26th Dubrovnik Economic Conference

The Wave Has Risen: Central Banks' Response to Climate Change

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Dubrovnik, July 2020

First draft, please do not quote

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The views in this paper are those of the authors and do not necessarily reflect the views of the Croatian National Bank and Faculty of Economics & Business.

Abstract

This paper gives an overview of central banks' response to climate change. It explains how climate change creates risks for central banks' main objectives and describes the changing perception of their own role and responsibility in line with 2015 Paris Agreement. It analyses recent activities in the main policy areas: microprudential and macroprudential policy, portfolio alocation and monetary policy.

Keywords: green finance, green monetary policy, climate change

JEL classification: Q54, Q58, E52, E58

Content

1. Introduction

In the period preceding the outburst of the pandemic crisis caused by coronavirus, the issue of climate change and environmental degradation has been attracting unprecedented attention of scientists, activists and policymakers.

The turning point was the 2015 Paris Agreement signed by 195 countries which committed to keeping the global average temperatures well below 2°C above pre-industrial level and as close as possible to 1.5°C by reducing emission of greenhouse gases (UN, 2015). They also committed to two additional goals: (i) climate change adaptation, i.e. increasing their ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, and (ii) climate change mitigation, i.e. making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development. The Agreement gave additional boost to streamlining the institutional efforts towards understanding the climate-change related risks, managing those risks, and preventing disastrous outcomes. It was also a path-breaking event that put climate change on the radar of economists, businesspeople and wide public.

In 2018 William Nordhaus was awarded a Nobel Prize "for integrating climate change into long-run economic analysis" proving that climate change became an essential part of the mainstream economics. At the end of 2019, the European Commission published the European Green Deal, a comprehensive EU growth strategy with the aim to achieve Union's climate neutrality by 2050. In its Global Risk Report for 2020 published on January 15 2020, the World Economic Forum counted five environment risks, all related to climate change, among top five risks in terms of their likelihood, and three environmental risks among top five risks in terms of their impact (WEF, 2020).[1]

Even the central bankers, who were traditionally hesitant to engage in systemic issues beyond their explicit mandates, fully embraced the necessity to join the wide community of institutions that decided not only to adapt their activities to the facts of climate change, but also to take active part in climate change mitigation.

As in the first half of 2020 almost all economies implemented lockdowns and massive restrictions in response to the pandemic, it became obvious that coronavirus will determine global economic situation and trends for quite some time. Such a disruption could have shifted

[1] Interestingly, risk of infectious deseases was counted as tenth, out of the top ten global risks in terms of their impact (WEF, 2020).

the focus away from climate change and environmental concerns for long. However, now when the uncertainty around the coronavirus has somewhat cleared, it seems realistic to believe that the pandemic, which in many respects resembles a climate emergency, would contribute to the awareness about likelihood and potential severity of global risks connected with the environment. The pandemic crisis has illustrated the possible transmission channels of shocks triggered by natural phenomena, and the vulnerability of contemporary society to such shocks (ESRB, 2020; Pereira da Silva, 2020, NGFS, 2020a). As people have quickly learned the importance of flattening the curve of the newly infected, some even argue that we will now more easily understand the necessity to flatten the curve of carbon dioxide emissions required to limit global warming (Aldern, 2020). COVID-19 crisis also demonstrated that the governments are able to intervene decisively, in the case of emergency, provided the presence of public support (Hepburn et al., 2020).

Central banks have in recent years made a remarkable progress in building their capacities to understand the challenges posed by climate change and environmental degradation. They have found the ways to categorize climate-related and environmental risks and to integrate them into the main areas of their activity, i.e. prudential supervision, financial stability, portfolio management and monetary policy. Central banks are even considering possibilities for their active involvement in combating climate change. In a very short period, the climate change and environmental degradation have advanced from peripheral issues far beyond the area of their responsibility, into the focal point of central banks' research and policy.

This paper gives an overview of status of current central banks' knowledge and understanding of the climate change and environmental degradation and economic effects thereof, the perception of their own role and responsibility regarding climate change adaptation and mitigation, and the current consensus that has been built regarding the adequate central banks' policy response in main policy areas. The paper is mainly based on speeches, reports and research papers by the central banks, their networks and international financial institutions that can be considered relevant sources of mainstream and official standpoints, and not merely theoretical possibilities.

The paper proceeds as follows. Section II briefly summarizes the findings on the observed climate changes and threats that they imply for the economic and financial stability. Section III explores the position of central banks regarding the climate change. The next section presents a broadly adopted categorization of climate-related and environmental risks that are the main reason for central banks' concern with climate change. Section V and VI addresses the developments in main areas of central banks' responsibility - prudential supervision, financial

stability and monetary policy, spurred by climate change adaptation and mitigation. Last section concludes.

2. Climate change, environmental degradation and their economic consequences

Recent observations clearly show that the climate is rapidly changing and that the human activity is destroying the environment. Growth of global population is coupled with deforestation, biodiversity destruction, marine life depletion, decline in freshwater availability, rising number of ocean dead zones, pollution, and dramatic increase in atmospheric CO_2 emission. Rising emission of greenhouse gasses caused by burning fossil fuels, deforestation and intensive agriculture prevents the Earth's natural cooling cycle and causes global warming (Ripple et al., 2017). It is estimated that the present-day global mean surface temperature is approximately 1°C higher than the average over 1850-1900, i.e. pre-industrial level. Since the global temperature is currently rising at 0.2°C per decade, global warming is expected to reach 1.5°C between 2030 and 2050 (IPCC, 2018). By the end of the century, in the absence of policies aimed at reduction of greenhouse gas emissions and global warming, global mean temperature is projected to rise by 4.1 – 4.8°C. Since past carbon emissions have the irrevocable impact on future global warming pathways, limiting global warming to 2°C above the pre-industrial level would be consistent with a substantial reduction of carbon emissions, the one that by far exceeds the existing pledges and targets (ESRB, 2016).

The accumulated increase in greenhouse gases results in climate change. It leads to higher incidence of weather and temperature extremes, more droughts and floods, rising sea level due to irreversible loss of ice sheet and consequent change in landscapes. Climate change affects people, species and plants in a variety of complex ways, and the impact of such change on ecosystems can be so severe that it includes even species loss and extinction (IPCC, 2018; Stern, 2008). Therefore, climate change and environmental degradation imply deep societal and economic disturbances, unequally distributed across the globe, leading to important redistributive effects within and among the nations. The most pronounced social and economic effects of climate change would be triggered by water crisis and desertification leading to migration; decline in crop yields and food supply due to extreme weather conditions, soil erosion, saltwater intrusion and loss of marine life; productivity loss caused by unbearable temperature and humidity levels, and destruction of existing infrastructure caused by floods, rising sea water or devastating fires (Bolton et al., 2020).

If the societies do not take actions to reduce CO_2 emissions and if, consequently, global temperature keeps rising, this might significantly reduce global output. Alternative scenarios expect better economic outcomes, but might have some negative economic implications, too. Since people become aware and concerned with its harmful consequences, countries have started, individually and in cooperation, to undertake efforts aimed at curbing further global warming. By signing the Paris Agreement in 2015, 195 countries committed to keep the global warming to well below 2°C with the aim of limiting the increase to 1.5°C. In order to fulfil this goal, they will have to transform into low-carbon economies. Transition to low-carbon economies requires implementation of different policy measures, many of which are in the short run connected with negative economic consequences, such as stricter energy efficiency standards, carbon taxes or removing carbon subsidies. Besides the negative effects of transition to a low-carbon economy, there are its foreseeable positive effects, too. Reluctance to implement adequate measures and procrastination may lead to abrupt and disorderly carbon transition with even more pronounced harmful economic and financial effects. Out of all conceivable scenarios, the one with the most devastating economic outcome is the one with no mitigation policies in the longer run and with belated but sharp policy response at some later stage (ESRB, 2016; ECB / ESRB, 2020).

Harmful effects of global warming are already present since the increasing frequency of extreme weather events can be attributed to change in mean climate variables (European Academies Science Advisory Council, 2018). Such extreme weather events - storms, floods, and heatwaves cause direct damage or loss. According to Global Climate Risk Index developed by Germanwatch, between 1999 and 2018, there were more than 12 thousand extreme weather events, causing deaths of around 495 thousand persons, and losses estimated at 3.54 trillion USD (in PPP) or around 3.5 percent of an annual global GDP. Those figures do not take into account the damages caused by slow-onset processes such as rising sea-level, glacier melting or more acidic or warmer seas (Eckstein et al., 2019). Cost of direct damages are just a small fraction of the total social and economic costs of climate change and environmental degradation. According to some estimates, global GDP could be reduced by 23 percent in 2100 due to a decline in economic productivity caused by higher temperatures in a policy inaction scenario (Burke, Hsiang and Miguel, 2015).

However, damages due to extreme weather events and productivity loss caused by gradual global warming are only two out of many channels through which climate change could affect economic output. According to NGFS (2019a) and Batten (2018), climate change can cause both demand and supply-side shocks. Demand-side shocks affect the economy via private or public consumption and investment, business investment and international trade. E.g. private and public consumption could be restrained due to the increased uncertainty and therefore more

savings for hard times, while investment can also be discouraged by rising uncertainty about future demand and growth prospects. Climate change can as well affect the components of aggregate supply, i.e. labor supply could be reduced due to migration and productivity loss; energy, food and other inputs could be affected through shortages of imported products and volatility of import prices; capital stock and infrastructure could be damaged and technological development slowed down if resources are diverted from innovation into the climate change adaptation (Batten, 2018).

It is evident that the challenges posed by the climate change and environmental degradation are overwhelming and that the endeavors to curb it did not prove efficient so far. With the passage of time, it is becoming more and more evident that the viewpoint expressed in Stern (2007) is true - climate change is the "greatest market failure the world has ever seen" which therefore deserves to be adequately considered and managed. Following important characteristics of climate change should be additionally emphasized – (1) climate change is global both in its causes and consequences; (2) it has far-reaching impact in terms of duration, breadth and magnitude; (3) this impact is irreversible; (4) it is foreseeable; but to some extent also (5) dependent on actions taken today; (6) there are many uncertainties regarding its economic consequences (Stern, 2007; Batten, 2018; NGFS, 2019).

3. Central banks' evolving approach to climate change

Understanding of contemporary macroeconomics is not complete without taking into account the climate change and its economic effects. Global warming, as the major symptom of climate change, is an externality resulting from greenhouse gas emission caused mainly by burning fossil fuels, which implies that the price of fossil fuels paid by consumer and businesses does not reflect their total, private and social costs. Introducing so-called "Pigouvian tax", or in this specific case a tax on the fossil fuels in proportion to their carbon content is therefore deemed as the first best and most efficient measure to reduce the CO_2 emission (Parry, de Mooij and Keen, 2012; Mankiw, 2009; IMF, 2019). Good alternative measures, such as emission trading system, other energy taxes, feebates[2], and regulations also fall within the government's jurisdiction, not within the jurisdiction of central banks (IMF, 2019). It is therefore understandable that the central banks, which are traditionally focused predominantly on their core objectives, did not until recently consider themselves responsible for tackling the climate change.

However, in the past decade, the position of central banks towards climate change has radically changed. There are two types of reasons for that – first, the reasons that are external to the central banks, and are related to the overall concern with global warming and its socioeconomic consequences, and second, the reasons that are internal, stemming from the central banks' own concern with climate-related and environmental risks directly affecting the central banks' ability to fulfill their primary mandates. External reasons are connected with the fact that the government responses implemented thus far were not sufficient and have not achieved any substantial success in climate change mitigation. Due to inadequate political commitment, pressure of various interest groups, low public support, lack of coordination among countries, and also due to the magnitude of the problem, fiscal and other governmental policy did not offer a sufficient response to the climate change. It is now understood that climate change requires a mix of policy responses, a right combination of coordinated fiscal, financial and monetary instruments (Krogstrup and Oman, 2019; Bolton at al., 2020).

Even without the public and media pressure, central banks realized that they cannot continue to act as an outside observer when it comes to the climate change. They know that the climate change is a structural change creating immense economic risks that can directly affect central goals of their activity, namely price stability and financial stability (Dikau and Volz, 2020;

[2] Feebates - systems of fees and rebates on products or activities with above or below-average emission intensity (IMF, 2019).

NGFS, 2019; Campiglio et al., 2018; Cœuré, 2018[3]). In that respect, acknowledging risks connected with climate change and environmental degradation, and exploring the channels through which they affect economic output, prices, safety and soundness of the banking system and resilience of the whole financial system does not undermine the primary mandates of central banks, and it is fully consistent with them.

Consensus is emerging that the environmental protection already falls under central banks' broad mandate. Their mandate was already redefined to include stronger emphasis on the financial stability after the Global Financial Crisis in 2008/09, within the existing legal framework. Over the last few years, however, central banks were forced to consider a variety of other possible objectives, including supporting the environment, in the scope of their broader mandate. In the EU, the existing legal framework already includes broadly defined secondary objective of contributing to objectives of the Union as laid down in Article 3 of the Treaty on European Union, which among others includes protection of the environment.[4] This opens the door for stronger emphasis on environmental protection, i.e. taking into account climate-related risks in the context of price and financial stability, but only if such secondary goals are not in conflict with achievement of primary goals (Schoenmaker, 2019). Thus the inclusion of climate-change mitigation into the monetary policy design does not jeopardize the central bank independence nor introduce market distortions.

Central banks rightly insist on avoiding being overburdened with mandates, which might impair their efficiency in promoting price and financial stability. The fulfilment of the central banks' core objectives requires independence from the politically elected officials, but is thus coupled with central banks' limited accountability. Therefore, they should refrain from policies that would entail distributional choices or interfere with the principle of open market economy with

[3] "I will argue that climate change can be expected to affect monetary policy one way or the other. That is, if left unchecked, it may further complicate the correct identification of shocks relevant for the medium-term inflation outlook, it may increase the likelihood of extreme events and hence erode central banks' conventional policy space more often, and it may raise the number of occasions on which central banks face a trade-off forcing them to prioritise stable prices over output" (Benoît Cœuré, November 8, 2018).

[4] Article 127 of the *Treaty of the Functioning of the European Union* states sets objectives for the EU central banks: "The primary objective of the European System of Central Banks (hereinafter referred to as "the ESCB") shall be to maintain price stability. Without prejudice to the objective of price stability, the ESCB shall support the general economic policies in the Union with a view to contributing to the achievement of the objectives of the Union as laid down in Article 3 of the Treaty on European Union." General economic objectives of the Union are presented in the Article 3(3) of the *Treaty of the European Union*: "The Union shall establish an internal market. It shall work for the sustainable development of Europe based on balanced economic growth and price stability, a highly competitive social market economy, aiming at full employment and social progress, and a high level of protection and improvement of the quality of the environment. "

free competition. These two facts explain the predominant position of the central banks that their responsibility should be restricted to exploring and addressing climate and environmental risks only in as much as they affect their core objectives.

More specifically, there is a broad consensus that central banks and financial supervisors should concentrate their efforts in tackling climate change around research, i.e. developing methodologies and tools that enable better understanding of climate-related and environmental risks and their economic and financial implications, bridging data gaps and developing taxonomies, and around following policy areas – risk disclosure, climate-aligned financial regulation, and evaluation of climate-related risks in their own portfolios i.e. international reserves and assets purchased as part of quantitative easing programs. Engaging in wider societal debates on low-carbon global economic systems and contributing to coordination of policies with focus on resilience on national and international level are additional tasks that central banks could potentially assume without impairing their primary roles (Bolton et al., 2020; NGFS, 2019; Kyriakopoulou, 2019; Campiglio et al., 2018).

Still, it is legitimate to question the justification of stretching the central banks' responsibility further to the active promotion of sustainability and green finance. There are some good reasons for that – first, central banks are well-placed to correct market failures in the area of fostering underdeveloped market segments such as green bond market, incentivizing investment into some desirable activities and restricting lending to undesirable activities. In addition, central banks unlike governments can solve the time-inconsistency problem (Dikau and Volz, 2020). Central banks' active engagement in climate change mitigation is to some extent controversial since it might conflict with their primary mandates and jeopardize the neutrality of monetary policy, so the appropriate ways of such engagement are still being explored (Krogstrup and Oman, 2019; Dikau and Volz, 2020). Two policy options which are often mentioned as possible areas of central banks' active involvement in promoting sustainable finance, are: adding "green quantitative easing" within their monetary policy tool and including "green supporting or brown penalizing factors" into the prudential policy tools. There is still substantial further data and evidence needed to evaluate the potential effectiveness of those options and design the operational measures (NGFS, 2020b; Krogstrup and Oman, 2019; Kyriakopoulou, 2019). Having in mind that the President of the ECB proclaimed mitigating climate change as a

priority, more proactive role of the ECB in that respect should not be excluded in the future (The Parliament Magazine, 2019)[5].

Central banks' attitude towards climate change has notably changed after the Paris Agreement in 2015. Although the Agreement does not directly address central banks, it implies their important role in global response to the climate change, by including the goal of "making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development" (UN, 2015). Paris Agreement was followed by the establishment of several multilateral initiatives in which many central banks took active role, such as the Financial Stability Board's Task Force on Climate-Related Financial Disclosures (TCFD) that was set up in 2015 and the Central Banks and Supervisors Network for Greening the Financial System (NGFS) was founded in 2017. Central banks' multilateral action aimed at tackling the climate issues got strong support from the international financial institutions as well (Krogstrup and Oman, 2018)[6].

NGFS was established at the initiative of Banque de France and eight other institutions, and has meanwhile grown to include 66 members and 13 observers – central banks, supervisors, regulators, international financial institutions and associations. Most Eurozone central banks and supervisors participate in the NGFS (except central banks of Cyprus and Slovenia), as well as European Central Bank, EBA and central banks and regulators of four non-eurozone EU countries – Hungary, Denmark, Norway and UK. Synergies created by mutual endeavors of numerous members have led to rapid advancements in understanding the economic and financial impact of climate change and incorporating this understanding in areas under the responsibility of central banks. Thus, the NGFS' work in recent years has been indispensable in providing guidance for coordinated response in all the relevant areas of their activity, from macroprudential supervision and financial stability to monetary policy and macroeconomic research. Although the NGFS guidance strictly stays within narrow mandates, the messages

[5] „The discussion on whether, and if so how, central banks and banking supervisors can contribute to mitigating climate change is at an early stage but should be seen as a priority" (Christine Lagarde, Speech in the European Parliament on September 4, 2019, The Parliament magazine, 2019).

[6] In addition to that, there are other international forums examining possible policy measure in financial domaine - G20 are working on sustainable finance; the United Nations has defined responsible investment principles; the OECD established the Centre on Green Finance and Investment and the World Bank created the Sustainable Banking Network. Within the EU, the European Commission is implementing its action plan on sustainable finance.

sent by the leading members have important role in promoting sustainability and raising awareness about the perils of climate change (Bank of England, 2019)[7].

Many national central banks have since undertaken activities directed towards better understanding of the issue of climate change, including addressing the climate and environmental risks to their core objectives – price and financial stability. Some have also started using their position to actively contribute to the mitigating the effects of climate change in the spirit of the third objective of the Paris Agreement – guarding the financial sector and contributing to the financing of the transition towards green economy. In that respect, some emerging markets' central banks, with broader mandate, moved faster towards such climate goals and provided direct financing.

The European Central Bank has included the climate change in its monetary strategy review, with the aim to determine where and how the issue of climate change and the fight against climate change can have an impact on its policies. Almost all parts of the ECB are involved in this assessment. Within the Economic analysis function, the issue of climate change is being included in macroeconomic models, forecasting methods, and risk assessments. Within Monetary policy and investment portfolios, special emphasis is put on the purchase of green bonds. Banking supervision is focused on raising awareness of climate-related risks with the aim to ensure proper risk management by individual banks. This analysis is further extended to examine risks for the entire financial system with aim to ensure the financial stability. Finally, The ECB has been publishing triannual Environmental Statement since 2010 in order to assess and decrease its own carbon and environmental footprint.[8] Christine Lagarde, president of the European Central Bank, has opened the door to using its €2.8tn asset purchase scheme to pursue green objectives, promising to examine changes to all of its operations in the fight against climate change.[9]

[7] "The catastrophic effects of climate change are already visible around the world. From blistering heatwaves in North America to typhoons in south-east Asia and droughts in Africa and Australia, no country or community is immune. These events damage infrastructure and private property, negatively affect health, decrease productivity and destroy wealth. And they are extremely costly: insured losses have risen five-fold in the past three decades. The enormous human and financial costs of climate change are having a devastating effect on our collective wellbeing." (Open letter from the Governor of Bank of England Mark Carney, Governor of Banque de France François Villeroy de Galhau and Chair of the Network for Greening the Financial Services Frank Elderson, April 17, 2019; Bank of England, 2015).

[8] ECB (2020c).

[9] Lagarde (2020) and ECB (2020b).

In the following sections this paper further explores climate and environmental activities through different central bank functions, as shown in Table 1.

Table 1. Central bank functions involved in climate-related activities

Function	Description
ECONOMIC ANALYSIS	Developing understanding of the impact of climate and environmental related shocks on economy and financial system. Integrating climate and environmental shocks in existing policy analysis framework, forecasting, and risk assessments.
PRUDENTIAL SUPERVISION	Developing awareness and methodology for managing climate and environmental risks in the supervised banks.
FINANCIAL STABILITY	Assessing the risks posed to the financial system by climate change.
RESERVE MANAGEMENT	Recognition and classification of climate risks within bank portfolios.
MONETARY POLICY	Examining policies for promoting green investments as part of the ECB's monetary operations, taking into account the need to avoid market distortions.
ENVIRONMENTAL FOOTPRINT	Monitoring and reducing own ecological footprint.

Source: Authors adaptation based on Climate change and the ECB (ECB, 2020b).

4. Economic and financial effects of climate change and environmental degradation

For central banks and financial supervisors, the most important issue related to the climate change is how they might affect output, prices and financial system. Therefore, they strive to understand complex transmission channels, in order to be able to identify and manage climate risks to the economies and the financial sectors.

4.1. Climate-related and environmental risks

The Bank of England was the first to propose a classification of climate-related risk consisting of three broad categories, physical, transition and liability risk (Carney, 2015; Bank of England PRA, 2015). This classification is sometimes used in a modified way – e.g. literature that refer only to the banking sector do not treat liability risks as a separate risk category, whereas literature dealing with the climate change in insurance sector find the liability risk equally important (Cleary et al., 2019). In its recent guide for supervisors, the NGFS has included environment-related risks as well (NGFS, 2020b).

Climate-related risks are risks caused or related to climate change, while environment-related risks refer to risk caused or affected by environmental degradation, such as air pollution, water pollution, scarcity of fresh water, land contamination, reduced biodiversity and deforestation (NGFS, 2020b; NGFS, 2019). Sometimes, climate-related and environment-related risks overlap – e.g. global warming can influence the biodiversity and change ecosystems. Generally, financial risks connected to climate change are thus far better assessed then the risks that arise due to the environmental degradation, but it is highly recommendable for the central banks and financial institutions to take into account locally specific types of environmental degradation since its financial impact can be materially important (NGFS, 2020b).

Physical risks arise when hazards related to the climate change affect health and cause damages on human and natural systems because of their vulnerability or inability to adapt (Batten, Sowerbutts and Tanaka, 2016). In financial terms, those risks cause higher or unexpected costs or financial losses, which can have further monetary and nonmonetary macroeconomic implications such as disruption of trade flows and supply, diversion of investments, reallocation of workforce, migration, productivity loss etc. (NGFS, 2020c). Physical risk can be either acute or chronic. The former can be connected with the climate or weather-related events such as heat waves, storms, wildfires, landslides, floods and droughts, and the latter result from progressive longer-term change in climate or weather patterns. The examples of chronic physical risks are

rising average temperatures, rising sea levels, ocean acidification etc. Chronic physical risks have dominantly negative macroeconomic consequences since they result in material damage, lower productivity and migration flows, but can as well enhance investment in climate adaptation technologies (NGFS, 2020c).

Transition risks result from behavioral changes and actions taken in the process of adjustment to lower-carbon and more circular economy. There are three major sources of transition risk – change in consumers' preferences and social norms, adoption of environmental policy measures and technological breakthroughs. Macroeconomic effects of transition to low-carbon and more circular economy are uncertain and depend on the choice of environmental policy measures and their dynamics, certainty about the future polices, use of the proceeds from the fiscal measures, ability of the economy to adapt to the shift in consumer preferences towards greener goods etc. (NGFS, 2020c). One of the often used example of transition risk materialization are stranded assets. This term refers to the companies who, due to introduction of environmental policy measures, cannot earn the economic return on past investment (usually in fossil fuel reserves, but also in obsolete technologies), which leads to the reduction of their financial valuation or downgrades in their credit ratings. Banks with high exposures to such companies can experience substantial market losses. Classification of risk factors with examples of each of the risk factor is presented in Table 2 and the possible impact of climate-related risks on key macroeconomic variables is presented in Table 3.

Although physical and transition risk should be treated as two separate types of risks, one can also notice the connection between them. In the case of strong and rapid mitigation action, future physical risks might be lower, but negative implications of such transition on financial stability might be substantial (Carney, 2015)[10]. On the other hand, delayed transition to low-carbon economy would lead to high physical risks. The result of such policy might be abrupt but late corrective action that would result in high both physical and transitional risks.

Liability risks appear when climate or weather events cause legal cases to emerge, for example in situations when a legal person would be required to pay in case it is deemed to be legally responsible for loss or damage resulting from the effects of climate change (ACPR Banque de France, 2019). This risk can be considered as a subset of either physical or transition risk which, in terms of prudential risk categories, are often categorized as operational risks (NGFS, 2020b).

[10] In his speech seminal speech titled "Breaking the tragedy of the horizon - climate change and financial stability" Mark Carney coined afterwards often used term "climate Minsky moment" to denote the dangerous effects of the abrupt and concentrated climate change mitigation policies (Speech at Lloyd's of London, September 29, 2015; Carney, 2015) .

Categorization of risks into physical and transition risks (and liability risks) can be used both for climate-related and environment-related risks.

Climate-related and environmental risks are drivers of conventional prudential risk types – credit risk, market risk, liquidity risk and operational risk (plus insurance risk for insurance and reinsurance sectors) (NGFS, 2020b). For some examples, see Table 2.

Table 2. Classification of climate-related and environmental risk factors with examples

TYPE OF RISK FACTORS	CLIMATE-RELATED	ENVIRONMENTAL
PHYSICAL RISKS		
ACUTE	▪ extreme weather events (floods, storms, wildfires, heatwaves)	▪ water pollution ▪ soil contamination
CHRONIC	▪ gradual warming ▪ more volatile precipitation patterns ▪ rising sea level ▪ ocean acidification	▪ scarcity of fresh water ▪ biodiversity loss ▪ reduced availability of fresh water ▪ gradual loss of animal pollination
TRANSITION RISKS		
POLICY	▪ introduction of carbon pricing ▪ introduction of higher energy-efficiency standards	▪ regulation of supply of available water through extraction restrictions or pricing ▪ limitation of business activities to areas with high biodiversity
TECHNOLOGY	▪ sudden technological breakthrough allowing rapid reduction in emission of GHG – technological progress in renewable energy generation, energy storage etc.	▪ technological progress in agriculture, transport, infrastructure etc., diminishing environmental risk
CONSUMER PREFERENCES	▪ lower demand for carbon-intensive products	▪ higher demand for recycled products

Source: Authors' elaboration based on NGFS (2019a).

4.2. Impact of climate-related risks on economic variables

Important part of central bank's early response was to undertake research and increase understanding of the macroeconomic impact of the climate change. With that aim, central banks developed and proposed particular models aimed to increase understanding of the impact of climate change on economic variables. Overall view of this impact by main economic variables is shown in Table 3.

Table 3. Possible impact of climate-related risks on key macroeconomic variables

TYPE OF RISK / VARIABLE	PHYSICAL		TRANSITION
	ACUTE	CHRONIC	
OUTPUT	- physical destruction, crop failures, disruption of supply chains and tourism	- lower labor productivity, loss of arable land, diverted investment	0 frictions across sectors due to distortive policies, impact dependent on use of proceeds from fiscal measures
CONSUMPTION	0 lower due to rising uncertainty / higher due to hoarding and replacing destroyed goods	+- shifts in sectoral demand	0 likely lower due to increased sustainability awareness, but higher towards greener goods and services
INVESTMENT	- lower due to increased uncertainty, diverted towards mitigation, higher only following extreme events due to reconstruction and replacement	0 shift towards climate adaptation technologies	0 higher due to shift towards climate mitigation technologies, lower due to uncertainty, stranded assets and lower productivity gains from international division of labor
PRODUCTIVITY	- lower due to capital and infrastructure destruction	- lower due to lower human capital accumulation	0 higher due to technological progress, lower due to underinvestment and stranded assets
EMPLOYMENT	- lower due to physical destruction and dislocation of people plus frictional unemployment	0 reduction in labor supply in exposed industries, increase in labor supply due to increased migration flows	- potential rise in structural unemployment
WAGES	0 uneven effect across sectors and economies	- wage decrease due to lower productivity	0 shift of workers across sectors, rising training needs
INTERNATIONAL TRADE	- loss of export markets and higher import costs, supply chain interruptions	- disruption of trade, diminished export values due to higher temperatures	- disruption of trade routes due to taxes, regulation and restrictions, structural shift due to changed demand, risk of distortion due to asymmetric and unilateral climate policies
EXCHANGE RATE	depreciation pressures	depreciation pressures	depreciation pressures, shock absorption in case of freely floating exchange rate
INFLATION	+- increased inflation volatility, heterogeneous impact on headline inflation	0 relative price changes due to shifts in consumer demand or preferences	+ increase in energy prices and price increase due to policy uncertainty, inflationary pressures could be mitigated by technological changes and shifting consumer preferences
INFLATION EXPECTATIONS	frequent revision of inflation expectation, potential decline in dispersion of inflation expectations	longer-term impact of climate-related shocks may affect inflation expectations	inflation expectation affected by tax changes

Legend: (+) – increase; (-) – decrease; (+-) – volatile; (o) – ambiguous.

Source: Authors' elaboration based on NGFS (2020c).

Using this set or relations, central banks are developing a series of economic models in order to better understand the transmissions of climate related and environmental shocks, and devise policies and measures to counter and mitigate those shocks. Those models typically fall within four broad groups of models – integrated assessment models (IAMs), nowcasting models, semi-structural models or DSGE models. []

Integrated assessment models of climate change integrate elements of environmental sciences with macroeconomics. IAMs are important tools for understanding the implications and policy aspects of climate change. They have fundamentally transformed the way economists and environmentalists approach climate policy, shifting from a pure engineering approach — "do this and don't do that" — to approaches like cap-and-trade or carbon taxes that emphasize market mechanisms. However, this type of models has certain problems which make them insufficient for policy analysis.

Current set of nowcasting models are being extended in order to be able to include climate and weather related shocks. Models are being augmented with weather forecasts or temperature anomalies to account for impacts of extreme weather events on inflation (food prices), impact on energy demand and supply and therefore prices, and short-term disruptions and impact on activity in order to account for physical risks. For transition risks forecasting models should be expanded to account for impacts of climate policy on fiscal variables (like taxes), sectoral composition of the economy, and energy prices.

Semi-structural models is primarily explored for estimating the impact of transition risks. Of particular importance is the impact on potential output by adjusting TFP by the impact of carbon taxes, including energy directly as a separate factor of production, and estimating link between carbon tax and TFP. This type of models is also explored to address Macro-Financial and International dimensions, and stress testing.

In order to improve understanding and explain the impact of climate change on the economy, climate and weather related shocks and linkages are being added to the existing DSGE models. Monetary policy conduct can influence the effectiveness of climate change policy by shaping the optimal policy. Physical risks are modelled by including a climate disaster process into the production sector or aggregate consumption process or by using temperature shocks as a proxy for climate change. Transition risks are introduced by means of implementing technological changes or economic policies to arrive at a lower-carbon economy.

4.3. Financial risks

Impact on climate-related and environmental shocks on the financial sector are of particular importance from the perspective of prudential regulation and financial stability. For this reason the NGFS has identified ways how climate and weather related risks impact standard risks in the financial system.

Table 4. Examples of climate-related financial risks as drivers of prudential risk categories

TYPE OF RISK	PHYSICAL	TRANSITION
CREDIT	▪ increase in probability of default of the company operating on production site destroyed by wildfire	▪ increased probability of loss stemming from default of mortgage-backed loans after a decrease in collateral value due to new energy-efficiency standards
MARKET	▪ severe weather events leading to repricing of financial instruments held on bank's balance sheet	▪ lower asset values due to the introduction of a carbon tax
LIQUIDITY	▪ withdrawing of deposits from clients' accounts as a result of severe weather events	▪ reduction of bank's high quality liquid assets as a result of an abrupt repricing of securities, with the effect on bank's liquidity buffers
OPERATIONAL	▪ impaired business continuity through damage affecting bank's critical functions	▪ ruined reputation of a bank exposed to carbon-intensive sectors

Source: Authors' adaptation based on NGFS (2020b) and ECB (2020).

In particular, it is important to understand the channels how physical and transitional risks are transmitted to the financial system.

5. Financial stability and prudential supervision

Central banks can address the issue of climate risks in the financial system in two ways. First is to internalize climate related risks in its operation and focus on the adaptation to the climate change. Second is to steer the financial system towards contributing to the green investment needed for the adaptation and mitigation of the climate change. Central banks readily included the climate and environmental risks in their supervisory and financial stability activities. More contentious issue is whether central banks should use their position as the financial supervisor to actively promote channeling of financial resources and investments into so-called green investments, through the use of microprudential and macroprudential tools developed for risk-control purpose.

5.1. Financial stability

By proclaiming the climate change a source of financial risks, it became obvious that it is important to assess the actual risk for the financial stability. Furthermore, the insights in the transmission of climate risks to the financial sector allowed central banks and financial supervisors to integrate climate related risks into financial stability monitoring and supervision, generate necessary data for this activity, and contribute towards building awareness and intellectual capacity. Most of the undertaken work is focused on the understanding and reducing climate-related financial risks, while the activities related to encouraging green investments is postponed until better understanding on the climate related financial risks and development of the taxonomy of green investments.

Central banks are focusing on the following activities related to the impact of climate change on financial stability:

Understanding sources and channels of climate change risks for the financial system. As explained in the previous section, both physical and transition risk will have a negative effect on the financial system. According to the ECB/ESRB (2020), physical risks related to extreme weather events constitute a major source of risk for the financial system (insurance sector in particular). At the same time, transition risk to the financial sector arising from carbon taxation and other carbon-reducing policies that could affect market prices (stranded assets) and industrial shifts over the next five years is likely to be contained. However, additional research is needed in order to better understand climate related risks for the financial system and their transmission. In particular, current research is focused on the direct and indirect channels, climate related risk exposures, financial market pricing of those risks, financial sector resilience, and potential feedback and contagion effect of climate related financial risks on the

financial sector and the real economy.[11] Understanding the time horizon and combination of those risks is of particular importance for their inclusion in the existing macro and micro prudential framework.

Pricing of climate related market risks. An important issue for the financial stability is whether the climate related risks are already priced in the financial instruments and asset values. If not, there could be sudden repricing of the assets held by the financial sector once those climate risks are realized and those assets could become stranded. ECB/ESRB (2020) study concludes that "financial market pricing of climate risks appears heterogeneous at best and absent at worst. This might not only reflect allocative market failures associated with the pricing of externalities, but also the potential for information market failures." A large part of the problem stems from the data disclosure which remains insufficient, incomplete and inconsistent. Rising the awareness for climate risks could contribute to the reduction of this problem.

Measuring and monitoring financial system's climate exposure. Based on the theoretical underpinnings, further analysis is needed to understand the exposure of climate risks at national level. Most work in this area has been done on the exposure to the CO_2 intensive sectors. ECB/ESRB report concludes that direct exposures of European financial institutions to CO_2 intensive sectors appears limited with concentrations in a few sectors and firms. Further work is needed in order to understand climate risks on particular sectors such as agriculture and tourism and geographical areas (coast) and related exposures. There is a need for better data, so the work is underway to provide necessary **granular data on climate exposures**.

Scenario analysis and stress testing. The basic analytical toolbox is being extended to include climate related risk in the existing scenario analysis and stress testing framework. A particular challenge is to develop models with longer horizons (above five year). NGFS (2019a) provided a framework of assessing climate related scenarios according to physical risks related based on whether climate targets are met on not met, and transition pathways orderly or disorderly. Within this framework, the NGFS (2020 climate scenarios) proposed standardized scenarios to be used in national stress testing. This proposal is based on the stress-testing framework for the climate related risks developed by the De Nederlandsche Bank (Vermuelen et all (2018)) and Banque de France.

[11] NGFS 2020 Research Priorities.

Capital based macroprudential measures. A possible use of recently developed capital based macroprudential measures tools in this context change is not yet being seriously discussed. However, it is possible to include climate-related risks as a part of the systemic risk buffer at national level, as recognized under the CRD-IV, which aims to address systemic risks of a long-term, non-cyclical nature that are not covered by the Capital Requirements Regulation. However, although some countries use the systemic risk buffer to address country-specific risk, no country has so far introduced them for the purpose of climate related financial risks.

Even further from the development is a possible use of the macroprudential measures and regulatory encouragement to steer the financial sector towards financing technological transformation and green investments. As explained later, this is unlikely to be done. First, it is difficult to assess the size of the climate related risks related to individual exposures. Second, improper application of those buffers could endanger the financial stability since the reduction of risk buffers for specific green investments despite their riskiness would jeopardize the current risk management framework, while imposing additional capital requirements would decrease the efficiency of the banking and financial system.

5.2. Banking supervision

Central banks and financial supervisors are already charged with assessing and mitigating risks for supervised institutions. In that respect, integrating climate and environmental risks in the existing framework is a technical issue. On the other hand, at this time there is no support for using the prudential and regulatory framework for steering the financial system into stronger contribution to green financing.

Financial supervisor approached the integration of the climate related risks into the existing prudential framework with a great caution. They first studied the transmission of the climate-related shocks on economy and financial system and related risks. Second step was to determine sectoral and geographical impact of such shocks in order to assess the prevalence of such risks in the financial system and with the view to develop methodology for assessing those risks on the level of supervised institutions. This work was done in collaboration with the financial industry and helped raising the awareness of climate induced financial risks. Currently supervisors are devising and communicating their supervisory expectations in order to further raise the awareness and set qualitative procedure for assessing the climate related risks. Financial supervisors are still exploring possible ways how to quantity and include climate related risks into the existing capital requirements.

Based on the experience of its members, the NGFS (2020b) recommended five particular steps in order to contribute to the development of integration of climate related risks into the existing supervisory framework as shown in Table 5. They include increasing the knowledge about those risks, development of international supervisory capacity, identification of risky exposure, raising the awareness for climate risks in supervised institution and ensuring adequate risk management.

Table 5. NGFS' recommendations for supervisors:

Determine how climate related and environmental risks transmit to the economies and financial sectors in their jurisdictions and identify how these risks are likely to be material for the supervised entities.
Develop a clear strategy, establish an internal organization and allocate adequate resources to address climate related and environmental risks.
Identify the exposures of supervised entities that are vulnerable to climate related and environmental risks and assess the potential losses should these risks materialize.
Set supervisory expectations to create transparency for financial institutions in relation to the supervisors' understanding of a prudent approach to climate related and environmental risks
Ensure adequate management of climate related and environmental risks by financial institutions and take mitigating action where appropriate.

Source: NGFS (2020b).

Such setup envisages creating the framework for addressing the climate related risks and rising the awareness by the supervising entities before the use of stronger supervisory tools related towards capital requirements. This work is well underway. In December 2019 European Banking Association (EBA) published its Action Plan on Sustainable Finance where it focused on its expectations on strategy and risk management, disclosure, and scenario analysis and stress testing. Whereas the action plan covers longer horizon of industry consultation and definition of guidelines, it encourages institutions to act proactively in incorporating ESG considerations into their business strategy and risk management and operation.

Building on this approach, in May 2020 ECB (2020) published its supervisory expectations relating to risk management and disclosure on climate-related and environmental risks and opened public consultation regarding the supervisory activities. Those expectations are to be used as a part of regular supervisory dialogue with supervised institutions and are presented in Table 6.

Table 6. ECB supervisory expectations relating to risk management and disclosure

BUSINESS AREA	RECOMMENDATION
BUSINESS MODELS AND STRATEGY	▪ understand the impact of climate and environmental risks on the business environment in the short, medium and long term ▪ integrate climate and environmental risks with material impact in the short, medium or long term
GOVERNANCE AND RISK APPETITE	▪ include climate and environmental risks in the risk appetite framework ▪ assign responsibility for the management of climate and environmental risks ▪ report aggregated risk data that reflect exposures to climate and environmental risks with a view to enabling the management body and relevant sub-committees to make informed decisions.
RISK MANAGEMENT	▪ incorporate climate and environmental risks into risk management framework, with a view to managing and monitoring these over a sufficiently long-term horizon ▪ identify and quantify these risks within the overall process of ensuring capital adequacy
Credit risk	▪ consider climate and environmental risks at all stages of the credit-granting process and to monitor the risks in the portfolios
Operational risk	▪ consider how climate-related events could have an adverse impact on business continuity and the extent to which the nature their activities could increase reputational and/or liability risks
Market risk	▪ monitor, on an ongoing basis, the effect of climate and environmental factors on their current market risk positions and future investments
Stress testing	▪ incorporate climate and environmental risks in stress-testing
Liquidity risk	▪ assess whether material climate and environmental risks could cause net cash outflows or depletion of liquidity buffers and, if so, incorporate these factors into their liquidity risk management and liquidity buffer calibration
DISCLOSURES	▪ publish information and key metrics on climate and environmental risks

Source: Guide on climate-related and environmental risks, ECB (2020b).

Most central banks and financial supervisors have not yet applied their strongest microprudential tools - capital requirements - to address the climate and environment risks, as further analysis is needed in order to better understand the transmission channels, potential losses, and whether those risks are already included in the current capital requirements.

BIS (2020) describes how the three pillars of the Basel Framework could integrate climate-related risks.

If climate related risks generate financial risks then they should be included in Pillar 1 minimum capital requirements. It can be done either by "green supporting factor" (which would reduce capital requirements for banks with lower exposure to climate-related risks) or a "brown penalizing factor", which would increase capital requirements for banks with higher exposure to exposed sectors (Thöma and Hilke (2018)). Although additional research is needed, it seems

that discussions are evolving towards favoring a “brown penalizing factor” as more appropriate, since it is not obvious why being exposed to “green” sectors would necessarily reduce non-climate-related financial risks, and thereby justify lower capital requirements. Special problem causes the fact that using green taxonomy being developed by the European Commission, does not translate into actual risks of such exposures. Thus, regulators are reluctant to adjust the capital requirement. Brunnermeier and Landau (2020) raise a triple challenge for the inclusion of climate risks in the prudential ratios. First, green investments may be intrinsically riskier and would require higher capital buffers. Second issue is the taxonomy of the green investments which might not consider the climate risks proper for this type of assessment. Finally, using prudential rations to influence the allocation of credit would resemble "direct credit" policies that were abandoned in most advanced economies but are present in many emerging economies. The question is whether the central banks are equipped to implement such policies.

Regulators could prescribe additional capital on a case by case basis as part of Pillar2, for instance if a financial institution does not adequately monitor and manage climate-related risks. However, this would require first to set up new expectations.

Supervisory authorities can contribute to improving the pricing of climate-related risks and to a more efficient allocation of capital by requiring more systematized disclosure of climate-related risks (Pillar 3 on disclosure requirements). As indicated in the NGFS first comprehensive report, “authorities can set out their expectations when it comes to financial firms’ transparency on climate-related issues” (NGFS (2019a, p 27)). For this to happen, guidance is needed to ensure a more systematic, consistent and transparent disclosure of climate-related risks.

Difficulty of properly assessing the climate and environmental risks within the existing capital requirement framework without endangering their other objectives, sheds light on the problem central banks are facing with considering ways how to guide the financial system towards stronger financing of climate related investments, in line with third goal of the Paris Agreement. The conflict with other objectives requires additional tools for achieving the climate mitigation objective.

6. Green monetary policy and portfolio management

The most powerful tool of central banks lies in their ability to create money. They implemented massive quantitative easing in to counter the effect of the financial and sovereign debt crises during the last decade and are currently providing necessary liquidity and financing for addressing the impact of corona crisis. Thus it natural also to consider their role in the fight against the climate change.

Central bankers in advanced economies have long considered the climate change outside of their responsibility. At most, they were concerned about its long term impact on their core objectives, outside of their policy horizon. However, central bankers recently started considering the climate change for three reasons: substantial impact on primary objective(s), widening of their mandate, and overall inadequacy of fiscal response. As the result, there are proposals and examinations how to use their monetary policy tools to contribute to activities related to adoption and mitigation of climate change, without endangering their main objectives and free-market principle.

Greater orientation to new and expensive green technologies and renewable energy sources could affect prices. This is why outright monetary financing of green investments can be applied only gradually in order to avoid negative impacts. For example, Chinese green credit policy with punitive high-interest for energy-intensive industries has reduced investments in target industries, but it has also caused negative impacts on economy due to inadequate adjustments in the industrial production structure (Liu *et al.*, 2017). In the terms of the operative cost of businesses and expenditures of households, accelerating of transition to green economy is desirable with the same dynamic as renewable sources (like solar and wind electricity) and low-carbon infrastructure will become cost-effective.

From another point of view, the question is whether the existing monetary operations have remained market neutral with respect to the carbon intensity related to purchased assets and accepted collateral. According to Schoenmaker (2019) and Matikainen, Campiglio and Zenghelis (2017) a market neutral approach “leads to The Eurosystem’s private sector assets and collateral base being relatively carbon-intensive”. The same view could be valid for Fed's purchases of mortgage bonds, Swiss and Japanese central banks’ investments in equities, as well as standard instruments of monetary policy. Since capital-intensive companies are more carbon intensive, a carbon bias contributes to higher share of brown investments in banks’ claims. If central banks do not work as a catalyst for greening the financial system, their liquidity programs indirectly support the market imperfections. The market failure arguments,

and consequently monetary policy market non-neutrality, are thus the most important justification for the implementation of green central banking.

Finally, the issue of allocation and redistribution through monetary policy can be avoided by adoption of external taxonomy for portfolio allocation or better coordination of monetary, fiscal and other policies in the fight against the climate change (BIS 2020).

There are three main ways how monetary policy can support green financing: (i) portfolio allocation and reserve management, (ii) asset purchases programs and collateral structure of monetary operations and (iii) outright green financing.

6.1. Portfolio allocation and foreign reserves

Central banks hold large asset portfolios for the conduct of regular monetary policy operations. Traditionally, they held primarily government securities, but with recent quantitative easing their portfolios increased and diversed into the private sector securities. The structure of this portfolio can strongly influence asset demand and liquidity. One of the first NGFS' recommendations was to integrate sustainability factors into their portfolio management and issued a technical guide (NGFS, 2019b). Such portfolio allocation can help to better manage the existing climate and environmental risks included in the existing portfolios. It can also go a step further and use their considerable power and lead the financial system towards green financing[12] by deepening the market for green investments, and leading by example.

There are a couple of issues with moving towards the support of financial flows to green investments that need to be solved. First, portfolio structure corresponds to a policy objective, so central banks need to determine whether sustainability objectives can be adopted in this framework. Second is how to invest responsibly and manage risks related to such investments while preserving liquidity. Third is to safeguard their independence and preventing conflict of

[12] There is no single definition of green finance. Most definitions list the activities that are considered to be a part of the green finance. Lindenberg (2014) focuses on three groups of activities: (1) the financing of public and private green investments in the areas of environmental goods and services and the prevention, minimization and compensation of damages to the environment and to the climate; (2) the financing of public policies that encourage the implementation of environmental and environmental-damage mitigation or adaptation projects and initiatives; and (3) components of the financial system that deal specifically with green investments, including their specific legal, economic and institutional framework conditions. European Commission (2017) in its report Defining "green" in the context of green finance develop a comprehensive approach of defining framework for recognizing specific financial products as green. Other definitions distinguish special aspects of the green finance, such as the existence of positive environmental externalities related to those financing activities (G20 Green Finance Study Group, 2016).

interest which could arise from such investment. Finally, it is important to combine between transparency required and confidentiality that is needed for achieving the primary objective. Additional problem lies in maintaining market neutrality and quasi-fiscal transfers that are described in the next section.

Foreign reserves

Foreign exchange reserves have a significant role for central banks in small open economies with strong exchange rate channel. In such countries central banks hold FX reserves in order to be able to influence exchange rate and provide necessary liquidity if needed. By definition, FX reserves consist from other countries assets. In such respect, the international dimension of such investments is clear making it more difficult for such central banks to focus on green investments at the cost of some other objectives. Fender at all (2019) examine the possibility of including the sustainability objective into the usual triad of reserve management objectives – liquidity, safety and return. It could be approached from explicit (by including the sustainability into the explicit mandate of central banks) and implicit integration through focus on traditional economic uses of the FX reserves, such as risk management. They argue that the inclusion of green bonds into the central bank portfolios could achieve this sustainability without forgoing safety and return, but with some loss in term of accessibility and liquidity currently pose some constraint. Further development of market for green bonds that is underway could reduce this problem.

6.2. Asset purchases and collateral structure of monetary operations

As already explained, major central banks already hold large amount of private sector assets acquired under regular monetary operations. Under assumption that the Treaty on European Union allows redesign of monetary policy instruments according to climate-related issues, Schoenmaker (2019) develops a model of green allocation decisions within the framework of eligible collateral in refinancing operations and the asset purchase program (APP) of the Eurosystem.

The APP includes several purchase programs under which public sector securities and private sector securities (like corporate bonds, covered and uncovered bank bonds and asset backed securities) have been purchased „to address the risks of a too prolonged period of low inflation over the medium term" (ECB). In December 2018 the European Central Bank (ECB) decided to end the net purchases under the APP and the Eurosystem currently only reinvests principal payments from maturing securities held in its portfolio (ECB). In combination with standard liquidity-providing repurchase agreements and collateralized loans to credit institutions, this

means a long-time horizon of opportunities for managing the carbon risk (the risk of high carbon bias) in central bank assets.

To minimize market distortions, Schoenmaker (2019) suggest the tilting approach which would gradually lead to the relatively lower share of asset holdings and collateral holdings related with higher carbon intensity. In order to this, the Eurosystem asset purchase programs and credits against eligible collateral should include additional haircut for acceptable medium and high carbon intensive securities issued by private sectors.

Since the Eurosystem primary holds public sector securities and other official assets, the current share of private securities purchased under the APP is relatively low in relation to total asset (11 percent in 2019) and outstanding holdings under the Asset Purchase Program (20 percent). However, bank loans and private sector securities accepted as eligible collateral for the Eurosystem liquidity-providing operations make over 80 percent of all collateral holdings. In both cases, it may be important to reduce the carbon intensity in the operations of the central bank. Namely, current reinvestment purchases of private sector securities are carried out according to the market capitalization principle, while securities with medium and high carbon intensity make the dominant part of the private sector securities available on financial markets and available for all types of the Eurosystem operations.

Working as catalyst for greening the financial system, the Eurosystem and other monetary authorities can correct market failures and reduce the high carbon bias in their assets. Additionally, as eligible securities are more liquid, lower haircut implemented on low-carbon intensive securities can relatively reduce cost of capital for their issuers relative to high-carbon intensive sectors.

By overweighting the low-carbon assets (collateral) and underweighting the high-carbon assets (collateral), central banks can reduce the share of their assets (collateral) related to high-carbon activities and help the directing of capital towards sustainable activities. The green finance could be stimulated also by regulative measures of micro-prudential and macro-prudential policies for safeguarding financial stability, as well as by other central bank activities, such as the development of green guidelines and standards for bank lending.

This approach towards achieving climate objective while maintaining focus on the primary objectives is raising the profile among central bankers. On one hand, ongoing and expected quantitative easing pushes central banks into holding ever-increasing portfolios that related choices about their structure and riskiness. In such situation previously unheard ideas of favoring certain type of investments are gaining ground, as explained by Ms. Lagarde

announcing the possibility to include the green objective into planned €2.8tn asset purchase scheme.

6.3. Green monetary instruments (direct financing)

While advance economy central banks argue that the greening of monetary policy is not compatible with their mandate and principle of market neutrality, the green central banking is already implemented in several emerging and developing countries which are more exposed to consequences of environmental pollution or in which financial markets are not developed. The fields of green central banking implementations are green credit allocation policies, green prudential regulations and other activities such as developing green finance guidelines or setting up green bond markets (New Economic Foundation, 2017).[13]

In a broader context, examples of credit allocation policies in developing countries include:

- ***Differential reserve requirement*** in practice of the Bank of Lebanon, defined as the lower required reserve ratio for banks' claims related with less carbon-intensive activities and higher ratio for brown-carbon-intensive assets (Dikau and Volz, 2018);
- ***Green-targeted refinancing lines*** (for commercial banks at preferential terms) implemented by the People's Bank of China, the Bank Bangladesh and the Reserve Bank of India in order to support banks' green investment in renewable energy projects and energy-efficiency projects at lower-than-market interest rates;
- ***Minimum credit quotas*** (share in the banks' loan portfolio) that must be allocated to priority sectors (40% of net commercial credit in India and 5% of total loan portfolio in Bangladesh);
- Combination of monetary and prudential ***restrictions of lending*** to carbon- and energy-intensive industries and firms that violate environmental compliance rules (case of China) and restrictions on lending in environmentally sensitive areas (implemented by Banco do Brazil for Amazon region);
- Voluntary ***green lending guidelines*** issued by central banks or banking regulatory agencies in Bangladesh, Brazil, China, India and Indonesia to encourage banks to build environmental and social (E&S) risk governance standards (New Economic Foundation, 2017).

[13] Dikau, S., and Ryan-Collins, J. 2017. Green Central Banking in Emerging Market and Developing Country Economies. London: New Economics Foundation, http://neweconomics.org/wp-content/uploads/2017/10/Green-Central-Banking.pdf.

All mentioned instruments and measures are more administrative than market-oriented. They usually represent recalibration of old credit allocation policies in developing countries (implemented in 1950s, 1960s, and 1970s), but with a new green focus defined according to government's development goals.

With possible positive impacts on green transition and economic activity, but also unwanted impacts on inflation, such credit allocation policies can contribute to financial distortions due to differential interest rates, direct supports to certain industries, and lower efficiency of financial markets. For those reasons, explained instruments of green monetary policy are not acceptable for advanced economies.

7. Conclusion

All institutions must contribute towards the fight against the climate change. 2015 Paris Agreement issued a broad call for adaptation and mitigation of the climate change with a specific request to the financial sector to provide necessary financing.

After a hesitant start and examination of the impact of climate change on their existing objectives, central banks are increasing their activities in this area. As the first step, central banks focused only on their own carbon footprint. However, in 2019 central banks and financial supervisors joined in the NGFS have reached a consensus that climate change presents a risk for the financial system and their own objectives – price and financial stability. Central banks need to adapt to the effects of the climate change warming by addressing growing physical and transition risks for their main objectives.

Recently the central banks are starting to recognize their responsibility towards the third objective of the Paris Agreement – their leadership in steering the financial flows low greenhouse gas emissions and climate-resilient development. In the EU, the acceptance is emerging that environmental objective already falls within the existing central bank mandate. In that respect, central banks are moving from their initial position that governments bear the sole responsibility to use the first best solution to the problem of global warming (CO_2 externalities). Instead, central banks are assuming the responsibility towards active contribution towards tackling the problem of the global warming. The issues of market neutrality, allocation and redistribution are also being addressed through the taxonomy for green finance adopted by governments and including it as an objective in portfolio allocation and structure of monetary operations.

Contribution to the climate adaptation and mitigation is horizontal issue that will affect all areas of central banking operations. In the area of financial stability and supervision, the awareness is increasing regarding the existing climate related risks in the financial system that needs to be addressed. Central banks are also exploring ways how to steer the financial system towards stronger contribution to green investments. In the area of monetary policy, the understanding of different channels how climate change is influencing economy is needed in order to understand impact on core objectives and monetary policy decisions. Introduction of climate objective will also significantly impact the structure of monetary operations and portfolio management. Finally, stronger emphasize is being put on their own carbon footprint.

Such a broad mobilization of the financial sector and deployment of significant financial resources raises the hope that the rising wave of the climate change can be addressed and appropriately confronted.

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