PSL Quarterly Review

vol. 77 n. 311 (December 2024)

Article

Central banks and climate change: Main issues and perspectives

LORENZO ESPOSITO*

Abstract:
In the last decades, during the unfolding of momentous events, we saw the growing awareness of the need for a transition to a sustainable economy. The radical economic and social change will require the mobilization of colossal resources, and hence the alignment of the financial system to this goal. Climate change also affects the functions of central banks. First of all, it can affect macroeconomic conditions, forcing a different approach to monetary policy and financial stability. Secondly, it affects the risks of banks and other financial intermediaries, thus financial supervision. Finally, the transition also affects the payment system. In this work, we will try to sum up the main topics concerning the links between central banks, the transition, and the possible objections to them. We conclude that an efficient transition requires that the financial markets business model become sustainable, a goal that becomes more difficult in the new geo-political situation.

Bank of Italy and Università Cattolica del Sacro Cuore, Milan (Italy), email: lorenzo.esposito@unicatt.it

How to cite this article:
Esposito L. (2024), "Central banks and climate change: Main issues and perspectives", *PSL Quarterly Review*, 77 (311), pp. 493-509.

DOI: https://doi.org/10.13133/2037-3643/18312

JEL codes:
E50, P18

Keywords:
central banks, financial stability, banking supervision, climate change, sustainable finance

Journal homepage:
http: //www.pslquarterlyreview.info

Nothing is more harmful than uncertainty.
(G. Carli, 2000)

In the last 15 years, central banks have faced stormy times. In 2008, there occurred the strongest global financial crisis since the end of the Second World War, and it left the financial establishment and policymakers in what Greenspan described as "a state of shocked disbelief" (Andrews, 2008). Then we had the Euro crisis, and other local crises. When the situation looked stabilized, the Covid-19 pandemic broke out, provoking human, social and financial havoc. When the pandemic was receding, Russia started a war in Ukraine. The ensuing economic sanctions and the diplomatic and trade clashes between the West and the China-Russia bloc are creating the conditions for a new cold war (Harding, 2023). During the unfolding of these momentous events, we saw a growing awareness of another key threat to the world economy: climate change and the ensuing need of a transition to a green sustainable economy.[1]

* The views expressed are those of the author and do not involve the responsibility of the Bank of Italy.

[1] From now on, "transition" means the transition to a green sustainable economy.

This work is licensed under a Creative Commons Attribution – Non-Commercial – No Derivatives 4.0 International License. To view a copy of this license visit http://creativecommons.org/licenses/by-nc-nd/4.0/

This transition is the most important economic transformation that will take place globally in the coming decades. The radical change in industrial processes, energy production, transport, house building, and agriculture as well as consumer habits will require the mobilization of colossal resources, a continuous flow of technological innovations, and a new regulatory framework concerning every economic sector. If the 2008 crisis has shown the paramount importance of ensuring financial stability, extreme weather events and climate change as a whole are emerging as a new source of systemic risk for the world economy (WEF, 2017). The risks posed to financial stability by climate change are increasingly at the centre of policymaking worldwide, especially after the "tragedy of the horizon" speech by Mark Carney, Governor of the Bank of England (Carney, 2015). Some simulations have shown that global warming could increase the frequency of banking crises, also increasing their economic fallout (Lamperti et al., 2019). In fact, climate change can cause adverse macroeconomic effects (recessions, rising food or energy prices, etc.); secondly, it can lead to unforeseen risks, especially for the funders of polluting companies (as banks or bondholders), which can provoke damages to the entire financial system. The need for a rapid economic transformation also implies mobilization of the financial sector to help the transition (see ESRB, 2016; G20, 2016; and PRA, 2015). The world needs a financial system aligned with the Paris Agreement aims and, more generally, with the transition goals. For their part, it is important that banks, asset managers, and the other financial operators do not look at sustainable finance merely as a way to prop up their reputation and their product offerings but as an actual change in important aspects of their business model (Warmerdam et al., 2015). To this aim, the role of central banks and banking supervisors is also important to create effective regulatory incentives for the change. On the one hand, banks' brown assets (those issued by companies whose activities negatively impact the climate) are still huge. For instance, the European Banking Authority (EBA) calculates the EU banks' total exposure in these sectors at more than €2 trillion, while the sum of the high-quality component of their own funds is around €1,650 billion (EBA, 2018). On the other hand, the need for energy-related investments is also impressive, having been calculated at $830 billion annually for the period 2016-2050 (NGSF, 2019). A report by the Intergovernmental Panel on Climate Change (IPCC) of the United Nations estimated that $2,400 billion of investment will be needed annually until 2035 merely to transform energy systems (Kocher, 2019). Already the New Climate Economy Report estimated that some US$90 trillion would have been needed between 2015 and 2030 to achieve global sustainable development and climate objectives (GFT, 2018). A United Nations report put the costs to the world economy at US$6.6 trillion for 2008, which will grow to US$28.6 trillion in 2050 18% of the world GDP, (UNEP-FI, 2010). Although these numbers are staggering, delaying action is even worse: "In the absence of further action to tackle climate change, the combined negative effect on global annual GDP could be between 1.0% and 3.3% by 2060. As temperatures could continue to rise to a projected 4°C above pre-industrial levels by 2100, GDP may be hurt by between 2% and 10% by the end of the century relative to the no-damage baseline scenario" (OECD, 2015).

This dramatic outcome derives from the situation on the ground in terms of warming, as many international reports have shown in the last years. In particular, the IPCC (2022) underlined that, in the 2006-2015 period, warming reached 0.87° C relative to 1850-1900, predominantly due to human activity increasing the amount of greenhouse gases in the atmosphere. Moreover, the global temperature is currently rising by 0.2°C per decade and, if this pace of warming continues, the increase would reach 1.5°C by 2040. The situation is so worrying that every resource, both public and private, must be mobilized to change direction. This is why the United Nations has issued a Green Finance Progress Report (UNEP, 2017) that includes an assessment of the

engagement of the financial system. As Solheim noted introducing the report: "We will not be able to truly reshape our societies without throwing the weight of the global financial system behind our ambitions and finding better and greener ways of doing business". In the analysis of the OECD, in the absence of further action to tackle climate change, the combined negative effect on global annual GDP could reach 3.3% by 2060 (OECD, 2015). This is as if, every two years, an event of the scale of the Covid-19 pandemic would hit the planet.

For their part, international financial institutions, in particular the International Monetary Fund and the Bank for International Settlements, are pushing for an increase in the efforts towards the transition (Bolton et al., 2020). This is not due solely to a moral duty felt towards the environment and the well-being of humankind but reflects the fact that climate change is already a threat to financial stability. Of course, the rapid shift of attention of central banks and policymakers is also connected to the interests of private finance (Quorning, 2023), although this time lobbying seems more aligned to general social needs.

As we will see, climate change affects all the ordinary functions of a central bank, making the analysis of this connection a key point for the sound development of the financial sector. In this work, we will try to sum up the main topics that are on the table for central banks and financial operators concerning the transition, giving a wide range of references to help clarify the issues we expose. We will also describe the main objections to the role of the central banks and how this role is connected to a more prudent attitude of large financial institutions toward the transition that developed in the new geo-political situation.

1. The climate change debate and the rise of sustainable finance

Environmental economics pre-existed the debate on climate change but the field is now expanding rapidly. Its main aim, as far as our topic is concerned, is "to examine how temperature, precipitation, and windstorms influence economic outcomes" (Dell et al., 2013). It is a complex analysis because data are not easy to assess, the links between weather and the economy are hard to figure out, and the effects are highly nonlinear. Ideally, economists should be able to create a loss function similar to what is done to assess the probability of default for countries and corporations. Therefore, one of the main aim of economics in this field has been the measurement of the costs of climate change. For instance, Stern found a loss of at least 5% of global GDP each year if climate change is be stopped. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% or more of GDP. In contrast, the costs of action are put at around 1% of global GDP each year (Stern, 2006). We already reported on the OECD forecast. However, these exercises come with a host of very complex assumptions. An example is the literature that deals with the connections among sectors, to analyse the overall emissions of a given commodity. The input-output analysis is widely used for this end (see Chen, 1977; UN, 2000; Miller and Blair, 2009; Guilhoto, 2021). These analyses are useful, although they suffer from the incompleteness of empirical data (Forssell and Polenske, 1998). That is the reason why so-called separate satellite accounts, like the National Accounts Matrix, including Environmental Accounts (NAMEA), have been created (Steenge, 1999; see also Eurostat, 2011 and 2016).

Central banks rely on a huge mass of data to analyse the economic situation and to make their policy decisions. Climate change and the transition are connected to different kinds of data whose sources are different from those of the usual expertise of monetary authorities, for instance the aforementioned NAMEA data. Although neither inflation nor unemployment definitions are immune to quarrels, environmental issues are much more often subjected to divergent opinions,

even in terms of costs and benefits. For instance, Nordhaus and Moffat (2017) found very different impacts due to the limited nature of the specific studies. As Alessi et al. (2019) pointed out, there are hundreds or even thousands of impact studies concerning different areas (health, agriculture, energy, etc.) and only a few are general assessments of the whole economy. This problem also affects the impact assessment of the new rules as the EU taxonomy. Data are needed not only for public authorities but also for market operators to make more efficient decisions (Visco, 2021).

These difficulties also originate from the fact that a structured discussion on climate change is a relatively recent issue. In fact, the first World Climate Conference was held in 1979, and the second not until 1990. After episodes like the 1953 'killer smog' in London that showed how pollution could cause thousands of deaths in just a few days, the 1980s acid rains, and the 'ozone hole' over Antarctica, in 1988 the IPCC was set up by the World Meteorological Organization and UNEP to coordinate researches on global climate change. In 1992, the UN Framework Convention on Climate Change (UNFCCC) was adopted at the Rio Earth Summit. The framework called for action aimed at stabilizing atmospheric concentrations of greenhouse gases to avoid "dangerous anthropogenic (human-emitted) interference with the climate system". In 1995 the first Conference of the Parties (COP) was held in Berlin to review implementation of the UNFCCC, followed by subsequent conferences almost every year (Sinha, 2015; UNFCCC, 1995). The proof of the new attitude by governments as well as firms and public opinion was the 1997 Kyoto Protocol (COP3), which set binding targets for 37 industrialized countries and the European Union to reduce greenhouse gas emissions by roughly 5% below 1990 levels by 2012. Not only it there were (and are) competing interests among countries, firms, and parties, but their attitudes towards the transition could also change. The US case is particularly clear, with the Kyoto Protocol signed by Clinton and refused in 2001 by Bush; a similar situation occurred with the Paris Agreement, which was signed by Obama, refused by Trump, and signed again by Biden. At any rate, after all these years, nowadays the issue is at the centre of the policy of basically every country, and the huge financial dimension we mentioned is acknowledged. A delicate issue is the distribution of the costs of the transition among countries, sectors, and economic agents. The potential for wealth and income redistribution is immense, although the costs associated with the protocol are difficult to measure and elicit strong disagreement (see Nordhaus and Boyer, 1999, and MacCracken et al., 1999).

As we noted, the huge investment needed for the transition implies an important role of the financial system (Batten et al., 2016). This has resulted in the debate developing a focus on the *sustainable finance* that aims at finding ways to fund investments for the transition and, more generally, taking into account environmental, social, and governance considerations in the financial assets valuation (Rezende de Carvalho et al., 2016). Governments will have to intervene too. For instance, the Paris Agreement established a financial mechanism to provide financial resources to developing country parties, starting with a Green Climate Fund that has the frankly ridiculous commitment of $3.7 billion.

The mobilization of private investors is not easy. Pollution is one of the most emblematic examples of negative externality (Stiglitz, 2000); therefore, the associated risks are underestimated by financial markets (Silver, 2017; Thomä and Chenet, 2017). Typically, governments tackle environmental degradation using a price mechanism such as the carbon tax. Sustainable finance is a different way to change relative prices using funding costs as a lever. What is needed is a general policy to connect all these tools. A point in favour of using finance instead of taxes is that changing the relative price of funding green projects sustainable finance could prevent the externality to be produced in the first place; after all, no economic sector can exist without extensive funding by the banking system. The interest of finance is also connected to legal

consequences. In fact, there is a growing literature on banks' environment responsibility (Bouma et al., 2001) that deals with the direct legal costs and the reputational risks resulting from the funding of controversial projects and firms (Ulph and Valentini, 2004). The idea of "lender liability" is also part of many laws, such as the US 1980 Comprehensive Environmental Response, Compensation, and Liability Act (Bearden, 2012; see also Wolford, 2014), the 1993 Lugano Convention (EC, 1993), and the UK 1995 Environment Act (Dechezleprêtre and Sato, 2014). These laws confirm, although in a negative way, the importance of the connections between the banking system and the transition. Moreover, the use of fiscal policy for the transition opens up many debates (Dafermos and Nikolaidi, 2019; Faiella and Lavecchia, 2021). Among the major issues we must prevent are unfair competition due to green fiscal policies in only some countries (McEvoy and McGinty, 2018; Weitzman, 2014) and the difficulty of conceiving a unified set-up for fiscal policy that avoids the problems arising from partial equilibrium analyses (Bovenberg and Goulder, 2001). Fiscal policies are paramount also, because, although sustainable (private) finance is important, no transition is possible without a strong direct commitment by the states, which are the only investors with a long-term perspective (Mazzucato, 2013).

2. Climate change and financial risks

Scientific literature has identified two main risks by which climate change affects the financial system: physical risk and transition risk. *Physical risk* is connected to catastrophic weather events and their higher frequencies. It can have an acute expression, like tornados and floods, and a chronic expression, as with a permanent reduction in snowfall or higher average temperatures. Both have consequences on firms' revenues and costs and hence on the associated credit risk for their lenders. *Transition risk* is connected to changes in public sector policies, innovation, and the affordability of existing technologies due to the shift towards a low carbon economy. This kind of risk is connected to the governments' stance towards the transition, which, in turn, is connected to public opinion on the issue (ECB, 2020; for the Italian scenario, see Matikainen et al., 2017). Other categories of risks often analysed in this context are the reputational risk (Ulph and Valentini, 2004) and the legal risk, which are in different ways linked to the transition.

Broadly speaking, financial risks are complex to measure, and their connection with environmental make them even more complex. However, firms and financial operators are trying to take into account the effects of climate change in their business models. For instance, credit rating agencies are incorporating climate risks in their assessment (CIEL, 2015); this is also to prevent possible litigation. Unfortunately, many surveys show that the timeframe of a credit rating is still too brief and, as a result, many long-term sustainability risks are not fully taken into account. One important asset manager concluded: "Our research suggests many of these risks are not priced in. Why? First, financial markets tend to be short-sighted – and underestimate risks that appear uncertain and distant. This may lead to a discounting of physical risks that are already biting. Second is a lack of tools and data" (BlackRock, 2019). Models are difficult to produce because climate risks' specific characteristics (for instance, deep uncertainty and nonlinearity) pose fundamental challenges to traditional methods for macroeconomic and financial analysis, which have been shown to be unable to capture these characteristics (Battiston et al., 2020; see also Zlatic et al., 2015). Several studies have tried to assess empirically the impact of transition risks and physical risks on macro stability and/or financial stability, for instance using ecological (E-)DSGE models (Vollmer, 2022). More generally, many different models have been proposed to predict the environmental impacts of energy policy scenarios, from the already mentioned input-

output analysis (Serrano, 2007; Igos et al., 2015) to agent-based models (Lamperti et al., 2019), to the stock-flow consistent approach (Jackson, 2020). The problem is that all these models entail complex measurement of the effects of future policies, such as the carbon tax, that affect costs and revenues of the firms (Carattini et al., 2021). However, transition risk is endogenous and hence intrinsically difficult to introduce in an economic model. For instance, the deadline for the use of fossil fuels is decisive to assess the value of the assets of oil companies. Different assumptions produce very different scenarios in terms of investment and stranded assets and, thus, on a macroeconomic level, on economic growth, income distribution, etc. (for a recent survey on the connection between stranded assets and climate change, see Daumas, 2023). The difficulties derive also from the fact that causality can go both ways: emissions influence macroeconomic development, for instance growth, but growth influences emissions. This makes it difficult to shape rules and policies to tame climate change. But, for all the uncertainties, what is already clear is that climate change significantly affects key industries. For instance, agricultural production is strongly hit, with ensuing consequences on food prices and inflation. The transport industry is also heavily impacted, and this, once again, has a significant effect on prices.

Given that decarbonizing is costly, the complexity of climate risks and the long-term horizons in which they can materialize can be used as an excuse to underestimate climate risks (ECB, 2021a). Moreover, since environment-related costs are an externality, they cannot be fully priced in the default risks of the firms. For instance, it has been noted that the prices of financial assets of fossil-fuel-producing firms do not fully reflect their credit risks (Pereira da Silva, 2019). Sometimes market indicators find that green finance is working and "companies with high environmental performance benefit from a lower cost of debt" (Fatica et al., 2021); other studies found that green assets underperform their asset class (Alessi et al., 2021), even if there are signs that markets are reflecting the increasing risk of brown firms because of a strong increase in climate change risk awareness (Donadelli et al., 2019). Other reports estimated that "the median additional annual returns of coal and oil firms are expected to drop to around –4% in a 35-year horizon" (Moliterni and Vernizzi, 2017). Another problem of using the ordinary measurement of financial contagion is that financial risk metrics, like the value at risk measurement, are backward looking, while funders should be able to identify prospective default risks (Roncoroni et al., 2021). It is also difficult to assess whether this performance is connected to the actual default risk of the greener firms or to investor preferences (Ilhan et al., 2019). At any rate, studies on climate risk as a potential source of financial disruption are multiplying (Aglietta and Espagne, 2016; Scott et al., 2017), as it is clear that policymakers and financial operators must deal with these risks.

3. The role of the central banks and what they are actually doing

Economic policies are aimed at intervening in problems that the price system and markets in general cannot face (Chenet et al., 2021). Climate change is probably the clearest example of this failure. As we noted, every policy should be grounded in empirical data but, in the case of climate change, uncertainty is very strong and this makes it difficult for the government to shape a tax or a subsidy. For instance, the range of estimates for the carbon tax needed to reduce emissions in European OECD countries ranges from $25 to $825 per ton of carbon (McKibbin and Wilcoxen, 2002). These uncertainties also derive from the vagueness that characterizes international agreements like the Kyoto protocol, which are political more than technical documents. Given this uncertain framework, it is difficult to structure an efficient policy, because measures like a carbon tax can affect prices and the economy as a whole in many different ways (Ferrari and Nispi Landi,

2023). From one side, the quicker the transition the better, because adverse effects are reduced. From the other, a too-rapid transition, in terms of taxes, banning fossil fuels, etc., could be unsustainable, for instance because it lowers by too much firms' profitability or raises prices too high. The build-up of productive capacity takes time and the wrong policy can drive prices of a given commodity up, forcing a strong subsidy to make it affordable. Both high prices and high subsidies can have important macroeconomic effects. The issue of inflation has been unimportant for decades but, with the pandemic and the war in Ukraine, it has returned. This development has been connected to disruptions in global supply chains, together with geopolitical issues weighting on fossil fuel prices. This experience has opened a debate on "greenflation" (Olovsson and Vestin, 2023).

This discussion shows that central banks are touched by climate change issues in a number of ways. Basically, every major institutional function that central banks perform is affected. Firstly, as policymakers, monetary authorities are interested in assessing whether climate change will have an impact on growth and inflation (as with "greenflation"), an issue that affects both economic research and market operations duties of central banks. In the last couple of years, inflation has been driven by energy prices and supply chain problems, but a similar dynamic can result from extreme climate events, and central banks have already been analysing how they should respond to catastrophic events (Cantelmo et al., 2024). The first analyses showed a limited impact of climatic disaster on inflation in advanced economies (Mersch, 2018) but this could change because of political decisions. For instance, by changing the prices of energy products and their share in the goods' price basket, climate policies could impact the inflation rate (Bernardini et al., 2021). Given the growing economic impact of climate change, monetary policy decisions will be increasingly connected to it. In the Eurozone, the European Central Bank (ECB) monetary strategy decided by the Governing Council for 2021 (ECB, 2021b) includes a climate action plan, and the ECB published a number of documents on the issue (for instance, ECB, 2021a) to discuss the consideration of climate change in the monetary policy of the Eurozone. The People's Bank of China went even further, introducing a range of measures aimed at greening its policy, while the central banks of Brazil, India, and Japan have introduced credit facilities that favour sectors more connected to the transition (Vollmer, 2022).

Secondly, as banking supervisors, central banks are interested in deepening the links between climate change and banks' risks and business models. For instance, according to the Institute of International Finance, more than US$2.5 trillion in global financial assets in 2016 were subject to some kind of risk derived from the impacts of climate change (Canuto, 2020). This amount has increased ever since. Given the possible rapid shifts in asset prices, prudential policies should evolve to acknowledge the effects of climate risk, although it is not easy (Grippa et al., 2019). As for macroprudential policies, although they are not necessary in the explicit mandate of central banks, financial stability has become more and more important, even before the great financial crisis of 2008, due to the frequent financial crises that punctuated international markets from the 1990s. After 2008, for at least a decade, maintaining financial stability has been the key duty of central banks. Once again, experts in academia, in the financial system, and at the authorities are trying to understand the connection between the transition and the stability of the financial system. This is not an easy task for the measurement issues we cited.

Also, the payment system is interested in the transition, for direct and indirect motivations. The most direct one is that digital payments have much less of a carbon footprint. However, this is not true for crypto-currencies due to their proof-of-work mechanism. For instance, the Cambridge Bitcoin Electricity Consumption Index measured the electricity consumed to mine Bitcoin in 2022 at a minimum of 176 TWh (terawatt-hours), which is around half of the entire

consumption of a country like Italy; for 2023, the consumption was in excess of 241 TWh.[2] This is why there is a discussion in the cryptocurrency community about switching to the proof of stake mechanism.[3] The use of other forms of digital payment, for instance central banks' digital currencies, would be far better for the environment. They could also help financial inclusion, thus improving other dimensions of the environmental, social and governance (ESG) goals (Banet et al., 2022; Auer et al., 2022). This issue is connected to the broader discussion on green fintech (UNEP, 2017). Finally, it has been noted that carbon-intensive sectors accounted for nearly half of the bonds eligible for the ECB's corporate sector purchase programme at its beginning (Mersch, 2018), showing that the credit risk posed by brown assets is an important consideration for central banks as well as investors.

If it is now widely accepted that central banks should include the effects of climate change in programming their action, the way to achieve it can vary significantly. A reduced approach sees the role of central banks only inasmuch as they help to reduce a negative externality, both in their own investment and as regulators (Thiemann et al., 2022). In this sense, central banks serve as an example, for instance in measuring climate-related financial risks (Bernardini et al. 2021). However, after the global financial crisis and the pandemic, the role of central banks is far more important than before. This larger role has translated into the field of transition. It can be seen in the founding of the Network of Greening the Financial System (NGFS) in December 2017, a self-dubbed 'Coalition of the Willing' (NGFS, 2018). The network was initially founded by eight central banks and regulators, including the Bank of England, Banque de France, and Bundesbank, but over the years it has grown in importance and duties, pointing to a strong change in the central banks' commitment regarding climate change.

Given this development, the central banks' tools are evolving. For monetary policy, the first step was to develop methodologies and tools that promote a better understanding of these risks (Campiglio et al., 2018) and that take them into account as far as policy is concerned. For instance, on July 2021, the ECB signaled an important shift in its monetary policy strategy when it released an action plan to integrate climate change into the core of its missions (Ribeiro and Schröder Bosch, 2021). The stage of collecting data is paramount because, for now, these data are "not sufficiently consistent, comparable, granular and reliable" (FSB, 2022). However, at least in Europe, the standardized and complete classification system proposed by the EU taxonomy has greatly helped (EBA, 2022). On the basis of a well-structured taxonomy of industries and financial products, a "green quantitative easing" could be attempted, with the aim of increasing the green bonds held by central banks to reduce the interest rate paid by green firms (Ferrari and Nispi Landi, 2024).

As far as banking supervision is concerned, a first example is the green asset ratio proposed by the EBA as a key performance indicator for the EU banks (EBA, 2021). In the specific field of prudential regulation, there is a debate on how to incorporate risks from climate change into the traditional supervision tools such as capital requirement and risk weighted assets (Esposito et al., 2019; EBA, 2022; Hidalgo-Oñate et al., 2023, for a recent survey). Other examples of micro-prudential tools are the SME (small and medium-sized enterprises) supporting factor and the green weighting factor (Berenguer et al., 2020). Even in the framework of Basel III, a possible funding gap for the green economy has grown (Liebreich, 2013; Narbel, 2013). This analysis is important, because it is easier to pledge brown-sector-related assets as collateral, thus discouraging the greening of financial assets (Andersen, 2017). Secondly, in a situation of credit

[2] See https://ccaf.io/cbnsi/cbeci

[3] See https://ethereum.org/en/developers/docs/consensus-mechanisms/pos/

crunch, or at least risk aversion by banks, financing the green economy can be considered too dangerous and banks can play it safe by funding more traditional technologies, entrenching technological lock-ins and old oligopolies (Ghisetti et al., 2015. A more macro-oriented tool is a climate stress test, which can help central banks and supervisory authorities better understand the implications of the transition for financial stability (ECB, 2022).

4. Greening the financial sector

We have discussed a green quantitative easing as a way to help fund the transition. This is a welcome development, because the current asset composition of central banks is not particularly green. For instance, before the pandemic, the ECB held green bonds amounting to only 3.5% of its portfolio, because traditional industries that are heavier in emissions (manufacturing, utilities, and transport) issue more bonds than do other sectors (Jia and Ilzetzki, 2021). Increasing the share of green assets in central bank financial portfolios is part of a broader trend in the financial system. The task is difficult because, for the banks, decarbonizing their assets is a long and hard process that is well-documented, for instance, in the 2021 report *Banking on Climate Chaos* (2021). Banking regulators must also take into account that, the quicker the transition, the higher the risk of incurring credit losses due to the disruption of their assets. For instance, for the oil and gas sector, it has been noted that: "If strong action is taken on climate change, to prevent anthropogenic global warming from exceeding safe limits, most of the world's fossil fuel reserves will have to remain left in the ground and there will be 'stranded carbon assets'. There is a risk that fossil fuel companies' stocks will at some point be significantly reduced in value" (Silver, 2017); this is the transition risk in practice. Many analyses show that capital stranding will be likely (Cahen-Fourot et al., 2021). Moreover, banks and asset managers could be called, as we noted, to share borrowers' losses connected to environmental damages.

The awareness of the importance of greening financial assets also explains the rapid growth of sustainable investment. For instance, the PRI (the UN initiative for responsible investment) has 3,600 signatories managing more than $100 trillion in assets, which represents more than half of the world's institutionally managed funds (Walsh, 2021). Although the difficulties in comparing ESG data makes it difficult to assess this growth, the picture is sufficiently clear. It is true that, in 2022, the issuance of sustainable assets retrenched due to the pandemic-war situation, but the rebound has been strong. Green bonds issuances been totalled around $444 billion in 2022, compared to $596 billion in 2021, with China, the US, and Germany the three top issuers (Wass et al., 2023). In the last decade, green finance has grown over 100 times (Reuters, 2022). Given that the difficulty in comparing ESG data remains as a strong hurdle for investors, public initiatives are important. For instance, the strong increase in the acquisition of green bonds under the "Eurosystem's asset purchase programme" is a relevant support for the growth of green finance and a signal to private operators (De Santis et al., 2018).

There are many examples of the development of green finance as far as credit is concerned. While corporate claims are obviously connected to firms' transition-related investments, a particular niche of the market that is rapidly growing is green mortgages. The housing sector is key to the transition, due to the strong environmental impact of buildings (Khasreen et al., 2019). European studies show that buildings account for 40% of the EU's final energy consumptions and 36% of its CO2 emissions (Artola et al., 2016), thus representing the largest source of energy consumption in Europe. This trend is worsening, due to the old age of the building stock. For banks, mortgages constitute the main component of their assets in Europe (around 30%). This

strategic importance explains the development of the Energy Efficient Mortgages Initiative (EEMI), which is based on the idea that green mortgages are good for the environment but also for banks because they are less risky for the lender (Billio et al., 2022; see also EeMAP, 2019, EC, 2021, and Esposito et al. 2022).

From the point of view of the banks' business model, this is a welcome turn away from short-termism, because sustainable finance cannot develop in a context where investment is dominated by short-term considerations, and central banks can use the transition to lengthen the time horizon and broaden the concept of risk. It is also important that the commitment of banks and other financial intermediaries be genuine and not reduced to greenwashing. Green financial products are a good development for the industry and are welcomed by private and institutional investors alike. However, this development cannot change the landscape of the financial system rapidly enough. Public finance, more oriented to the long term, is needed and this is acknowledged by government and central banks, although the actions taken are sometimes inconsistent. For instance, in 2012 the UK government created a Green Investment Bank but in 2017 it was sold to private investors.4 A more structured approach is needed to put together the state and the markets.

5. Critiques of the role of central banks in the transition and the new attitude of banks towards it

We have discussed the multiple links between central banks and climate change and also the role of central banks in helping the growth of sustainable finance. This connection is not unquestioned, and objections to a greater role for central banks in the climate change issue are numerous. We describe the most relevant of them. A first critique concerns the use of monetary policy rather than fiscal policy. The latter is considered the superior policy, better suited than monetary policy for addressing climate change through tools such as carbon taxation and investment in green technologies (Cockrell, 2021); thus, climate policies should be left to fiscal authorities (Masciandaro and Russo, 2022). A second objection is related to the idea that, in pursuing climate change goals, central banks would be overstepping their current mandates (Ferrer and Gili, 2021), with a risk of ignoring their core mission of taming inflation. In this regard, it has been noted that central banks should have discretion to interrupt any action connected to the transition if their priority objective in terms of monetary stability were to be compromised (Landau and Brunnermeier, 2020). Declaring ambitious programs as far as the transition is concerned would also put at risk the reputation of central banks if the target were to be missed (Hansen, 2021). A third, more theoretical, critique is connected to a democratic issue: central banks would have a lack of legitimacy to act against climate change and would thus need a political mandate to enlarge their missions (Tirole, 2022). Although this new goal could be considered in line with the general public opinion on the need for a green transition, it comes after decades of increasing the role and power of central banks regarding the economy so it would worsen the trend towards what has been described as "a distinctively Hobbesian quality" (Langley and Morris, 2020).

A different line of objections is linked to the role of central banks as investors. In this respect, a first observation is that central banks that pretend to tackle climate change by investing only in green assets not only undermine their independence but raise exaggerated expectations

[4] See the announcement of the British government at: https://www.gov.uk/government/news/uk-governments-sale-of-green-investment-bank-completed

regarding their contribution (Jia and Ilzetzki, 2021). Another critique is that green investment is more uncertain and riskier, thus transferring these risks to public finance (Hansen, 2021). A third objections is that, if central banks are forced to buy specific assets, they would lose their independence and market neutrality (*The Economist*, 2019).

All these objections should be analysed taking into account the situation resulting from the de-globalization/new cold war era caused by the pandemic and the war in Ukraine. Before the pandemic, Europe was at the forefront of the transition. In fact, the EU had placed sustainability at the heart of its development model (HLEG 2017 and 2018, TEG, 2019) and European institutions have been engaged in a conspicuous regulatory production on the topic, including rules for financial products such as bonds, mutual funds, and loans. When the pandemic hit Europe, all these projects seemed even more important, and initiatives like Next Generation EU seemed to be a confirmation of this approach. The plan was presented as a way to allow Europe to become the first climate-neutral continent by 2050.[5] Unfortunately, the war has changed the political priorities. It is difficult to foresee how the EU will come out of the war economically and politically, but there is an actual risk that transition issues will become secondary to geopolitical necessities.

This new situation, sharpened by the strong anti-transition agenda of the Republican Party in the US, has been reflected by the different attitude of the banking system towards green finance. In the first months of 2024, a number of financial giants, like J.P. Morgan, State Street, BlackRock and Pimco, have pulled out of Climate Action 100, an international coalition of money managers that was pushing big companies to address climate issues. Moreover, Bank of America reneged on a commitment to stop financing new coal mines, coal burning power plants, and Arctic drilling projects. Although the motivations proposed are different, the trend is unmistakable (Gelles, 2024). During the same period, the first four US banks by assets (Citi, Bank of America, J.P. Morgan Chase and Wells Fargo) have left the Equator Principles, a set of minimum industry standards to address environmental and social risks. It is clear that they are more afraid of being labelled as "woke capitalism" banks than condemned by climate groups as cowards (Lakhani and Rushe, 2024).

The situation is difficult. In 2015, at the COP 21, 196 national governments signed the Paris Agreement, which aimed to limit global warming by rapidly reducing traditional energy sources. However, the COP 28 in Dubai was chaired for the first time by a CEO, and more specifically the CEO of a fossil fuel firm (the Abu Dhabi National Oil Company).[6] Once again, these are unmistakable signals.

6. Conclusions: the transition at a crossroad

Halfway measures simply delay the inevitable disaster.
(Pope Francis, *Laudato Si'*)

The transition is the main world policy goal of the next decades. Everybody formally acknowledges it, in particular EU institutions; but, due to the war in Ukraine, which produced a new geo-political situation, the transition could be slowed. It is impossible to predict what situation will prevail after the war, but, whatever the relationship among the blocs will be, they will still have to deal with climate change.

[5] See https://next-generation-eu.europa.eu/index_en
[6] See https://www.cop28.com/en/cop28-presidency

The radical and quick transformation of industrial processes, technologies, and consumer habits requires an immense effort by states in terms of financial resources and a flow of new rules. The transition cannot be achieved in time without a functional and pro-active financial system, based on a long-term vision and a healthy business model, something that in the 2008 crisis was lacking. In this sense, the transition can be seen as a historic opportunity to critically re-examine how the financial system works and what is the most functional relationship between the state and the financial system. Before the 2008 crisis, mainstream economics downplayed the role of public investment and of active economic policies more generally. Laissez-faire policies and deregulation were considered the right choices by default. After financial markets were saved by public resources, the appraisal has become more balanced. However, short-termism still prevails and this is a key issue because of the uncertainties that surround the transition, while "sustainability cannot develop in a context where investment is dominated by short-term considerations" (EC, 2018, p. 45). This can explain why in Europe a pioneering role in green financing has been played by public banks (HLEG, 2017, p. 11). Before the pandemic, the scale of the interventions was considered beyond the capacity of the public sector alone. However, governments have been forced to spend even higher sums to save national economies during the pandemic. The problem is that now states have been left with a heavy public debt to manage, especially in a situation of rising interest rates. Therefore, when public resources would be more vital than ever, public policies risk a turn to austerity.

For sure, green financial products will need to grow rapidly to help the transition, but it is important that this does not confine sustainable finance to a fad, as recently happened with non-fungible tokens (NFTs) or cryptocurrencies, but that this growth becomes a leverage to change the way finance is done. It is interesting to note that some international reports on the transition underline this needed change (for instance, the UNFCCC, 2015, p. 6). A sustainable finance, part of a sustainable economy and society, implies a redesign of a far wider social context, starting from income distribution. The fight against climate change is also a fight against poverty and inequality, as, for instance, noted by the UN Food and Agriculture Organization (FAO) in its analysis of climate change (FAO, 2017, Ch. 4) and by the EU Reports that speak about the need to build a fairer Europe and to strengthen its social dimension (EC, 2018, p. 85).

Our main conclusion is that sustainable finance will really help the transition if it will be a tool to regain a stronger public control on financial markets. The transition is decisive for the future of humankind. A radical change in the financial landscape implies a strong public guide for the financial sector, which should be founded on new rules, different behaviour, and a different attitude towards the environment. Either there is a serious commitment to transition – which implies major changes also in how financial markets work – or it will remain a goal at the horizon, and the threat of climate change will not be dealt with as it must be. The recent cooler attitude of the main banks and asset managers toward the transition reflects the defence of entrenched business models and, more broadly, of the present set-up of the financial system, the same set-up that was exposed as a disaster in the 2008 financial crisis.

References

Aglietta M. and Espagne E. (2016), "Climate and Finance Systemic Risks, more than an Analogy? The Climate Fragility Hypothesis", *CEPII Working Paper*, no. 2016-10, Paris: Centre d'études prospectives et d'informations internationales (CEPII). Available online.

Alessi L. Battiston S., Melo A.S. and Roncoroni A. (2019), "The EU Sustainability Taxonomy: a Financial Impact Assessment", *JRC Technical Reports*, EUR 29970 EN, Luxembourg: Publications Office of the European Union.

Alessi L., Ossola E. and Panzica R. (2021), "What Greenium Matters in the Stock Market? The Role of Greenhouse Gas Emissions and Environmental Disclosures", *Journal of Financial Stability*, 54 (June), art. 100869.
Andersen D.C. (2017), "Do Credit Constraints Favor Dirty Production? Theory and Plant-level Evidence", *Journal of Environmental Economics and Management*, 84, pp. 189-208.
Andrews E.L. (2008), "Greenspan Concedes Error on Regulation", *The New York Times*, 23 October.
Artola I., Rademaekers K., Williams R. and Yearwood J. (2016), "Boosting Building Renovation: What Potential and Value for Europe? Report for the European Parliament", *Directorate general for internal policies, Policy Department A: economic and scientific policy*, no. PE 587.326, Brussels: European Parliament. Available online.
Auer R., Banka H., Boakye-Adjei N.Y., Faragallah A., Frost J., Natarajan H. and Prenio J. (2022), "Central Bank Digital Currencies: A New Tool in the Financial Inclusion Toolkit?", *FSI Insights*, no. 41, Basel: Bank for International Settlements. Available online.
Banet J. and Lebeau L. (2022), "Central Bank Digital Currency: Financial Inclusion vs. Disintermediation", *Federal Reserve Bank of Dallas Working Paper*, no. 2218, Dallas: Federal Reserve Bank.
Banking on Climate Chaos: Fossil Fuel Finance. Report 2021 (2021), Rainforest Action Network and others. Available online.
Batten S., Sowerbutts R. and Tanaka M. (2016), "Let's Talk about the Weather: the Impact of Climate Change on Central Banks", *Bank of England Staff Working Paper*, no. 603, London: Bank of England.
Battiston S., Dafermos Y. and Monasterolo I. (2020), "Climate Risks and Financial Stability", December 14, available at SSRN. Available online.
Bearden D. M. (2012), *Comprehensive Environmental Response, Compensation, and Liability Act: A Summary of Superfund Cleanup Authorities and Related Provisions of the Act*, Washington: CRS Report for Congress.
Berenguer M., Cardona M. and Evain J. (2020), *Integrating Climate-related Risks into Banks' Capital Requirements*, Paris: Institute for Climate Economics.
Bernardini E., Faiella I., Lavecchia L., Mistretta A. and Natoli F. (2021), "Central Banks, Climate Risks and Sustainable Finance", *Questioni di Economia e Finanza (occasional paper)*, No. 608, Rome: Bank of Italy.
Billio M., Costola M., Pelizzon L. and Riedel M. (2022), "Buildings' Energy Efficiency and the Probability of Mortgage Default: The Dutch Case", *The Journal of Real Estate Finance and Economics*, 65, pp. 419-450.
BlackRock Invesment Institute (2019), *Getting Physical. Scenario Analysis for Assessing Climate-related Risks*, New York: BlackRrock Investment Institute. Available online.
Bolton P., Despres M., Pereira da Silva L.A., Samama F. and Svartzman R. (2020), *The Green Swan. Central Banking and Financial Stability in the Age of Climate Change*, Basel: Bank for International Settlements. Available online.
Bouma J.J., Klinkers L. and Jeucken M. (2001), *Sustainable Banking. The Greening of Finance*, Sheffield (UK): Greenleaf Publishing.
Bovenberg A.L. and Goulder L.H. (2001), "Environmental Taxation and Regulation", *NBER Working Papers*, no. 8458, Cambridge (MA): National Bureau of Economic Research.
Cahen-Fourot L., Campiglio E., Dawkins E., Godin A. and Kemp-Benedikt E. (2021), "Capital Stranding Cascades: The Impact of Decarbonisation on Productive Asset Utilization", *Ecological Economic Papers*, no. 18, Vienna: Vienna University of Economics and Business. Available online.
Campiglio E., Dafermos Y., Monnin P., Ryan-Collins J., Schotten G. and Tanaka M. (2018), "Climate Change Challenges for Central Banks and Financial Regulators", *Nature Climate Change*, 8, pp. 462-468.
Cantelmo A., Fatouros N., Melina G. and Papageorgiou C. (2024), "Monetary Policy under Natural Disaster Shocks", *Temi di Discussione (working paper)*, no. 1443, Rome: Bank of Italy. Available online.
Canuto O. (2020), "Climate Change: Three Reasons for Central Banks to Engage", *policycenter.ma*, February 17. Available online.
Carattini S., Heutel G. and Melkadze G. (2021), "Climate Policy, Financial Frictions, and Transition Risk", *NBER Working Paper*, no. 28525, Cambridge (MA): National Bureau of Economic Research.
Carli G. (2000), *Scritti scelti*, Roma: Laterza.
Carney M. (2015), "Breaking the Tragedy of the Horizon—Climate Change and Financial Stability", speech by Mark Carney, Governor of the Bank of England and Chairman of the Financial Stability Board, at Lloyd's of London, September 29, London. Available online.
Chen K. (1977), "Input-Output Economic Analysis of Environmental Impacts", *IEEE Transactions on Systems, Man and Cybernetics*, 6 (3), pp. 539-547.
Chenet H., Ryan-Collins J. and van Lerven F. (2021), "Finance, Climate-Change and Radical Uncertainty: Towards a Precautionary Approach to Financial Policy", *Ecological Economics*, 183 (May), art. 106957.
CIEL – Center for International Environmental Law (2015), *(Mis)calculated Risk and Climate Change. Are Rating Agencies Repeating Credit Crisis Mistakes?*, Washington (DC): Center for International Environmental Law. Available online.
Cockrell J. (2021), "Don't Rely on Central Banks to Fight Climate Change", *CBR Climate Change*, October 18. Available online.

Council of Europe (1993), "Convention on Civil Liability for Damage Resulting from Activities Dangerous to the Environment", *European Treaty Series*, no. 150, 21 June, Lugano. Available online.
Dafermos Y. and Nikolaidi M. (2019), "Fiscal Policy and Ecological Sustainability: A Post-Keynesian Perspective", *PKES Working Paper*, no. 1912, London: Post Keynesian Economics Society. Available online.
Daumas L. (2023), "Financial Stability, Stranded Assets and the Low-Carbon Transition – A Critical Review of the Theoretical and Applied Literatures", *Journal of Economic Surveys*, 38(3), pp. 601-716. Available online.
De Santis A., Roos M., Hettler K. and Tamburrini F. (2018), "Purchases of Green Bonds under the Eurosystem's Asset Purchase Programme", *ECB Economic Bullettin*, 7/2018. Available online.
Dechezleprêtre A. and Sato M. (2014), "The Impacts of Environmental Regulations on Competitiveness", *Policy Brief*, November, London: Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment. Policy Brief, Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science. Available online.
Dell M., Jones B.F. and Olken B.A. (2013), "What we Do Learn from the Weather? The New Climate-Economy Literature", *NBER Working Papers*, no. 19578, Cambridge (MA): National Bureau of Economic Research.
Donadelli M., Grüning P. and Hitzemann S. (2019), "Understanding Macro and Asset Price Dynamics During the Climate Transition", *Bank of Lithuania Discussion Paper*, no. 18/2019, Vilnius:Bank of Lithuania.
EBA – European Banking Authority (2018), *Risk Assessment of the European Banking System*, London: European Banking Authority.
EBA – European Banking Authority (2021), *Advice to the Commission on KPIS and Methodology for Disclosure by Credit Institutions and Investment Firms under the NFRD on how and to what Extent their Activities Qualify as Environmentally Sustainable According to the EU Taxonomy Regulation*, EBA Report no. 3, Paris: European Banking Authority.
EBA – European Banking Authority (2022), "The Role of Environmental Risks in the Prudential Framework", *EBA Discussion Paper*, no. 2022/02, Paris: European Banking Authority.
EC – European Commission (2018), "Proposal for a Regulation of the European Parliament and of the Council on the Establishment of a Framework to Facilitate Sustainable Investment", COM(2018) 353, Brussels: European Commission. Available online.
ECB – European Central Bank (2020), *Guide on Climate-Related and Environmental Risks. Supervisory Expectations Relating to Risk Management and Disclosure*, November, Frankfurt a.M.: European Central Bank, Banking Supervision. Available online.
ECB – European Central Bank (2021a), *Climate-related Risk and Financial Stability*, July, Frankfurt a.M.: European Central Bank, Eurosystem. Available online.
ECB – European Central Bank (2021b), "ECB's Governing Council Approves its New Monetary Policy Strategy", Press Release, 8 July, Frankfurt: European Central Bank. Available online.
ECB – European Central Bank (2022), "2022 Climate Risk Stress", July, Frankfurt: European Central Bank, Banking Supervision. Available online.
EEFIG – Energy Efficiency Financial Institutions Group (2022), *The Quantitative Relationship between Energy Efficiency Improvements and Lower Probability of Default of Associated Loans and the Increased Value of the Underlying Assets. Final Report on Risk Assessment*", Luxembourg: Publications Office of the European Union. Available online.
EeMAP – Energy efficient Mortgages Action Plan (2019), *Final Report on the Correlation between Energy Efficiency and Probability of Default*, WP5/D5/4, June 11, Brussels: European Commission. Available online.
Esposito L., Mastromatteo G. and Molocchi A. (2019). "Environment Risk Weighted Assets: Allowing Banking Supervision and Green Economy to Meet for Good", *Journal of Sustainable Finance & Investment*, 9 (1), pp. 68-86.
Esposito L., Mastromatteo G., Molocchi A., Brambilla C., Carvalho M.L., Girardi P., Marmiroli B. and Mela G. (2022), "Green Mortgages, EU Taxonomy and Environment Risk Weighted Assets: A Key Link for the Transition", *Sustainability*, 14(3), art. 1633, DOI: https://doi.org/10.3390/su14031633.
ESRB – European Systemic Risk Board (2016), "Too Late, too Sudden: Transition to a Low-carbon Economy and Systemic Risk", *Reports of the Advisory Scientific Committee*, No. 6/February, Frankfurt: European Systemic Risk Board. Available online.
Eurostat (2011), *Creating Consolidated and Aggregated EU27 Supply, Use and Input-Output Tables, Adding Environmental Extensions (Air Emissions), and Conducting Leontief-type Modelling to Approximate Carbon and Other 'Footprints' of EU27 Consumption for 2000 to 2006*, Luxembourg: Eurostat. Available online.
Eurostat (2016), *Environmental Goods and Services Sector Accounts*, Luxembourg: Eurostat. Available online.
Faiella I. and Lavecchia L. (2021), "Households' Energy Demand and the Effects of Carbon Pricing in Italy", *Bank of Italy Occasional Paper*, no. 614, Rome: Bank of Italy.
FAO – Food and Agriculture Organization (2017), "The Future of Food and Agriculture. Trends and Challenges", Rome: Food and Agriculture Organization. Available online.

Fatica S., Panzica R. and Rancan M. (2021), "The pricing of Green Bonds: Are Financial Institutions Special?", *Journal of Financial Stability*, 54 (June), art. 100873.
Ferrari A. and Nispi Landi V. (2023), "Will the Green Transition Be Inflationary? Expectations Matter", *ECB Working Paper*, no. 2726, Frankfurt a.M.: European Central Bank.
Ferrari A. and Nispi Landi V. (2024). "Whatever it Takes to Save the Planet? Central banks and Unconventional Green Policy", Temi di Discussione (working paper), Rome: Bank of Italy, No. 1320.
Ferrer R. and Gili R. M. (2021), "Central Banks and Climate Change: to Act or not to Act", *CaixaBank Research*, June 14. Available online.
Forssell O. and Polenske K.R. (1998), "Introduction: Input–Output and the Environment", *Economic Systems Research*, 10 (2), pp. 91–97.
FSB. (2022). "Supervisory and Regulatory Approaches to Climate-related Risks", Interim Report, Basel: Financial Stability Board.
G20 (2016), *G20 Green Finance Synthesis Report*, September 5, G20 Green Finance Study Group. Available online.
GAC – Global Agenda Council on New Energy Architecture (2013), *Financial Regulation – Biased against Clean Energy and Green Infrastructure?*, Geneva: World Economic Forum. Available online.
Gelles D. (2024), "More Wall Street Firms Are Flip-Flopping on Climate. Here's Why", *Wall Street Journal*, February 19. Available online.
GFT – Green Financial Taskforce (2018), "Accelerating Green Finance", London: Green Financial Taskforce. Available online.
Ghisetti C., Mazzanti M., Mancinelli S. and Zoli M. (2015), "Do Financial Constraints Make the Environment Worse Off? Understanding the Effects of Financial Barriers on Environmental Innovations", *SEEDS Working Paper*, no. 1/2015, Ferrara: University of Ferrara, Sustainability Environmental Economics and Dynamics Studies. Available online.
Grippa P., Schmittmann J. and Suntheim F. (2019), "Climate Change and Financial Risk", *Finance & Development*, December, pp. 26-29. Available online.
Guilhoto Joaquim J. M. (2021), "Input–Output Models Applied to Environmental Analysis", In Shugart Hank (ed.), *Oxford Research Encyclopedia of Environmental Science*, London: Oxford University Press.
Hansen L.P. (2021), "Central Banking Challenges Posed by Uncertain Climate Change and Natural Disasters", *BFI Working Paper*, No. 2021-64, Chicago: University of Chicago, Becker Friedman Institute.
Harding A. (2023), "America Is in a New Cold War With China", *The Heritage Foundation*, March 29. Available online.
Hidalgo-Oñate D., Fuertes-Fuertes I. and Cabedo J. D. (2023). "Climate-related Prudential Regulation Tools in the Context of Sustainable and Responsible Investment: A Systematic Review", *Climate Policy*, 23(6), pp. 704-721.
HLEG – High Level Expert Group on Sustainable Finance (2017), *Interim Report*, Brussels: European Union. Available online.
HLEG – High Level Expert Group on Sustainable Finance (2018), *Final Report*, Brussels: European Union. Available online.
Igos E., Rugani B., Rege S., Benmetto E., Drouet L. and Zachary D.S. (2015), "Combination of Equilibrium Models and Hybrid Life Cycle–Input-Output Analysis to Predict the Environmental Impacts of Energy Policy Scenarios", *Applied Energy*, 145, pp. 234-245.
Ilhan E., Krueger P., Sautner Z. and Starks L.T. (2019), "Institutional Investors' Views and Preferences on Climate Risk Disclosure", *Swiss Finance Institute Research Paper Series*, no. 19-66, Geneva: Swiss Finance Institute.
IPCC – Intergovernmental Panel on Climate Change (2022), *Global Warming of 1.5°C. Summary for Policymakers, Technical Summary and Frequently Asked Questions*, Geneva: Intergovernmental Panel on Climate Change. Available online.
Jackson A. (2020), "A Stock-flow Consistent Framework for the Analysis of Stranded Assets and the Transition to a Low Carbon Economy", PhD doctoral thesis, Guildford: University of Surrey. Available online.
Jia J. and Ilzetzki E. (2021), "The ECB's Green Agenda", *CEPR.org*, March 10. Available online.
Khasreen M., Banfill P.F.G. and Menzies G.F. (2019), "Life-Cycle Assessment and the Environmental Impact of Buildings: A Review", *Sustainability*; 3, pp. 674-701.
Kocher I. (2019), "Green finance, at the heart of the ecological transition", in *Greening the Financial System: The New Frontier* (pp. 59-68), special issue of *Financial Stability Review*, no. 23, June. Paris: Banque de France. Available online.
Lakhani N. and Rushe D. (2024), "US Banks abandon 'bare minimum' Environmental Standards Projects, Alarming Climate Groups", *The Guardian*, March 6. Available online.
Lamperti F., Bosetti V., Roventini A. and Tavoni M. (2019), "The Public Costs of Climate-induced Financial Instability", *Nature Climate Change*, 9, pp. 829-833.
Landau J. and Brunnermeier M. (2020), "Central banks and Climate Change", *CEPR.org*, January 15. Available online.
Langley P. and Morris J. H. (2020), "Central Banks: Climate Governors of Last Resort?", *Economy and Space*, 52(8), pp. 1471–1479.

MacCracken C.N., Edmonds J.A., Kim S.H. and Sands R.D. (1999), "The Economics of the Kyoto Protocol", *The Energy Journal*, 20(1_suppl.), pp. 25-71.
Masciandaro D. and Russo R. (2022), "Central Banks and Climate Policy: Unpleasant Trade–Offs? A Principal–Agent Approach", *Bocconi Working Paper Series*, no. 181, June, Milan: Bocconi University, Baffi Carefin. Available online.
Matikainen S., Campiglio E. and Zenghelis D. (2017), "The Climate Impact of Quantitative Easing", *CCCEP Policy Paper*, May, London: LSE Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy. Available online.
Mazzucato M. (2013), *The Entrepreneurial State: Debunking Public vs. Private Sector Myths*, London: Anthem Press.
McEvoy D.M. and McGinty M. (2018), "Negotiating a Uniform Emissions Tax in International Environmental Agreements", *Journal of Environmental Economics and Management*, 90(C), pp. 217-231.
McKibbin J. and Wilcoxen P.J. (2002), "The Role of Economics in Climate Change Policy", *Journal of Economic Perspectives*, 16(2), pp. 107-129.
Mersch Y. (2018), "Climate Change and Central Banking", speech by Yves Mersch, Member of the Executive Board of the ECB, Workshop discussion: *Sustainability is becoming mainstream*, Frankfurt, 27 November. Available online.
Miller R.E. and Blair PD. (2009), *Input–Output Analysis. Foundations and Extensions*, Cambridge (MA): Cambridge University Press.
Moliterni F., Vernizzi F. and Pareglio S. (2017). "Disclosing Climate-Related Risks: Current and Future Prospects", FEEM Policy Brief, no. 3/2017, July, Milan: Fondazione Eni Enrico Mattei. Available online.
Narbel P.A. (2013), "The Likely Impact of Basel III on a Bank's Appetite for Renewable Energy Financing", *Norwegian School of Economics Discussion Paper*, no. 2013/10, Bergen: NHH Norwegian School of Economics.
NGFS – Central Banks and Supervisors Network for Greening the Financial System (2018), *NGFS First Progress Report*, October, Paris: Network for the Greening of the Financial System. Available online.
NGFS – Central Banks and Supervisors Network for Greening the Financial System (2019), *A Call for Action. Climate Change as a Source of Financial Risk*, April, Paris: Network for Greening the Financial System. Available online.
Nordhaus W.D. and Boyer J.D. (1999), "Requiem for Kyoto", *The Energy Journal*, 20, pp. 93-120.
Nordhaus W.D. and Moffat A. (2017), "A Survey of Global Impacts of Climate Change: Replication, Survey Methods, and a Statistical Analysis", *NBER Working Paper*, no. 23646, Cambridge (MA): National Bureau of Economic Research.
OECD – Organisation for Economic Co-operation and Development (2015), *The Economic Consequences of Climate Change*, Paris: OECD Publishing. Available online.
Olovsson C. and Vestin D. (2023), "Will a Green Transition lead to Greenflation?", *SUERF Policy Brief*, no. 577, Wien: The European Money and Finance Forum – Société Universitaire Européenne de Recherches Financières. Available online.
Pereira da Silva L.A. (2019), "Research on Climate-related Risks and Financial Stability: An 'Epistemological Break'?", remarks by Mr Luiz Awazu Pereira da Silva, Deputy General Manager of the BIS, at the Conference of the Central Banks and Supervisors Network for Greening the Financial System (NGFS), Paris, 17 April. Available online.
PRA – Prudential Regulation Authority (2015), *The Impact of Climate Change on the UK Insurance sector*, London: Bank of England, Prudential Regulation Authority. Available online.
Quorning S. (2023), "The 'Climate Shift' in Central Banks: how Field Arbitrageurs Paved the Way for Climate Stress Testing", *Review of International Political Economy*, 31(1), pp. 74-96.
Reuters (2022), "Global Green Finance Rises over 100 Fold in the Past Decade -Study", *Reuters.Com*, March 31. Available online.
Rezende de Carvalho F.M.C., Amorim Sobreiro V., Kimura H. and de Moraes Barboza F.L. (2016), "A Systematic Review of Literature about Finance and Sustainability", *Journal of Sustainable Finance & Investment*, 6(2), pp. 112-147.
Ribeiro H.B. and Schröder Bosch J. (2021), "Climate as a Monetary Policy Dilemma: A Critical Investigation into the European Central Bank's "Green" Framework" thesis for the EPOG Erasmus Mundus Joint Master's Degree, Paris. Available online.
Roncoroni A., Battiston S., Escobar-Farfán L.O.L. and Martnez-Jaramillo S. (2021), "Climate Risk and Financial Stability in the Network of Banks and Investment Funds", *Journal of Financial Stability*, 54 (June), art. 100870.
Scott M., van Huizen J. and Carsten J. (2017), "The Bank of England's Response to Climate Change", *Bank of England Quarterly Bulletin*, Q2, pp. 98-109. Available online.
Serrano M. (2007), "The Production and Consumption Accounting Principles as a Guideline for Designing Environmental Tax Policy", *FEEM Nota di Lavoro* 8-2007, Milan: Fondazione Eni Enrico Mattei.
Silver N. (2017), "Blindness to Risk: why Institutional Investors Ignore the Risk of Stranded Assets", *Journal of Sustainable Finance & Investment*, 7(1), pp. 99-113.
Sinha S. (2015), "COP21: All about History, Goals and Timeline of Paris Climate Change Conference", *International Business Times*, November 30. Available online.
Steenge A.E. (1999), "Input–Output Theory and Institutional Aspects of Environmental Policy", *Structural Change and Economic Dynamics* 10(1), pp. 161-176.

Stern N. (ed.) (2006), *The Economics of Climate Change: The Stern Review*, London: HM Treasury.
Stiglitz J.E. (2000), *Economics of the Public Sector*, New York: W.W. Norton.
TEG – Technical Expert Group on Sustainable Finance (2019), *Taxonomy Technical Report*, Brussels: European Union. Available online.
The Economist (2019), "Green Envy: The Rights and Wrongs of Central-Bank Greenery", December 14. Available online.
Thiemann M., Buttner T. and Kessler O. (2022), "Beyond Market Neutrality? Central Banks and the Problem of Climate Change", *Finance and Society*, 9(1), pp. 1-21.
Thomä J. and Chenet H. (2017), "Transition Risks and Market Failure: a Theoretical Discourse on why Financial Models and Economic Agents May Misprice Risk Related to the Transition to a Low-carbon Economy", *Journal of Sustainable Finance & Investment*, 7(1), pp. 82-98.
Tirole J. (2022), "Socially Responsible Agencies", mimeo Toulouse School of Economics (TSE). Available online.
Ulph A. and Valentini L. (2004), "Environmental Liability and the Capital Structure of Firms", *Resource and Energy Economics*; 26(4), pp. 393-410.
UN – United Nations (2000), *Integrated Environmental and Economic Accounting: An Operational Manual. Studies on Methods*, New York: United Nations. Available online.
UNEP – United Nation Environment Programme (2017), *Green Finance Progress Report*, July, New York: United Nations. Available online.
UNEP – United Nation Environment Programme (2010), *Universal Ownership: Why Externalities Matter to Institutional Investors*, New York: United Nations, PRI Association and UNEP-FI.
UNFCCC – United Nations Framework Convention on Climate Change (1995), *Report of the Conference of the Parties on its First Session. Addendum Part Two: Action taken by the Conference of the Parties at its First Session*, Berlin 28 March–7 April, New York: United Nations Framework Convention on Climate Change. Available online.
UNFCCC – United Nations Framework Convention on Climate Change (2015), *Adoption of the Paris Agreement*, New York: United Nations Framework Convention on Climate Change. Available online.
Visco V. (2021), "The Conference Messages in Light of the G20 Presidency Programme", remarks by Ignazio Visco, Governor of the Bank of Italy, at The Green Swan 2021 Global Virtual Conference, Bank for International Settlements, 4 June 2021, Rome: Bank of Italy. Available online.
Vollmer U. (2022), "Central Bank Policies and Climate Change. Where Do We Stand?", *Credit and Capital Markets*, 55(3), pp. 381-411.
Walsh T. (2021), "UN PRI Raises the ESG Bar for Signatories", *IFRE.Com*, April 15. Available online.
Warmerdam W., Christopoulou A., Herder A., Bosma C., de Wilde J., Riemersma M. and van Gelder J.W. (2015), *Undermining Our Future. A Study of Banks' Investments in Selected Companies Attributable to Fossil Fuels and Renewable Energy*, The Hague: Profundo Banktrack and Fair Finance Guide International.
Wass S., Wu J., Yamaguchi Y. and Ramos M. (2023). "Global Green Bond Issuance Poised for Rebound in 2023 Amid Policy Push", *S&P Global Market Intelligence*, January 25. Available online.
WEF – World Economic Forum (2017), *The Global Risks Report 2017. 12th Edition*, Geneva: World Economic Forum. Available online.
Weitzman M.L. (2014), "Can Negotiating a Uniform Carbon Price Help to Internalize the Global Warming Externality?", *Journal of the Association of Environmental and Resource Economists*, 1 (1/2), pp. 29-49.
Wolford E.A. (2014), "Lender Liability under CERCLA: Interpreting the Security Interest Exemption Using Common-Law Principles of Lender Liability", *Notre Dame Law Review*, 67(4), pp. 1161-1213.
Zlatic V., Gabbi G. and Abraham H. (2015), "Reduction of Systemic Risk by Means of Pigouvian Taxation", *PLoS ONE*, 10(7), art. e0114928.