

Central Banks and the Transition to a Low-Carbon Economy

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March 2018

Discussion Note 2018/1

ABSTRACT

Climate change is a fundamental challenge for our societies. Containing it will require a profound and radical transformation of our economic system, including a substantial reorientation of investments toward low-carbon technologies. The question to what extent central banks can and should contribute to this effort is moving up agendas worldwide. Building on the research presented at a CEP DNB workshop on “Central Banking and Green Finance” in November 2017, this discussion note explores policy options available to central banks to contribute to the transition to a low-carbon economy. The studies presented in the workshop reassert that climate change is a potential risk for the stability of the financial system. Against this background, and as a first step, central banks should develop a comprehensive evaluation of climate-related systemic risks in the financial sector. They should also consider regulatory measures to mitigate these risks, in particular by implementing higher capital requirements for loans to carbon-intensive economic activities – a measure which would support the transition to a low-carbon economy, increase capital levels and thus strengthen financial system stability. Academic research also highlights that current large-scale asset purchases by central banks are biased toward incumbent carbon-intensive sectors. Central banks should further assess these biases and ensure that climate-related risks are adequately reflected in their own balance sheets as well as their collateral frameworks.

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1 INTRODUCTION

Failure of climate change mitigation and adaptation ranks among the top five global risks identified by the World Economic Forum (2018), in terms of both likelihood and impact. Scientists have clearly highlighted the role of greenhouse gas emissions linked to human activities as the main driver behind climate change (see, e.g., IPCC, 2014). Politicians have acknowledged that climate change threatens our societies. With the Paris Agreement, adopted in 2015, the world community committed to efforts aimed at keeping the global temperature rise below 2 degrees Celsius above pre-industrial levels.

Reaching this goal requires a profound and radical transformation of our economic system, and thus a substantial reorientation of capital flows. Investments in new low-carbon technologies must increase drastically. Investments in incumbent carbon-intensive technologies must be reduced.¹ The Paris Agreement reflects this by highlighting the need to make finance flows consistent with a low-carbon and climate resilient pathway.

The question to what extent central banks can and should contribute to this effort is moving up agendas worldwide. A key factor for this increasing spotlight on central banks is the growing role they have taken in the economy since the 2007-2008 financial crisis. To stabilize the financial system and to foster the economic recovery, major central banks have created unprecedented amounts of money. Between 2007 and 2017, the Federal Reserve, the European Central Bank and the Bank of Japan injected more than USD 10 trillion into financial markets, which has more than tripled the aggregate size of their balance sheets.² Since the crisis, central banks, alongside other financial regulators, have also implemented new macroprudential measures to strengthen the financial system.

Do these extraordinary actions taken by central banks support or hinder the transition to a low-carbon economy? Do they increase or reduce climate resilience? And which alternative policies could central banks implement within their mandate to ensure policy coherence with the commitments their countries have made in the Paris Agreement?

This note explores answers to these and related questions and suggests policy options for central banks to play a more active role in addressing the fundamental threat of climate change. It builds on the research presented by academics and practitioners at the workshop on “[Central Banking and Green Finance](#)” co-organized by the Council on Economic Policies (CEP) and De Nederlandsche Bank (DNB), the Dutch central bank, in November 2017, in

¹ IPCC (2014), for example, estimates that, to limit global warming to 2°C above pre-industrial levels, annual investments in conventional fossil fuel technologies associated with the electricity supply sector must decline by about 20% compared to 2010 while annual investments in low-carbon electricity supply must double compared to 2010.

² Source: Yardeni Research Inc. (2018). *Global Economic Briefing: Central Bank Balance Sheets*.

Amsterdam. The conclusions are our own and the results highlighted in this note do not cover all the issues addressed during this workshop.

The next section focuses on the impacts of climate change and the transition to a low-carbon economy on the stability of the financial system. It argues that physical, transition and liability risks from climate change are likely to weaken financial stability and highlights macroprudential measures to mitigate these risks. Section 3 analyses the effects of large-scale asset purchase programs implemented by central banks since the 2007-2008 financial crisis on the transition to a low-carbon economy and suggests policy alternatives to increase consistency with a low-carbon and climate resilient pathway. Section 4 proposes further central bank measures to foster the alignment of financial markets with climate goals. Section 5 concludes with the following policy proposals:

- Central banks should develop a comprehensive evaluation of climate-related systemic risks in the financial sector. This would set standards for such assessments and help investors adequately price climate-related risks.
- Central banks should consider regulatory measures to mitigate climate-related risks for the financial system, in particular by implementing higher capital requirements for loans to firms with carbon-intensive economic activities – a measure which would support the transition to a low-carbon economy, increase capital levels and thus strengthen stability in the financial system.
- Central banks should further assess the biases toward carbon-intensive activities in their asset purchase programs and ensure that climate-related risks are adequately reflected in their own balance sheets as well as their collateral frameworks.

All three proposals would send clear policy signals in-line with the objective of a transition to a low-carbon economy to investors and financial institutions. They would also foster the alignment of financial markets with climate goals.

2 MACROPRUDENTIAL REGULATION, FINANCIAL STABILITY AND CLIMATE-RELATED RISKS

The risk that climate change poses to financial stability is taken seriously by a growing number of central banks and financial regulators.³ It is also increasingly scrutinized in academic research.⁴ This section takes a closer look at the sources of climate-related risks for the financial system. It outlines first that carbon-intensive firms are likely to bear higher climate-related risks than others, that climate change costs as well as funding the transition

³ See, e.g., studies by the DNB (Regelink, Reinders, Vleeschhouwer and van de Wiel, 2017, and Schotten, van Ewijk, Regelink, Dicou and Kakes, 2016) and the Bank of England (Scott, van Huizen and Jung, 2017).

⁴ See, e.g., Battiston, Mandel, Monasterolo, Schütze and Visentin (2017), University of Cambridge Institute for Sustainable Leadership (2016) and Dietz, Bowen, Dixon and Gradwell (2016).

to a low-carbon economy will require increasing levels of debt and leverage, which weakens financial stability, and that central banks should develop a comprehensive assessment of climate-related systemic risks in the financial sector to evaluate its magnitude. It then argues that a macroprudential measure such as higher capital requirements for loans to firms with carbon-intensive economic activities could both dampen climate-related risk for the financial system and give an incentive for banks to shift their loan portfolios toward low-carbon technologies.

2.1 CLIMATE-RELATED RISKS FOR THE FINANCIAL SYSTEM: SOURCES AND SCENARIOS

Climate change engenders three kinds of risks for the financial system: physical, transition and liability risks (Batten, Sowerbutts and Tanaka, 2016). Physical risks stem from potential economic and financial losses caused by climate-related hazards. Transition risks can be defined as the risks of economic dislocation and financial losses associated with the transition to a low-carbon economy. Transition risks also include the costs of a possible tightening of carbon emission policies through, for example, the implementation of a carbon price or emissions restrictions (i.e. transition risks include policy risks). Liability risks materialize when firms are judged legally responsible for climate-related physical and transition losses and must financially compensate other parties.

Climate change induces risks for individual market participants, but also represents a risk for the financial system as a whole – i.e. a so-called *systemic* risk. It is worth noting here that even if individual participants correctly reflect climate-related risk in their own decisions, this does not preclude climate-related risks to be a systemic source of risk for financial markets.⁵ Central banks are generally responsible for guaranteeing the stability of the financial system as a whole and thus more concerned by systemic risks than by risks in individual financial institutions.

Carbon-intensive economic activities are likely to face higher climate-related risks

Investments in incumbent carbon-intensive technologies and in new low-carbon technologies alike face climate-related physical risks. However, carbon-intensive technologies are more likely to become obsolete and to face higher abatement costs resulting from carbon policies. Thus, everything else equal, they face higher transition costs than others to adapt to the standards required by a low-carbon productive system. They are also more likely to be held legally responsible for environmental damages and thus to have to compensate for the losses that third parties may seek to recover. In other terms, carbon-

⁵ Systemic risk arises, for example, when individual financial institutions fail to internalize the fact that their own choices have an externality on the payoffs of other financial institutions. A bank failure, for example, can trigger a cascade of other failures which has macroeconomic consequences that is not reflected in banks' individual strategy choices. Macroprudential regulation can be a way to mitigate risk at the collective, i.e. systemic, level (see, e.g., Acharya, 2009).

intensive firms bear higher transition and liability risks than firms based on low-carbon technologies and thus a higher level of climate-related risk.

This higher level of climate-related risks for firms with carbon-intensive activities is relevant for the financial sector: higher transition and liability costs make them more likely than others to face solvency and liquidity problems when servicing their bonds and loans. This translates into higher credit risks for the financial sector in general and for the banking sector more particularly.

To what extent climate-related risks are already priced in by financial market participants remains an open question. Görgen, Jacob, Nerlinger, Rohleder and Wilkens (2017) assess the explanatory power of a carbon risk factor in factor models and suggest that exposure to carbon risks is an important driver for the variation in stock returns. Campiglio *et al.* (2017) argue that, despite promising recent advancements, rating agencies do not fully incorporate climate-related risk in their ratings yet. Their focus on short term risks (i.e. up to one year) make them also more prone to underestimate climate-related risk that could materialise in the mid to long term. As key component for the valuation of some asset classes (e.g. bonds and loans), these ratings may thus introduce biases in prices. Delis, de Greiff and Ongena (2017) assess whether banks price the risk that fossil fuel reserves will become stranded. Using data on syndicated loans for the period 1996 to mid-2017, they find that banks have not charged higher prices for loans to fossil fuel firms that are the most exposed to climate policy risks until 2015. They also point out, that from 2015 onwards, data show initial indications that banks might have started to price in this risk. A longer data span is nevertheless needed to confirm this new trend.

Climate-related risks for financial stability are likely to increase even with a transition to a low-carbon economy

The transition to a low-carbon economy will require trillions of dollars in investments in the next 20 years to fund clean and sustainable infrastructures.⁶ A significant share of these investments is likely to be debt-based. Giraud, Mc Isaac and Bovari (2017) study the interactions between debt, investment and climate change dynamics. They show that debt must increase in the future both to cope with higher costs related to climate events, and to fund the abatement costs and investments associated with the transition to a carbon neutral economy. They warn that if no policy action is taken to internalize the cost of carbon emissions – e.g. with a price for carbon – the level of debt is likely to explode in the long term to cope with the increasing output losses induced by climate change. If adequate policy measures are taken in time, debt can be contained to sustainable levels in the long term, but a significant increase of aggregate debt remains nonetheless necessary in the short and

⁶ The New Climate Economy Report (Global Commission on the Economy and Climate, 2014) estimates that USD 90 trillion are needed at the world level over the next 15 years to fund clean infrastructure that would make it possible to reach zero net CO₂ emissions.

medium term. In both cases, Giraud *et al.* expect the productive sector to leverage its debt to compensate for the output losses due to climate change and to fund the transition costs.⁷

Higher debt levels are a source of risk for the stability of the financial sector, especially if they are accompanied by a higher leverage – i.e. by more risk-taking. More debt and higher leverage might translate into higher losses for banks through more non-performing loans, and for the financial sector through higher default rates on bonds. This can then translate into financial instability. Several empirical studies have documented the link between fast-growing debt and banking crises.⁸ Two situations can magnify the danger of growing debt for financial stability: first, when market prices do not correctly reflect the risks associated with financial assets and second, when banks are insufficiently capitalised to withstand losses resulting from a materialisation of these risks.

A comprehensive assessment of climate-related systemic risk is needed

To minimize the risks for financial stability resulting from climate change, supervisors, including central banks, must make sure that financial markets correctly reflect climate-related risks in asset prices and that the financial institutions that are the most exposed to these risks are adequately capitalized. A comprehensive and accurate assessment of climate-related systemic risk is key to evaluate whether these two conditions are fulfilled.

While some central banks have started working on this issue, to our knowledge, none of them has put together a comprehensive assessment of climate-related systemic risks in the financial sector.⁹ To fill this gap, there is an urgent need to develop a better understanding of the complex and evolving dynamics linking environmental, macroeconomic and financial systems, through theoretical and empirical research. Assessing systemic risk is traditionally in the remit of central banks. In similar cases, e.g. with regard to housing markets, they have developed stress tests to gauge potential systemic risks. They could use the same approach for climate-related systemic risks. However, stress tests focused on climate risks are still under-researched, and no standards exist on how to design and apply them.

Central banks should play a key role in assessing the resilience of financial systems to climate-related shocks. This information is not only crucial for regulators, but also for financial market participants to adequately reflect climate-related risks in their investment decisions. Developing and disclosing a comprehensive measure of systemic risk that would include physical, transition, and liability risk would thus be a critical contribution by central banks to the alignment of financial markets with climate goals.

⁷ Debt leveraging is used to generate sufficient volumes of investment, but is also exacerbated by the possibility for firms to borrow money to finance dividends – a possibility that is considered in Giraud *et al.*'s model.

⁸ See, e.g., Borio and Lowe (2002) and subsequent BIS studies on credit growth and financial stability.

⁹ Regelink, Reinders, Vleeschouwer and van de Viel (2017) is, to our knowledge, the most comprehensive study on this issue and focuses on the Dutch case.

2.2 MACROPRUDENTIAL MEASURES FOR CLIMATE-RELATED RISK MITIGATION

The research presented in the previous section highlights that climate change and the transition to a low-carbon economy pose risks to financial stability. This section argues that higher capital requirements for loans to carbon-intensive economic activities would mitigate this risk and give an incentive to investors to shift to a low-carbon economy.

Macroprudential policies can be used to mitigate climate-related risks for financial stability

Supervising authorities have experience in managing systemic risk and macroprudential tools to cope with it. Capital requirements are at the core of their toolkits. The Basel III framework, for example, introduced a countercyclical capital buffer to dampen risks associated with periods of excess aggregate credit growth. The effectiveness of such measures is still open to debate, but recent international empirical evidence seems to validate that higher capital requirements are associated with lower credit growth¹⁰ and thus with less risks for financial stability.

Note also that, when confronted with risks on specific debt markets, regulators can use sector specific macroprudential policies. In Switzerland for example, authorities have introduced higher capital requirements for banks issuing mortgages in reaction to imbalances developing in the Swiss housing markets. This measure is intended both to dampen mortgage growth and to increase bank capital for banks exposed to higher risks on unbalanced markets.

Against this background, higher capital requirements for loans to firms with carbon-intensive economic activities seem an adequate solution to cope with the higher climate-related risk that they face. It would be in-line with existing macroprudential regulation: higher requirements are already widely used to dampen risk and measures aimed at specific segments of the credit market are also common practice.

However, as pointed out by van Tilburg and Boot (2017, p. 27): “the reality is that risk weights do not take into account climate-related risks. Risk modelling in banking (and Basel) is based on models that do not deal with climate-related risks, and largely exclusively based themselves on historical data.” Climate-related risk thus would add to the risks that are reflected in current capital ratios.¹¹

At the same time, it is important to be conscious of the fact that higher capital requirements pose a trade-off for regulators: they must be high enough to ensure financial stability but not too high as to prevent banks to provide an adequate amount of loans to the economy. Finding the right balance might be an arduous task especially because, as pointed out by van

¹⁰ See, e.g., Cerruti, Claessens and Laeven (2017) or Budnik and Kleibl (2018).

¹¹ This also speaks in favor of higher capital requirements for carbon-intensive loans rather than lower capital requirements for low-carbon loans which have been proposed by the European Banking Federation (2017).

Tilburg and Boot, risk weighting is “more art than science”. How to fix the right level of capital requirements is still discussed and is a challenge for a new phenomenon like climate change for which no historical data are available.

Higher capital requirements for carbon-intensive loans would align banks’ loan portfolios with climate goals

Higher capital requirements for loans to carbon-intensive activities would change the relative cost of lending for banks: it would make loans to carbon-intensive activities more expensive for them than loans to low-carbon ones. This creates an incentive for banks to lend relatively more to low-carbon firms. Higher capital requirements for carbon-intensive loans would thus change the mix of loans provided by banks and align it with a low greenhouse gas emissions and climate resilient pathway.

Recent evidence shows that capital requirements have an impact on bank lending activities (see previous section). Higher capital requirements on carbon-intensive loans are thus likely to decrease the amount of loans given by banks to firms using carbon-intensive technologies. Whether this transmission channel would induce a significant shift in banks’ loan portfolios toward low-carbon activities is still an open question. However, as pointed out by van Tilburg and Boot, such a change in macroprudential regulation would in any case send a clear signal on the commitment of financial authorities to the transition to a low-carbon economy, which could significantly affect market expectations.

Higher capital requirements for loans to carbon-intensive firms seem thus to be a win-win policy option: first, they would increase the resilience of the financial system by adding a capital buffer to banks to reflect climate-related risks and, second, they are likely to create an incentive for banks to lend relatively more to economic activities in-line with the transition to a low carbon economy. As pointed out by the EU High-Level Expert Group on Sustainable Finance in its interim report (2017, p. 32) " a ‘brown-penalising’ factor, raising capital requirements towards sectors with strong sustainability risks, would yield a constellation in which risk and policy considerations go in the same direction. Moreover, it would be more focused and easier to rationalise as capturing the risk of sudden value losses due to ‘stranded assets’."

3 LARGE-SCALE ASSET PURCHASES AND THE TRANSITION TO A LOW-CARBON ECONOMY

Large-scale asset purchases, also referred to as quantitative easing, is one of the unconventional policy measures that central banks have implemented to stimulate economic activities in response to the 2007-2008 financial crisis. The sheer size of the amounts purchased by central banks since then has profoundly impacted financial markets. However,

studies on the composition of these purchases and the biases they entail remain scarce. The next section presents initial findings on the biases in large-scale asset purchase programs and the carbon exposures that result from them. The following section looks at the impact on the economy and the alignment with low-carbon pathways of alternative large-scale asset purchase programs that central banks could implement.

3.1 CARBON INTENSITY OF LARGE-SCALE ASSET PURCHASES

Matikainen, Campiglio and Zenghelis (2017) study the composition of the corporate bond purchase programs of the European Central Bank (ECB) and the Bank of England (BoE). Both programs are parts of their wider large-scale asset purchase programs. The ECB started purchasing corporate sector bonds in June 2016 and, at the end of 2017, held about EUR 131 billion of such bonds, 85% having been purchased on the secondary market and 15% on the primary market. This represents 5.8% of ECB's holdings resulting from its different asset purchase programs.¹² The BoE started its corporate bond purchase scheme in September 2016 and has accumulated GBP 10 billion in corporate bonds since then, which represents 2.2% of the assets purchased in its different large-scale asset purchase programs.¹³

ECB's and BoE's corporate sector purchase programs are skewed toward carbon-intensive sectors

Matikainen *et al.* find that the ECB's and BoE's corporate sector purchase programs both display a similar structural bias toward carbon-intensive industry incumbents. They estimate that 62% of the ECB's corporate bond purchases are in manufacturing and electricity production sectors, which are responsible for 59% of Eurozone area greenhouse gas emissions, but only 18% of its economy in terms of gross value added. For the BoE, manufacturing and electricity production – the source for 52% of UK greenhouse gas emissions – make up 49% of the estimated purchases, but only 12% of the gross value added. Matikainen *et al.* also underline that renewable energy companies are not represented in the ECB and the BoE corporate bond purchases. Moreover, they note that the ECB's asset-backed securities purchase program includes securities backed by car loans and leasing contracts.

The carbon-intensive skew reflects bond markets' biases as well as central banks' choices

The bias in favour of carbon-intensive sectors highlighted by Matikainen *et al.* is mainly a result of the structure of corporate bond markets. Central banks allocate their purchases of eligible corporate bonds in line with their outstanding volumes. As a result, sectors such as

¹² The corporate sector purchase program is the third largest asset purchase program of the ECB; the other asset purchase programs are the public sector purchase program, accounting for 83% (EUR 1 889 bn) of its holdings resulting from all asset purchase programs at the end of 2017, the covered bonds purchase program, accounting for 10.5% (EUR 241 bn) of its holdings, and the asset-backed securities purchase program, accounting for 1.1% (EUR 25 bn) of its holdings. Source: ECB website.

¹³ Source: Bank of England website.

manufacturing and electricity production where debt capital plays a significant role account for a higher share in central bank allocations compared to those sectors with less outstanding debt. Central banks motivate their choice to hold a portfolio reflecting the structure of corporate bond markets by their aim to remain market neutral. While this choice is understandable, it leads to an allocation that favors those companies that are most indebted and – as these happen to be firms with significant carbon emissions – an allocation that is skewed toward carbon-intensive sectors.

In addition to this structural market bias in corporate bond markets, the ECB as well as the BoE also display a bias toward carbon-intensive sectors in their purchase choices. The ECB reduces its starting universe of about 80'000 corporate bonds to 1'156 bonds that are eligible for purchase but purchases only 846 of them.¹⁴ Matikainen *et al.* find that the integrated oil and the utilities sectors, both being carbon-intensive, are overrepresented in the bonds bought by the ECB when compared to the set of eligible bonds. Similarly, they find that the utilities sector is significantly overrepresented in the bonds bought by the BoE when compared to the set of eligible bonds.

Finally, low-carbon investments, e.g. into renewable energy projects, are largely funded through equity and project loans, and less through bond markets. As a result, and while the ECB and the Bank of England argue that their interventions are market neutral, the mere focus on bonds already introduces a bias into its policies. One way to mitigate this might be for them to purchase other types of assets like, for example in the case of the Bank of Japan, equities.¹⁵

The carbon-intensive bias in central bank corporate bond purchases runs counter to the transition to a low-carbon economy

With large-scale asset purchases, central banks aim to reduce financing costs for firms and households and thus stimulate private spending in investments and consumption either by reducing the cost of debt issuance for firms or by encouraging bank lending. However, the pass-through from the assets bought by central banks to all asset classes is not perfect. While there is compelling evidence that large-asset purchases were indeed successful in lowering interest rates across bond markets,¹⁶ the evidence also suggests that the yield on bonds that are eligible for central bank purchases decreased more than on bonds that are not eligible.¹⁷

¹⁴ Matikainen *et al.*, p. 13-14.

¹⁵ Note that the Swiss National Bank, the Czech National Bank, the Bank of Lithuania and the Bank of Israel, among others, also already purchase equities.

¹⁶ Large-scale asset purchase programs impact interest rates beyond assets bought by the central bank through the so-called portfolio rebalancing channel. Gagnon *et al.* (2011) give evidence on this channel for the Fed's quantitative easing programs. Andrade *et al.* (2016) find similar evidence for the ECB's asset purchase programs. Abidi and Flores (2017) focus specifically on the ECB's corporate bond purchase program and also highlight a portfolio rebalancing channel. Finally, Joyce, Liu and Tonks (2017) find evidence of a portfolio rebalancing channel for the BoE's quantitative easing program.

¹⁷ See, e.g., Krishnamurthy and Vissing-Jorgensen (2011) who find that the Fed's second quantitative easing program (QE2), which relied on the purchase of Treasuries only, had a disproportionate effect on Treasuries yield. Rogers, Scotti and Wright (2014) show that quantitative easing programs by the Fed, the ECB, the BoE and the Bank of Japan, which all primarily purchased sovereign bonds, had a bigger impact on sovereign bond yields than on other bond yields.

Corporate bond issuance by firms, of which bonds have been purchased, also increased disproportionately, implying larger funding benefits for them.¹⁸ The bias toward carbon-intensive sectors in the ECB's and BoE's corporate sector purchase programs is thus likely to have resulted in better funding conditions for carbon-intensive firms and thus runs counter to the transition to a low-carbon economy.

Note that even if large-scale asset purchase programs prove to be a temporary response of central banks to cope with a cyclical economic downturn, a bias toward carbon-intensive firms in their purchases can have long term implications. Additional debt issuance for investments in carbon-intensive infrastructure contributes to carbon lock-in. It also increases the level of debt issuance from carbon-intensive sectors and thus may weaken financial system resilience to climate-related risks, which undermines central banks' own efforts in addressing risks for financial stability.

3.2 ALIGNING LARGE-SCALE ASSET PURCHASES WITH A LOW-CARBON PATHWAY

As highlighted in the previous section, large-scale asset purchase programs as currently implemented by central banks are skewed toward carbon-intensive sectors. What would happen if central banks would not only correct this bias, but go one step further by intentionally directing their asset purchases toward low-carbon technologies?

Monasterolo and Raberto (2017) study this question in a stock-flow consistent agent-based model. Their model allows to analyze the impact of large-scale central bank purchases of sovereign green bonds – i.e. bonds that finance investments with environmental benefits – on the economy, on financial markets as well as on income distribution. Monasterolo and Raberto's model has four key features: first, it distinguishes between carbon-intensive and low-carbon productive sectors. Second, it differentiates between three sources of funding for firms (bank loans, bonds and equities). Both features allow for a separate analysis of traditional quantitative easing, i.e. large-scale purchases of a mix of carbon-intensive and low-carbon bonds, and of green quantitative easing, i.e. large-scale purchases of green bonds only.¹⁹ Third, it considers agents with diverse sources of income, which allows studying the impact of different monetary policy scenarios on income inequality. Finally, in the Post-Keynesian tradition, it assumes endogenous money creation by the banking sector, i.e. endogenous bank loans. Monasterolo and Raberto's results are based on a simulation calibrated on the Italian economy.

¹⁸ See, e.g., Di Maggio, Kermani and Palmer (2016) who find evidence that large purchases of mortgages guaranteed by government-sponsored enterprises (GSE), such as Fannie Mae or Freddie Mac, by the Federal Reserve during the first phase of its quantitative easing program (QE1) increased GSE-eligible mortgage originations significantly more than the origination of GSE-ineligible mortgages.

¹⁹ Monasterolo and Raberto also study the case of conventional monetary policy through changes in interest rates.

Green quantitative easing could accelerate the transition to a low-carbon economy and stimulate job creation as well as investments

Monasterolo and Raberto find that quantitative easing based on large-scale purchases of sovereign green bonds stimulates the overall issuance of both green bonds and green loans more than traditional quantitative easing. It thus provides a key impetus for developing both the green bond market and bank lending to the low-carbon productive sector. They also find that central bank's purchases of green bonds boost investment and decrease unemployment more than traditional quantitative easing. This result stems from the fact that, in their calibration, the low-carbon productive sector is more reactive to funding conditions than the carbon-intensive sector. Since buying green bonds lowers the cost of funding for the low-carbon productive sector more than traditional quantitative easing, it also generates more investment and more jobs than in the traditional case. As most of these investments and job creation take place in the low-carbon productive sector, a green quantitative easing also accelerates the transition to a low-carbon economy.

At the same time, green quantitative easing could increase aggregate debt and widen income inequality

However, purchasing green bonds does not only have benefits: it also potentially generates larger systemic risk and higher income inequality. In Monasterolo and Raberto's model, green quantitative easing induces more investments than traditional quantitative easing. These investments are funded by bank loans, bonds or equity. The larger systemic risk results from the larger increase in bank loans in the case of green quantitative easing. The higher income inequality reflects the fact that the additional capital income and banking sector gains derived from funding investments in the low-carbon sectors accrue only to the agents that own capital and not to those relying on labor income only.

Green quantitative easing: an option for central banks?

The results presented by Monasterolo and Raberto indicate that large-scale asset purchases of green bonds could accelerate the transition to a low-carbon economy. This impact is also found in similar stock-flow consistent models like, e.g., Dafermos, Nikolaidi and Galanis (2017). The modelling of such targeted quantitative easing is however in its infancy and further efforts should be made to get models that can be used by central banks to evaluate their policy actions. In particular, it is yet unclear if scenarios considering a mix of traditional and green quantitative easing, which is an option that central banks are more likely to adopt than a "green-only" scenario, would deliver the same results in terms of transition acceleration and impact on prices and economic activities, which are at the core of central bank mandates. Another relevant question for central banks is whether changing the composition of the current assets that they hold resulting from past quantitative easing by, reinvesting their proceeds into green assets, would induce a similar impact in terms of transitioning to a low-carbon economy. However, even if a lot uncertainty remains on the

impact of large-scale asset purchases of green assets on the economy, the initial results available so far call for central banks to seriously consider this option. Presenting in-house estimations of the impact of such policies would be a first step in that direction.

4 FURTHER CENTRAL BANK MEASURES TO ALIGN FINANCIAL MARKETS WITH CLIMATE GOALS

Apart from assessing climate-related systemic risk, implementing macroprudential policies for risk mitigation and aligning their large-scale asset purchases with a low-carbon pathway, central banks should explore the following further measures to ensure policy coherence with climate goals.

Accounting for climate-related risk in central banks' collateral frameworks

The collateral framework of central banks defines the list of assets that financial institutions can pledge to borrow liquidity from the central bank, as well as the amount that they can borrow against those assets. The criteria used by central banks to establish the eligibility of an asset as collateral and the 'haircut' imposed is a key factor for the desirability – and thus price – of this asset (Mésonnier, O'Donnell and Toutain, 2017). Central banks choose the assets eligible for collateral based on several criteria, high credit quality being one key aspect in their choice. Similar to the benefit of being on the list of assets that are purchased by central banks (see Section 3.1), being included in the collateral framework gives an incentive to financial institutions to issue such assets in larger quantities (Van Bakkum, Gabarro and Irani, 2017). It thus increases the volume of funding available to the issuers of eligible assets, which can potentially have an impact on real production. If the bonds issued by carbon-intensive entities are included into the list of eligible assets and those issued by low-carbon entities are not, the collateral framework introduces more favorable funding conditions for the former. Against this background, central banks should take a closer look at potential biases in their collateral frameworks. They may also want to consider higher haircuts to carbon-intensive assets or to exclude them altogether to reflect the higher climate-related risk that they face (see Section 2.1).

Promoting and applying disclosure standards

Promoting disclosure standards is in line with the wider strategy of encouraging the financial industry to appropriately price climate-related risks, and thus to support the efficient allocation of capital. Central banks and financial regulators have been at the forefront of encouraging better disclosure of climate-related risks in recent years. In particular, the Financial Stability Board established a Task Force on Climate-related Financial Disclosures, which made recommendations for voluntary corporate disclosure of climate-related financial risks, to better inform investors, lenders and insurers. The French Energy Transition law,

adopted in 2015, goes further and requires listed companies to disclose information on their exposures to climate-related financial risks. Central banks should support these initiatives and set an example by disclosing the exposure of their own balance sheet to climate-related financial risks.

Supporting the development of low-carbon bonds market

As highlighted by Zerbib (2017), there are currently signs of a lack of green debt issuance by the financial industry despite strong buying demand.²⁰ Against this background, central banks should also explore possible contributions to the development of low-carbon bonds markets. Including low-carbon bonds in central banks' collateral frameworks is one option available. Based on an analysis of the green bonds market, Guiliani, Kidney and Meng (2017) propose that, when they are responsible for approving bond issuance, central banks could simplify and speed up the approval process for low-carbon bonds. They also suggest that central banks consider providing financial support for the issuance of low-carbon assets.²¹ Note that such measures could be designed as temporary support for low-carbon bonds markets in a development phase and ended as these markets move into a more mature stage.

5 CONCLUSIONS AND POLICY PROPOSALS

Climate change is a significant risk for our societies and transitioning to a low-carbon economy a key challenge we must meet. Central banks must not stand on the sidelines in this process. They need to safeguard financial stability by taking appropriate measures to strengthen financial market resilience vis-à-vis climate-related risks, and they need to align their policies with the shift in investments that the transition to a low-carbon economy requires.

Concretely, central banks should explore the following three measures:

- They should expand information about climate-related systemic risks by developing a comprehensive evaluation of these risks through, e.g., climate stress tests of the financial system. This information is currently lacking, and, by providing it, central banks would help financial markets to adequately price climate-related risks, which would reduce current distortions in the allocation of capital.
- They should implement higher capital requirements for loans to carbon-intensive economic activities. Higher capital requirements would reflect the potentially higher risk of these activities. This measure would both increase financial system resilience

²⁰ Zerbib (2017) looks at the price of newly issued green bonds. He finds that, at issuance, green bonds offer a lower yield than equivalent synthetic conventional bonds. This negative premium could be explained by the demand for green bonds being higher than the supply – as put forward by the author – as well as an intrinsic value that investors associate with green bonds.

²¹ The Monetary Authority of Singapore, for example, has announced a Green Bond Grant Scheme to cover the additional costs of going green for issuers.

and give an incentive for banks to shift their loan portfolios toward low-carbon economic activities.

- They should mitigate the bias toward carbon-intensive sectors in their current large-scale asset purchase programs by reflecting climate-related risk in their purchase decisions. Such a change in their purchases is possible provided it would not reduce the ability of central banks to achieve their objectives in terms of price stability and aggregate economic activity. They should also introduce climate-related risk analysis into eligibility criteria and haircuts of the collateral they accept to further ensure policy coherence.

All three proposals would send clear policy signals in-line with the objective of a transition to a low carbon economy to investors and financial institutions. They would also foster the alignment of financial markets with climate goals.

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