

Climate crisis, central banks and the IMF reform¹

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The Earth's climate does not respond to forcing in a smooth and gradual way. Rather it responds in sharp jumps which involve large-scale reorganization of Earth's system.

W.S. Broecker (1987)

No amount of economic cost-benefit analysis is going to help us. We need to change our approach to the climate problem.

T.M. Lenton et al. (2019)

Abstract: This paper explores some of the ways in which international central banking can contribute to containing the imminent worldwide climate crisis in a context in which the role of national central banks is important but effectively limited to employing two new stabilization policy tools: macroprudential policy and QE programmes. The authors argue in favour of institutional reform that would gradually transform the IMF into an international central bank and the SDR into a genuine international currency. Even its limited scope would substantially increase the IMF's capacity to solve one of the key problems of the global climate policy, namely the shortage of funding for the decarbonization of developing economies.

Keywords: climate crisis, central banks, Special Drawing Rights.

JEL codes: F33, F42, G15.

Introduction

Global warming poses a serious threat to the Earth's natural environment and no respectable scientific organization in the world questions this challenge (Popkiewicz, Kardaś & Malinowski, 2019). Unfortunately, the burning of fossil fuels still remains the main source of energy worldwide leading to in-

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creased CO₂ concentrations in the atmosphere and the mounting risk of a climate crisis. The main responsibility for containing it rests with governments which can impose carbon taxes, eliminate subsidies to fossil fuels, enact the necessary environmental regulations and invest in the development of clean energy production technologies. The role of national central banks in coping with the climate crisis is important yet limited to the use of two new stabilization policy instruments, namely macroprudential policy and quantitative easing (QE) programmes.

The authors of this paper argue that central banking could play an important role in climate policy if the international community decided to launch institutional reform with a view to transforming the IMF into an international central bank. Such a reform would significantly increase the IMF's capacity to overcome one of the main problems of the global climate policy, namely the fact that developing countries lack sufficient funding to pursue effective decarbonization policies. As a result, global CO₂ emissions continue to rise even though the European Union and the United States have succeeded in limiting their discharge of this greenhouse gas (SIERP, 2017).

The motivation for writing this paper was the IMF's recent decision to resume the issuance of Special Drawing Rights (SDR) and the exceptionally large scale of their allocation in the summer of 2021 which suggests that in the face of global challenges, such as the SARS-CoV2 pandemic and the threat of climate change, the international community may be ready to accept an IMF reform in the spirit of several proposals formulated in the past (Keynes, 1942; Stiglitz, 2006; Eichengreen, 2009; Ocampo, 2017).

Such IMF reform would not only modify the existing rules of SDR allocation to enable a more flexible response to recent global challenges such as mobilizing decarbonization funds earmarked for developing countries. Transforming the IMF into an international central bank would also lead to the emergence of markets for SDR-denominated securities given the fact that today's globalized financial markets would make it a much easier task than in the 1970s when similar efforts had failed.

The development of markets for SDR-denominated securities is necessary to convert the SDR into a genuine international currency that would substantially broaden the IMF's capacity to meet new challenges and possibly much more serious than transitional economic and financial market turbulences in individual countries. The international community must brace itself for long-term global issues such as climate change and biodiversity loss which have already seriously damaged the Earth's natural environment (Dasgupta, 2021).

To make it politically viable the proposed IMF reform, at least initially, should be limited. Attempts to make the SDR a dominant global currency too rapidly would be politically unfeasible and actually unnecessary. The SDR need not compete with the dollar and the euro because the latter fulfil their function of international currencies very well due to the highly developed financial

systems in the United States and the Eurozone managed by independent and trustworthy institutions.

Nonetheless, even though in some respects major central banks have recently played the role of international central banks (especially the Federal Reserve, which extended foreign exchange swap lines to central banks in a number of countries worldwide during the global 2007–2009 financial crisis and then during the SARS-CoV2 pandemic), they are obviously not in a position to take risks associated with providing loans to central banks in developing countries. To that end an international central bank equipped with such powers would have to be established.

Technically speaking transforming the IMF into an international central bank would be quite straightforward. The two necessary steps involve endowing the IMF with a payment system (Keynes, 1942) and converting SDR quotas into true SDR deposits (Obstfeld, 2015; Ocampo, 2017).

The remainder of this paper is structured as follows. Section 2 focuses on the key impacts of the impending climate crisis and the main components of decarbonization policies. Section 3 analyses the central banks' policy tools best suited for supporting such policies. Section 4 proposes a reform of the IMF in order to make it a much more effective tool for coping with global challenges such as the climate crisis. Section 5 contains concluding remarks.

1. Global warming and climate policy

1.1. The challenge of global warming

Economists often employ the concept of multiple equilibria which assumes that an economy can shift from a *good* to a *bad* equilibrium and that this process is accelerated by adverse feedback loops (Masson, 1999). A similar mechanism is at work behind the abrupt acceleration of climate change.

In the Holocene—the current interglacial period—the balance (equilibrium) between the solar energy coming to the Earth and reflected back to space stabilized at a level at which the average global temperature permitted human civilizations to thrive. This *good equilibrium* lasted until industrialization which ultimately led (about 50 years ago) to increasing concentrations of greenhouse gases (GHGs) in the atmosphere. This effect is seen as a major cause of the recent global warming.

Currently the main contributor to this effect is CO₂ whose presence in the atmosphere reduces the amount of solar energy radiated back into space. This may result in a *bad equilibrium* where a further rise in temperature will trigger a cascade of adverse feedback loops that will ultimately lead to an irreversible deterioration of the Earth's climate and pose an increasing threat to the human civilization as we know it (Mora et al., 2018).

The feedback loops between global warming and adverse climate change are already apparent. The thawing of permafrost with the concomitant release of CO₂ and other GHGs further exacerbates global warming (Schuur et al., 2015). The melting ice cap in the Arctic Sea and Greenland pushes massive amounts of fresh water into the North Atlantic which slows down the ocean currents and contributes to the drying out of the Amazon rainforest and the Sahel compromising the capacity of these regions to absorb CO₂ (Hua, Dai, Zhou, Qin, & Chen, 2019; Pattyn et al., 2018).

In contrast to financial crises (Danielsson, Shin, & Zigrand, 2013) climate disasters are caused by physical factors yet it is uncertain to what extent rising temperature will aggravate the adverse feedback loops produced by global warming (Lenton et al., 2019; Thompson & Sieber, 2010). Two decades ago, it was believed that such tipping points might occur if the global average temperature increased by 5°C above the preindustrial level but today we know that this domino effect, which may irreversibly change the Earth's climate, is likely to be triggered once the average global temperature has risen 1.5–2°C above that level (IPCC, 2018).

This means that a catastrophic chain of events may start any time soon hence the only rational option is to adopt the 'whatever it takes' approach to climate policy even despite its political unfeasibility, the risk of slowing down economic growth and the lobbying efforts of the polluting industries (IPCC, 2021). Focussed policy measures must be urgently implemented since the effects of hysteresis and bifurcation may make the associated adverse climate changes irreversible; in consequence the Earth would be a much more difficult place to live in for subsequent generations (Hansen et al., 2017).

1.2. The main climate policy tools

One of the greatest problems facing effective climate policy is that once CO₂ has been released into the atmosphere it will remain there for hundreds of years (Hansen et al., 2017). Under these circumstances the best way to stop global warming would be to deploy technologies to bind or remove excess CO₂. Attempts to develop such technologies have continued since the late 1970s. The most promising ones include Carbon Capture and Storage (CCS) and Bioenergy with Carbon Capture and Storage (BECCS); regrettably they are unlikely to become technically, financially, or environmentally feasible in the nearest future (McLaren & Markusson, 2020; Dyke, Watson, & Knorr, 2021).

Until effective solutions to that end have been developed the key climate policy tool is the pricing of carbon emissions that forces polluters to pay for the environmental damage they cause. The revenue from taxing CO₂ emissions should be used to pay households a *carbon dividend* in order to maintain public support for decarbonization policy.

For a long time, it was believed that the price of a metric ton of CO₂ emitted into the atmosphere should reflect the discounted value of average (expected) damages to the natural environment and the economy (Nordhaus, 1992). Weitzman argued that since humanity faces the risk of abrupt and irreversible degradation of the natural environment it is impossible to precisely set an upper limit for the price of emitted carbon (Weitzman, 2009). Accordingly, Kent, Litterman and Wagner proposed the imposition of a high fee on carbon emissions which would reflect the risks inherent in continued global warming until new technologies enable us to reduce these risks and lower the price to be paid for CO₂ emissions (Kent, Litterman, & Wagner, 2018). This however is bound to take time which, in the light of the recent IPCC report, we simply do not have (IPPC, 2021).

Since it is notoriously difficult to set an optimal fee for carbon emissions it is rational to combine pricing with caps to promote achieving zero emissions as soon as possible (Kaufman, Barron, Krawczyk, Marsters, & McJeon, 2020). Carbon pricing may involve taxing carbon emissions, establishing *cap and trade* systems, or using both in various branches of industry. Taxing emissions is necessary not only to incentivize producers to reduce their carbon footprint but also for the governments to inform the public on the social costs of burning fossil fuels and thus demonstrate the need to enact effective regulations limiting the scale of GHG emissions (Stern, 2008).

Taxing the carbon footprint and setting emission caps makes sense from the environmental perspective but international coordination of efforts and a holistic approach are critical otherwise production will simply be relocated to countries with less stringent climate policies. A case in point is the appalling practice of burning biomass by power stations using imported wood from the Amazon rainforest (Brack, 2017). Climate policy also has to take into consideration the emissions of other GHGs, the use of water (access to which may shortly become a game-changer for a number of industries) and the disquieting pace at which the Earth's biodiversity is being lost (Dasgupta, 2021).

Climate policy should also take advantage of the informational efficiency of financial markets as postulated by the Efficient Market Hypothesis which assumes that asset prices discount all available information and change in response to new data that diverge from expectations. Accordingly, the reporting standards that require firms to provide information on how a progressively tighter climate policy is likely to influence their profit margins will lead to a steady decline in the relative stock prices of firms with a large carbon footprint, a factor which has yet to be fully taken into account by investors (Buckley, Sanzillo, & Shah, 2019). As a result, capital flows will be redirected to investment in clean technologies (CRMRS, 2020).

It must be acknowledged that some progress has been made in this respect as climate reporting standards are being increasingly introduced in many industries and stock exchanges. Climate risk management has become an in-

tegral part of corporate governance: international companies made ESG requirements part and parcel of investment strategies pursued by institutional and private investors alike.⁴

2. The role of central banks in containing climate change

Central banks are mandated to ensure price and financial stability. To this end they address deviations from inflation and GDP growth targets (Taylor, 1993). Since climate change increases the incidence of extreme weather episodes that adversely affect the said price and financial stability central banks contribute to climate policy by responding to them.

The main tools which central banks can deploy to encourage decarbonization are macroprudential policy and quantitative easing programmes (QE). Even though both are fairly new they already have a proven track record.

2.1. Macroprudential policy

Central banks implement macroprudential policy in much the same way as monetary policy, i.e. with a view to maintaining overall economic stability. The main goal of monetary policy is to stabilize inflation by containing demand shocks and second-round effects of supply shocks, whereas macroprudential policy is expected to contain financial instability which tends to occur in the wake of excessive risk-taking by financial institutions (Minsky, 1986). In simpler terms macroprudential policy consists in adopting and countercyclically calibrating regulations that impose limits on risks taken by banks, insurance companies and other financial institutions.

Macroprudential policy originated in South-East Asia after the wave of speculative attacks in 1997–1998 which culminated in a significant depreciation of local currencies, large balance-sheet losses and a severe banking crisis (Corsetti, Pesenti, & Roubini, 1999). Building on their experiences South-East Asian countries started to apply macroprudential policy tools (mainly LTV ratios) in order to tame unsustainable lending booms (Ren, 2011). Developed economies initially refused to follow suit due to the widespread belief that the development of new methods for measuring and managing risk would enable banks to adjust potential losses to their capital on an ongoing basis which was expected to minimize the risk of bankruptcies. However, in the wake of the severe global banking crisis of 2007–2009 when the losses sustained by many

⁴ On Robert Litterman's advice the World Wildlife Fund reaped substantial profits from entering the stranded assets total return swap based on the above-mentioned assumption that the stocks of polluters would fall relative to those with a small carbon footprint (Litterman, 2016).

banks significantly exceeded their capital, macroprudential policy came to be applied worldwide (Matysek-Jędrych, 2018).

Macroprudential policy tools differ from those of monetary policy but their ultimate goal is the same, namely to stabilize the GDP growth rate around its potential rate that ensures long-term price stability (Blanchard, 2012). The recent rapid increase in the incidence of extreme weather events such as heat-waves, wildfires, flash floods and hurricanes (Hansen et al., 2016) may seriously undermine financial and price stability. Accordingly, macroprudential policy that urges commercial banks to take into account climate risks is consistent with the central banks' mandate (Krogstrup & Oman, 2019; ESRB, 2020), even if the resulting climate benefits can constitute only a positive byproduct of central banks' stabilization policy (Restoy, 2021).

Recent developments in macroprudential policy illustrate how climate change encourages international cooperation. In 2017 central banks and supervisors launched the Network for Greening the Financial System (now it consists of 95 members and 15 observers) whose goals include promoting cooperation in setting guidelines on how to incorporate climate change in stress tests for banks (NGFS, 2020).

2.2. Quantitative easing programmes

The other new tool in the central banks' arsenal are quantitative easing (QE) programmes, i.e. large-scale purchases of securities which are mainly treasury bonds. These programmes are intended to enable commercial banks to weather financial crises by providing them with ample liquidity⁵ and reducing the risk premia on financial markets.

The first QE programmes were employed in Japan in the early 2000s when the national central bank decided to start large-scale purchases of treasury papers in order to engineer monetary expansion after the interest rate hit the zero lower bound (Bernanke, 2000). During the 2008–2009 global financial crisis many other central banks used QE programmes to contain liquidity crises and prevent sharp declines in treasury bond prices (De Grauwe & Ji, 2013).

The SARS-CoV2 pandemic pushed central banks towards using QE programmes to increase not only the commercial banks' liquid reserves but also the overall money supply. This was achieved by purchasing securities not only from financial institutions but also directly from governments and corporations. In practice this translated into using 'helicopter money' as such purchases resulted ultimately in increased money holdings of households and the corporate sector.

⁵ When a central bank purchases assets from commercial banks it pays them by increasing their liquid reserves, i.e. the balances they hold on their current accounts at the central bank.

The fact that central banks were buying both treasury papers and commercial debt securities paved the way for using QE programmes as a component of climate policy by ‘decarbonizing’ central banks’ commercial paper portfolios (Dafermos, Gabor, Nikolaidi, & van Lerven, 2021).

Initially, however, central banks were careful to adhere to a *market neutral* approach in order not to distort the relative prices of securities. The reason was that they tended to buy and hold such portfolios of corporate debt securities that replicated the *market portfolios* mirroring the capitalization structure of corporate bond markets.

Central banks rightly assumed that such an approach was consistent with modern portfolio theory (Sharpe, 1970) but the problem was that this theory is based on the efficient markets hypothesis which assumes that the prices of securities reflect all the available information. However, this is not yet the case with the *brown* securities (i.e. those issued by firms with a large carbon footprint). As was mentioned above one of the reasons is that the reporting standards applied to date do not sufficiently reflect the risk of climate change and the consequences of future tightening of government climate policy for the polluting industries (ESRB, 2020; Andersson, Bolton, & Samana, 2018). The other reason why the market neutral approach has recently become debatable is that polluting firms represent capital-intensive traditional branches of industry and tend to issue more debt than the less capital-intensive *green* ones (Dafermos et al., 2021).

Another reason why QE programmes are discussed as a climate policy component is that some economists perceive them as a convenient source of funding for decarbonization policies. They argue that such programmes amount to an *ex post* monetization of the part of public debt held by a central bank (De Grauwe, 2019).⁶ This is the case when a central bank (e.g. the Bank of Japan) does not resell the treasury bonds it has purchased under QE programmes. To all intents and purposes treasury bonds held by the central bank become zero-coupon perpetuities as the principal payments are reinvested in new issues of treasury paper while coupon payments return to the government as seigniorage (Paris & Wyplosz, 2014).

The reasons why such *ex post* partial monetization of public debt can be used to underwrite budget deficits include Japan’s 30-year experiences with QE and similar and over decade-long practices of other developed economies which have shown that that under stagnant economic growth and in highly liberalized labour markets partial overt monetary financing of fiscal expansion does not produce vicious price-wage spirals of the kind seen in the 1970s (De Grauwe, 2020). The main reason why an expansionary fiscal policy sup-

⁶ Paul De Grauwe’s proposal is that even if a given central bank does not want to increase the stock of T-bonds purchased under a QE program, it can redirect reinvesting of principal payments increasingly toward green bonds.

ported by QE programmes may not produce a substantial rise in inflation is that it effectively amounts to transferring excess savings held by the corporate sector from financial markets to the real economy (Rachel & Summers, 2019).

3. The case for transforming the IMF into an international central bank

One of the crucial problems inherent in global climate policy is that unlike the rich developed countries the poorer developing ones cannot afford to finance the decarbonization of their economies. If the latter decided to increase their public debt or government spending, they would inevitably face a considerable rise in inflation and capital outflows. Consequently, they make insufficient progress in this area. To make matters worse any reductions in GHG emissions in the developed economies are more than offset by their increases in developing ones (IEA, 2021) and the main source of GHG emissions in the former are the industries outsourced from the latter. Although the emergence of global value chains has brought obvious benefits to the developing economies such as the rise or increase in their middle class—a process so impressively captured by Milanovic in his famous elephant curve (Lakner-Milanovic graph; see Lakner & Milanovic, 2016)—the existential nature of the looming climate crisis makes it only rational for developed countries to provide sufficient funding to developing ones in order to enable them to implement effective climate policies.

It is widely accepted that the best way to channel such funds to developing economies are SDR allocations. In 2021, SDR issuance amounted to \$650 billion, whereas in 2020 the overall cumulative volume of IMF lending amounted to \$790 billion (Collins & Truman, 2020).

The obvious benefit from SDR allocations is that they constitute the least politically controversial way of funding climate policy in emerging economies. One reason is that a stable climate is a global public good which places direct responsibility on all the countries to do ‘whatever it takes’ to contain global warming (Stiglitz & Greenwald, 2010). Besides most carbon emissions come from developed economies whereas the damage occurs mainly in developing ones which already suffer most from global warming (Wagner et al., 2021). There are also two purely pragmatic reasons in favour of such SDR allocations: first they do not increase net public debts in the target economies,⁷ and second developed countries are now entering a period of protracted low eco-

⁷ For example when the U.S. government has to issue debt in order to raise dollars needed for conversion into SDRs, it does not increase the public debt because such conversion only increases the stock of SDRs owned by the United States. Moreover, the interest on these assets tends to be higher than in the case of the public debt (U.S. Department of Treasury, 2021).

conomic growth which makes it rational for them to approve SDR allocations as this would boost the global demand for their exports.

The key message from the discussion so far is that the benefits of the recent resumption of SDR allocations could be much greater if the IMF was gradually transformed into an international central bank.

3.1. Keynes' proposal to establish an international central bank

The idea of establishing an international central bank was put forward by John Maynard Keynes during the Bretton Woods conference in 1944 where he submitted his plan to create an International Clearing Union (Keynes, 1942). According to the plan over time the ICU was to evolve into a global central bank issuing an international currency which he named the *bancor* (Skidelsky, 2005). While central banks are rightly perceived as institutions that set interest rates to stabilize the economy and inflation, technically speaking they are clearing houses for transactions conducted in the currency issued by them (Lubik & Rhodes, 2012). The goal of the Keynes Plan was to re-establish capital flows from creditor to debtor countries immediately after World War 2 when many currencies were inconvertible (until the late 1950s). The solution he proposed involved loans made by the ICU to debtor countries and financed with foreign exchange deposits of creditor countries. The clearing house was thus necessary to settle transactions related to these loans (Keynes, 1942).⁸

Perhaps the best evidence that Keynes saw the ICU as a prospective global central bank was his proposal that the *bancor* should be issued in a countercyclical manner in order to smooth out the global business cycle (Joshi & Skidelsky, 2010). Exactly the same benefits from having an international central bank were observed in the Eurozone when the ECB's liquidity loans shielded several member states from sudden stops during the 2007–2009 global financial crisis and the 2010–2012 Eurozone public debt crisis (Chmielewski & Sławiński, 2019).

Despite the potential advantages of the ICU, the Keynes Plan was rejected at the Bretton Woods conference. Instead, its participants chose to establish the IMF—a global stabilization fund rather than a supranational central bank (Bordo & Schenk, 2016).

3.2. The limited prior role of the SDR

In the late 1960s, economists became concerned that the demand for dollars to fuel the dynamically growing international trade might necessitate such large deficits in the U.S. balance of payments that they would seriously deplete the Fed's gold stocks. This in turn would endanger the dollar's convertibility into

⁸ Ernst Friedrich Schumacher also made a significant contribution to the concept of multilateral clearing (1943).

gold which at that time was still believed to be a necessary condition for maintaining trust in it as the global currency (Triffin, 1960).

It was thus proposed that the IMF should supplement the supply of international liquidity by issuing Special Drawing Rights (SDRs). They were not intended to be an international currency but only a reserve asset giving their holders the right to convert them into key global currencies. Ultimately SDRs were only occasionally allocated between 1970 and 1981 (Byrne, 1982) and afterwards they were not issued again until 2009.

Debates on replacing the U.S. dollar with the SDR intensified only in the 1970s which in the U.S. were marked by high inflation and a weak dollar after it had been floated in 1971 (McCauley & Schenk, 2014). Once the Federal Reserve became fully independent in 1978 and Paul Volcker launched his tight monetary policy which helped to stabilize inflation and the dollar, the issue ceased to attract so much attention.

Among the main reasons for the almost 30-year gap in the issuance of SDRs (1981–2009) was the fact that the dollar dominated the international monetary system which emerged after the collapse of the Bretton Woods system, operated fairly smoothly. The two important sources replenishing the global dollar supply were the large capital outflows from the U.S. and the emergence of the Eurodollar market where non-American banks domiciled in third countries extended dollar-denominated loans to become an important source of the global supply of dollar deposits (McCauley, McGuire, & Sushko, 2015).

In the 1990s, recurring waves of speculative attacks on a number of currencies after the liberalization of short-term capital flows posed a severe test for the international financial system. Nonetheless, the system proved to be sufficiently resilient to withstand it. In 1992–1993, similar attacks on the currencies of the European Monetary System accelerated efforts to adopt the euro, i.e. the European common currency whose market would become too big to be attacked (Kenen, 1995). Similar events in 1997–1998 forced South-East Asian countries to float their currencies and maintain large stocks of foreign exchange reserves (Jurek, 2018).

Precautions against the threat of speculative attacks were also taken by many other emerging economies (e.g. in Eastern Europe) whose authorities also floated their currencies and accumulated large stocks of foreign exchange reserves as insurance against currency crises (Sławiński, 2020). The developing countries had to bear the costs of holding a substantial part of their domestic savings in low-yield foreign exchange reserves, but speculative attacks became only sporadic.

A much more serious threat to the international financial system was the 2007–2009 global financial crisis considered to be potentially the worst in history. Ultimately however its impact was reduced by governments' covering bank losses and central banks' QE programmes which alleviated the liquidity crises in banking and financial markets. Moreover, the Federal Reserve success-

fully took on the role of global lender of last resort by supplying other countries with international liquidity. To that end it extended loans to large foreign banks acting as its prime dealers (Shin, 2012) and entered foreign exchange swaps with selected foreign central banks which amounted to extending dollar loans to them by accepting their domestic currencies as collateral (Flemming & Klagge, 2010).

Even so the 2007–2009 global financial crisis proved to be so devastating that the international community decided to resume the issuance of SDRs. In 2009, their allocation amounted to \$250 billion whereas the most recent one (2021) totalled \$650 billion. Although such a large SDR allocation can be considered a critical milestone in internationally coordinated policy interventions it would be a much more effective policy tool in the hands of the international community if the IMF became an international central bank.

3.3. The benefits of IMF reform

As emphasized above the dollar and the euro are likely to remain the key international currencies for a long time to come. They owe their global status to both their wide use in international trade and the access they give to large and liquid financial markets. Corporates from all over the world can borrow the funds they need by offering their debt instruments on the U.S. and the Eurozone debt markets which are highly liquid and offer many derivatives providing ample possibilities to hedge against a host of risks.

However, even though the financial systems in the United States, the Eurozone, Japan and the United Kingdom are highly developed they are plainly insufficient to effectively address all current problems. The transformation of the IMF into an international central bank would considerably improve the functioning of the global monetary system capacity to cope with global challenges, including the unfolding climate crisis. IMF reform would enable a more efficient allocation of SDRs and bring tangible benefits from the development of financial markets for SDR-denominated securities.

3.3.1. More efficient SDR allocation

The problem with SDRs is that they are still distributed in proportion to the member states' contributions to the IMF. As a result, most SDRs are allocated to creditor countries which do not really need them.⁹ Despite this flaw the

⁹ By way of comparison consider SDR quotas allocated in 2021 to three populous emerging economies should be considered (population/SDR quota): India (1,355,000 m/\$18 bln), Indonesia (271 m/\$5 bln), and Brazil (211 m/\$15 bln) vs. three creditor countries: Germany (83 m/\$28 bln), South Korea (52 m/\$12 bln) and Australia (25 m/\$9 bln). The recent G20 proposal that developed countries should voluntarily transfer a proportion of their quotas to developing ones is far from sufficient.

general rule of allocation should not be changed too hastily since it provides the basis for political support for their issuance. Still if the IMF became an international central bank the obvious inefficiencies of the current distribution system would be remedied by allocating larger quotas to the neediest countries which happen to be those most exposed to climate risk.

In the Eurozone political support for QE was analogously built by using the *capital key* according to which the ECB was obliged to buy treasury papers in proportion to the GDPs of individual member states (Paris & Wyplosz, 2014). In consequence the ECB purchased treasury bonds mostly from creditor countries which did not need such assistance. This inefficient response was amended already during the SARS-CoV2 pandemic when the ECB started to purchase proportionally more Italian and Spanish bonds (Reuters, 2020).

Transforming the SDR into an international currency would also make it possible to exploit synergies to improve the existing international monetary system. During the 2007–2009 global financial crisis the Federal Reserve, even if it wanted to do so, was not in a position to extend foreign exchange swap lines to central banks in poorer developing economies since their currencies would have been too risky to be accepted as collateral. If the SDR became a genuine international currency central bank in developing countries could put it up as collateral when entering foreign exchange swaps with the Federal Reserve or with other major central banks (Obstfeld, 2015). This is why it would not be necessary to empower the reformed IMF with the capacity to issue unlimited international liquidity as this would easily become a highly sensitive and controversial political issue.

As an international central bank, the IMF could boost its firepower by issuing SDRs on a regular basis (naturally, within the limits agreed upon by its member states) as was the case in the late 1970s (Sobol, 1981). Moreover, with time SDR-denominated loans would start to be extended by commercial banks in countries with sufficiently developed financial centres. This would increase the supply of SDR deposits in much the same way as dollar deposits issued by commercial banks on the Eurodollar market (McCauley et al., 2015). The payments accruing from these SDR deposits could be easily cleared and settled by the IMF payment system just as payments tied to dollar deposits created on the Eurodollar market are cleared and settled by the Federal Reserve's Fedwire payment system. Subsequently, the supply of SDRs would be gradually adjusted to global demand and the IMF would be required to make fewer new SDR allocations.

3.3.2. The development of markets for SDR-denominated securities

In the 1970s, attempts to launch markets for SDR-denominated securities failed (Sobol, 1981), because the IMF did not have a payment system and SDR quotas were not genuine deposits. Under such circumstances the official and private

SDR circulations became separated and the IMF was unable to support the liquidity of the private SDR market.¹⁰

One of the reasons behind this failure to develop markets for SDR-denominated instruments in the 1970s was weak arbitrage. It should be borne in mind that the main factor that makes markets liquid is arbitrage, i.e. stabilizing speculation when traders in a variety of financial institutions attempt to arbitrage away short-term price anomalies. In the 1970s, financial markets were not globalized and consequently arbitrage was not strong enough to make private SDR markets liquid. Nowadays the chances for the emergence of large and liquid markets for SDR-denominated instruments are much larger since in today's highly globalized economy numerous financial institutions engage in arbitrage transactions and provide in this way liquidity to a variety of markets.

In the 1970s, there were only a handful of truly liquid markets even in the United States, namely the stock, treasury bond and foreign exchange ones. Nowadays there are numerous financial markets for a wide variety of financial instruments. Moreover, the scope of arbitrage has recently been expanded by the emergence of machine learning (ML) and artificial intelligence (AI), which play a crucial role in the automation of trading (Buckmann, Haldane, & Huser, 2021).

Accordingly, globalization makes the development of financial markets for SDR-denominated securities a perfectly achievable goal. If SDR quotas were converted into genuine deposits and the IMF was equipped with a payment system for clearing and settling SDR-denominated transactions financial markets would do the rest.

Investors would accept SDR-denominated securities once the SDR became a genuine international currency backed by the IMF and offering a natural diversification of exchange rate risk due to its basket composition (Hoguet & Tadesse, 2011). In consequence their market would become liquid within a relatively short timeframe thanks to massive arbitrage. SDR-denominated bonds would become attractive to a wide range of institutional investors—to mention only mutual funds, insurance companies, pension funds and large corporations—as a way of parking their excess cash in safe assets (Pozsar, 2014). Therefore, the issuance of such bonds by development banks e.g. could provide an efficient channel for moving excess savings from developed economies into investment projects undertaken with a view to decarbonizing developing economies.

¹⁰ The importance of central banks' market-making operations is perhaps best illustrated by the Federal Reserve's activities on the acceptances market which greatly helped the dollar to acquire its status of the key international currency in the interwar period (Eichengreen & Flandreau, 2010).

3.3.3. *Reduced costs of investing in the decarbonization of developing economies*

The development of SDR-denominated securities markets would not only contribute to overcoming the scarcity of funds available to developing economies but also reduce the costs of investing in their decarbonization.

The cost of financing long-term investments in a given country reflected in long-term interest rate levels depends on the expected inflation rate and the risk premium. On average developing economies are characterized by higher inflation and higher country risk premia which manifest themselves as relatively high long-term interest rates. As a result, technology investments in developing countries—including those in renewable energy—are less competitive compared to similar projects undertaken in developed economies.

A measure often used to evaluate an investment in energy technology is the levelized cost of energy (LCOE) which facilitates choosing the most cost-efficient option. The average LCOE levels are naturally higher in countries where high risk premia need to be factored in (IRENA, 2020).

Governments and corporations in developing countries try to reduce these costs by borrowing in dollars or euros (Maggiore, Neiman, & Schreger, 2018). However, quite often they are unable to hedge their long-term exchange rate risk by using cross-country interest rate swaps (CIRS), e.g. as such instruments are usually unavailable for many currencies issued by developing countries. The exchange rate risk could be reduced if a major proportion of funding for sustainable investment in developing economies was provided by SDR-denominated debt instruments, again due to the basket nature of the latter.

The country risk premia included in the expected yields from SDR-denominated securities would be further reduced by the IMF acting as a dealer of last resort ready to curb price volatility in these markets. At present a similar policy is being pursued by the Bank of Japan to control the yield curve with increasingly smaller *ad hoc* operations (Posen, 2020).

What may send a credible signal to markets that the IMF is ready to play such a role would be its engagement in SDR-denominated bond market-making. As an internationally trusted institution it would still substantially reduce the risk premia demanded by investors even though it might choose to do so on a relatively modest scale. These premia would be further cut if developing countries were able to hold SDR deposits as natural collateral at the IMF.¹¹

All of the above could bring the costs of investing in renewable energy in developing economies down to levels typical of the developed world. This

¹¹ In future, the IMF could sponsor the issuance of more sophisticated debt instrument involving financial engineering, e.g. loans which would only become cancellable (convertible into grants) upon achieving a planned environmental benefit. Shiller regards deploying financial engineering to achieve social goals as a new frontier in finance (Shiller, 2012).

in turn would significantly narrow the gap between the costs of comparable technology-intensive projects to be carried out in different parts of the world.

Overcoming the capital cost barrier would create a space for international coordination of investment in environmental protection projects in countries most exposed to climate change and located in ecosystems which are crucial for preserving the Earth's natural environment. This would set the stage for the IMF as a facilitator of such cooperation. Most likely the IMF would be ready to assume such responsibility as it has recently announced that climate policy is to become part of annual assessment of its member states (IMF, 2021). Global climate policy could thus capitalize on both the efforts of thousands of scientists whose research contributes to successive IPCC reports and the knowledge of the economic, social and political characteristics of individual countries accumulated by the IMF over the years.

Conclusions

The key message of this paper is that while the unfolding climate crisis and the SARS-Cov2 pandemic contributed to a strengthening of international cooperation which allowed an unprecedentedly large issuance of SDR in 2021 the international community's capacity to address the looming global challenges would be considerably enhanced by a gradual transformation of the IMF into an international central bank. The technical side of the process would be quite straightforward: the IMF member states would have to agree to convert their SDR quotas into genuine deposits and equip the Fund with a payment system necessary to develop liquid markets for SDR-denominated securities. Today's financial globalization would make creation of such markets much easier than in the 1970s when similar efforts failed.

The paper argues that the proposed conversion of SDR into a fully-fledged reserve currency does not imply that it should become the dominant one globally. A limited SDR role is much more politically viable. Moreover, the existing major reserve currencies such as the dollar and the euro are satisfactorily playing their role of key international currencies which obviates the need to rapidly substitute them with a new global money.

Nonetheless, the need for another currency is visible as even the major central banks, such as the Federal Reserve and the European Central Bank, at least within their current mandates, are not in a position to cope with global challenges. In the authors' view this gap should be filled by the IMF transformed into an international central bank and backed by an international mandate.

Such an IMF reform would enable the international community to overcome one of the most serious obstacles to a truly global climate policy, namely mobilizing sufficient funds to decarbonize poorer economies. The IMF's transformation into an international central bank and the emergence of markets for

SDR-denominated securities would increase the availability of funds and reduce the costs of investments in clean energy technologies in developing economies.

Last but not least argument in favour of the proposed institutional reform is that the new challenges with which the IMF will have to cope anyway are unlikely to be temporary or limited to specific regions as was often the case with financial crises. The unavoidable future challenges to be faced by the international community, such as climate change, biodiversity loss (Dasgupta, 2021) and pandemics (WHO, 2021) will be massive and long term and they will have to be tackled simultaneously. The proposed conversion of the IMF into an international central bank would stimulate international cooperation, which would amplify substantially the effectiveness of policies protecting Earth's environment (Ferrari & Pagliari, 2021).

References

- Andersson, M., Bolton, P., & Samana, F. (2018). Hedging climate risk. *Financial Analysts Journal*, 72(20), 1-18.
- Bernanke, S. B. (2000). Japanese monetary policy: A case of self-inflicted paralysis?. In R. Mikitani & A. S. Posen (Eds.), *Japan's financial crisis and its parallels to U.S. experience* (pp. 149-166). Washington, DC: Institute for International Affairs.
- Blanchard, O. (2012). Monetary policy in the wake of the crisis. In O. Blanchard, D. Romer, M. Spence & J. Stiglitz (Eds.), *In the wake of the crisis* (pp. 7-14). Cambridge: The MIT Press.
- Bordo, M., & Schenk, C. (2016). Monetary policy cooperation and coordination: A historical perspective on the importance of rules. In M. D. Bordo & J. Taylor (Eds.), *Rules for international monetary stability: Past, present and future* (pp. 205-261). Stanford: Hoover Institution Press.
- Brack, D. (2017). *Woody biomass for power and heat impacts on the global climate*. London: Chatham House, The Royal Institute of International Affairs.
- Broecker, W. S. (1987). Unpleasant surprises in the Greenhouse?. *Nature*, 328, 123-126.
- Buckley, T., Sanzillo, T., & Shah, K. (2019). *Inaction is Black Rock's biggest risk during the energy transition*. Lakewood: Institute of Energy Economics and Financial Analysis.
- Buckmann, M., Haldane, A., & Huser, A.-C. (2021). *Comparing minds and machines: Implications for financial stability*. (Bank of England Staff Working Paper No. 937).
- Byrne, W. J. (1982, September). Evolution of the SDR, 1974-1981: Changes in the basket, interest rate, and use of the SDR. *Finance & Development*, 31-35.
- Chmielewski, T., & Sławiński, A. (2019). Lessons from TARGET2 imbalances: The case for the ECB being a lender of last resort. *Economics and Business Review*, 5(19), 48-63.
- Climate-Related Market Risk Subcommittee (CRMRS). (2020). *Managing climate risk in the U.S. financial system*. Washington DC: U.S. Commodity Future Trading Commission, Market Risk Advisory Committee.
- Collins, G. C., & Truman, E. M. (2020, April 10). Special Drawing Rights to the rescue. *Real Time Economic Issues Watch*, PIIIE.

- Corsetti, G., Pesenti, P., & Roubini, N. (1999). What caused the Asian currency and financial crisis?. *Japan and the World Economy*, 11(3), 306–372.
- Dafermos, Y., Gabor, D., Nikolaidi, M., & van Lerven, F. (2021). *Greening the UK financial products system—a fit for purpose approach*. (SUERF Policy Note No. 226, 1–14).
- Danielsson, J., Shin, H. S., & Zigrand, J.-P. (2013). Endogenous and systemic risk. In J. G. Haubrich & A. Lo (Eds.), *Quantifying systemic risk* (pp. 73–93). Chicago: University of Chicago Press.
- Dasgupta, P. (2021). *The economics of biodiversity: The Dasgupta review*. London: HM Treasury.
- De Grauwe, P. (2019). Green money without inflation. *Economics, Finance, Business & Management*, 88(20), 51–54.
- De Grauwe, P. (2020). The need for monetary financing of corona budget deficits. *Intereconomics*, 55(3), 133–134.
- De Grauwe, P., & Ji, Y. (2013). Self-fulfilling crises in the Eurozone: An empirical test. *Journal of International Money and Finance*, 34, 15–36.
- Dyke, J., Watson, R., & Knorr, W. (2021, April 27). Climate scientists: Concept of net zero is dangerous trap. *Social Europe*.
- Eichengreen, B. (2009). *Out of the box thoughts about the international financial architecture*. (IMF Working Paper, WP/09/116).
- Eichengreen, B., & Flandreau, M. (2010). *The Federal Reserve, the Bank of England and the rise of the dollar as an international currency, 1914–39*. (BIS Working Paper No. 328).
- ESRB. (2020). *Positively green: Measuring climate change risks to financial stability*. Frankfurt: ECB.
- Ferrari, M., & Pagliari, M. S. (2021). *No country is an island: International cooperation and climate change*. (ECB Working Paper No. 2568).
- Flemming, M., & Klagge, N. (2010). The Federal Reserve's foreign exchange swap lines. Federal Reserve Bank of New York. *Current Issues in Economics and Finance*, 16(4), 1–7.
- Hansen, J., Sato, M., Hearty, P., Ruedy, R., Kelley, M., Masson-Delmotte, V., ... Lo, K.-W. (2016). Ice melt, sea level rise and superstorms: Evidence from paleoclimate data, climate modelling, and modern observations that 2°C global warming could be dangerous. *Atmospheric Chemistry and Physics*, 16, 3761–3812.
- Hansen, J., Sato, M., Kharecha, P., von Schuckmann, K., Beerling, D. J., Cao, J., ... Ruedy, R. (2017). Young people's burden: requirement of negative CO₂ emissions. *Earth System Dynamics*, 8, 577–616.
- Hoguet, G., & Tadesse, S. (2011). The role of SDR-denominated securities in official and private portfolios. *BIS Papers*, 58, 165–186.
- Hua, W., Dai, A., Zhou, L., Qin, M., & Chen, H. (2019). An externally forced decadal rainforest seesaw pattern over the Sahel and south east Amazon. *Geographical Research Letters*, 46, 923–932.
- IEA. (2021). *Financing clean energy transitions in emerging and developing economies*. Paris: International Energy Agency.
- IMF. (2021). *2021 Comprehensive Surveillance Review—Background Paper on Integrating Climate Change into article IV consultations*. (IMF Policy Paper). Retrieved from <https://www.elibrary.imf.org/view/journals/007/2021/032/article-A001-en.xml>

- International Renewable Energy Agency (IRENA). (2020). *Renewable power generation costs in 2019*. Abu Dhabi: International Renewable Energy Agency.
- IPCC. (2018). *Global warming of 1.5°C. Special report*. Geneva: Intergovernmental Panel on Climate Change, World Meteorological Organization.
- IPCC. (2021). *Climate change 2021. The physical science basis*. Geneva: Intergovernmental Panel on Climate Change, World Meteorological Organization.
- Joshi, V., & Skidelsky, R. (2010). Keynes, global imbalances, and international monetary reform. In S. Classens, S. Evenett & B. Hoekman (Eds.), *Rebalancing global economy: A primer for policymaking* (pp. 173–181). London: CEPR.
- Jurek, M. (2018). Choosing the exchange rate regime—a case for intermediate regimes for developing and developing economies. *Economics and Business Review*, 4(18), 46–63.
- Kaufman, N., Barron, A. R., Krawczyk, W., Marsters, P., & McJeon, H. (2020). A near-term to net zero alternative to the social cost of carbon for setting carbon prices. *Nature Climate Change*, 10, 1010–1014.
- Kenen, P. B. (1995) *Economic and Monetary Union in Europe*. Cambridge: Cambridge University Press.
- Kent, D. D., Litterman, B., & Wagner, G. (2018). *Declining CO₂ price path*. (NBER Working Paper No. 22794).
- Keynes, J. M. (1942). Proposals for an International Currency (or Clearing) Union: fourth draft of the ‘Keynes Plan’. In J. K. Horsefield (Ed.), (1969), *The International Monetary Fund 1945–1965* (vol. 3: *Documents*, pp. 3–36). Washington, DC: International Monetary Fund.
- Krogstrup, S., & Oman, W. (2019). *Macroeconomic and financial policies for climate change mitigation: A review of literature*. (IMF Working Paper, WP/19/185).
- Lakner, C., & Milanovic, B. (2016). Global income distribution: from the fall of the Berlin Wall to the Great Recession. *World Bank Economic Review*, 30(20), 203–232.
- Lenton, T. M., Rockström, J., Gaffney, O., Rahmstorf, S., Richardson, K., Steffen, W., Schellnhuber, H. J. (2019). Climate tipping points—too risky to bet against. *Nature*, 575, 592–593.
- Litterman, R. (2016). Selling stranded assets: Profit, protection, and prosperity. Retrieved from <https://www.intentionalendowments.org>
- Lubik, T., & Rhodes, K. (2012). *TARGET2: Symptoms, not causes of European woes*. (Economic Brief No. 2). Richmond: The Federal Reserve Bank of Richmond.
- Maggiore, M., Neiman, B., & Schreger, J. (2018). *The rise of the dollar and fall of the euro as international currencies*. (NBER Working Paper No. 25410).
- Masson, P. R. (1999). *Multiple equilibria, contagion, and the emerging market crises*. (IMF Working Paper No. WP/99/164).
- Matysek-Jędrzych, A. (2018). On the growing accountability of central banks for financial stability—the macroprudential perspective. *Economics and Business Review*, 4(18), 30–45.
- McCauley, R. N., & Schenk, C. R. (2014). *Reforming the international monetary system in the 1970s and 2000s: Would an SDR substitution account have worked?*. (BIS Working Papers No. 444, 1–34).
- McCauley, R. M., McGuire, P., & Sushko, V. (2015). *Global dollar credit: Links to U.S. monetary policy and leverage*. (BIS Working Paper No. 483).

- McLaren, D., & Markusson, N. (2020). The co-evolution of technological promises, modelling policies and climate change targets. *Nature Climate Change*, 10, 392–397.
- Minsky, H. (1986). *Stabilizing an unstable economy*. New Haven: Yale University Press.
- Mora, C., Spirandelli, D., Franklin, E. C., Lynham, J., Kantar, M. B., Miles, W., ... Hunter, C. L. (2018). Broad threat to humanity from cumulative climate hazards intensified by greenhouse gas emissions. *Nature Climate Change*, 8, 1062–1071.
- NGFS. (2020). *Guide to climate scenario analysis for central banks and supervisors. Report issued by the Central Bank and Supervisors Network for Greening the Financial System*. Paris: Banque de France.
- Nordhaus, W. D. (1992). *The DICE model: Background and structure of Dynamic Integrated Climate-Economy model of the economics of global warming*. (Cowles Foundation Discussion Paper No. 1009).
- Obstfeld, M. (2015). *The SDR as an international reserve asset: What future?*. Berkeley: International Growth Centre, University of California.
- Ocampo, J. A. (2017). *Resetting the International Monetary (non)System*. New York: Oxford University Press.
- Paris, P., & Wyplosz, C. (2014). The PADRE plan: Politically Acceptable Debt Restructuring in the Eurozone. *Geneva Reports on the World Economy. Special Report 3*. London: CEPR.
- Pattyn, F., Ritz, C., Hanna, E., Asay-Davis, X., DeConto, R., Durand, G., ... van den Broeke, M. (2018). The Greenland and Antarctic ice sheets under 1.5°C global warming. *Nature Climate Change*, 8, 1053–1061.
- Popkiewicz, M., Kardaś, A., & Malinowski, S. (2019). *Nauka o klimacie*. Warszawa: Post Factum.
- Posen, A. (2020). *Bank of Japan's policies have been success*. Washington, DC: Peterson Institute for International Economics. Retrieved from <https://www.piie.com/commentary/op-eds/bank-japans-policies-have-been-success>
- Pozsar, Z. (2014). *Shadow banking: Money view*. (Office of Financial Research Working Paper No. 14-04).
- Rachel, L., & Summers, L. (2019). *On secular stagnation in industrialized world*. (NBER Working Paper No. 26198).
- Ren, H. (2011). *Countercyclical financial regulation*. (Policy Research Working Paper No. 5823). Washington, DC: World Bank.
- Restoy, F. (2021). *The role of prudential policy in addressing climate change*. (SUERF Policy Brief No. 213, 1-8).
- Reuters. (2020, March 18). *Ready to do everything it takes*. ECB steps up Italian bond buys.
- Schumacher, E. F. (1943). Multilateral clearing. *Economica*, 10(38), 150–165.
- Schuur, E. A. G., McGuire, A. D., Schädel, C., Grosse, G., Harden, J. W., Hayes, D., ... Vonk, J. E. (2015). Climate change and the permafrost carbon feedback. *Nature*, 520, 171–179.
- Sharpe, W. (1970). *Portfolio theory and capital markets*. Boston: McGraw-Hill.
- Shiller, R. (2012). *Finance and the good society*. Princeton: Princeton University Press.
- Shin, H. S. (2012). *Adapting macroprudential policies to global liquidity conditions*. (Bank of Chile Working Paper No. 671).

- SIERP. (2017). *Ten facts about the economics of climate change and climate policy*. The Hamilton Project and Stanford Institute for Economic Policy Research. Stanford: Stanford University.
- Skidelsky, R. (2005). Keynes, globalization and Bretton Woods Institutions in the Light of changing ideas about markets. *World Economics*, 6(1), 15-30.
- Sławiński, A. (2020). Central, Eastern and Southeastern Europe's reunion with Europe. In R. Holzmann, D. Ritzberger-Grunwald & H. Schuberth (Eds.), *30 Years of transition In Central, Eastern and Southeastern Europe* (pp. 94-105). Cheltenham/ Northampton: Edward Elgar.
- Sobol, D. M. (1981, winter). The SDR in private international finance. *Federal Reserve Bank of New York Quarterly Review*, 29-41.
- Stern, N. (2008). The economics of climate change. *American Economic Review: Papers and Proceedings*, 98(2), 1-37.
- Stiglitz, J. E. (2006). *Making globalization work*. New York: W. W. Norton & Company.
- Stiglitz, J. E., & Greenwald, B. (2010). Toward a new global reserve system. *Journal of Globalization and Development*, 1(2), 1-24.
- Taylor, J. B. (1993). *Discretion versus policy rules in practice*. (Carnegie-Rochester Conference Series on Public Policy No. 39, 195-214).
- Thompson, J. M. T., & Sieber, J. (2010). Predicting climate tipping as noisy bifurcation: A Review. *International Journal of Bifurcation and Chaos*, 21(2), 399-423.
- Triffin, R. (1960). *Gold and the dollar crisis: The future of convertibility*. New Haven, CT: Yale University Press.
- U.S. Department of Treasury. (2021, April 3). *Fact sheet: How an allocation of international monetary fund special drawing rights will support low-income countries, the global economy and the United States*. Washington DC.
- Wagner, G., Anthoff, D., Cropper, M., Dietz, S., Gillingham, K. T., Groom, B., Stock, J. H. (2021). Eight priorities for calculating the social cost of carbon. *Nature*, 590, 548-550.
- Weitzman, M. L. (2009). On modelling and interpreting the economics of catastrophic climate change. *Review of Economics and Statistics*, 91(1), 1-19.
- WHO. (2021). *Nature, biodiversity, and health: An overview of interconnections*. Geneva: World Health Organization.