climate change on inflation may increase. The impact of other measures of the ECB on mitigating climate change is probably small. The extent to which the ECB will be supportive will vary over time, given that the ECB aligns policies, including the volume of bond holdings, to its primary objective.

There could be unwarranted side effects the ECB has to consider when supporting the green transition. The ECB has instruments that allow to efficiently achieve price stability, however, they might be not efficient in supporting other objectives. Moreover, there is a lack of market standards for green investments and forward-looking indicators with regard to the green transition. Therefore, it is difficult to assess the impact of the measures of the ECB with regard to supporting the green transition

and how they interact with other measures implemented by governments. The more the ECB would try to support the green transition the stronger potential conflicts with its mandate and the higher the risks for a loss of its credibility with regard to its primary objective and a de-anchoring of inflation expectations. There is even the risk that in a tightening phase monetary policy could to some extent discriminate against green investment if in order to achieve its primary target it should find it necessary to unwind bond holdings, which have been accumulated with a disproportionate share of green assets. Against this backdrop, the ECB has also to carefully evaluate potential additional measures to support the green transition, such as green targeted longer-term refinancing operations.

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ANNEX

Table 1: Overview of literature on inflation and climate change

Study	Sample period	Country	Variable explained	Measure of climate risk	Estimated effect
Allen et al. (2023)		France	GDP, consumer price inflation	Transition shocks (e.g., disorderly carbon taxation)	Transition might induce inflation deviations ranging between -0.8 and +2 p.p., depending on the scenario
Ciccarelli et al. (2023)	01/1991-12/2019	Germany, France, Italy and Spain	Consumer price inflation and several components	Temperature anomalies	Heterogenous effects of temperature mean and variability shocks; in summer, increases mean temperatures increase inflation
Heinen et al. (2019)	2001-2012	15 Caribbean countries	Consumer price inflation	Natural disasters (hurricanes and floods)	Hurricanes and floods lead to inflation, especially in the case of food prices;
ECB (2021a)		Euro area	Headline and core inflation	Transition scenarios: orderly and disorderly transition to carbon-neutral economy	Orderly transition: negligible effects on inflation; disorderly transition: 0.5 p.p. increase of headline inflation above the baseline after four years
Faccia et al. (2021)	1990-2018	48 countries	Consumer, food and producer price inflation	Temperature anomalies	Hot summers increase food prices by 0.38% in the short run; the effect is stronger for emerging economies; in the medium term, negative effects on inflation occur
Kotz et al. (2023)	1991-2020	121 countries	Consumer and food price inflation	Temperature (global warming)	Future warming could increase annual headline inflation by 0.32-1.18 p.p. per year until 2035; even stronger effects on food inflation
Lucidi et al. (2022)	01/2000-12/2019	Belgium, France, Germany, Italy, Greece and Spain	Consumer and energy price inflation	Temperature anomalies (warm and cold spells)	Warm spells incur (small) downward pressure on headline and energy prices; cold spells show mixed results; annual headline inflation was 0.05% in 2015-2021 due to temperature anomalies
Mukherjee and Ouattara (2021)	1961-2014	107 countries	Consumer price inflation	Temperature anomalies	Temperature shocks induce inflationary pressures, potentially persisting several years; 1% increase in temperature induces inflation increase of 2.6%
Parker (2016)	1980-2021	212 countries	Consumer, food, housing and energy price inflation	Natural disasters (droughts, storms, earthquakes)	Heterogenous effects: results differ between rich and poor countries and between types of disasters; disasters can have large and persisting effects on inflation in emerging and developing countries

Table 2: Overview of literature on economic activity and climate change

Study	Sample period	Country	Variable explained	Measure of climate risk	Estimated effect
Dell et al. (2012)	1950-2003	125 countries	Aggregate output, GDP components, Political instability	Temperature and precipitation	Increase by 1 degree Celsius reduces economic growth on average by 1.3 p.p. in a poor country
Deschênes and Greenstone (2007)	1978 - 2002	USA	Agricultural profits	Temperature and precipitation	Overall, climate change leads to 4% increase in annual agricultural profits
Felbermayr and Gröschel (2014)	1979-2010	108 countries	Growth rate of real GDP per capita	Natural disasters	Natural disasters negatively affect real GDP per capita; low- and middle-income countries experience stronger effects; weakest 95% of disaster years cause a GDP loss of up to 0.46%
Felbermayr et al. (2022)	1992-2013	24,000 grid cells, covering area of 197 countries	Night-light emission as a proxy for economic activity	Local weather anomalies (storms, precipitation, droughts, cold spells)	Weather anomalies tend to reduce night-light growth, on average between 0.1 and 0.3 p.p.
Jones and Olken (2010)		USA and "World"	Exports	Temperature	Increase by 1 degree Celsius reduces a poor country's export growth rate by 2.0- to 5.7 p.p.

Climate considerations have entered the agenda of the ECB in recent years. The ECB has intensified its analyses of the macroeconomic impact of climate change and started to evaluate and implement more active approaches and best practices to support the green transition. In this paper we discuss how climate change could affect monetary policy, other policies available to the ECB to support the green transition, and potential trade-offs with its primary objective of price stability.

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