

Green-Digital Finance: the potential role of Central Bank Digital Currencies in addressing climate change

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Abstract:

As institutions tasked with managing money, central banks (CBs) are not recognized for being innovative. On the contrary, as the institutions responsible for monetary and financial stability - their main role since the first CBs started to emerge - a great dose of conservatism has been said to be necessary. This has become especially true since the adoption of the so-called New Monetary Consensus prescriptions of rules for monetary policy and central bank independence. However, since the 2008 crisis and with more intensity after the COVID-19 pandemic, there were significant changes in CBs' instruments and, more recently, in the format for State currency, with the creation of Central Bank Digital Currencies (CBDC). CBDC is a digital currency that is issued by the central bank to be used by non-financial actors, similar to a 'reserves for all', and it represents a significant shift in the way monetary systems currently work.

In parallel, it is becoming increasingly imperative that central banks consider climate change and the achievement of the Sustainable Development Goals (SDGs) established by the United Nations. To contribute to the financial stability and resilience of financial systems in the face of uncertainties posed by climate change, central banks will have to adopt a comprehensive approach involving new mandates, prudential regulation, financial and credit policies, active participation in international cooperation with monetary and financial authorities on environmental issues, and the promotion of systemic integration of climate and sustainability dimensions in corporate and national accounting frameworks. Such integration will aid private and public actors in managing environmental risks effectively. In essence, central bank operations should align with the political and social objectives of the State, particularly in the pursuit of a sustainable transition, towards a more democratic monetary policy for the 21st century.

This paper aims to discuss how central banks are currently discussing their role in green transition and in climate change mitigation policies and propose new approaches and tools, particularly focusing on the Brazilian Central Bank . For that, it is divided into three parts

besides the introduction and conclusion. We first discuss the challenges that climate change effectively poses to the financial system, to monetary policy and financial stability. Then, we discuss the current mandates of central banks and investigate current initiatives in place to include climate concerns, broadly speaking, in CBs' policy framework. Finally, we argue that central banks need to have much larger roles and mandates that they have today to deal with the climate emergency, particularly investigating how CBDCs can be considered an additional instrument in this task. For that, we will focus on the case of Brazil, where the Central Bank (BCB) is in its final stages of research to introduce the 'Drex'.

Introduction

In this first quarter of the 21st century, the world has been experiencing a double shift. On the one hand, life as we know it is threatened by climate change, with rising global temperatures and an increasing number of natural disasters like floods, wildfires, and hurricanes. In 2015, the United Nations (UN) introduced a new and bold framework to address the challenges the global economy is facing in the 21st century: inequality, injustice, poverty and climate change. In what is probably one of its most ambitious initiatives since the Declaration of Human Rights, the UN introduced seventeen goals, each with its own set of sub-targets. The goals are highly interrelated: it is impossible to think of no poverty (goal 1) without tackling inequalities within and among countries (goal 10), for example. Focusing specifically on goal 13 – “Take urgent action to combat climate change and its impact” – the UN alerts that we are on the brink of Earth’s tipping point, or, according to some, even passed it^[1]. As pointed out by the United Nations, a just transition process can be a powerful driver to achieve twelve of the seventeen Sustainable Development Goals.

The concept of just transition was originally formulated in the 1970s within the context of discussions on work and the environment led by unionists and environmental activists. Since then, it has been gaining importance, becoming a central piece of the conceptual framework that underpins the debate on green transition at the international level, as it manages to articulate the need for a transition to a low-carbon or carbon-neutral economy with the social dimension of human rights. In 2013, at its 102nd Session, the International Labour Conference (ILO) adopted a resolution with a set of conclusions on sustainable development, decent work, and green jobs, proposing a set of policies for a just transition. An important milestone in this journey was the recognition of the need for a just transition within the framework of the 2015 Paris Agreement, which refers to "the imperatives of a just transition of the workforce and the creation of decent work and quality jobs in accordance with nationally defined development priorities". Although the end goal of the SDGs is a just transition, we will focus in this paper mostly on the green transition and climate emergency.

The size and complexity of the tasks that lie ahead require the participation of a broad array of players, private and public, in this process. The literature has been pointing out that an important bottleneck for the transition process is the huge amount of financial resources necessary to its implementation, as well as the risks to the financial system that are expected with climate changes and the transition itself (Campiglio, 2016; Dikau and Volz, 2018; Zhang, 2022; Braga and Ernst, 2023). In this sense, financial institutions - mainly public banks, as well as multilateral banks - are of paramount importance. The only way to effectively promote the necessary transition to more renewable energy sources on a global scale taking into consideration also the social impacts related to the destruction of traditional sectors of the economy and the creation of new ones - a just transition - is through bold public policies which require strong and capable governments and coordination between nations. As institutions that create and manage money and as a powerful creation of societies in order to better allocate its resources and model the future, central banks have to be involved in this transition

However, in the last decades monetary authorities have encapsulated their mandates and considered that delivering monetary stability - mainly by adopting Inflation Targeting Regimes - was their main role (Arestis and Sawyer, 2008; Fiebieger and Lavoie, 2020; Rochon, 2022). In this sense, monetary policy came to be almost a synonym of fine-tuning short-term interest rates in order to reach the target. Also, in terms of providing financial stability, central banks in their majority have adopted the so-called Basel approach, a framework for risk management which is centered on the idea that banks have to hold a minimum amount of capital based on the risk parity of their assets, ensuring they can absorb a reasonable amount of loss while maintaining sufficient capital to continue operating. More recently, as a response to technological as well as political changes, central banks have been incorporating the challenge of developing their digital currencies (Central Bank Digital Currencies - CBDCs), a crucial innovation that can lead to substantial changes in the monetary and financial landscape, but that also carries a lot of new opportunities.

This paper aims to analyze how central banks are currently discussing and incorporating in their roles green transition and climate change mitigation policies, and propose new approaches and tools. Besides the introduction and a final concluding section, we first discuss what risks climate change and mitigation pose to the financial system. Then, we look at how central banks are currently considering the inclusion of climate concerns in their operational framework, considering in particular the case of the Brazilian Central Bank. As Brazil possesses the largest area of native tropical vegetation on the planet, it bears a significant responsibility for reducing GHG emissions (Stussi and Souza, 2024), which makes the focus on the role of the BCB in addressing climate change particularly relevant. The third section is dedicated to a critique, arguing that central banks need a broader scope of action and new tools like CBDCs to deal with the climate emergency, focusing on the case of Brazil.

1. Climate change and risks to the financial system

Climate change, driven by increasing greenhouse gas emissions (GHG) and the rising concentration of carbon dioxide (CO₂) in the atmosphere, is propelling the planet towards critical ecological thresholds, as articulated in the literature on planetary boundaries. The effects are already felt all over the globe: storms and hurricanes, wildfires, floods, and rising sea levels. By 2050, achieving net-zero emissions is imperative to limit global temperature rise to 1.5 to 2 degrees Celsius above pre-industrial levels, as stipulated by the Paris Agreement (IPCC, 2018). This ambitious target necessitates unprecedented efforts from governments and organizations worldwide to transition towards sustainable practices and mitigate both the direct impacts of climate change and the secondary effects of policies designed to address it.

Growing awareness of the severity of climate change has prompted important reactions at various levels and from a wide range of actors and organizations: international, multilateral and domestic organizations, governmental and civil society organizations, financial and business institutions. Several initiatives in the financial sphere for coordinating and implementing measures to confront the challenges have been put in place such as the Glasgow Financial Alliance for Net Zero, the Network of Central Banks and Supervisors for Greening the Financial System (NGFS) and the International Development Finance Club (IDFC). Within this context, there has been extensive debate regarding the role that central banks and regulatory authorities must play in addressing these questions.

The primary concerns of central banks and regulatory authorities remains both price stability and financial stability. However, climate change imposes a new set of risks - both physical and transitional - which are sources of new financial risks, challenging CB's concerns. This has been leading to efforts to understand and incorporate climate-related risks into regulatory frameworks, with the aim of preserving financial stability. The incorporation of green instruments, such as green bonds, into monetary policy is still in its early stages and not yet widespread would represent a significant step towards aligning monetary policy with environmental objectives. Additionally, there is an emerging dialogue around green monetary and credit policies, indicating a needed recognition of addressing environmental sustainability within the financial system. This reflects a shift towards considering the broader implications of monetary policy in the context of climate change and sustainability.

As central banks and regulatory authorities increasingly recognize the imperative to address climate-related challenges, they are tasked with navigating the intricate intersection of environmental sustainability and financial stability. This dual responsibility requires not only supporting the transition to a low-carbon economy but also deeply understanding and managing the novel risks that climate change introduces into the financial system. Chief among these are *physical* risks—arising from the increased frequency and intensity of climate and weather-related events—and *transition* risks, which stem from the abrupt and often unpredictable adjustments toward greener policies and technologies (BIS, 2021; D'Orazio and Popoyan, 2022). As Carney (2018) pointed out, a sudden and disorderly shift to a low-carbon economy could lead to what he describes as a "climate Minsky moment," where rapid revaluations of assets and a widespread reassessment of financial prospects could destabilize markets and tighten financial conditions. These risks are significant enough to cause major market disruptions, highlighting the need for early and coordinated actions to manage the transition effectively and avoid amplifying financial instability¹.

Physical risks stem from the impacts of changing climatic conditions, which can be assessed through both their direct and indirect effects. These risks are evidenced by the increasing frequency and severity of extreme weather events - such as storms, floods, heatwaves, and wildfires, as well as through broader shifts in climate patterns, including changes in precipitation and rising sea levels. Such events can lead to significant losses in human lives, damage to natural and urban environments, and significant disruptions to businesses. The destruction of physical capital and the decline in profitability for firms, coupled with reduction in household incomes, can lead to a reallocation of financial assets, resulting in significant negative wealth effects.

These wealth effects may, through second-round consequences, place additional pressure on demand and prices, exacerbating the adverse economic and financial impacts. As losses accumulate, firms and households may face difficulties in meeting their debt obligations, and collateral values may deteriorate, leading to heightened exposure to financial risk. Insurance liabilities may also increase due to the rising costs of claims. As a result, financial institutions may experience capital shortages that impair their ability to absorb losses and potentially triggering contagion effects that could lead to widespread asset devaluations throughout the financial system (Giuzio et al., 2019). Ultimately, physical risks pose a threat to financial stability by generating irreversible losses, as both physical and financial capital are affected by climate shocks, leaving financial institutions vulnerable and often unable to protect themselves against such risks. The inability to mitigate these climate-induced financial shocks underscores

¹ While Minsky's original theory of financial instability emphasizes the inherent fragility of the financial system, Carney's analogy underscores the potential magnitude of climate-related disruptions. The risks are significant enough to prompt major market dislocations, similar to the crises described by Minsky, even though Minsky's framework does not focus on a singular moment but rather on the cumulative build-up of instability. Such risks reinforce the need for early and coordinated actions to ensure a smoother transition and mitigate the risks of exacerbating financial instability.

the systemic nature of physical risks and their capacity to disrupt financial systems (Giuzio et al., 2019; BIS, 2021).

Transition risks emerge from the transformation towards a low-carbon economy and carry unpredictable financial consequences. These risks materialize when mitigation strategies such as policies, technological advances, or swings in public perception, are implemented, leading to abrupt revaluations of assets, particularly if the transition occurs suddenly. Unanticipated introduction of greening policies or significant changes in consumer preferences can trigger abrupt rapid decline in asset prices tied to carbon-intensive industries and sectors (Giuzio et al, 2019). Transition risks are associated with various factors, including the introduction of environmental legislation, the obsolescence of polluting industries, changes in policies, reputational effects, technological advancements or constraints, and alterations in market preferences and societal norms (Carney, 2018; BIS, 2021). The unpredictability of these changes can cause substantial disruptions in financial markets, as investors reassess the value and viability of firms heavily reliant on carbon-intensive activities. This can lead to sharp reallocations of capital from "brown" (high-carbon) to "green" (low-carbon) assets, driven by market repricing of risks and efforts to mitigate reputational and legal liabilities.

Central banks and regulatory authorities may inadvertently contribute to or exacerbate these market disruptions, particularly in credit markets (Campiglio, 2016). The rapid shift away from carbon-intensive activities could lead to a "climate Minsky moment," where the success of climate mitigation efforts intensifies financial instability. As Carney (2016) pointed out, this paradox of transition risks highlights that the more successful the strategies for mitigating climate change, the more severe the financial disruptions associated with the transition can become—what he terms as "success is failure." In essence, transition risks reflect the financial repercussions of moving towards a sustainable economy, where the speed and scale of policy, market, and technological shifts can destabilize existing financial structures and lead to significant financial losses in carbon-intensive sectors.

BIS (2021) outlines five key pathways through which climate-related risks—both physical and transition—can turn into financial risks, each capable of threatening the stability of the financial system. Firstly, credit risk arises as climate-related disruptions undermine borrowers' ability to repay their debts. Extreme weather events, a form of physical risk, can result in capital destruction, lower business profitability, and reduced household incomes, which in turn negatively affect borrowers' capacity to meet their financial obligations. In a similar way, transition risks, caused by abrupt regulatory shifts or advancements in technology, can lead to a sharp decline in the value of carbon-intensive assets, increasing the chance of defaults. Furthermore, collateral used to secure loans may also lose value in sectors vulnerable to climate impacts, thereby compounding the credit risk.

Secondly, market risk occurs when sudden changes in investor sentiment regarding climate risks lead to heightened market volatility. A rapid shift towards a low-carbon economy could cause a significant drop in the value of "brown" assets, leading to investor sell-offs at discounted prices. This process, known as fire sales, can trigger broader disruptions in the financial markets, as the revaluation of assets spreads across various sectors, generating instability.

Thirdly, insurance risk is closely tied to the increasing occurrence of extreme weather events due to climate change. As these events become more frequent and severe, the costs of insurance claims rise, placing financial strain on insurers. If insurers find it difficult to meet these rising costs, it could lead to solvency issues, potentially threatening the stability of the entire insurance sector. The impacts could spillover into the broader financial system, particularly in regions heavily dependent on insurance to mitigate risks.

Fourthly, liquidity risk emerges when the repricing of assets in response to climate risks leads to a sudden withdrawal of liquidity. Companies and financial institutions with significant exposure to climate-sensitive sectors may face difficulties in obtaining financing, as investors and lenders become more cautious. This reduced liquidity can exacerbate financial stress, further destabilizing the markets.

Lastly, operational risk becomes a concern as climate-related events disrupt the day-to-day operations of financial institutions. Extreme weather, for instance, can damage critical infrastructure, interrupt business operations, or can decrease employee productivity. Additionally, regulations aimed at addressing climate risks may impose new compliance costs, which can put further pressure on institutions' operational capacities.

Together, these pathways illustrate the varied and interconnected ways in which climate-related risks can infiltrate the financial system. Their interdependence highlights the potential for cascading effects, where initial shocks from climate events escalate into broader financial instability, simultaneously affecting credit, market, insurance, liquidity, and operational risks (BIS, 2021). In summary, climate-related risks can, and often do, evolve into financial risk. This reality underscores the necessity for central banks and other regulatory authorities - whose mandates typically include financial stability - to incorporate these risks into their frameworks. Such integration must account for the intricate interactions between the macroeconomic, financial and climate systems (NGFS, 2019). It was clearly recognized by the NGFS, network of Central Banks, that "climate-related risks are a source of financial risk. It is therefore within the mandates of central banks and supervisors to ensure the financial system is resilient to these risks" (NGFS, 2018, p 3).

However, integrating climate-related risks into regulatory and financial frameworks as they currently stand presents significant challenges. Traditional risk management relies heavily on historical data and assumes that shocks are normally distributed. This is particularly

problematic in the context of climate change, where risk is inherently unpredictable, and historical patterns fail to capture the potential severity of future events. Capital requirements and regulatory frameworks, built around credit, market, and operational risks, may not adequately account for the complexities introduced by climate change.

In regular times, the regulatory frameworks most widely and globally used by central banks and other regulatory authorities in the pursuit of financial stability rely above all on risk assessment, measurement, monitoring, and management. Yet, climate change not only introduces new risks into this equation but also raises questions about the fundamental design of these frameworks. The sheer intensity and unpredictability of climate-related events challenge the conventional backward-looking risk assessment models that rely on historical trends.

The incorporation of climate risks into the financial stability framework seems to be even more complex, given that the “new risks”, physical and transition, can interact in broad, far-reaching, nonlinear, chain reaction effects. Even more, cases of exceeding “climate tipping points could lead to catastrophic and irreversible impacts that would make quantifying financial damages impossible.” (BIS, 2021, p.1). Climate change introduces a level of unpredictability that defies probabilistic models typically used in financial risk assessments. Consequently, traditional methods of risk assessment - such as stress testing and scenario analysis - may fail to capture the full extent of climate-related risks, particularly in the face of extreme, low-probability events that could have catastrophic consequences. In addition, abrupt policy changes aimed at mitigating climate change may trigger transition risks, which in turn exacerbate physical risks by affecting vulnerable sectors of the economy. The interconnectedness of these risks complicates efforts to develop comprehensive regulatory responses that can adequately address the full spectrum of climate-related financial risks.

Traditionally, besides and beyond the presence of regulatory frameworks, the central bank's financial stability mandate imposes reactions once financial instability sets in and leads to a financial crisis. These authorities have no choice but to act as lenders of last resort in the quest to tackle and re-establish financial stability. Climate events may force central banks to act as “climate rescuers of last resort” (Bolton et al, 2020) and avoid further devaluation of assets and try to restore the financial system. Yet, the challenge here is different—climate-related crises may have continuous, irreversible impacts, making the stabilization efforts more complex and the typical interventions less effective.

François Villeroy de Galhau, Governor of the Banque de France affirms that climate risks can not only threaten central banks' mandates of price and financial stability, but also our socio-economic systems. As he notes, climate changes can impose non-linear and irreversible financial losses and also, the required economic transition to fight can affect “every single agent in the economy and every single asset price” (BIS, 2021, p. viii).

Given this broad spectrum of challenges, central banks have a crucial role in coordinating efforts across various sectors, including governments, the private sector, and civil society. As BIS General Manager Agustín Carstens argues, this coordination role aligns with central banks' mandates and could contribute to better assessing and monitoring climate-related risks. Central banks can also help develop and assess green and brown taxonomies, ensuring that the regulatory responses are well-tailored to the emerging risks. Moreover, they can enhance prudential regulations that address the financial stability threats posed by climate change (BIS, 2021).

However, there is still a lack of consensus on how to integrate climate risks into monetary policy, which remains central to controlling inflation and maintaining price stability. Some argue that central banks should not adopt "green targets" within their mandates, suggesting that fiscal and regulatory measures might be more efficient in addressing climate risks. They point out that climate change complicates central banks' traditional role of price stability, and "the last thing they need is to feel pressure to load additional objectives on their limited instruments" (Buiter, 2021, p. 1). From this perspective, central banks should focus on responding to the fragile economic and inflationary contexts created by climate change, rather than actively pursuing the transition to a low-carbon economy.

On the other hand, others defend that the price stability mandates can be jeopardized by climate change and that central banks should take their part in the transition to low-carbon economies. However, this could lead to an overburdening of central banks' existing mandates and that they should be part of a broader range of interventions, including fiscal and regulatory actions (BIS, 2021). According to Galhau (2019, p. 10-12), it could push central banks to consider whether they should take preventive action to join efforts aimed at limiting global warming and thus adopt an approach of "leaning against climate change". [...] monetary policy is also involved in this collective mobilization [...] thoroughly integrating climate change into the monetary policy framework.

In this strand, the diversity of arguments is wide-ranging, but what seems to be at stake is not a reactive stance, in the sense of adapting the current model to the new environment, but a more emphatic action by central banks through the use of monetary policy to promote the transition to a low-carbon economy, in order to minimize climate damage to price stability. In other words, it involves using monetary policy as a tool to facilitate the transition to a low-carbon economy, thereby reducing the potential climate-related risks that could threaten price stability.

Climate related events can and do have direct impact on agricultural and food products and on energy, which can put inflationary pressures on production costs, which can happen through supply-side and demand-side shocks. Extreme weather conditions have a broader impact on infrastructure, buildings, the health of employees and productivity, and consequently production and price structures, which can happen through supply-side and demand-side shocks

(Galhau, 2019; BIS, 2021). So, climate related events are likely to affect price stability mandates and even the traditional policy instruments, which can be less effective at smoothing these shocks, as they are more or less permanent biophysical shocks, rather than transitory economic shocks. As pointed out by Galhau (2019, p. 9-12), former president of Banque de France, “ [...] the times we live in require action; and the sooner the better, given that the majority of the benefits of corrective action may only be felt in the longer term.”

2. Central Banks’ mandates and climate change: Federal Reserve, European Central Bank and the Brazilian Central Bank

Given the challenges climate change and mitigation of the risks discussed in section one, what would be the roles a CB would be in the transition to a greener economy? Dikan and Volz (2018) state that a potential “green central bank” may, first, be concerned with climate change as it poses threats to their current mandates of financial and macroeconomic stability. In this case, the CB would only respond in a "passive" way; climate change would not be an explicit concern. Kedwar, Gabor and Ryan-Collins (2024), in a similar way, call this a "risk-based approach" for the CB, one that "stresses 'fixing' market signals, both by enhancing price discovery and by steering green/dirty credit and asset prices (derisking)" (p. 1594). This is the dominant model and a structural unfolding of the macro-financial status-quo, which involves information-based measures - such as disclosure of climate-risk and stress tests - and reinforces the power of private finance as the best decision maker when it comes to the allocation of resources. DiLeo et al (2023), distinguishing three different climate approaches to CB's policies, call this "Foundational norms – no evolution from basic Central Bank Independence (CBI) norms". There is no change to the mandate or instruments, and the CB only integrates climate change to the extent that it can affect the financial system (see Table 1). As we will discuss, this has been the current approach taken by the Federal Reserve (Fed), the European Central Bank (ECB),, as well as by the Brazilian Central Bank (BCB).

Table 1: Three types of Central Bank policy approach to climate change

Three Sets of Climate-Related Norms	New tasks for central bankers and supervisors	Policy implications (examples)
Foundational norms – no evolution from basic CBI norms	Take into account potential impact of climate change on prudential and monetary objectives without introducing new instruments and objectives	Research economic and financial effects of climate change; conduct stress tests to identify financial risks; clarify existing supervisory rules and standards
Proactive norms – reinterpretation of CBI norms	Acknowledge profound challenges for achieving monetary and prudential objectives, which require new instruments and indicators	Climate considerations inform monetary policy operations (e.g., asset purchases) and financial supervision (e.g., stress tests with potential implications for bank capital)
Reformist norms – moving beyond CBI norms	Support for transition toward a sustainable economy; climate objectives in ways that go beyond, and may potentially conflict with, monetary and prudential objectives	Monetary-fiscal coordination; green credit guidance in support of specific industrial strategies

Extracted from DiLeo et al., 2023.

There are, however, other possibilities. One is what Dikan and Volz (2018) call an “activist” central bank, which would have in its mandate promoting green investments using the tools it currently has. Kedwar, Gabor and Ryan-Collins (2024) refer to an "allocative green credit policy"- which they support - that requires a "revival of credit policy" in order to allow the monetary authority discretion in the selection of sectors to be incentivized or not and/or in the use of more coercitive tools to steer credit. DiLeo et al. (2023) similarly put two other possibilities: a CB with "proactive norms" that would take into consideration the challenges posed by climate change on monetary policy and regulation of financial institutions, but still not taking further action to steer the economy in a "greener" direction. The third possibility for the authors would be a "reformist" CB, using credit policies to really support a green/just transition. Our argument is that this would be a truly "**democratic** central bank" (Deos e Ultremare, 2024), one that can effectively help societies face the huge challenges that lie ahead. It is crucial to transform central banking, meaning the political and technical management of money and credit, in order to serve the majority of society. The idea would be not only to mitigate the financial

risks, but would be even more comprehensive than incorporating credit policies to tackle climate change, utilizing new instruments like CBDCs.

The idea is not merely to mitigate the financial risks associated with environmental degradation but to proactively contribute to a social-ecological transformation. This entails revising central banks' mandates to include environmental objectives, employing differentiated interest rates to incentivize green investments, and incorporating ecological criteria into their asset purchases and regulatory practices. Such a transformative approach underscores the need for central banks to align their operations with broader societal goals, recognizing that financial stability and socioeconomic prosperity are intrinsically linked to the health of our planet (Deos e Ultremare, 2024, p.12-13).

It is important to note that this wouldn't be a total novelty in terms of central banks' mandates, since it was a relatively standard approach in the 1950s and 1960s. Tools to influence credit allocation were common in the post-War period, such as i. differentiating interest and discount rates according to the sector (an example would be the Bundesbank in 1973 excluding export credit from tighter interest rates) , ii. specific agencies that lend with lower rates to strategic sectors², iii. direct credit from the central bank to firms and local governments, iv. window guidance, v. clear guidelines for banks to lend to certain sectors, and vi. indirect instruments that work as price signals such as preferential refinancing terms, capital and reserve requirements, and government subsidies (Monnet and van 't Klooster, 2023).

In this sense, the idea that monetary policy needs to have one goal - price stability - and one instrument - the short-term interest rate - was not always the norm. Much to the contrary. Throughout their history, central banks have transformed and adapted to the challenges of their times. The Great Depression and then WWII, for instance, brought a need for central banks (and especially the Federal Reserve) to reinvent themselves from being mostly lenders of last resort operating in the discount window to become more proactive, using the open market instrument and controlling interest rates (Deos e Ultremare, 2024). By the 1970s higher global inflation sparked yet again a review in the operational framework for monetary policy following the Monetarist school's prescription to control money supply. The disastrous effects of this experience left, however, an inheritance: price stability became the main goal in central banks' mandates. The so-called New Monetary Consensus (NMC) rose as the dominant school of economic thought for monetary policy in the late 1980s, influencing virtually all large central banks in the world to adopt either a formal or informal inflation targeting regime in their mandates. Fiscal policy was transformed into an accessory of monetary policy in a regime of

² Examples here could include Fannie Mae, Freddie Mac, and Ginnie Mae, that support and promote the residential mortgage sector in the United States.

monetary dominance (Kedwar, Gabor and Ryan-Collins, 2024), where the government spending is marked by austerity, limited and dependent on funding with market instruments.

The 2008 global financial crisis (GFC) and its impacts on financial systems obligated central banks to respond quickly to manage both the financial and economic instability. For that, they used the traditional instrument of short-term interest rates but also created new tools - which came to be known as non conventional monetary policies - to stabilize the financial system. Despite changes in their operational framework - the Fed, for example, moved from overnight open market operations to paying interest on excess reserves to control the short-term interest rate - central banks' mandates have changed little from what the NMC prescribes. The current setup is still the same: CBs have a mandate given by the Congress and enjoy operational autonomy, or independence, to pursue economic stability (for most central banks, this still means price stability only) and financial stability with prudential regulation and lender of last resort tools. This framework is not one equipped to deal with the kind of issues that arise with climate change, even if one takes in consideration only the issue of price stability. As Schroeder (2023) points out, the instruments CBs have today were designed to impact a *demand-driven* inflation, when climate change will provoke *supply-side* inflation, much like after the pandemic, but with much longer-term impacts.

Nonetheless, it is important to note that the ways CBs responded to the emergency brought on by the GFC, and then more recently by the COVID-19 pandemic, show us that central banks can adapt and innovate when the circumstances demand them to: *"history reminds us that central banks – even independent ones – have not hesitated to give priority to certain loans when they felt that it was absolutely necessary for the economy"* (Monnet and van 't Klooster, 2023, p. 12). The climate crisis is already an emergency, but so far CBs' responses have been weak.

2.1 International experiences: Federal Reserve, European Central Bank, and the Brazilian Central Bank

The establishment of the Network for Greening the Financial System (NGFS) during the Paris One Planet Summit in 2017 marked a significant milestone in the commitment of central banks to addressing the challenges posed by climate change. The purpose of this network would be to enhance global responses to this new environment and, in a more specific way, the role of the financial system in order to manage risks and mobilize capital to face the challenge. (<https://www.ngfs.net/en/about-us/governance/origin-and-purpose>)

According to Dileo et al (2023), becoming a member of the NGFS implies the recognition of the two broad channels of adverse climate impact. The first is the direct damage of climate change in the economy: heat waves, droughts, floods etc. The second channel is related to the huge efforts that will be necessary to the transition of the economic system. In spite of that, the approaches taken by different central banks to tackle climate change remain quite different and that can be attributed not only to their different mandates, but to several factors.

Since 1977, the US Central Bank, the Federal Reserve, has had a dual mandate: to promote stable prices and maximum employment. When it comes to policies to directly address climate change, the Fed has always been very adamant in its non-role to promote green transition. According to DiLeo et al (2023), the Fed has advanced in the understanding that climate change may pose risks to financial institutions and, in 2023, conducted the first Climate Scenario Analysis, a pilot program with the sole goal to understand how six large financial institutions in the US are preparing their businesses for climate-related risks. However, the exercise was merely informative so far, and there is no repercussion in terms of changes in regulation or supervision. Although the Fed joined the NGFS in 2020, US policymakers have made it clear that they do not intend to consider climate concerns in their mandate, and that they will not adopt any kind of credit policy in the future:

"It is also important to continue to be clear on what we are not doing. The Federal Reserve is not and will not be a "climate policymaker." Decisions about policies to address climate change must be made by the elected branches of government. Over time, we must be vigilant to avoid crossing or blurring that line. It is not the Fed's role to tell banks which businesses they can and cannot lend to." (Powell, J. 2023)

For the European Central Bank, there was a supportive domestic environment for an early emergence of climate actions by the European Central Banks and national banks in the euro area (DiLeo et al, 2023). In fact, starting in 2016, the ECB came under pressure from the European parliament, NGOs, and academics to take in consideration climate impact in monetary policy programs (Dileo et al, 2023, p. 15).

The year of 2019 can be considered a starting point for the ECB in terms of more explicitly to consider climate change issues. With the appointment of Christine Lagarde as a new president, the bank started a review of its monetary policy strategy, in order to investigate how to design new instruments in light of the new environment. It is worth noting that, in terms of its core mandate, the ECB clearly states that without prejudice of its primary goal, the bank supports the green transition of the economy in line with the EU's objectives.
<https://www.ecb.europa.eu/press/key/date/2024/html/ecb.sp240526~ef011def12.en.html>

In terms of monetary policy, since 2020-2021 the bank has been incorporating climate concerns into the monetary policy framework. In 2021, for instance, the banks started to introduce climate change risks in the collateral framework for Eurosystem liquidity operations and for outright monetary policy purchases (ecb.pr210708_1_annex~f84ab35968.en.pdf). Beginning in 2022, the ECB started the integration of climate considerations into its primary macroeconomic model, enabling an assessment of their effects on economic growth. In spite of that, according to Kedwar, Gabor and Ryan-Collins (2024), the European Bank didn't pursue a

policy of explicit credit allocation. The attempt to abandon market neutrality in a period of inflationary pressures proved to be very challenging.

In regards to emerging markets and developing economies (EMDCs), Dikau and Rollin (2017) state that, in general, compared to what happens in the developed countries, central banks have a wider mandate in order to support development and the government's economic policy agenda (p. 2). In a similar fashion, Baer et al (2021) state that in emerging economies, relying only on "information policies" appears to be more the exception than the rule, since one can find evidence of the introduction of incentive-based and coercive financial policies in these countries. If that can be the case for other countries that fit into the EMDCs scope, this is not the case in Brazil. Since 1999, the BCB has committed to a narrow inflation targeting mandate. More recently, in 2021, reinforcing this direction, the Complementary Law N.179 established the BCB formal autonomy with the fundamental objective of reaching the inflation target and, ranked secondly and without prejudice of the fundamental goal, fostering the stability and efficiency of the financial system, smoothing fluctuations in the level of economic activity, and promoting full employment. The law also establishes a fixed term for the president and directors of the bank, which does not coincide with the term of the president of the republic. In spite of that, it is worth noting that the Brazilian financial system comprises an important group of public banks that many times in the past, and even more recently - in order to face the 2008 crisis effects, for instance - have performed as "arms" of the BCB (Deos and Mendonça, 2017).

It is worth noting that in Brazil, already in 2008, the National Monetary Council introduced resolutions requiring financial institutions and rural producers to have documentation proof of compliance with environmental regulations to have access to subsidized rural credit³. The measure, aimed at restricting credit for those who infringed environmental regulations, applied to all establishments in municipalities located entirely within the Amazon biome. For Stussi and Souza (2024, p. 1), this is relevant since in Brazil emissions are predominantly associated with land use changes and the agricultural sector. In this sense, according to the authors, the BCB could be considered a pioneer at the intersection of finance and environmental conservation.

In 2014, the National Monetary Council issued Resolution n. 4327, a first step in the process of integrating social and environmental factors into the risk analysis of financial institutions (BCB, 2024). In 2017, three years after, the council issued Resolution n. 4557, outlining the framework for risk and capital management. If, on the one hand, socio-environmental risk became an integral part of the broader requirements of traditional risk management structures with this issuing, on the other hand it was only implicitly considered, and

³ To be precise, in Brazil, the institution that is in charge of formulating guidelines for monetary and credit policies is the National Monetary Council (NMC), which is presently composed by the Minister of Finance (chairperson), the Minister of Planning and Budgeting and the Governor of the Central Bank. The CMN's deliberations are published in the form of CMN Resolutions. <https://www.bcb.gov.br/en/about/cmnen>

with no distinct emphasis, since it provided limited details on the treatment of social, environmental, or climate-related risks. (Stussi and Souza, 2024; Mendonça et al, 2024)

In 2017, the BCB implemented its Policy for Socio-Environmental Responsibility (PRSA), which was updated in June 2024 by the Resolution n. 387, becoming the Social, Environmental, and Climate Responsibility Policy (PRSAC). The goal was to improve the governance structure for its implementation and monitoring. In the Sole paragraph of Art.1 of the aforementioned resolution, it is stated that:

As the regulator and supervisor of the National Financial System (SFN), Banco Central do Brasil recognizes the emergence of social, environmental, and climate risks and the importance of its role in promoting the systematic adoption of sustainability practices and information in the internal and external decision-making processes.

(https://www.bcb.gov.br/content/about/legislation_norms_docs/resolution-387-esg-climate-responsibility-policy.pdf)

The BCB's PRSA is based on three pillars, including encouraging financial institutions to participate in the country's process of balanced development. Among the guidelines provided by the Resolution is that the BCB has to promote actions so that the financial and payment systems can increasingly contribute to sustainable economic development meaning, for instance, to consider the implementation of social, environmental, and climate responsibility policies in the scope of the Bank supervision of financial institutions and other institutions.

In 2020, the BCB launched the Sustainability dimension in its strategic Agenda, (<https://www.bcb.gov.br/en/about/bcbhashtag>) and since then the bank has been a supporter of the international Task Force on Climate-related Financial Disclosures (TCFD), created in 2015 by the Financial Stability Board (FSB). In 2021, the Brazilian Central Bank introduced improved regulations on socio-environmental risks, improvement of information disclosure by financial institutions, as well as the Green Bureau of Rural Credit, with the approval of a series of norms by the NMC (Resolutions 4943; 4944 and 4945/2021). In 2022, regulatory actions were introduced to adjust the accounting registration of sustainability assets (Normative Instruction n. 325). Lastly, it is worth noting that the bank is developing models aimed at tackling climate concerns, focusing on stress tests scenarios which can affect financial stability, as well as adapting its main macro model to incorporate not only the impact of climate change, but also of policies fostering the transition (Stussi and Souza, 2024). But in spite of its relatively early incorporation of "sustainability issues etc" in its agenda, up to the moment the BCB has no proposition in terms of monetary policies to address climate changes.

3. Can CBDCs be an instrument to tackle climate change? The case of Brazil

In this section, we aim to explore how CBs and especially the BCB can use new tools such as CBDCs to embolden their policies for a more democratic monetary policy. We first discuss how CBDCs are being researched and implemented, and then present ways CBs can use CBDCs to direct funding to specific green projects and serve as agents of green transition.

3.1 What are CBDCs?

When one analyzes the evolution of money and its forms, we see an increasing push to its 'dematerialization' as discussed by Guttman (2003). The form of money is constantly evolving, and the author argues that the transition to digital/electronic (dematerialized) money that started to take place with the advent of the internet is one of the most impactful ones yet. The trend that we have been observing since the 1990s is the rapid advancement of non-physical cash (not considering here the distinctions between previous 'electronic' formats⁴), culminating in the system that we have today. Demand deposits are still the dominant means of payments, but other forms of private digital currencies have emerged, like *cryptocurrencies* and *stablecoins*⁵.

As a response to the emergence of these new forms of money, Central Banks around the world began researching the creation of their own Central Bank Digital Currencies (CBDCs). In the system that we have today, Central Banks issue two types of money: paper currency (physical cash), which is in part in use by the public in transactions and in part sitting in banks' vaults, and bank reserves ('electronic' money, in the sense that it does not exist physically), which serve the purpose of settling interbank transactions and fulfill reserve requirements in those countries that still use them. Banks (and other financial institutions authorized to do so) have a reserve account with the CB where reserve balances are kept. CBDCs are a third type of CB liability: electronic money just like reserves, but the account holders are the non-financial private sector - families and firms that will use CBDCs in theory as a replacement for physical cash for their everyday transactions. CBDCs are sometimes referred to as 'reserves for all'.

⁴ For example, electronic money (e-money) - that comprises all mechanisms of money transfer that use a computer; 'cybercash' - fund transfers that use the internet; and 'digital cash' - transfers that need software installed by the vendor and/or consumer.

⁵ '*Cryptocurrencies*' are not backed by anything and they are not a liability to anyone - like Bitcoin, for example. '*Stablecoins*', on the other hand, are a type of digital currency that is backed by 'liquid assets'. They can be created by banks or other institutions (financial or not) and are unregulated, but their issuers claim they are *stable* as they have strong collateral. Stablecoins are actually similar to what *money market mutual funds (MMMF)* were before the 2008 subprime crisis. MMMFs also promised their investors that their quotas could be redeemed at par once the assets in the fund were considered liquid and safe. Nonetheless, several of those funds suffered a run on their liabilities once that promise could not be fulfilled with the decrease in the price of assets during the crisis.

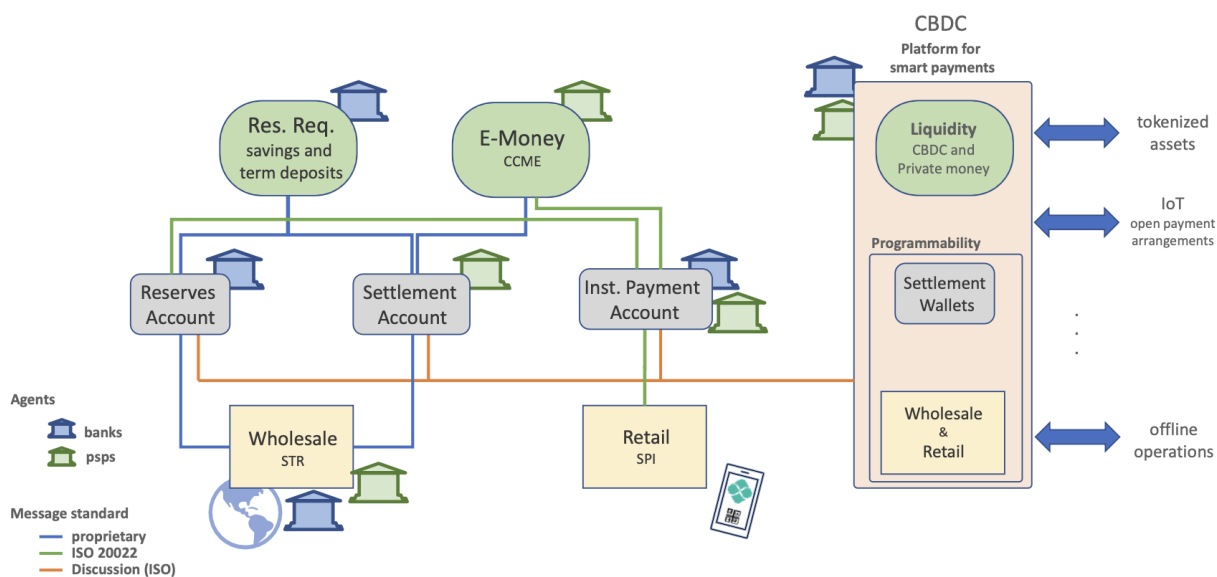
In 2022, it was estimated that around 80% of central banks in the world were considering issuance of digital money in some format (PwC, 2022). As of October 2024, there are 4 CBDCs already in full operation: Bahamas' Sand Dollar, Zimbabwe ZiG, Jamaica's JAM-DEX, and Nigeria's e-Naira.. There are 27 CBDCs in the pilot phase, the Chinese e-CNY being one of them. Interestingly, developing countries are leading the initiatives in the digitalization of cash, while developed countries are slower in defining formats and timelines. Some countries like the United Kingdom, for example, do not see reasons why a CBDC would be necessary, while the Federal Reserve and the ECB are expected to soon have a defined design for their digital currency. There is no doubt that digital cash issued by a central bank will be a reality soon for a great number of developed and developing countries.

The specific design of CBDCs is still in discussion. As for **availability**, a 'wholesale' CBDC would only be available to large institutions, whereas a 'retail' CBDC would serve transactions for small customers, with or without a limit on the amount of money one can hold in the CBDC account. As for the **format**, a direct CBDC would be one where the CB issues the currency and performs all functions including managing the accounts. In a hybrid or intermediated CBDC, the CB issues the currency, but some functions are delegated to intermediaries like banks, and the CB would not have any direct interaction with final customers. In both direct and hybrid formats, the CBDC will be a claim on the central bank. In a synthetic CBDC, the digital currency is issued by financial institutions and backed by CB's liabilities, similar to stablecoins. Most countries are working with a hybrid format. For the **technology** involved, the main design issue is deciding whether the CBDC will be *account based*, where the user is what is validated (just like a payment involving transferring a bank deposit, for example) or *token based*, where the transaction is validated, protecting the privacy of users. Another issue is the necessary **infrastructure** to clear and validate payments - if the chosen one will be DLT (Distributed ledger technology) like Blockchain, or a centralized, conventional one like CBs have today.

Other design issues revolve around i) guaranteeing or not that users and transactions are anonymous just like with cash - most countries are considering a tiered system with small transactions being anonymous; ii) whether there is a limit to the quantity of CBDC that a user can keep in their digital wallet - if there is no limit, there is that users could 'run' to CBDC and destabilize the banking system; iii) whether or not foreign citizens can open and maintain balances in the wallet; iv) if the CBDC will pay interest or not - main concern is not being a complete alternative to bank deposits, but the ability to pay interest could be interesting to circumvent restrictions like the *zero lower bound* (ZLB) in the current system; v) if it will be available offline; and vi) if physical cash will be completely phased out. Expanding on the discussions of CBDC architectures, the scheme depicted in Figure 2 from the BCB outlines the expected functioning of the Digital Real in Brazil, showcasing the coexistence of three payment environments. In the new architecture, the reserves of banks and payment service providers will

be divided into three accounts: the reserve account for banks or the settlement account for payment service providers (PSPs), used for gross real-time payments with existing reserves; the instant payment account for operations with the newly created PIX; and the CBDC account, to facilitate the maintenance of CBDCs. As an infrastructure for smart payments, the Brazilian digital real system should connect conventional sources of liquidity, provided by authorized agents, to regulated digital asset ecosystems that may incorporate new business models, such as the use of smart contracts and IoTs.

Figure 2. CBDC as a smart payment platform and interoperability



Source: Araújo, 2022.

This initiative is part of a broader agenda to modernize Brazil's payment systems, which already include real-time gross settlement services, e-money through payment service providers, and the instant payment system Pix (BCB, 2024). The digital real is envisioned as a key component of a smart payment platform, designed to coexist with existing liquidity frameworks between the CB and commercial banks. The primary objective of introducing a CBDC in Brazil is to create a secure and innovative environment using programmable technologies, such as smart contracts. The digital real aims to enhance Brazil's payment system by enabling new functionalities beyond those offered by current instant payment solutions. Araújo (2022) underscores the potential for financial innovation and efficiency gains through the integration of payment information, which could drive the development of new business models and services that better meet consumer demands, while ensuring regulatory oversight to maintain safety and stability.

The proposed model is designed to maintain existing relationships between clients and payment system institutions, while equipping the latter with an additional tool for integrating

new clients into the system. It also facilitates the introduction of innovative business models by leveraging cutting-edge technologies on the platform where the digital real will operate. This new digital currency will not bear interest, and online transactions will be seamlessly integrated into the current payment infrastructure, enabling activities such as in-store purchases and peer-to-peer transfers. The digital real will function as a hybrid CBDC, using a two-tiered distribution system in which the BCB issues the currency, and access is provided by custodians within the payment system.

To access services on the envisioned smart payments platform, individuals will convert their deposits with banks and PSPs into tokens, with the assurance that these tokens can be converted into CBDCs on demand. Tokens derived from deposits with commercial banks or PSPs will carry all the regulatory attributes and features of their underlying assets, such as fractional reserve requirements for banks and full reserve requirements for PSPs. This system will thereby support the existence of at least two distinct regulated stablecoins within the Brazilian economy.

Tokens issued by PSPs, fully backed by reserves held at the central bank, align with the classic definition of stablecoins. In contrast, incumbent banks will issue their own stablecoins, derived from tokenized deposits and subject to regulatory constraints on portfolio risk and liquidity backstops. These bank-issued stablecoins will maintain stability equivalent to that of traditional deposits, and the design of this system aims to prevent disruptive financial disintermediation. Additionally, mechanisms such as backstops and regulatory constraints on conversion flows between CBDCs and tokens within the regulated liabilities network are expected to mitigate the risk of bank runs (Araújo, 2022).

The BCB has outlined several guiding principles for the design and implementation of the digital Real, focusing on promoting innovative business models, ensuring seamless integration with existing payment systems, and adhering to legal and regulatory standards. Key architectural elements of the CBDC include cross-border interoperability and resilience against cyberattacks. Moreover, individuals will use their bank and PSP deposits, converted into tokens, to facilitate a range of financial interactions while ensuring regulatory compliance. Importantly, as a non-interest-bearing instrument, the CBDC is not intended to serve as a tool for monetary policy (BCB, 2024).

According to Araújo (2022), the implementation of the digital real is expected to significantly advance digital inclusion, building on the foundation established by Pix. The incorporation of smart contracts will increase efficiency and composability, which are essential for meeting the needs of underserved populations. By leveraging these technologies, the digital Real can enhance the efficiency of financial transactions and services, broadening access to financial resources for those traditionally excluded from the formal banking system.

3.2 Climate change and monetary policy: can CBDC be a new tool?

The intersection of green finance and digital currencies, particularly Central Bank Digital Currencies, has emerged as a promising avenue for addressing the pressing challenge of climate change. From a heterodox standpoint, money and monetary policy hold a central position in the structure and functioning of the economy. CBDCs, as a digital form of sovereign currency issued by central banks, can serve as a powerful tool in channeling resources into strategic green sectors and aligning monetary policies with environmental objectives. This section will examine how CBDCs can be leveraged as an instrument to tackle the climate crisis, exploring both the technological capabilities of these digital currencies and their integration with existing monetary policies. As we discussed in section two, CBs have a first task in actually incorporating green transition in their mandates.

The first way CBDCs can help CBs in achieving climate goals is with the technology CBDCs provide. Blockchain and smart contracts can enhance traceability, transparency, and efficiency in financial transactions, allow governments to closely monitor the use of resources and ensure that funds directed towards green projects are appropriately allocated (Auer et al., 2020). Central banks, as key players in the financial system, have a crucial role to play in harnessing the potential of these innovations to catalyze a just transition towards a sustainable economy. By using smart contracts, CBDCs can automate financing processes, such as payments for environmental services or incentives for companies meeting sustainability goals. These contracts ensure that payments are automatically released when environmental criteria, such as emission reductions, are achieved. Blockchain, in its turn, provides a transparent record of transactions, allowing the tracking of the origin of products and services, ensuring they are sustainable and sourced from responsible suppliers.

CBDCs can be utilized for monetary policies focused on sustainable investments, ensuring that funding is exclusively directed to projects with positive environmental impact. Smart contract technology enables payments to be programmed for release only when specific environmental targets are met. For example, in a renewable energy project, funds could be disbursed in stages linked to the implementation of solar panels or verified reductions in carbon emissions. The automation provided by smart contracts increases efficiency and reduces risks of fund misallocation, promoting accountability and environmental alignment (BIS, 2022; Van Gansbeke, 2021). Central banks can issue CBDCs to financial institutions on the condition that the funds are used for decarbonization projects, such as circular economy initiatives or sustainable transport. The use of digital tracking technologies allows the central bank to monitor the real-time allocation of these resources, ensuring that they are applied in accordance with sustainability goals (BIS, 2022; Naderi & Tian, 2022; Klooster & Tilburg, 2020). CBDCs can also play a crucial role in green monetary stimuli, reinforcing the link between monetary policy and environmental sustainability. Through the use of blockchain and asset tokenization, central banks can implement measures that incentivize the flow of capital to sustainable initiatives, like utilizing some form of Green Quantitative Easing and lending against haircuts commensurate

with the degree in ESG (Environmental, Social, Governance) feature intensity of the securities under consideration (Van Gansbeke, 2021).

A bolder use of CBDCs to tackle climate change would be a direct lending from the CB to governments, financial institutions, and firms tied to specific green goals or a particular SDG, for example. A revival of credit policy as part of a broader understanding of monetary and financial policy would allow the CB to serve as a “developmental” institution (Schroeder, 2023). Interest rates, collateral and terms could be differentiated according to the specific project. In the case of Brazil, the new CBDC - Drex - could be used to capitalize development banks, like the BNDES, and public banks like Caixa Economica Federal and Banco do Brasil, to lend it to projects that satisfy the conditions of public environmental policy.

Concluding remarks

The goal of this paper was to discuss how central banks are currently considering the challenges of climate change and their role in supporting the green transition. In the first section, we present the several risks that the financial system faces with climate change, both physical from climate events themselves and transitional ones from the policies aimed to curb and mitigate climate change. It is increasingly clear that those risks are great and unpredictable. That makes central banks, as institutions responsible for managing money and credit, indispensable. Beyond the risks that threaten their current mandate of price and financial stability, central banks’ actions during the 2008 financial crisis and the COVID-19 pandemic have shown that monetary policy can have much broader goals and be much more innovative in the instruments that the CB utilizes. The CB, much more than just adopting green goals or incorporating the green transition in its mandate, should use new instruments, like CBDCs, to effectively help tackle climate change. This digital currency, first thought to compete with private digital currency, is being considered by the majority of central banks in the world and already in full operation in some smaller countries. As a liability of the CB and as legal tender issued directly to the public, it has the potential to serve as a powerful new instrument to achieve climate goals either using the technology of smart contracts and Blockchain, or assisting in credit policies towards green investments. With new mandates and new tools, central banks can advance in becoming truly democratic institutions.

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^[1] According to the Stockholm Resilience Center, for example, six of the nine planetary boundaries have already been crossed in 2023. (<https://www.stockholmresilience.org/research/planetary-boundaries.html>)