Macroeconomic implications of climate change and transition risks for central banking in the Global South – the case of Nigeria[1]

Anne Löscher[2]

Annina Kaltenbrunner[3]

Abstract

The research sheds light on a largely under-researched topic: What effects do physical *and* transition effects of climate change have for central banking transmitted through the balance-of-payments in the Global South? We conduct a country case study of Nigeria by triangulating primary qualitative data generated from ten semi-structured interviews with secondary quantitative data. The latter is used in a time series analysis, where we built two structured Vector Autoregressive models. We find that physical and transition risks both impact Nigeria's balance-of-payments through the financial and current account channel to the detriment of the central bank's objectives. Long-term physical effects of climate change and the strong oil dependence of Nigeria's domestic economy, its financial system and trade balance play a major role. Central banking in Nigeria is adversely affected when climate risks reduce foreign exchange income and increase the need thereof; when they put pressure on the exchange and inflation rate and undermine the acceptance of Nigerian financial assets. As a consequence, the central bank will have to keep interest rates notoriously high. These effects have recessionary implications for the domestic economy and impede economic diversification and a green transition in Nigeria.

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[2] University of Siegen, Germany. Corresponding author: loescher@geld-und-nachhaltigkeit.de.

[3] Leeds University Business School, United Kingdom.

1 The challenges at hand

"[G]lobal imbalances and ecological unsustainability
are perceived as two isolated problems that now need
to be resolved at the same time."
Romain Svartzman and Jeffrey Althouse (2020: 2)

The direct physical and indirect transition effects of the climate catastrophe – here summarised as climate risks[4] – have important implications for central banking and monetary policy making. Climate risks increase inflation rates by harming agricultural productivity and increase prices of consumer goods as a result of carbon taxes (Batten, Sowerbutts, and Tanaka 2020; Parker 2018; Heinen, Khadan, and Strobl 2018; Dennig et al. 2015). They heighten financial instability by increasing price volatility in primary commodities; by increasing inequality which translates into lowered effective demand and recessionary pressure; and by adversely impacting investors' financial positions e.g. when assets are destroyed by extreme weather events or when transition risks lower the value of fossil based assets held on investors' balance sheets (Dafermos, Nikolaidi, and Galanis 2018; 2017; Carnevali et al. 2021; Bolton et al. 2020; Campiglio et al. 2018; Monnin 2018; Lamperti et al. 2019; Carney 2015). Finally, climate risks impact domestic and global growth as the literature on natural disasters shows (Dellink et al. 2017; Leiter, Oberhofer, and Raschky 2009; Noy 2009; Cuaresma, Hlouskova, and Obersteiner 2008; Cavallo and Noy 2011; Hsiang and Jina 2014; Dafermos, Nikolaidi, and Galanis 2017).

Despite this considerable set of existing literature on the link between climate risks and monetary policy making, two important gaps remain. Firstly, while a lot of research focuses on the Global North, the interaction between the international monetary system, climate risks and central banking in the Global South is still under-researched. However, the reduction of policy leeway and its effectiveness due to climate risks is likely to be greater in the context of Global South countries given the structural external constraints posed by their balance-of-payments. In countries of the Global South, pressures from the balance-of-payments are the most important limiting factors for effective central banking and its objectives of ensuring low inflation rates, sufficient foreign exchange reserves, as well as the stability of and sufficient liquidity in domestic financial markets (Andrade and Prates 2013; Dafe 2017; Kaltenbrunner 2015; Bonizzi 2013; Powell 2013; Bortz and Kaltenbrunner 2018; Rey 2018; Akyüz 2013; Fischer 2018; Kregel 2008; McCombie and Thirlwall 2004; Paula, Fritz, and Prates 2017; Harvey 2009; Davidson 1991).

Secondly, most research focuses on either transition (Kapfhammer, Larsen, and Thorsrud 2020; Bovari, Lecuyer, and Mc Isaac 2018; Carnevali et al. 2021; Mercure et al. 2019; Svartzman and Althouse 2020; Althouse, Guarini, and Gabriel Porcile 2020; Carnevali et al. 2021) *or* physical effects of climate change (Cavallo and Noy 2011; Cuaresma, Hlouskova, and Obersteiner 2008; Coulibaly, Islam, and Managi 2020; Keen, Freeman, and Mani 2003). But very few contributions look at both simultaneously (exceptions being: Löscher and Kaltenbrunner 2023; Bolton et al. 2020; Dafermos, Nikolaidi, and Galanis 2018). This is another important gap as Global South countries bear the disproportionate burden of both types of risks due to their geographical positioning and the concentration of carbon-intense exports and production in the Global South (Malm 2015; Mitchell 2011).

[4] We use the term *climate risks* as umbrella term for both physical risks stemming from climate change, that encompass direct physical destructions due to natural disasters such as droughts and floods, and transition risks, i.e. the indirect effects coming with climate change such as climate policies aiming at decarbonisation, sudden divestment strategies, changes in demand patterns, recessionary pressure and the heightened risk of economic and financial crises.

This report fills those gaps in the existing literature. We use the case of Nigeria to shed light on the impacts of physical and transition climate risks transmitted through the balance-of-payments on central banking in the Global South. Nigeria is an appropriate case study because of its susceptibility to both: physical risks due to its position in proximity to the equator and the sea, and transition risks because of its oil dependence. Although there is some discussion of the nexus between the oil prices and macroeconomic variables in Nigeria (Adesete and Bankole 2020; Ogundipe, Ojeaga, and Ogundipe 2012; Musa et al. 2019; Adi, Adda, and Wobilor 2022; Ozili 2020; Asaleye et al. 2019) – and the extent to which central banking and monetary policy making is shaped by the state's power over the extraction of the oil resources (Dafe 2019) – so far little has been said about how both physical and transition effects of climate change impact central banking in Nigeria.

To address this research area we use an innovative mixed-method design which triangulates insights from ten semi-structured interviews with two structured Vector Autoregressive (SVAR) models. Based on the interview results, the SVAR estimate both physical and transition risks for key monetary policy variables, namely the exchange rate, the interest rate, and foreign exchange reserves. We find that physical and transition risks have important implications for central banking and monetary policy making in Nigeria transmitted through the balance-of-payments: Climate risks reduce foreign exchange income and make the holding of foreign exchange reserves more important. Moreover, they exercise pressure on the exchange rate, render the exchange rate more volatile, respectively, and undermine the confidence in Nigerian financial assets. This is particularly pronounced when global instability rises. As a consequence, the central bank is incentivised to keep interest rates high to uphold the acceptance of its financial assets including the domestic currency. These effects have recessionary implications for the domestic economy and impede economic diversification as well as green transition efforts. The findings are in line with other conceptual research on the interaction between climate risks and balance-of-payments in peripheral countries (Löscher and Kaltenbrunner 2023). We conclude that efforts to tackle the climate catastrophe need to gain traction and that the design and implementation of climate policies have to consider foreign exchange dependence in the Global South to alleviate the impediments to an equitable post-fossil transition.

Following this introduction, section 2 provides some background to the choice of Nigeria as case study. Section 3 sets out the mandates and conditions of central banking in Nigeria. Section 4 introduces our methodology, and Section 5 presents our qualitative data analysis. Section 6 discusses the two SVAR models whilst section 7 concludes.

2 Economic Background

Nigeria is an important case study to assess how climate risks impact central banking in the Global South for three main reasons as elaborated in this section. Firstly, Nigeria's balance-of-payments becomes increasingly unsustainable which is apparent in a deteriorated current account and an increasing degree of external financial fragility. Figure 1 represents Nigeria's external trade and current account balance in relation to its GDP for the years 2003-22.

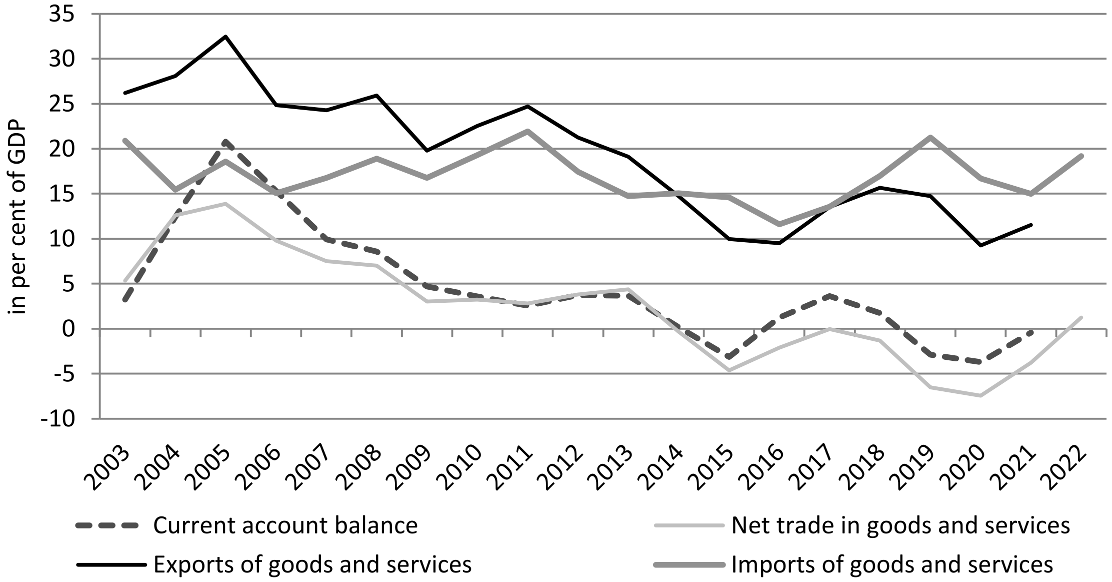

Figure 1: Nigeria's current account, trade balance, export and imports as percentage of GDP, 2003-22. Source: Own representation of data from World Bank (2023).

Exports as percentage of GDP almost halved between mid-2000 and 2021, whilst imports are fairly stable and fluctuate between around 15 and 20 per cent of GDP. Consequently, Nigeria's current account and trade balance as per cent of GDP have deteriorated since 2005. The trade balance became negative in 2014 and reached nearly -7.5% of GDP in 2020. These trends might have been more pronounced if the Nigerian government had not imposed import and foreign exchange restrictions (International Trade Administration 2023).

This deterioration of Nigeria's external trade position was accompanied by an increasing degree of external financial fragility (for the concept see: Paula and Alves 2000). Figure 2 shows how Nigeria's external liability stock is on the rise, with liabilities to BIS banks[5] as percentage of GDP increasing since 2009 and the ratio between external debt securities and foreign exchange reserves dropping.

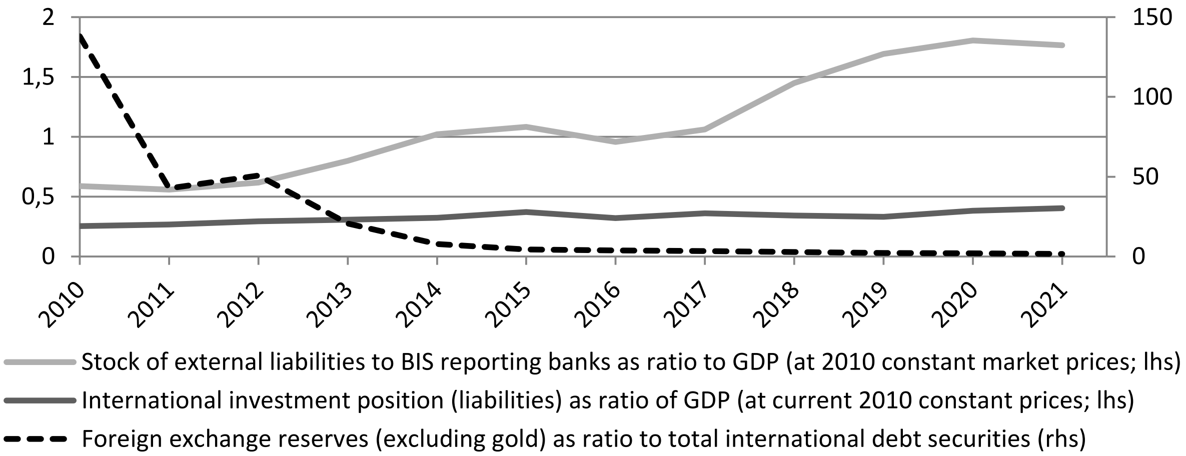

Figure 2: Total external liability stock held by BIS reporting banks and international investment positions (liabilities) in relation to GDP (at 2010 constant market prices); and foreign exchange reserves (excluding gold) in relation to total international debt securities. Source: Own calculation and representation of data from Bank of International Settlement et al. (2022), CBN (2023d), World Bank (2023) and IMF (2023).

[5] We approximate Nigeria's liability stock by using the liabilities to banks reporting to the BIS because of their vast coverage. About 94 percent of all cross-border liabilities are covered hereby (BIS 2020).

Nigeria's growing exposure to external liabilities takes place against the backdrop of its vulnerability vis-à-vis its exposure to portfolio flows and foreign direct investments (FDI). This type of external liabilities is particularly dangerous for small economies because they are an important channels through which international volatility spills into the domestic economy (Grabel 1996; Bortz and Kaltenbrunner 2018; Kaltenbrunner and Painceira 2017; Bonizzi 2013; Kohler, Bonizzi, and Kaltenbrunner 2023). Figure 3 provides insights into the volatile nature of these flows in the case of Nigeria.

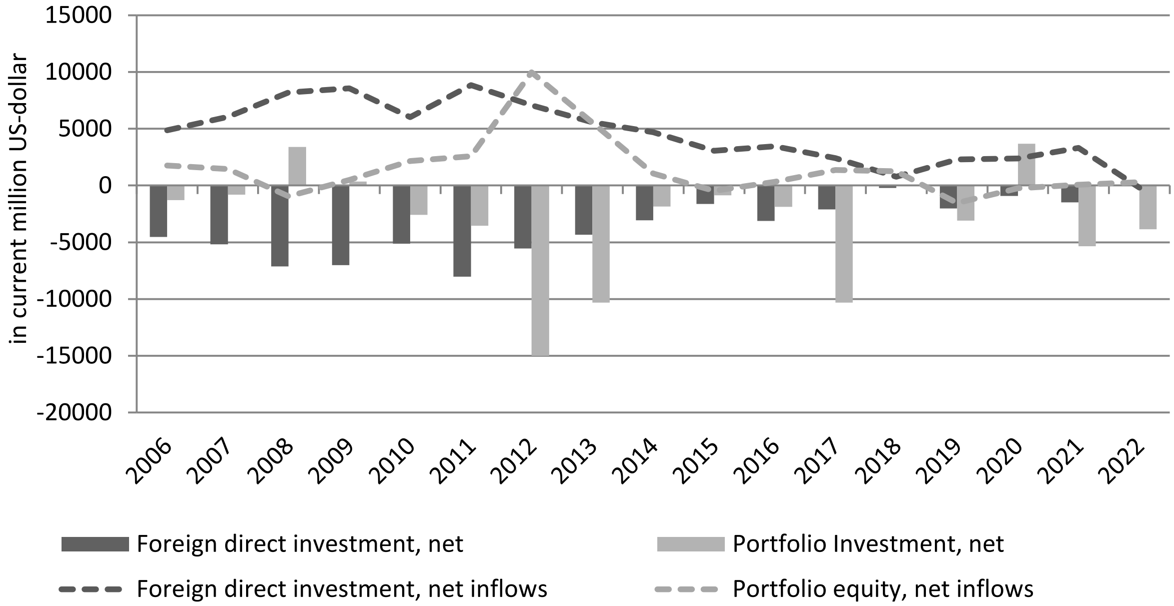

Figure 3: Net positions of FDI and portfolio investments (assets, outward investments, minus liabilities, inwards investments) and net inflows of FDI and portfolio equity (in current million US-Dollar), 2006-22. Source: Own representation of data from World Bank (2023).

A second reason why we chose Nigeria as case study is that it is likely to be affected heavily by climate transition as its balance-of-payments, financial sector and currency are strongly intertwined with the oil sector. Nigeria's foreign exchange income through exports predominantly comes from the export of crude oil and petroleum gases, which constitute more than 90% of its net exports (see Figure 4).[6] As oil is the primary source of foreign exchange income, there is a strong correlation between Nigeria's GDP and the price for Brent crude oil – even though the oil sector only makes up 9% of GDP (*The Economist* 2019).

The exposure of Nigeria's trade balance to oil prices makes it particularly vulnerable to transition risks coming in the form of decarbonisation efforts. One estimation predicts that by 2050 the demand for oil will be a quarter of what it is today, whilst that for gas will be halved (Mercure et al. 2021).[7] Jewell and colleagues (2013) project that because of climate transition effects international trade in oil will fall by 10–70% until 2050 and by 40–74% by 2100. Most of this shift will take place after 2030 (IEA 2021). Van

[6] Accordingly in 2017, Nigeria was ranked 130 out of 133 countries in respect to complexity of export goods, which is on a decline since the mid-1990ies in relation to other countries (Center for International Development 2022). Notwithstanding, Nigeria's economy is more diversified with the financial, entertainment, information technology and merchandise sectors playing an increasingly important role. These sectors experienced growth rates of 7 per cent per annum between 2003 and 2011(Usman 2022). However, they are not even close to the importance of crude oil as primary income of foreign exchange.

[7] About 31 countries and US-American states have already passed legislations which aim at phasing out of internal combustion engines for vehicles in the next ten to 30 years (Hanley 2021). Decarbonisation efforts such as the abandonment of combustion engines play a significant role for the demand of oil (IEA 2021).

de Graaf and Bradshaw (2018, 25) purport that the "key uncertainty is not whether global oil demand will peak, but how soon it will peak and how quickly demand will fall thereafter".

Another aspect of how transition risks might impact monetary policy making in Nigeria is the exposure of domestic financial markets to the oil sector and hence the potential stranding of domestic financial assets.[8] According to Itaman and Awopegba (2021), the strong intertwining of the Nigerian oil and financial sector is the result of financial deregulation carried out in the course of Nigeria's first Structural Adjustment Programme: high interest rates, the result of market determination starting from 1987, were only payable by profitable sectors such as oil and gas industries and short-term trading (Itaman and Awopegba 2021).

The third reason why we chose Nigeria as case study is its vulnerability to the physical effects of climate change. According to the Notre Dame Global Adaptation Index (ND-GAIN) Nigeria's ranking of 192 countries deteriorated from rank 104 in 2006 to 158 in 2020. The deterioration of projected change in yield and agricultural capacities, and a simultaneously lower level of readiness to tackle climate risks contributed to this bad ranking in particular (ND-GAIN 2023). This points to another aspect of how climate risks are likely to impact Nigeria's balance-of-payments: Nigeria is a net importer of food stuff which makes it susceptible to higher food prices as result of climatically induced reduction of agricultural productivity.

Figure 4 shows that food and fuel imports make up about 40 per cent of merchandise imports in recent years. Oil rents play a relative small roll in GDP, but a massive one in the determination of exports.

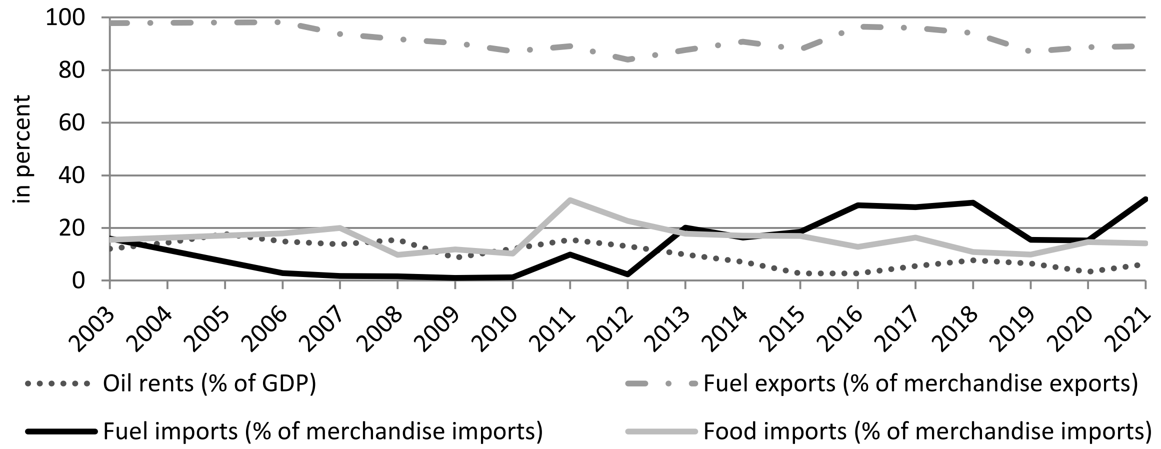

Figure 4: Oil rents as share of GDP, fuel and food imports as share of merchandise imports and fuel exports as share of merchandise exports in Nigeria, 2003-21. Source: Own representation of data from World Bank (2023).

In sum, this section has shown that Nigeria's is an interesting case to assess pressures arising from climate risks on central banking through the balance-of-payments. These risks feed into challenges coming in the form of falling exports, decreasing foreign exchange reserves in relation to Nigeria's external liabilities and the financial account's exposure to volatile financial flows. Climate risks are hence exponents of challenges to central banking in Nigeria as its trade balance and financial sector are strongly interwoven with the oil sector; and because Nigeria is vulnerable to physical effects of climate change mainly due to its agricultural sector.

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[8] Globally, climate transition effects are projected to cause a wealth loss of US$1-4 trillion (Mercure et al. 2018).

3 The main mandates and instruments of central banking in Nigeria

The CBN has the following objectives (CBN 2023e):ensure monetary and price stability;

1. issue legal tender currency in Nigeria;
2. maintain external reserves to safeguard the international value of the legal tender currency;
3. promote a sound financial system in Nigeria; and
4. act as Banker and provide economic and financial advice to the Federal Government.

Additionally, the CBN is endowed with some developmental tasks of Nigeria's financial, agricultural and industrial sectors (CBN 2023e). We here focus on three main mandates in particular, namely price stability, stable domestic financial markets and ensuring sufficient foreign exchange funds. This section elaborates how all mandates are limited by the balance-of-payments and feed back into it – establishing a strong nexus between central banking and the balance-of-payments.

Price stability

The CBN targets to retain inflation within a range of 6-9% (Olurounbi and Osae-Brown 2023). The CBN herein hopes that predictable price levels ensure financial stability by reducing uncertainty and helping economic agents to make rational decisions (CBN 2021). In July 2023, year-on-change inflation rates stood at 24.08% and hence missed the CBN's target by being more than twice as high as the higher end of its target (CBN 2023b). The CBN itself identifies the exchange rate, energy and food prices, foreign capital flows, government spending, reduced output ensuing poor energy supply and social conflict as main factors determining the price level (CBN 2023f). The CBN's most important policy tool to impact expectations of the price level are interest and exchange rates (CBN 2023f; 2018). In the latter the connection between the balance-of-payments and domestic inflation rates becomes particularly pronounced: stable inflation rates in import-dependent countries in the Global South largely hinge on the exchange rate – in turn determined by the structure of the balance-of-payments – because of the high pass-through of prices for imports to the consumer price levels (Flassbeck 2018; Kaltenbrunner 2015; Andrade and Prates 2013; Paula, Fritz, and Prates 2017).

Stability of domestic financial markets

Another primary mandate of the CBN is to ensure the well-functioning of their domestic financial markets, which helps to ensure sufficient credit supply to the domestic economy and provides the transmission channel of monetary policies (CBN 2023e). According to the CBN, the main threats to financial stability in Nigeria are posed by oil price shocks and global contractions, which imply reduced international trade and foreign portfolio investments outflows (CBN 2019; 2022b). The CBN's main instruments to ensure stability of domestic financial markets is aiming to ensure price and exchange rate stability, the deepening of financial markets, the writing-off of non-performing loans, the setting of minimum capital, reserve and tenor requirements, the regulation of foreign exchange denominated debt exposure of domestic financial institutions by imposing outright limits and making hedging obligatory (CBN 2017; 2023f).

Beyond domestic factors such as sudden asset re-evaluations and changes in the domestic interest rate level, sufficient liquidity denominated in foreign exchange and exchange rate stability are central for financial market stability in countries of the Global South and closely connected to the balance-of-payments. Scarcity of foreign exchange causes liquidity crunches in countries where domestic financial actors' face a large exposure to foreign exchange denominated liabilities. Financial stability also depends on stable exchange rates for two reasons: Firstly, as exchange rate depreciation and volatility destabilises the entire economy, they come with spill-over risks for the financial sector if domestic bank debtors are unable to pay back their loans. Secondly, exchange rates determine in part the acceptance of domestic financial assets and their integration in financial portfolios – independent of the currency denomination.[9] Sudden currency devaluations hence lead to divestments of domestic assets coming with solvency problems and adversely affecting the asset side of domestic financial actors' balance sheets – explaining the phenomena of the twins of currency and banking crises in countries of the Global South (Flassbeck 2018; Kaltenbrunner 2015; Rey 2018; Taylor 1998; Maxfield 1997; Dafe 2014; Kaminsky and Reinhart 1999).

Sufficient foreign exchange funds

The third mandate of the CBN is to hold sufficient foreign exchange reserves to defend the naira (CBN 2023f).[10] Since oil has become Nigeria's major export good, the naira's external value has started to become largely dependent on international oil prices. To avoid that volatility in international oil prices and associated balance-of-payments problems impact the exchange rate were one of the rationales of the CBN to continue the management of the naira until recently – as highlighted by the previous governor of the CBN (Sanusi 2004, 5).[11] Foreign exchange reserves ensure the ability to service Nigeria's liabilities denominated in key currencies such as import bills and external debt payments, to conduct currency stabilisation measures and to inject foreign exchange liquidity into domestic financial markets when needed. Holding safeguarding foreign exchange funds is based on the hope to dispose over enough liquidity to lean against sudden outflows ensuing international turmoil (Akyüz 2013; Rodrik 2006).

This section discussed the main mandates of the CBN and its instruments as well as the way these are constrained by Nigeria's balance-of-payments pressures. The next section describes our methodology, before we investigate empirically the importance of these channels and instruments.

[9] If the financial asset is denominated in the domestic currency, a currency depreciation devalues the asset denominated in this currency directly. If financial assets are foreign exchange denominated, it is through the assessments of investors of the country's ability to service its foreign exchange liabilities, the sustainability of its balance-of-payments, respectively, how domestic currency depreciation translates in lower asset values: currency devaluation is associated by higher import bills and capital outflows, which often lead to balance-of-payments difficulties and foreign exchange outflows. This assessment is behind the mechanics of the sovereign ceiling (Eichengreen 2004).

[10] Whilst this mandate was still relevant during the time span considered in this research, the recent liberalisation of the naira might have weakened this objective. That interventions have been abandoned or massively reduced is indicated by the increase in volatility of the official dollar-naira exchange rate. However, the CBN might still need to intervene in foreign exchange markets as a fully floating regime might prove too costly in countries of the Global South, which are exposed to a high degree of external spill-over effects of international instability (see also fear-of-floating literature, e.g. Hausmann, Panizza, and Stein 2002).

[11] Before the CBN gave up the management of the naira, it pursued a managed exchange rate regime. 2015 marked the CBN's introduction of the Interbank Rate System Regime and the declaration of a smaller degree of central bank interventions (CBN 2022a). In response to the oil price shock in 2016, the CBN introduced a system of multiple exchange rates (CBN 2022a): 1.) the official rate managed by the central bank, 2.) the market-determined exchange rate benchmark called *Nigerian Autonomous Foreign Exchange Rate Fixing* (NAFEX) based on the mean value of submissions of ten banks and used by investors and exporters, 3.) and the so-called *parallel* exchange rate used by authorised dealers such as bureaux de change (Ohuocha 2021; FMDQ Securities Exchange Limited 2020).

4 Methodology

We deploy a mixed-method approach to capture both qualitative and quantitative aspects of climate risks and central banking in our case study of Nigeria. Whilst qualitative research is fit to capture specific social context in its complexity, quantitative research can help to gain insights in developments and interactions over the course of time and is reproducible. Broadly speaking, qualitative research is purposeful for hypothesis development, whereas quantitative approaches can help to test hypotheses (Creswell and Creswell 2018). In that sense, qualitative research allows us to uncover the potential links between climate change and balance-of-payments dynamics, whereas the quantitative analysis enables us to test the observable implications for monetary policy. Mixed methods have proven helpful in unveiling the complex mechanisms behind exchange rate determination from a Critical Realism and Post-Keynesian theoretical viewpoint (e.g. Kaltenbrunner 2017).

Following Morse (1991), we chose sequential triangulation as mixed method design, where the interviews were carried out prior to the time series analysis and informed the quantitative data analysis (see also: Bell, Warren, and Schmidt 2022). In triangulation designs “different but complementary data on the same topic” (Morse 1991, 122) are collected and analysed with the aim to “improve, test or validate the accuracy of the observation [...] from two or more different vantage points” (Mason 2006, 8). This is of particular importance for novel and evolving research topics (Mason 2006, 3f.; Ritchie 2003, 44) – such as the repercussions of climate risks for central banking in the Global South.

5 Analysis of the qualitative data

This section describes the collection and analysis of our primary qualitative data and presents their results, i.e. in-depth, contextual insights into the interrelation of the physical and transition risks of climate change, Nigeria’s balance-of-payments and central banking.

5.1 Data collection and analytical approach

We conducted ten semi-structured expert interviews (Kvale 1996) with experts in the fields of central banking, financial regulation, green finance and post-carbon transition in the Nigerian context. Appendix 1 provides an overview of the background of the interviewees. We did non-randomised purposeful sampling, more specifically maximum variation sampling following the snowball principle (Byrne 2001). The interviews took place online between April and July 2022 and lasted between 18 and 70 minutes. The interviews were recorded, transcribed and independently coded. Coding results were reflexively incorporated in subsequent interviews. The interviews were semi-structured in so far as the questionnaire was used as guidance by the interviewer, i.e. the order and wording of the questions could vary and follow-up questions were included in accordance with the interviewees’ field of expertise (Kvale 1996). Interview transcripts cannot be made available due to anonymity and confidentiality reasons. The interview findings were embedded in existing literature, official documents and news to gain a broader picture.

5.2 Results: Challenges and chances of climate risks for central banking in Nigeria

This subsection identifies the main challenges and chances for central banking posed by climate risks in Nigeria as identified by the analysis of the qualitative data. We first provide an analysis of the interviewees’ responses with regards to how climate risks impact Nigeria’s balance-of-payments through the current and financial account. This is then followed by an analysis of how climate risks impact the

CBN's three primary instruments – foreign exchange reserve management, the exchange and interest rate – and complicate central banking in Nigeria.

5.2.1 Climate risk impacts on Nigeria's balance-of-payments

Current account[12]

The physical effects of climate change are likely to weigh heavy on Nigeria's import bill. Most interviewees highlighted that the productivity of Nigeria's agricultural sector is hampered by climate breakdown. When domestic production of food stuff does not suffice, more has to be imported. Land for pasture disappears in the North-East of the country due to the spreading of the Saharan desert, forcing herders to migrate southwards, which, in turn, causes lethal clashes with local farmers over scarce resources (I2, I3, I4, I5, I6, I8, I9, I10). The Northern part of Nigeria was once the production site of groundnut and rice – formerly exported, now imported as domestic production is not sufficient to meet domestic demand anymore (I6). In addition to the reduction of arable land, the drying up of the lake Chad, which has shrunk by 90% in the past 50 years, destroyed the potential of local industries such as fishing and agriculture in that area (I6, I8). Floodings in the coastal and riverine areas cause salienisation of the land (I2, I3, I5, I8, I9), and lead to the displacement of communities at an accelerating rate (I9). Interviewee 3 also stated that growing piracy on Nigeria's shore is caused by the decline in income generated by fishing due to the severely reduced fish stock rooted in overfishing and climate change. The displacements of communities and conflicts over scarce resources deteriorate the security situation, leading farmers to abandon their plots (I2, I3). When infrastructure and productive capital such as machinery are destroyed by physical effects of climate change, more material has to be imported (I5).

Additionally, transition effects increase import bills when material for climate adaption and mitigation measures need to be sourced from abroad. An example for such costly adaptation measures is Eko Atlantic City on the shore of Lagos – a multi-billion public-private partnership land reclamation project to counter coastal erosion caused by rising sea levels (Ajibade 2017; Eko Atlantic 2022). Mitigation measures also prove costly: Nigeria's Economic Sustainability Plan, launched in 2020 as part of a Covid-19 emergency response package, aims to expand Nigeria's off-grid solar electricity generation by creating 5-10 million solar homes through the Solar Intervention Connection Facility (I4, I9; CBN 2020b). Its estimated costs currently stand at US$ 5.9 billion (2.3 trillion Nigerian naira; IEA 2022). As necessary resources and capital needed for those ambitious projects cannot be sourced locally, they have to be imported (I4, I5, I9).

Nigeria will also need to pay more for its imports, when climate policies such as carbon taxes increase the prices for refined oil. Nigeria acquires most of its fuel imports from EU-countries, where successive increases of carbon taxes are the primary climate policy strategy (Eicke et al. 2021). This puts upward pressure on prices for carbon-intensive goods imported from the EU such as refined oil – with higher import costs for Nigeria as result.

[12] We here focus on the trade balance part of the current account, as the interviews revealed little about climate risks' impact on the export of services.

A possible solution to Nigeria's high dependency on oil imports might be the Dangote refinery, which was initially projected to cost US$12-14 billion and to start operation in 2020 (Payne and George 2018). It has the potential to become Africa's largest refinery and might ease Nigeria's import dependency of refined oil or even become a reliable source of foreign exchange income if produced petrol gets exported (I4).[13] However, not only have its construction costs jumped to US$19 billion, but its start of operation has been repeatedly delayed (Ishiekwene 2023). Reasons for those delays and higher costs encompass, among others, the difficulties to import needed capital, currency crises, but also conditions related to physical effects of climate change, namely swampy grounds, recurrent sea storms and electricity shortages (Addeh 2023; Payne and George 2018; Ishiekwene 2023). The refinery is built on a peninsula nearby Lagos and therefore impacted by sea level encroachment (I5, I7, I8, I9). The physical effects of climate change hence play a role in the venture being delayed and becoming potentially uneconomical.

The other side of the trade balance, exports, is also negatively influenced by the physical effects of climate change when they drive down production potentials, deter investments, and increase costs for export-oriented firms or their domestic suppliers. The estimated costs of rebuilding damages caused by the physical effects of climate change are enormous. The floods lasting from July to October 2022, for instance, were estimated to cause damage worth US$4.2 billion alone (CRED 2022a). Nigeria's most important manufacturing hub Lagos is susceptible to floods and sea-level rise (I5, I7, I8, I9). It is built on reclaimed land – 60% of Lagos is situated below sea-level and it is one of 11 megacities projected to disappear in the next 40-50 years (I5). Coastal erosion caused by rising sea levels already eats into Lagos at a rate of 30m per annum (Ajibade 2017). As the majority of manufacturing industries is situated in flood-prone coastal areas, manufacturers face high rebuilding and adaption costs, deterring investments in productivity enhancing facilities. Recurrent floods also impact Nigeria's aging oil and grid infrastructure leading to regular outages (I2, I3, I5). These outages not only reduce production output but also drive up production costs when exporting firms have to rely on generators burning diesel to generate electricity in the interim time (I5). The price for diesel is already a massive production cost factor (Addeh 2023). Interviewee 5 summarised the effects of floods as follows: "Whenever there is a serious flooding, commercial and industrial activities are coming to a halt. […] Whenever there's flooding, it affects everything, not just the grid power." What is more, falling investment rates ensue the deteriorated security situation physical effects contribute to by reducing in any case scarce resources (I3, I4, I9).

The effect of transition risks on Nigeria's exports is unequivocal. Some interviewees highlighted that policies such as carbon taxes will impact Nigeria's competitiveness and export potentials in the future. As Interviewee 9 noted: "The border adjustment tax will just further restrict that market access, which I think definitely threatens the potential for exports in the future." (I9) Though the European Carbon Border Adjustment Mechanism currently only affects goods coming under the European Carbon Trading System, the number of goods is going to be extended (I3), making it likely that crude oil exported from Nigeria to the EU will be subject to import taxes in the coming years (see also: Eicke et al. 2021). However, those risks have not materialised, yet. According to interviewee 2, most climate policies deployed outside of Nigeria are too recent to have an empirically detectable effect on Nigeria's trade

[13] According to Aliko Dangote, the owner of the Dangote refinery, once running at full capacity the refinery could save US$10 billion in foreign exchange for imports and generate another US$10 billion export revenues (Ishiekwene 2023).

balance. So far, the demand for Nigeria's oil is still stable (I2, I3, I4, I8), and the core of the problem of declining foreign exchange income coming from oil exports lies in low domestic production levels caused by sabotage and the destruction of pipeline infrastructure (I2, I4, I7, I9, I10). But because the physical effects of climate change contribute to social conflict in Nigeria, they might in part contribute to the recurrence of such acts.

However, once a decline in international trade of oil implicit in climate transition impacts oil prices, this will have pronounced repercussions for Nigeria's exports and investment rates as long as its oil dependence perseveres. A lower demand for oil is likely to exert larger downward pressures on the prices of crude oil than on those of refined oil due to a higher inelasticity of supply of raw material. Interviewee 4 stated: the "oil price is the mainstay of the Nigerian economy. [...] All sort[s] of crises that you can see in the country over the past years […; have] an element in dynamics of oil prices" (I4). Once a declining importance of fossil fuels translates into lowered prices for crude oil, it has important implications for the potential of foreign exchange generation through exports in Nigeria (I2, I3, I7, I8).

However, there are also chances in climate transition for Nigeria's export sector. Climate policies might incentivise the exploitation and export of Nigeria's abundant natural gas and the expansion of renewables, which might improve export revenues, diversify Nigeria's export base, and improve its power supply. There is a rising interest in natural gas and green hydrogen, which are viewed as transitional sources of energy (I2, I3, I8, I9).[14] The Nigerian government is willing to diversify its exports by exploiting its gas reserves as became apparent in its declaration of the "decade of gas" (I9). Recently, the flaring of natural gas – common practice for 50 years – became forbidden (I5). One strategy is to retrofit cars to use gas instead of oil (I9). These policy goals might be helped by the war in Ukraine as the EU's plan to replace Russian with Nigerian gas in the near future shows (Reuters 2022). However, there has been no European support for bilateral development programmes so far, which only target renewables (I3).

Another potential benefit of climate transition for Nigeria is represented by the synergies between Nigeria's Nationally Determined Contributions (NDC) agreed on in the Paris Agreement and a solution to its persistent energy shortage (I4). Energy poverty is the biggest problem Nigeria faces, according to Interviewee 8, and the most important for Nigerian exporters according to Interviewee 10.[15] Though the domestic solar industry is still in its infancy (I4), hopes lie in the potential of firms like *All On* to finance local solar panel manufacturers (I5). Recent plans envision the construction of Nigeria's first solar cell production plant, called NASENI Solar Energy Ltd, which aims to drastically reduce the prices for solar panels and to enable a fully domestic solar panel production (Salau 2023). If these plans materialise, this could be an important pathway towards green industrialisation.

Financial account

Climate risks are likely to negatively impact Nigeria's financial account by making the financial account more susceptible to spill-overs from global financial instability and by increasing the burden represented by Nigeria's external liabilities. The combination of lower foreign exchange income and higher needs

[14] Gas is for instance included in the EU's Green Taxonomy under certain conditions (Climate Bonds Initiative 2022).
[15] Only about 50% of households are connected to the aging centralised grid, which fails on a weekly basis (I3, I5).

thereof in the context of the climate crisis, are likely to increase Nigeria's need to attract foreign capital. But the interviewees emphasised that FDI shrink vis-à-vis falling oil prices (I2, I7, I8, I10). To the question of how much of investors' confidence depends on the oil price, Interviewee 2 replied: "A lot […] the main investors in Nigeria are still interested in fossil fuels. Their projections of future price developments will determine a lot." This claim was also put forward by Interviewee 7: "Periods that experienced an increase in oil price saw more private sector players entering into the oil industry […] The decline in oil prices and other issues in the sector have led to key stakeholders divesting from the industry".

Given the growing importance of portfolio finance vis-à-vis more traditional forms of finance internationally, the additionally needed external finance is therefore likely to come in the form of portfolio flows. But the latter are an important transmission channel of global financial instability spilling into Global South economies through the balance-of-payments (Grabel 1996; Bortz and Kaltenbrunner 2018; Kaltenbrunner and Painceira 2017; Bonizzi 2013). Climate risks therefore contribute to domestic instability by increasing countries' exposure to portfolio finance and but also by increasing the risk of global financial instability (Batten, Sowerbutts, and Tanaka 2020; Dafermos, Nikolaidi, and Galanis 2017; 2018; Carney 2015; NGFS 2019): As a result of climate transition effects, capital divests from financial assets nested in carbon-intensive industries leading to assets becoming stranded (I2, I6, I8; Carnevali et al. 2021; Mercure et al. 2018). Due to the strong intertwining of international financial markets and a fossil-based economy, this has important spill-over effects to overall financial stability (Malm 2015; Apostolakis et al. 2021). Physical effects also play a destabilising role by impacting primary commodity markets, e.g. in the case of bad harvests, or by impacting financial actors' balance sheets, e.g. when capital acting as securities is destroyed or the insurance sector faces large pay-out duties (Batten 2018). Climate change is also said to contribute to international recessionary pressures due to increased inequality and the reduction of productivity levels, which could also destabilise financial markets (Dafermos, Nikolaidi, and Galanis 2017; 2018; Diffenbaugh and Burke 2019; Bolton et al. 2020).

The servicing costs of external liabilities are also likely to rise due to climate risks. Research found that susceptibility to physical climate risks are added as risk premia on external debt (e.g. Buhr et al. 2018). Interviewee 3 stated that this also holds for Nigeria as bond rating agencies such as Fitch have started to take Nigeria's vulnerability towards physical climate risks into consideration. Moreover, a deteriorated rating based on Nigeria's exposure to transition risks might be added to this, where Nigeria's financial assets potentially stranding are regarded as liabilities by investors (I2, I6, I8). Interviewee 2 summarises "We will probably look at falling value of oil assets".

Climate transition might hence devalue Nigerian financial assets and lead to capital outflows, especially since the disclosures of carbon-intensity in financial portfolios has become more wide-spread and more mandatory (see e.g. Christophers 2017; Eicke et al. 2021; TCFD 2020). According to Interviewee 8, "invariably more financial institutions will require their clients to declare the climate risk position[s]. And that will filter its way through into the loan portfolio and how that is managed." This is also the case in Nigeria, where NDC-driven regulations such as the Sustainable Banking Principle and the Sustainable Finance Principles (Bella et al. 2023; CBN 2012) steer towards more mandatory carbon reporting (I5, I8). Though those regulations have had little effect so far (I5), they might represent a major disadvantage to domestic investors whose portfolio is still largely invested in the fossil fuel sector.

Another reasons why international investments might be drying up in the future is Nigeria's failure to meet international climate goals. Interviewee 6 put forward that "the way in which the country is perceived on the back of not being able to meet significant climate action that is required of the country that can definitely affect inflows of investment". Here, the lack of data collection and processing capacities poses an important challenge: "Data is always a big issue and present that in a way that paints the country in good light, as we see in the advanced countries" (I6).

Additionally, the form domestic green financial assets come in render the management of the Nigerian financial account more difficult. In Nigeria, all green financial instruments are naira-denominated (I5). But Local Currency Bonds Markets (LCBM) come with a number of risks in peripheral countries: interest paid on them is higher to compensate for their higher risk profile, risks of private investments are socialised by public guarantees, they are more short-term and presuppose a number of ex-ante measures to ensure the easy convertibility and expatriation of funds (Elsner et al. 2022; Gabor 2021; for an elaboration how LCBM reacted to the Covid-pandemic shock, see: Hofmann, Shim, and Shin 2020). Interviewee 8 emphasised the importance of convertibility of green bonds as well as the exchange rate of the local currency. Answering the question of what determines the demand for green bonds, they replied:

> "Returns, obviously, a structured and regulated environment, how easy it is for them to leave their repertoire, the perceived and actual risks […] associated with the markets, a number of things. […] *And of course the convertibility of the local currency, because* […] *they invest in assets with local currency returns, which obviously needs to be converted at some point.* So we go back to the FX [foreign exchange] risk again. I mean, *if there's a perception that [...; the exchange rate] will go against you in the short term, then that influences your need or wants to invest in such an economy*" (I8; emphasis added).

This quote supports research which highlight that LCBM do not solve foreign exchange dependence as convertibility is a major investor concern whose liabilities are denominated in US-Dollar (Bonizzi and Kaltenbrunner 2019; Bortz and Kaltenbrunner 2018).

What is more, Interviewee 8, who works in the Nigerian ESG-finance sector, highlighted another risk implied in greening financial markets. They purport that green taxonomies such as the EU's Green Taxonomy are too data-intensive and too demanding in respect to expertise and technology to be applicable in Nigeria:

> "We don't make the rules. It's not fit for purpose. *It's designed more for the Global North and for structured markets*. It's extremely scientific and data driven and right now *we don't have the tools necessary to defend the amount of data required for the disclosure*. […] They require a level of data which doesn't exist […] in the Global South" (I8; emphasis added).

ESG taxonomies will hence impact international capital flows to Nigeria:

> "So if we carry on this way […] the liquidity will dry up, less money will be lent. [...] And so I think that institutions will find it … or borrowers or bondholders or whatever bond issuance … will rather find it difficult to defend their position. […] And invariably, I think come 2050, you're going to have more poor people in Africa than you have today" (I8).

Consequently, investor confidence might dwindle against the backdrop of climate policies: "I think in terms of investor confidence, who want to invest how much in Nigeria, there you probably have a knock-on confidence in terms of future investments." (I2) Interviewee 4 contradicted. According to them, Nigeria's main recipients of foreign investments are the oil and telecommunication sector, from which no outflows of capital have been observed, yet (I4). However, they project that China and India take on the role as the most important investors in Nigeria (I4) – where China already has a green taxonomy in place and India might have one soon (IEEFA 2022).

5.2.2 Implications for the CBN's means of central banking

In this section we analyse the interviews to elaborate how each of the CBN's main instruments – foreign exchange reserves, exchange rate and interest rates–, is impacted by climate risks and the consequences for central banking thereof.

Foreign exchange management

Climate risks in Nigeria translate in lower foreign exchange income and a greater need for foreign exchange reserves due to the effects climate risks have on Nigeria's current and financial account: On the one hand, climate risks deteriorate the trade balance as long as chances of climate transition such as the diversification of exports via natural gas exploitation, improved energy security levels due to an expanded use of renewables and the potential for industrialisation through the expansion of the solar industry have not materialised. On the other hand, more foreign exchange safeguarding funds are necessary: Nigeria's financial account is exposed to a higher degree of external spill-overs at higher costs when climate risks increase its exposure to portfolio flows and deteriorate the ratings of Nigerian financial external liabilities. This increase in Nigeria's external fragility weighs particularly heavy because of the higher degree of turmoil in international financial markets climate risks come with: Peripheral countries will be the first victims of deteriorated confidence levels of internationally operating investors which scrabble to secure their portfolios' value by seeking refuge in safe havens (Rey 2018; Bonizzi 2017; Bonizzi and Kaltenbrunner 2019).

An aggravated foreign exchange scarcity can become self-perpetuating: Kaltenbrunner and colleagues (2022) elaborate that in commodity dependent countries – and the volatile foreign exchange income commodity dependence is associated with – low and volatile foreign exchange liquidity in the interbank sector and uncertain prospects about future foreign exchange inflows lead to foreign exchange hoarding. This deprives central banks of already scarce foreign exchange reserves and impedes their ability to conduct effective central banking and monetary policies.[16] Hoarding behaviour – either in cash or the holding of illegal foreign exchange deposits – as result of uncertain foreign exchange supply was also described in the Nigerian context by the interviewees (I2, I3, I8).

Exchange rate

The interviews identified the trade balance as the most important determinant of the exchange rate (I4, I8, I9, I10). As climate risks negatively impact Nigeria's current account, they contribute to foreign

[16] That foreign exchange scarcity and subsequent exchange rate devaluations translate into higher volatility in domestic financial markets was observable in Nigeria: moments of depreciation such as in 2009, 2014, 2016 and 2020 were accompanied by a stark capital divestment from the Nigerian stock market NGX and higher and more volatile interbank call rates (CBN 2023c; Kitching 2021, 13). This indicates that devaluations are accompanied by instable expectations concerning the solvency of other banks and deteriorated overall confidence levels in domestic financial markets.

exchange scarcity. The latter was a major factor behind recurrent devaluations and the recent abandonment of the management of the naira: It stripped the CBN of means to prop up its currency, and contributed to the perception of the naira to be riskier to hold as convertibility into hard currencies cannot be granted. The foreign exchange reserve scarcity was also behind the government resorting to import- and foreign exchange restrictions (International Trade Administration 2023). The foreign exchange restrictions in combination with foreign exchange scarcity, in turn, were a major factor for the importance of the parallel market, the potential to exploit arbitrage and the resulting gap between the parallel and the official exchange rate, which put further pressure on the naira (I2, I6, I8, I10).[17] The widening gap between the official and parallel rate as well as the lack of funds eventually led to the decision to let the naira float in June 2023.

The exchange rate was mentioned as the centrepiece challenge in Nigeria (I4, I8, I10) – or as Interviewee 10 put it: „everything we work with or everything […] going wrong in the country, it has to do with the exchange rate." Leaving the exchange rate to market forces reduces the CBN's repertoire of central banking and monetary policy making and increases the danger of external spill-over translating into domestic macroeconomic variables. This especially applies as climate risks are likely to increase the volatility of the Nigerian exchange rates. When climate risks shorten financial cycles and raise global uncertainty levels, this has adverse impacts on the acceptance of peripheral currencies, transmitted through the financial account, and consequently policy space (Löscher and Kaltenbrunner 2023). In the face of crumbling investor confidence vis-à-vis global instabilities, peripheral currencies like the naira are the first financial assets to experience divestments (Andrade and Prates 2013; Kaltenbrunner 2015; Paula, Fritz, and Prates 2017). This weighs particularly heavy as peripheral currencies are increasingly integrated investors' portfolio as means to generate profits in carry trade transaction (Bonizzi, Kaltenbrunner, and Powell 2019; Bortz and Kaltenbrunner 2018). The resulting volatility can no longer be curbed by foreign exchange market intervention carried out by the CBN.

The interviews revealed two further rationales to maintain the management of the naira. Firstly, the management of the naira as means to further exports, economic diversification and industrialisation via stable exchange rates and special exchange rate windows was highlighted by Interviewee 4. Especially non-oil investments are negatively impacted by a devalued or instable exchange rate in Nigeria (I2, I4). This is in line with research highlighting that excessive exchange rate volatility harms domestic firms, especially exporters importing input factors, because of the price, cost and income uncertainty their exposure to exchange rate volatility is associated with (Arize, Osang, and Slottje 2000; Doğanlar 2002; Serenis and Tsounis 2013).

The second mentioned rationale behind the management of the naira was the fight against inflation (I4). Inflation rates in Nigeria are predominantly determined by food and energy prices (I4, I6, I8, I9, I10; see also: Oyekanmi 2022). As most fuel and a large part of consumed foodstuff are imported, a depreciation of the naira translates into higher inflation rates. The exchange rate is also a major driver of cost push inflation as most production inputs are imported (I4, I6, I8, I10). In fact, following the liberalisation of the

[17] Nigerian officials were unsuccessfully trying to curb the problem of growing divergence between both rates by clamping down on bureaux de changes and illegalising websites like AbokiFX, a website where daily parallel exchange rates are published (Ikpoto 2022; Nairametrics 2022; Ohuocha 2021). Attacks on the naira were particularly fierce after the Covid-19 pandemic broke out and spreads between the official and parallel exchange rate were as high as 30% (Nairametrics 2021; BNP Paribas 2020).

exchange rate and the subsequent depreciation, the overhead inflation rate (year on change) rose from 22.41 in May 2023 to 24.08 per cent in July 2023 – the highest recorded since 2005 (CBN 2023b). The inflationary effect of a devalued exchange rate is complemented with the direct inflationary pressure climate risks come with against the backdrop of Nigeria's food and energy import dependency: Climatically induced destruction of harvests and overall lowered productivity levels translate into higher prices for food stuff, which can be aggravated by speculation on commodity markets (Bruno, Büyükşahin, and Robe 2017; Nissanke 2011; Peersman 2021; Pham 2022). Additionally, inflation increases when CO2-taxes increase the price for imported fuel (Dennig et al. 2015; Batten, Sowerbutts, and Tanaka 2020). But, higher inflation might further undermine social cohesion, leading to a deteriorated security situation in Nigeria – to the detriment of agricultural productivity and investment levels. There is also a feedback loop between Nigeria's high inflation and the exchange rate: High inflation affects the real effective exchange rate, which in turn undermines Nigeria's competitiveness and growth rates (see Rodrik 2008). Social conflict as well as reduced competitiveness and growth potentials negatively impact Nigeria's foreign exchange income and trade balance, which furthers depreciation. In view of these intertwined challenges, losing the option to reduce staggering inflation rates via exchange rate management is particularly severe.

The liberalisation of the exchange rate hence implies that structural conditions of the balance-of-payments are likely to have a more direct impact on the exchange rate. Against this backdrop, Nigeria's oil dependence as transition risk is especially dangerous. Interviewee 8 stated: "So if there's a shock to the oil industry, then it's going to impact our exchange rates". Interviewee 4 summarised the interaction between climate policies and the Nigerian exchange rate as follows:

> "[I]magine that just all of a sudden nobody is demanding fossil fuel. Now we have a huge, huge effect on exchange rate in Nigeria. […] Policies like reducing fossil fuels for cars and the rest, is – again – something that will affect demand for our oil and anything that affects demand at the present instance would affect our exchange rates. So definitely, global climate change and global climate policy will have [an] impact on exchange rates"

In addition, interviewee 6 identified the higher import dependency of food as result of physical risks of climate change as factor negatively impacting the exchange rate.

Both risen volatility and devaluation of the naira endanger the sustainability of Nigeria's balance-of-payments and financial stability. A depreciation of the naira increases the burden represented by foreign exchange denominated liabilities in real terms implying potential liquidity problems for Nigerian financial actors. Interviewee 5 elaborated:

> "if you had issued a dollar denominated instrument and you wanted to pay back and the exchange is not stable, then you run into some problems. Because if you issue that 300 net to the dollar and now the dollar is now exchanging at 500, it means […; y]ou need more naira to get the dollars to pay to your investors overseas"

Higher volatility and depreciation also undermine the acceptance of Nigerian financial assets with capital flight as likely consequence: It is the face value after conversion into a centre currency, determined by the nominal exchange rate – alongside their liquidity level and the interest paid on them – which matters for investors decision to hold peripheral currencies in their portfolios (Andrade and Prates 2013;

Kaltenbrunner 2015; Paula, Fritz, and Prates 2017). Whilst depreciation equals a loss in face value of the financial asset, volatility introduces uncertainty concerning the expected face value at the moment of conversion which has to be compensated by other means to ensure security and profitability of investments.

Interest rates

When climate risks negatively impact the balance-of-payments and increase the naira's volatility and its rate of depreciation, the CBN will have to increasingly rely on interest rates to uphold the naira's acceptance and to manage the balance-of-payments through the financial account. Additionally, the need to maintain high policy rates might grow as policy rationale *vis-à-vis* climate risks for at least three reasons. Firstly, as global instability is likely to increase due to climate risks, liquidity preference levels grow in the face of higher uncertainty implying that countries of the Global South will have to compensate the illiquidity of their currencies and the riskiness this comes with by higher interest to prevent capital flight (Löscher and Kaltenbrunner 2023) – independent of their balance-of-payments dynamics. Secondly, the consideration of climate risks by rating agencies ensues their incorporation as risk premia which has to be compensated by higher interest rates. This already represents a massive burden in many climate vulnerable countries (Buhr et al. 2018). Thirdly, as climate change pushes up inflation and as long as inflation targeting and attempts to manage the money supply via interest rates is the dominant monetary policy paradigm, it is probable that countries in the Global North will raise interest rates to fight climate risks related inflation (Batten, Sowerbutts, and Tanaka 2020). To maintain high enough spreads, which decide over the profitability in comparison to safer investments (Kaltenbrunner 2015; Paula, Fritz, and Prates 2017; Andrade and Prates 2013), peripheral countries have to raise their interest rate level even more.[18]

High interest rates suppress domestic growth and aggravate foreign exchange scarcity. They exercise recessionary pressure on the domestic economy by suppressing investments due to high credit costs and the decreased value of firms' long-term assets (Mishkin 1995). Moreover, a deteriorated rating of sovereign debt based on climate vulnerability could destabilise affected countries' private sector through the mechanics of the 'sovereign ceiling', i.e. the increase in risk premia on private financial assets following deteriorated sovereign ratings (To, Wu, and Zhang 2022; Eichengreen 2004).[19] This directly imperils the CBN's mandate of ensuring stability of domestic financial markets. Higher interest rates also increase refinancing costs and debt burden, which makes it necessary to deploy more foreign exchange to go into debt service which further exacerbating foreign exchange scarcity.

[18] That interest rate spreads are a key determinant of policy rates in the Global South became apparent during the Covid-19 pandemic. When the pandemic broke out, inflation rate hikes accelerated, but the CBN actually lowered the interest rate to stimulate the domestic economy by four per cent (CBN 2020a). This was enabled by centre countries' expansionary policies deployed in an attempt to fight the recession. Once policy rates in the Global North were raised again to fight inflation rates caused by the energy crisis, the CBN upheld spreads by reversing the lowering of the policy rate within quarter of a year during the second and third quarter of 2022 (CBN 2023c).

[19] The workings of the sovereign ceiling in Nigeria were exemplified in 2016: After foreign exchange reserves fell sharply, Nigerian public securities and subsequently Nigerian banks were downgraded by Moody's because of "the government's reduced capacity to provide support to Nigerian banks in times of stress" (Moody's Investors Service 2017).

5.2.3 Further consequences with negative implications for Nigeria's balance-of-payments and central banking: hampered diversification, green transition and aggravated global inequality

The negative implications of climate risks on the CBN's ability to conduct effective central banking have far-reaching consequences – also beyond the CBN's primary mandates – which negatively feed back into Nigeria's balance-of-payments. This section assess how climate risks impede economic diversification in Nigeria, get in the way of a domestic green transition and uphold if not increase global inequality levels.

Economic diversification away from crude oil could solve the adverse macroeconomic effects associated with Nigeria's oil dependence (I2, I8). It could potentially improve foreign exchange income and lessen the pressure on the naira. The interviewees quoted the lack of funds, an instable exchange rate, a weak naira and competition with other developmental goals, among others, as reasons for the failure to achieve economic diversification (I3, I4, I9). High interest rates and social conflict are also a hinderance to new investments. By contributing to higher interest rates, social conflict and a devalued or instable naira, climate risks hence hamper economic diversification. These negative side-effects of climate risks on investment rates are complemented with the direct adverse impacts, e.g. when funds are deployed for rebuilding and mitigation measures instead of new investments or when Nigeria's balance-of-payments exposure to the oil sector is viewed as liability by foreign investments diverting capital inflows. What is more, physical risks diminish agricultural productivity. But the agricultural sector is the most important mainstay of Nigerian policy makers' plans to economically diversify and was identified as the most feasible transformation trajectory by Interviewee 2.

Equivalently, a successful green transition in Nigeria could solve Nigeria's dependence on energy imports and improve its energy security levels. However, to conduct domestic climate policies requires policy space. According to Interviewee 3, climate policies cannot be prioritised because of other challenges such as high inflation, a collapsed exchange rate and high unemployment rates – all factors potentially exacerbated by climate risks. Interviewee 6 and 9 agreed that the exchange rate is a great deterrent to the expansion of the transition to solar energy generation: currency devaluations lead to the need to regularly update prices in the infant solar industry making it unprofitable (I6, I9). Interviewee 4 identified the squeezed fiscal budget as the main impediment: 75% of Nigeria's fiscal budget goes to recurrent expenditures and only 25% go to new investments (I4). Though international funds might in part solve the problem of lacking domestic funds, Nigeria has not tapped any climate adaptation funds such as the Green Climate Fund, yet (I9). According to Interviewee 9, reasons encompass the lack of expertise, the conditionality attached to them in terms of monitoring and a third party institution, which is needed to administer funds received through the Green Climate Fund. High interest rates, partially caused by climate risks, also get in the way of a domestic green transition by deterring investments.

If climate risks impede the potential to undertake effective central banking, economic diversification, industrialisation and a green transition in countries like Nigeria, they perpetuate or even increase global asymmetries. But global imbalances are directly aggravated by climate risks (Diffenbaugh and Burke 2019; Dennig et al. 2015). Physical risks disproportionately affect countries in the Global South, where capacities to mitigate them are smaller than in the Global North. But in the context of Nigeria, the interviewees highlighted how climate transition risks, climate policies which do not consider foreign exchange dependence in particular, bear the risk to increase global inequality. Interviewee 4 for instance projected: “we will see more […] imbalances between Nigeria or Africa and the other part of the world.” Interviewee 6 added that it is the climate policies’ reliance on markets which poses a particular challenge:

> ”Climate action globally is very much market driven and without considering the structural impediments and even the social impediments that […] countries like Nigeria face. […] The carbon budget adjustment […] only high income countries are able to meet that while developing countries are unable to do that. So that continues to reinforce the kind of inequality and uneven development that we see globally. But also the idea of carbon intensity […] tends to reinforce carbon proliferation by certain sectors, certain countries relative to others. And that can […] be problematic for countries like Nigeria.”

Interviewee 6 also said that mitigation measures in their current form reduce fiscal policy space for countries like Nigeria when they require the reduction of exploration of fossil fuels at the expense of energy security (I6). Speaking explicitly about carbon border adjustment mechanisms, Interviewee 9 explained that they “limit the choices in Nigeria or similar countries can make in terms of the type of energy, for example, they use to produce certain goods and commodities that they'd like to be traded. So it's definitely a threat” (I9).

By contributing to global inequality, climate risks reduce policy space in countries of the Global South even more, because inequality in macroeconomic policy space perpetuates or widens the gap between the real or perceived liquidity of financial assets originating in the Global North and South. This might aggravate flight-to-quality phenomena and increases the pressure of countries in the Global South to keep their interest rate level up.

6 Quantitative Data Analysis

The insights on the key mechanisms between climate risks, the balance-of-payments and central banking were assessed econometrically in SVAR-models aiming to cross-validate our findings of the interviews. This section presents the variables, methodology and results of the time series analysis.

6.1 Variables and data

We built two baseline models. In Model 1, we focus on transition risks coming in the form of higher international financial instability and falling prices for crude oil. As proxy for the former, we consider the VIX as provided by Chicago Board Options Exchange (Cboe Exchange 2023) which is the most commonly used indicator of global uncertainty levels (Kapfhammer, Larsen, and Thorsrud 2020).[20] As proxy for the risk of falling oil prices, we consider Nigeria’s revenues from the export of oil. We calculated these revenues by multiplying the price for crude oil (Bonny Light), with Nigeria’s monthly exports of crude oil as published by the CBN (CBN 2023g). Model 2 assesses the physical effects of climate change. To consider how physical risks spur food price inflation by lowering agricultural productivity both globally and in Nigeria, and therefore increase the prices for imported food stuff in Nigeria with implications for the CBN’s objective of low inflation, we include the FAO’s FoodPrice Index

[20] Alternatively, one could use the elaborate Equity Market Volatility Tracker as developed by Baker and colleagues (2019), which includes newspaper coverage of geopolitical risks, economic policies, commodity markets among other. We nevertheless resort to the VIX for reasons of simplicity and to reduce double-counting of oil price effects.

(FAO 2022). To estimate the effects of physical climate risks stemming from natural disasters,[21] we include a dummy variable where 1 denotes months during which a natural disaster was recorded in the Emergency Database (EM-DAT; CRED 2022a) and 0 indicates the absence of any recorded disaster.[22] We investigate the impact of these approximations of climate risks on the CBN's key three monetary policy instruments identified above: the nominal bilateral naira-dollar exchange rate, the level of foreign exchange reserves[23] and the differential between the Nigerian monetary policy interest rate and the US Fed Fund rate.

All monthly time series were available from January 2006 to December 2022. We cleaned the data sets and missing values were linearly imputed. Table 1 gives an overview over the variables included in the model and their data sources. Appendix 2 provides general descriptive statistics of the included time series.

Table 2: Overview over used time series and their variable names.

Variable name	Variable description	Source of original data
EXR_log	logarithmised monthly average of naira-dollar exchange rate (central rate between buying and selling rate)	CBN (2023a)
FAOFoodP_log	logarithmised index measuring the monthly change in international prices of a basket of food commodities	FAO (2022)
FXRes_log	logarithmised monthly average of foreign exchange reserves (in US-dollars)	CBN (2023d)
Infl_food_log	logarithmised food price increases compared to 12 months average	CBN (CBN 2023b)
NbAffwDDum1	dummy variable indicating 1 if there was a disaster recorded in the Emergency Database for a given month, 0 if there is no disaster recorded	CRED (2022)
PolicyRateSpread_log	logarithmised spread between the CBN's Monetary Policy Rate and the US-American Federal Funds Effective Rate	CBN (2023c) and FRED (2022)
RevEXOil_log	logarithmised monthly revenues generated from the export of Bonny Light crude oil (in million US-dollar)	CBN (2023e)
VIX_log	logarithmised monthly average of daily highs of VIX	Cboe Exchange (2023)

6.2 Methodology

We chose a (S)VAR-approach because it is suitable for the analysis of monetary policy, where variable influence each other mutually (Bordon and Weber 2010; Kilian and Lütkepohl 2017; Sims 1980; 1989; Cesa-Bianchi, Thwaites, and Vicondoa 2020; Bhattarai, Chatterjee, and Park 2021; Peersman 2018).

[21] Some authors call the concept of a *natural* disasters into question, as in their view, the adverse effects of weather phenomenon are preventable by social precautionary measures such as granaries to safeguard against the event of the destruction of harvests by pests, droughts or floods. So, the argument goes, those disasters are man-made and have a strong connection to power, inequality and social distribution of resources (see e.g. Davis 2017). Though we acknowledge the validity of these arguments, especially on a global scale, we speak of *natural* disasters out of lack of more appropriate concepts. And given the magnitude and severity of climate change induced disasters vis-à-vis available resources in the Nigerian context and in an effort to simplify, we assume affectedness by "natural" disasters as exogenous to domestic policy making in this research.

[22] In the Emergency Database disasters are recorded, which fulfil at least one of the following criteria: the death toll was ten or more people, at least 100 people were affected, a state of emergency was declared and/or international assistance was sought after because of the event (CRED 2023). EM-DAT is widely used in empirical research (CRED 2022b).

[23] Foreign exchange reserves are used in their nominal form without controlling for imports or the stock of external liabilities for two reasons: firstly, data paucity; and secondly, taking the absolute level of foreign exchange considers that for investors the immediate exchangeability of local financial assets into the currency hegemon, the US-Dollar, is most relevant – here approximated by the means to do conversion.

VAR-models also allow a minimum of ex-ante assumptions: there are no à priori assumptions about strict exogeneity; all variables are endogenised and the only à priori imposed restriction is the included lag-length (Sims 1980, 15). This enables the model to take all possible cross-dependencies into account (Sims 1980, 15). We chose a structured VAR to consider the sequence of effects of the variables based on theory.

Following Kilian and Lütkepohl (2017, 1f.) and abstracting from the intercept, a VAR(p)-processes in its reduced form can be written as

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + \ldots + A_i y_{t-p} + u_t$$

where, $$A_i = \begin{bmatrix} a_{11,i} & a_{12,i} & \cdots & a_{1k,i} \\ a_{21,i} & a_{22,i} & \cdots & a_{2k,i} \\ \cdots & \cdots & \cdots & \cdots \\ a_{k1,i} & a_{k2,i} & \cdots & a_{kk,i} \end{bmatrix} \quad i{=}1{,}2{,}\ldots{,}p \quad t{=}1{,}2{,}\ldots{,}T \quad u_t = \begin{pmatrix} u_{1t} \\ u_{2t} \\ \cdots \\ u_{Kt} \end{pmatrix}$$

For Model 1 (Transition Risks) with K=5, y_t is:

$$y_t = \begin{pmatrix} \Delta VIX_t \\ \Delta RevEx \text{ Oil}_t \\ \Delta \text{ PolicyRateSpread}_t \\ \Delta EXR_t \\ \Delta FX \text{ Res}_t \end{pmatrix}$$

And for Model 2 (Physical Risks) with K=6, y_t is:

$$y_t = \begin{pmatrix} \Delta FAO \text{ FoodP}_t \\ \text{NbAffwDDum1} \\ \Delta \text{ InflFood}_t \\ \Delta \text{ PolicyRateSpread}_t \\ \Delta EXR_t \\ \Delta FX \text{ Res}_t \end{pmatrix}$$

Following Kilian and Lütkepohl (2017, 2f.) and abstracting from the intercept, a SVAR(p)-model can be represented as:

$$B_0 y_t = B_1 y_{t-1} + \ldots + B_p y_{t-p} + w_t$$

where B_0 describes the temporal relationships between the variable, B_i is a $K \times K$ matrix of autoregressive slope coefficients, and w_t is a $K \times 1$ vector of mean zero shocks assumed to serially uncorrelated with the covariance matrix.

For Model 1, B_0 is:

$$B_0 = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ NA & 1 & 0 & 0 & 0 \\ NA & NA & 1 & 0 & 0 \\ NA & NA & NA & 1 & 0 \\ NA & NA & NA & NA & 1 \end{pmatrix}$$

For Model 2 B_0 is:

$$B_0 = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ NA & 1 & 0 & 0 & 0 & 0 \\ NA & NA & 1 & 0 & 0 & 0 \\ NA & NA & NA & 1 & 0 & 0 \\ NA & NA & NA & NA & 1 & 0 \\ NA & NA & NA & NA & NA & 1 \end{pmatrix}$$

For the recursive ordering of the variables used for the identification of the models, we ordered the variables according to a decreasing degree of exogeneity. For Model 1, we assume the VIX and international oil prices to be more exogenous to central banking in Nigeria. The interest rate spread,[24] Nigeria's exchange rate and foreign exchange reserves, that is the CBN's monetary policy instruments, are assumed to be more endogenous to central banking in Nigeria.[25] For Model 2, we assume international food prices and Nigeria's exposure to natural disasters to be least endogenous to policy making in Nigeria, whilst the ordering of the monetary policy instruments is the same as in Model 1.

We included a trend and a constant when calculating the optimal lag-length. For both models, the optimal length was calculated as p=2 where the maximum lag-length was set to 12 as we are dealing with monthly data.[26]

We follow Sims (1980; 1990) by incorporating all variables apart from the dummy variable in the model in their natural log-levels. As means of interpretation, we chose Impulse-Response-Functions (IRF) as they do not depend on normality of the residuals. This is important as test-statistics in (S)VAR-models are sensitive to non-normality, especially when dummy variables are present (Sims 1980, 17). The bias of the t- and F-statistics makes the interpretation of the coefficients difficult (Sims 1980, 17): the high degree of autocorrelation of coefficients in autoregressions lead to a high degree of oscillation and "complicated cross-equation feedbacks" (Sims 1980, 20). Following Sims (1980, 18), we therefore only report the results of the regression, but use IRF as means of interpretation to see if, in what direction, and within what time span variables react when being shocked with other variables. Because of the high number of variables included, we limit the reporting of the IRF to those representing the shocks relevant for our research question, that is, the CBN's monetary policy instruments.

We built a Qual SVAR – a SVAR model with a qualitative variable – to incorporate the dummy variable which indicates the existence or absence of a natural disaster in a given month.[27] Qual VAR-models have gained increasing popularity, but their applicability is still limited. El-Shagi and von Schweinitz (2016) emphasise that Qual VAR come with serious identification problems and should therefore only be used in simple models and when the chains of causality are clear-cut. According to the authors, general dynamics represented in the Qual VARs' IRF can still be derived, however not the magnitude of the shock represented by the IRF as the estimation as the variance is distorted (El-Shagi and von Schweinitz 2016). Because it is implausible that monetary variables cause natural disasters, the question of causality is clear in our model.

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[24] Strictly speaking this spread is only in part endogenous, as only the Nigerian policy rate can be influenced by the CBN.

[25] The study falls in a time when Nigeria still had a managed exchange rate.

[26] When the information criteria gave unequivocal results, we preferred Hannan-Quinn and Schwarz Information Criterion over Akaike's Information Criterion, as the latter tends to overestimate the optimal length (Kilian and Lütkepohl 2017, 60).

[27] A Qual VAR was first developed by Dueker (2005), who built a VAR model where the Romer and Romer estimation of monetary contraction by the FED was included as dummy to dynamically forecasting business cycles.

6.3 Results: The impact of climate risks on the CBN's monetary policy instruments

This section assesses the results of the SVAR model analysis by representing and interpreting the IRF. The results of the unstructured VARs, including the stability test, are reported in Appendix 3 and 4.

6.3.1 Baseline Model 1: Transition risks

The model is stable as indicated by all eigenvalues being smaller than 1 (see Appendix 3). We shock the variables representing the central bank policies with the VIX, approximating global uncertainty, and revenues generated from the exports of oil, which is our proxy variable for the effects of climate policies. Figure 5 shows the IRF for the three monetary policy instruments and the oil export revenues resulting from a shock represented by the VIX.

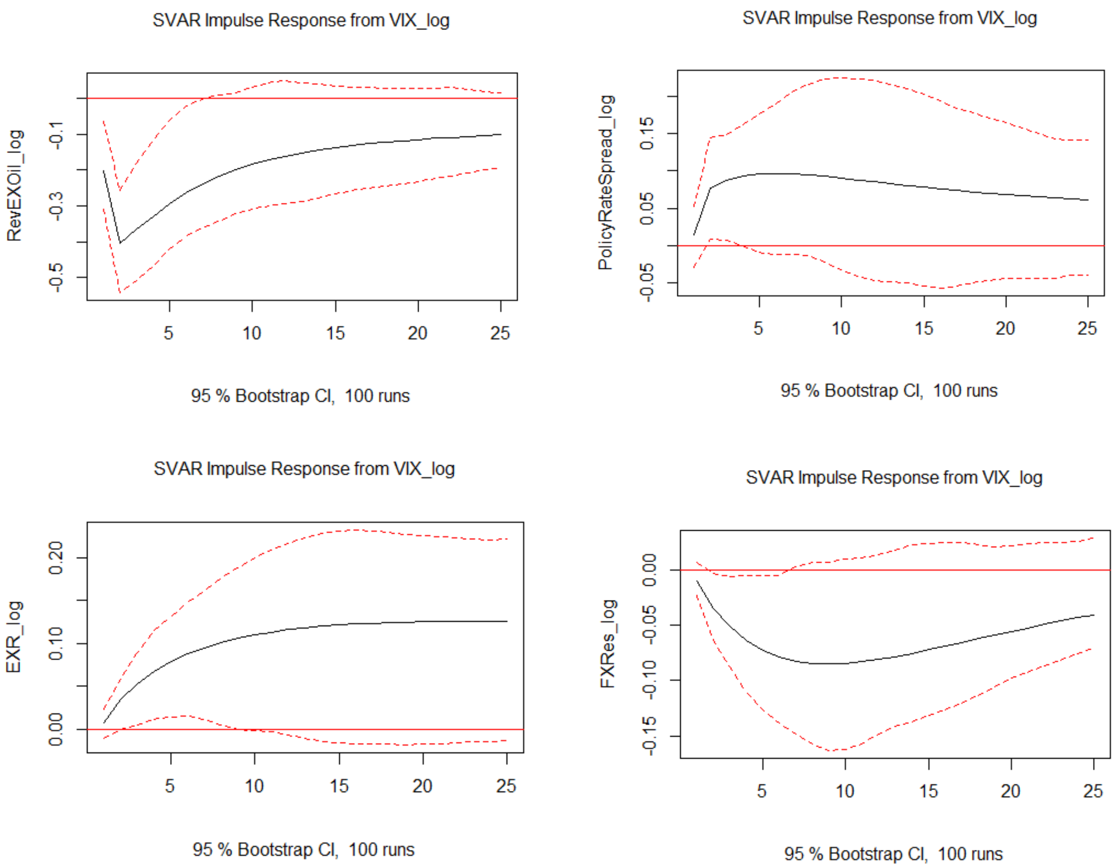

Figure 5: IRF of SVAR Model 1 with the logarithmised VIX as impulse variable and the revenues from export of oil, the foreign exchange reserves, the policy rate spread and the nominal naira-US-dollar exchange rate in their natural logarithm as response variables. Own representation of own calculation.

A one-percent shock in global uncertainty approximated by the VIX results in a fall in Nigeria's revenues from the export of crude oil by between 0.2-0.4 per cent for about seven months. When shocked with a one per cent increase of the VIX, the spread between the Nigerian and US-American monetary policy rate increases by 0.05-0.07 per cent, with effects persisting for quarter of a year. The naira depreciates by between 0.05 and 0.1 per cent when shocked with a one per cent change of the VIX. This impact persists to be significant for about nine months. Nigeria's foreign exchange reserves are negatively affected by higher levels of the VIX in about the same magnitude as the exchange rate, though the effects are only significant for about six months. All results are significant within the 95%-confidence-interval.

These results are in line with the theory: As global uncertainty grows, policy makers in countries in the Global South tend to increase the policy rate in an attempt to uphold the acceptance of their currencies and to avoid capital flight. As investor confidence crumbles so does the acceptance of currencies like the naira, which exercises depreciating pressure on them. Foreign exchange reserves fall as a consequence of diminished export income and capital flight, and because of central banks' attempt to defend their currencies.

Figure 6 depicts the IRF where the CBN's instruments of central banking are shocked with a one per cent increase in oil export revenues.

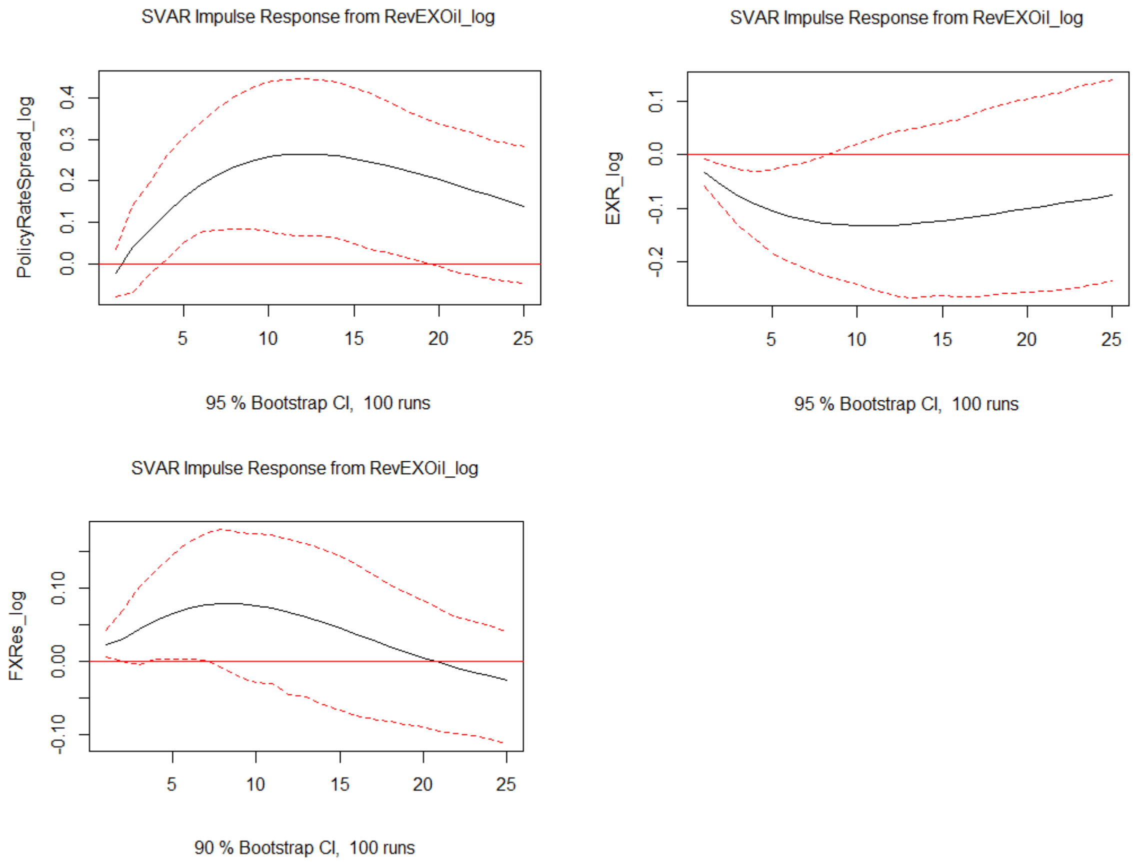

Figure 6: IRF of SVAR Model 1 with the logarithmised oil export revenues as impulse variable and the logarithmised nominal naira-US-dollar exchange rate, policy rate spread and foreign exchange reserves as response variables.

After three months, a shock coming in the form of a one per cent increase in the oil export revenues seems to have a positive effect on the policy rate spread between 0.1 and 0.25 per cent persisting to be significant at the 95 per cent confidence interval for about 20 months. The same shock results in an appreciation of the naira by about 0.1 per cent for about nine months at the 95 per cent confidence interval. The impact of the revenues from the export of oil seems to increase Nigeria's foreign exchange reserves by 0.04 to 0.08 per cent after three months. The impact is significant in the first and between the third and seventh month – however only within the 90% confidence interval.

The results are plausible. Higher revenues from oil exports contribute to an appreciation of the naira both directly, as more foreign exchange is converted into the naira and because the confidence in the currency and hence the readiness to hold it increases, and indirectly, by increasing foreign exchange reserves which the CBN can use to uphold the naira's value. That higher oil export revenues do not or only weakly positively impact the foreign exchange reserves can be explained by the exchange rate interventions by the CBN. The increase of the policy rate spread when shocked with higher oil revenues can be explained by lowered FED policy interest rates in response to recessionary pressure – often ante-dated by high commodity prices as was the case prior to the financial crisis 2007/08 – on the global and the US-American economy, which the FED reacts to by decreasing its policy interest rate. Policy authorities in Nigeria, in turn, have to react to the higher uncertainty coming with the recession by increasing Nigeria's policy rate to avoid capital flight. That the shock coming in the form of a unit increase in the oil export revenues only significantly positively impacts the policy rate spread after a lag of three months can be explained by policy adjustments taking time. A negative relation between the policy rate spread and the oil export revenues in the unstructured VAR version of Model 1 (see covariance matrix in Appendix 3) indicates that the reverse, i.e. a shock coming in the form of a one per cent decrease in oil export revenues leading to a decrease in the policy rate spread does not hold. It is possible that the policy rate spread increases both in reaction to higher and lower oil export revenues: If the decrease in oil export revenues is rooted in decreased oil prices or domestic supply problems, Nigerian monetary authorities are likely to increase the Nigerian policy rate to avoid capital flight as both factors will be considered by investors undermining the confidence in Nigeria as investment destination.

From the result of Model 1 it can concluded that transition risks negatively impact the ability to engage in effective central banking in Nigeria: higher global uncertainty and reduced oil revenues as likely results of climate transition effects excercise depreciating pressure on the naira and force the CBN to uphold the domestic interest rate level. Though the impacts are small, in their combined effects they can nevertheless represent important impediments to the ability to conduct effective central banking.

6.3.2 Baseline Model 2: Physical risks

The second model focuses on the physical risks of climate change and uses international food prices and the occurrence of a natural disaster in a given month as shock variables. The model is also stable (see Appendix 4). Figure 7 represents the IRF of the SVAR model 2 where the logarithmised FAO FoodPrice Index acts as impulse.

Nigerian food inflation responds to a one percentage increase in the FAO FoodPrice Index by increasing by 1-1.3 per cent after a lag of about one year. This is plausible against the backdrop of Nigeria's food import dependency. In response to the same shock, the policy rate spread first decreases after two months by about 0.5 per cent, but increases by 0.5-1 per cent after a lag of ten months, whilst there is not significant impact of international food prices on the policy rate spread during the intermittent phase. A widening policy rate spread as response to higher international food prices can be explained by the CBN reacting to higher food inflation by increasing its policy rate. A shock by one unit increase of the FAO FoodPrice Index does not seem to have a significant impact on foreign exchange reserves and the exchange rate at the five per cent significance level.

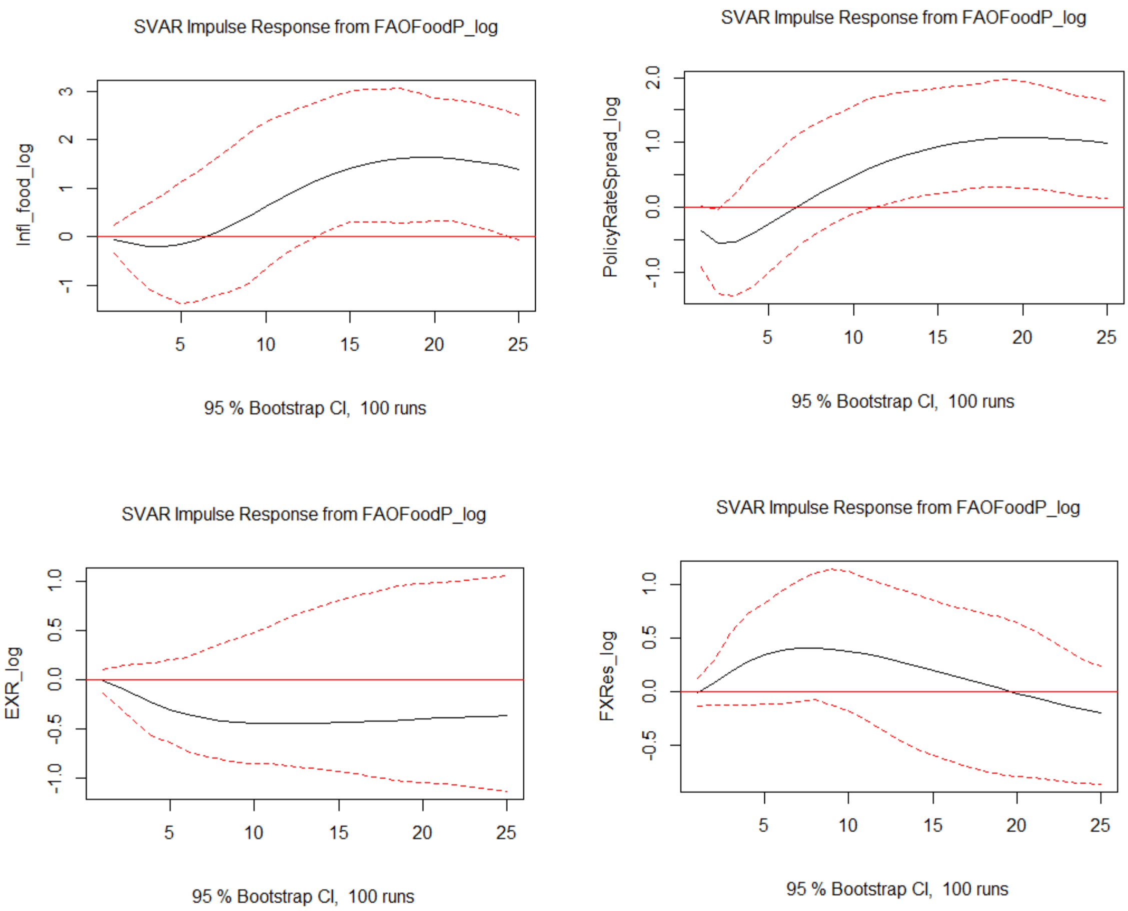

Figure 7: IRF of SVAR Model 2 for the logarithmised FAO FoodPrice index as impulse and the Nigerian food price inflation, its foreign exchange reserves, the policy rate spread and nominal naira-US-dollar exchange rate in their natural logarithm as response variables.

Figure 8 depicts the IRF where the natural disaster dummy variable represents the impulse variable. Here, only the direction and significance indicated by the IRF is interpretable, but not the amplitude of the reaction of the response variable (see El-Shagi and von Schweinitz 2016).

Whether a natural disaster occurred in one month or not neither seems to have a discernable effect on food price inflation, nor on foreign exchange reserves within the 90% confidence interval. However, it does seem to have a depreciating effect on the naira at a ten per cent significance level after a lag of two months lasting for about 17 months. Possible explanations might be that natural disasters impair the productivity of domestic firms with negative effects on the trade balance, affectedness by natural disasters diminishes foreign exchange reserves or that poor disaster management translates into weakened confidence in government capacities to conduct effective policies including exchange rate management. The policy rate differential reacts positively to a natural disaster shock with a lag of two months lasting for about 13 months at the 10 per cent significance level. The central bank reacting to deteriorated investor confidence as result of the natural disaster by increasing the policy rate might explain this.

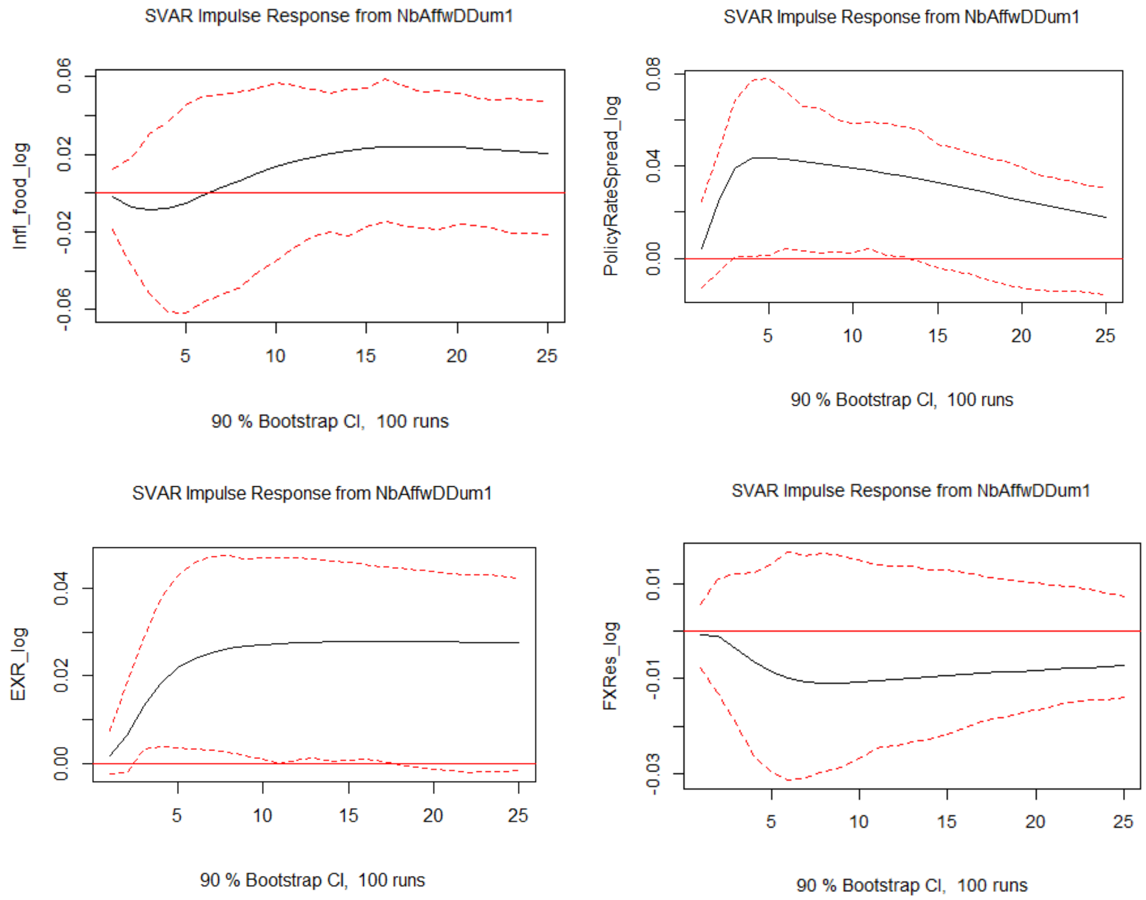

Figure 8: IRF of SVAR Model 2 for the natural disaster dummy variable as impulse and the Nigerian food price inflation, the policy rate spread, nominal naira-US-dollar exchange rate and its foreign exchange reserves in their natural logarithm as response variables.

In sum, the results of Model 2 seem to suggest that the capacity to conduct effective central banking has the potential to be impaired by physical climate risks by increasing the inflation rate, and by putting depreciating pressure on the naira.

7 Conclusion

This report provided insights in the extent of, and channels through which transition and physical risks of the climate catastrophe impact the ability to conduct effective central banking through the balance-of-payments in Nigeria. The interviews revealed that climate risks are likely to deepen trade deficits, make the financial account more susceptible to capital outflows, and increase the burden represented by Nigeria's external liabilities, among others. This has negative implications for the central bank's main instruments making the achievement of its mandates harder. Foreign exchange scarcity is aggravated and the naira is subjected to depreciating pressure. The currency depreciation together with reduced productivity contribute to the escalating inflation rates observable in Nigeria. Investment rates are impaired due to an instable exchange rate, the reduction of available funds and social conflict, climate change is an important explanatory component of. As climate risks render the acceptance of the naira more precarious, the CBN will have to resort to holding the interest rate level chronically high to avoid capital outflows, which exercises recessionary pressures in the domestic economy.

These results are confirmed in the SVAR-models. The model on transition risks revealed that shocks coming in the form of higher global uncertainty and diminished oil export revenues lead to a depreciating naira, lower foreign exchange reserves and higher policy rate spreads. Modelling impacts of the physical effects of the climate catastrophe on Nigerian central banking, we found that when a climatically induced reduction of agricultural productivity translates into higher international food prices, this is likely to inflate Nigerian food prices, which is a major component of total inflation. Moreover, the occurrence of natural disasters can depreciate the domestic currency. Both higher international food prices and natural disasters increase the spread between Nigeria's and the US-American monetary policy rate.

A depreciation of the naira associated with climate risks have particularly far-reaching potential macroeconomic consequences. These include inflationary pressures and increased debt burden in real terms. Repeated devaluations also get in the way of a catching-up industrialisation and a transition towards renewable energy generation in Nigeria through hampering profitability and investment certainty. This complements the impediments to late industrialisation associated with the physical effects of the climate catastrophe when investments are diverted into mitigation measures, when social conflict is spurred and when competitiveness is lowered due to lowered productivity and higher productions costs. The pressure on the naira will become more severe as climatically induced global instability increases and with it the frequency and severity of shocks. Those shocks have to be addressed by Nigerian policy makers and limit the policy space within which they can operate. A floating exchange rate regime is more risky as external shocks transmit to the naira more unhamperedly with adverse effects for the CBN's objectives.

The research findings are in line with theories highlighting the role of a differing acceptance of currencies in structurally perpetuating global inequality with subsequent implications for policy space between the Global North and South (e.g. Paula, Fritz, and Prates 2017; Andrade and Prates 2013). The climate catastrophe aggravates the macroeconomic challenges coming with this in low and middle income countries such as Nigeria. Climate risks are often transmitted through the balance-of-payments and crystallise in the exchange rate as a result of Global South countries' structural external constraint represented by their balance-of-payments and subordinate position in the international monetary and financial system (Löscher and Kaltenbrunner 2023). As global uncertainty caused by climate risks are projected to grow, so does the divergence of demand for centre and peripheral currencies. To safeguard against uncertainty, economic agents increase their demand of the more stable and liquid currencies issued by centre countries. Peripheral countries have to uphold their currencies' acceptance by increasing the interest rate level to the detriment of the domestic economy.

However, we also identified chances in climate transition. Nigeria's reserves of natural gas might help to diversify its export structure and the expansion of renewables might overcome energy poverty, a major impediment to the export sector. But as capital required for these transitions is currently still imported, the exploitation of these potentials requires foreign exchange and might exercise pressure on the balance-of-payments until benefits materialise.

Given the challenges at hand, domestic climate policies and economic diversification efforts cannot gain traction to the extent they could have otherwise. Against this backdrop, the validity of calls for reforms of the international monetary order becomes apparent.

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Appendix 1

Table 2: Professional background of interviewees, duration and mode of interviews.

	Professional Background	Duration of Interview	Mode of interview
Interview 1	Nigerian Incentive-Based Risk Sharing System for Agricultural Lending	18:30	Online via Jitsi
Interview 2	Heinrich-Böll Foundation Office Nigeria	46:44	Online via Jitsi
Interview 3	Consultant involved in the formulation of Nigeria's NDGs	40:20	Online via Jitsi
Interview 4	Economist at the Centre for the Study of the Economies of Africa	56:31	Online via Jitsi
Interview 5	FMDQ Exchange and Financial Centre for Sustainability (FC4S) Lagos	49:17	Online via Jitsi
Interview 6	Economist	39:22	Online via Jitsi
Interview 7	Senior fellow at the Centre for the Study of the Economies of Africa		Written response to questionnaire
Interview 8	Investor and export specialised on green bonds working at the Climate Bonds Institute	35:00	Online via Jitsi
Interview 9	Senior Associate with the Africa Energy Program	35:44	Online via Jitsi
Interview 10	Management CBN	70:00	Online via Jitsi

Appendix 2

Table 3: Statistical descriptives of used times series. Source: Own calculation.

```
      EXR        PolicyRateSpread      FXRes              RevEXOil           VIX
 Min.   :116.1   Min.   : 2.74    Min.   :2.342e+10   Min.   : 22.71   Min.   :10.59
 1st Qu.:148.3   1st Qu.: 8.37    1st Qu.:3.323e+10   1st Qu.: 76.33   1st Qu.:14.60
 Median :155.5   Median :11.61    Median :3.763e+10   Median :110.67   Median :18.31
 Mean   :224.9   Mean   :10.31    Mean   :3.828e+10   Mean   :124.60   Mean   :21.02
 3rd Qu.:306.0   3rd Qu.:11.97    3rd Qu.:4.222e+10   3rd Qu.:172.18   3rd Qu.:25.26
 Max.   :446.1   Max.   :13.61    Max.   :6.048e+10   Max.   :245.25   Max.   :68.00

   FAOFoodP         NbAffwD
 Min.   : 69.40   Min.   :       0
 1st Qu.: 93.80   1st Qu.:       0
 Median : 99.35   Median :      86
 Mean   :107.40   Mean   :  164133
 3rd Qu.:122.53   3rd Qu.:    4436
 Max.   :159.70   Max.   :19110398
```

Notes: For the number of people affected by natural disaster, the statistics were calculated using the absolute numbers.

Appendix 3

Table 4: Regression results of VAR-model 1. Source: Own calculation.

```
VAR Estimation Results:
=========================
Endogenous variables: VIX_log, RevEXOil_log, PolicyRateSpread_log, EXR_log, FXRes_log
Deterministic variables: const
Sample size: 202
Log Likelihood: 1374.481
Roots of the characteristic polynomial:
0.9976 0.9253 0.9188 0.9188 0.8109 0.6829 0.4054 0.2011 0.1932 0.03509
Call:
VAR(y = model1, lag.max = 2)


Estimation results for equation VIX_log:
========================================
VIX_log = VIX_log.l1 + RevEXOil_log.l1 + PolicyRateSpread_log.l1 + EXR_log.l1 + FXRes_log.l1 +
VIX_log.l2 + RevEXOil_log.l2 + PolicyRateSpread_log.l2 + EXR_log.l2 + FXRes_log.l2 + const

                         Estimate Std. Error t value Pr(>|t|)
VIX_log.l1               0.812510   0.074519  10.903   <2e-16 ***
RevEXOil_log.l1         -0.102223   0.103225  -0.990    0.323
PolicyRateSpread_log.l1  0.019141   0.188175   0.102    0.919
EXR_log.l1              -0.525981   0.605127  -0.869    0.386
FXRes_log.l1            -0.208338   0.470727  -0.443    0.659
VIX_log.l2              -0.008782   0.073523  -0.119    0.905
RevEXOil_log.l2          0.123955   0.104394   1.187    0.237
PolicyRateSpread_log.l2 -0.114253   0.187252  -0.610    0.542
EXR_log.l2               0.602642   0.593727   1.015    0.311
FXRes_log.l2             0.346393   0.473448   0.732    0.465
const                   -3.065579   1.989023  -1.541    0.125
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1


Residual standard error: 0.1967 on 191 degrees of freedom
Multiple R-Squared: 0.7339,  Adjusted R-squared:  0.72
F-statistic: 52.68 on 10 and 191 DF,  p-value: < 2.2e-16


Estimation results for equation RevEXOil_log:
=============================================
RevEXOil_log = VIX_log.l1 + RevEXOil_log.l1 + PolicyRateSpread_log.l1 + EXR_log.l1 + FXRes_log.l1 +
VIX_log.l2 + RevEXOil_log.l2 + PolicyRateSpread_log.l2 + EXR_log.l2 + FXRes_log.l2 + const

                         Estimate Std. Error t value Pr(>|t|)
VIX_log.l1              -0.215134   0.053618  -4.012 8.62e-05 ***
RevEXOil_log.l1          0.900514   0.074272  12.125  < 2e-16 ***
PolicyRateSpread_log.l1  0.041290   0.135395   0.305  0.76073
EXR_log.l1              -0.973491   0.435399  -2.236  0.02652 *
FXRes_log.l1            -0.035730   0.338696  -0.105  0.91610
VIX_log.l2               0.201363   0.052901   3.806  0.00019 ***
RevEXOil_log.l2          0.007077   0.075113   0.094  0.92503
PolicyRateSpread_log.l2 -0.098451   0.134731  -0.731  0.46584
EXR_log.l2               0.936867   0.427196   2.193  0.02951 *
FXRes_log.l2             0.016147   0.340653   0.047  0.96224
const                    1.281738   1.431134   0.896  0.37159
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Residual standard error: 0.1415 on 191 degrees of freedom
Multiple R-Squared: 0.9212,  Adjusted R-squared: 0.917
F-statistic: 223.2 on 10 and 191 DF,  p-value: < 2.2e-16


Estimation results for equation PolicyRateSpread_log:
=====================================================
PolicyRateSpread_log = VIX_log.l1 + RevEXOil_log.l1 + PolicyRateSpread_log.l1 + EXR_log.l1 +
FXRes_log.l1 + VIX_log.l2 + RevEXOil_log.l2 + PolicyRateSpread_log.l2 + EXR_log.l2 + FXRes_log.l2 +
const

                         Estimate Std. Error t value Pr(>|t|)
VIX_log.l1               0.076569   0.028797   2.659  0.00851 **
RevEXOil_log.l1          0.072441   0.039891   1.816  0.07094 .
PolicyRateSpread_log.l1  0.972532   0.072719  13.374  < 2e-16 ***
EXR_log.l1               0.389169   0.233848   1.664  0.09771 .
FXRes_log.l1             0.128506   0.181910   0.706  0.48078
VIX_log.l2              -0.032978   0.028412  -1.161  0.24722
RevEXOil_log.l2         -0.009352   0.040342  -0.232  0.81693
PolicyRateSpread_log.l2 -0.016187   0.072362  -0.224  0.82324
EXR_log.l2              -0.331853   0.229442  -1.446  0.14972
FXRes_log.l2            -0.184197   0.182961  -1.007  0.31533
const                    0.723713   0.768646   0.942  0.34762
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1


Residual standard error: 0.07602 on 191 degrees of freedom
Multiple R-Squared: 0.9532,  Adjusted R-squared: 0.9508
F-statistic: 389.3 on 10 and 191 DF,  p-value: < 2.2e-16


Estimation results for equation EXR_log:
========================================
EXR_log = VIX_log.l1 + RevEXOil_log.l1 + PolicyRateSpread_log.l1 + EXR_log.l1 + FXRes_log.l1 +
VIX_log.l2 + RevEXOil_log.l2 + PolicyRateSpread_log.l2 + EXR_log.l2 + FXRes_log.l2 + const

                         Estimate Std. Error t value Pr(>|t|)
VIX_log.l1               0.021141   0.008494   2.489   0.0137 *
RevEXOil_log.l1         -0.007069   0.011766  -0.601   0.5487
PolicyRateSpread_log.l1  0.004782   0.021449   0.223   0.8238
EXR_log.l1               1.426261   0.068975  20.678  < 2e-16 ***
FXRes_log.l1            -0.040597   0.053656  -0.757   0.4502
VIX_log.l2              -0.015109   0.008380  -1.803   0.0730 .
RevEXOil_log.l2         -0.002412   0.011899  -0.203   0.8396
PolicyRateSpread_log.l2  0.008330   0.021344   0.390   0.6968
EXR_log.l2              -0.440598   0.067676  -6.510 6.45e-10 ***
FXRes_log.l2             0.035172   0.053966   0.652   0.5154
const                    0.208664   0.226718   0.920   0.3585
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1


Residual standard error: 0.02242 on 191 degrees of freedom
Multiple R-Squared: 0.9975,  Adjusted R-squared: 0.9973
F-statistic:  7473 on 10 and 191 DF,  p-value: < 2.2e-16


Estimation results for equation FXRes_log:
==========================================
FXRes_log = VIX_log.l1 + RevEXOil_log.l1 + PolicyRateSpread_log.l1 + EXR_log.l1 + FXRes_log.l1 +
VIX_log.l2 + RevEXOil_log.l2 + PolicyRateSpread_log.l2 + EXR_log.l2 + FXRes_log.l2 + const

                         Estimate Std. Error t value Pr(>|t|)
VIX_log.l1              -0.019884   0.009269  -2.145   0.0332 *
```

```
RevEXOil_log.l1         -0.006267   0.012839  -0.488   0.6260
PolicyRateSpread_log.l1  0.004098   0.023405   0.175   0.8612
EXR_log.l1              -0.059651   0.075265  -0.793   0.4290
FXRes_log.l1             1.586187   0.058549  27.092   <2e-16 ***
VIX_log.l2               0.016031   0.009145   1.753   0.0812 .
RevEXOil_log.l2          0.011403   0.012984   0.878   0.3810
PolicyRateSpread_log.l2 -0.015161   0.023290  -0.651   0.5159
EXR_log.l2               0.067851   0.073847   0.919   0.3594
FXRes_log.l2            -0.611719   0.058887 -10.388   <2e-16 ***
const                    0.591052   0.247393   2.389   0.0179 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1


Residual standard error: 0.02447 on 191 degrees of freedom
Multiple R-Squared: 0.9851,  Adjusted R-squared: 0.9843
F-statistic:  1259 on 10 and 191 DF,  p-value: < 2.2e-16



Covariance matrix of residuals:
                       VIX_log RevEXOil_log PolicyRateSpread_log    EXR_log
VIX_log              0.0386955   -0.0078137            5.677e-04  3.065e-04
RevEXOil_log        -0.0078137    0.0200328           -5.145e-04 -6.886e-04
PolicyRateSpread_log  0.0005677   -0.0005145            5.779e-03  1.926e-04
EXR_log              0.0003065   -0.0006886            1.926e-04  5.028e-04
FXRes_log           -0.0003881    0.0004870            3.665e-05 -8.734e-05
                     FXRes_log
VIX_log             -3.881e-04
RevEXOil_log         4.870e-04
PolicyRateSpread_log  3.665e-05
EXR_log             -8.734e-05
FXRes_log            5.986e-04

Correlation matrix of residuals:
                     VIX_log RevEXOil_log PolicyRateSpread_log  EXR_log
VIX_log              1.00000     -0.28064              0.03796  0.06949
RevEXOil_log        -0.28064      1.00000             -0.04782 -0.21699
PolicyRateSpread_log  0.03796     -0.04782              1.00000  0.11301
EXR_log              0.06949     -0.21699              0.11301  1.00000
FXRes_log           -0.08065      0.14062              0.01970 -0.15921
                    FXRes_log
VIX_log              -0.08065
RevEXOil_log          0.14062
PolicyRateSpread_log   0.01970
EXR_log              -0.15921
FXRes_log             1.00000
```

Appendix 4

Table 5: Regression results of VAR-model 2. Source: Own calculation.

```
VAR Estimation Results:
=========================
Endogenous variables: FAOFoodP_log, NbAffwDDum1, Infl_food_log, PolicyRateSpread_log, EXR_log,
FXRes_log
Deterministic variables: const
Sample size: 202
Log Likelihood: 1908.185
Roots of the characteristic polynomial:
```

```
0.9981 0.9596 0.9596 0.944 0.944 0.7091 0.7091 0.4956 0.3884 0.3884 0.06399 0.06399
Call:
VAR(y = modelPhys2, lag.max = 2)


Estimation results for equation FAOFoodP_log:
=============================================
FAOFoodP_log = FAOFoodP_log.l1 + NbAffwDDum1.l1 + Infl_food_log.l1 + PolicyRateSpread_log.l1 +
EXR_log.l1 + FXRes_log.l1 + FAOFoodP_log.l2 + NbAffwDDum1.l2 + Infl_food_log.l2 +
PolicyRateSpread_log.l2 + EXR_log.l2 + FXRes_log.l2 + const

                          Estimate Std. Error t value Pr(>|t|)
FAOFoodP_log.l1          1.4299263  0.0659011  21.698  < 2e-16 ***
NbAffwDDum1.l1           0.0006215  0.0038234   0.163   0.8710
Infl_food_log.l1        -0.0107645  0.0236441  -0.455   0.6494
PolicyRateSpread_log.l1  0.0049496  0.0223423   0.222   0.8249
EXR_log.l1              -0.0611592  0.0667563  -0.916   0.3608
FXRes_log.l1            -0.0439196  0.0546007  -0.804   0.4222
FAOFoodP_log.l2         -0.4476463  0.0664590  -6.736 1.91e-10 ***
NbAffwDDum1.l2           0.0005679  0.0038685   0.147   0.8835
Infl_food_log.l2         0.0064914  0.0232576   0.279   0.7805
PolicyRateSpread_log.l2 -0.0275874  0.0218701  -1.261   0.2087
EXR_log.l2               0.0780857  0.0668336   1.168   0.2441
FXRes_log.l2             0.0297177  0.0543038   0.547   0.5849
const                    0.4013707  0.2357264   1.703   0.0903 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1


Residual standard error: 0.02304 on 189 degrees of freedom
Multiple R-Squared: 0.9854,     Adjusted R-squared: 0.9844
F-statistic:  1061 on 12 and 189 DF,  p-value: < 2.2e-16


Estimation results for equation NbAffwDDum1:
============================================
NbAffwDDum1 = FAOFoodP_log.l1 + NbAffwDDum1.l1 + Infl_food_log.l1 + PolicyRateSpread_log.l1 +
EXR_log.l1 + FXRes_log.l1 + FAOFoodP_log.l2 + NbAffwDDum1.l2 + Infl_food_log.l2 +
PolicyRateSpread_log.l2 + EXR_log.l2 + FXRes_log.l2 + const

                        Estimate Std. Error t value Pr(>|t|)
FAOFoodP_log.l1         -0.45310    1.25981  -0.360    0.720
NbAffwDDum1.l1           0.44258    0.07309   6.055 7.41e-09 ***
Infl_food_log.l1         0.24389    0.45200   0.540    0.590
PolicyRateSpread_log.l1  0.25474    0.42711   0.596    0.552
EXR_log.l1              -0.32189    1.27615  -0.252    0.801
FXRes_log.l1             1.62960    1.04378   1.561    0.120
FAOFoodP_log.l2          0.22551    1.27047   0.177    0.859
NbAffwDDum1.l2          -0.03869    0.07395  -0.523    0.601
Infl_food_log.l2        -0.22828    0.44461  -0.513    0.608
PolicyRateSpread_log.l2 -0.08892    0.41808  -0.213    0.832
EXR_log.l2               0.35870    1.27763   0.281    0.779
FXRes_log.l2            -1.66907    1.03810  -1.608    0.110
const                    2.34627    4.50629   0.521    0.603
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1


Residual standard error: 0.4405 on 189 degrees of freedom
Multiple R-Squared: 0.2596,     Adjusted R-squared: 0.2126
F-statistic: 5.522 on 12 and 189 DF,  p-value: 4.671e-08


Estimation results for equation Infl_food_log:
==============================================
```

```
Infl_food_log = FAOFoodP_log.l1 + NbAffwDDum1.l1 + Infl_food_log.l1 + PolicyRateSpread_log.l1 +
EXR_log.l1 + FXRes_log.l1 + FAOFoodP_log.l2 + NbAffwDDum1.l2 + Infl_food_log.l2 +
PolicyRateSpread_log.l2 + EXR_log.l2 + FXRes_log.l2 + const

                         Estimate Std. Error t value Pr(>|t|)
FAOFoodP_log.l1         -0.002186   0.134062  -0.016    0.987
NbAffwDDum1.l1          -0.004365   0.007778  -0.561    0.575
Infl_food_log.l1         1.709235   0.048099  35.536   <2e-16 ***
PolicyRateSpread_log.l1 -0.023743   0.045451  -0.522    0.602
EXR_log.l1              -0.035125   0.135802  -0.259    0.796
FXRes_log.l1            -0.146201   0.111074  -1.316    0.190
FAOFoodP_log.l2          0.043482   0.135197   0.322    0.748
NbAffwDDum1.l2           0.005077   0.007870   0.645    0.520
Infl_food_log.l2        -0.743849   0.047313 -15.722   <2e-16 ***
PolicyRateSpread_log.l2  0.039892   0.044490   0.897    0.371
EXR_log.l2               0.052191   0.135959   0.384    0.702
FXRes_log.l2             0.155582   0.110470   1.408    0.161
const                   -0.463147   0.479537  -0.966    0.335
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1


Residual standard error: 0.04687 on 189 degrees of freedom
Multiple R-Squared: 0.9924,     Adjusted R-squared: 0.9919
F-statistic:  2045 on 12 and 189 DF,  p-value: < 2.2e-16


Estimation results for equation PolicyRateSpread_log:
=====================================================
PolicyRateSpread_log = FAOFoodP_log.l1 + NbAffwDDum1.l1 + Infl_food_log.l1 + PolicyRateSpread_log.l1 +
EXR_log.l1 + FXRes_log.l1 + FAOFoodP_log.l2 + NbAffwDDum1.l2 + Infl_food_log.l2 +
PolicyRateSpread_log.l2 + EXR_log.l2 + FXRes_log.l2 + const

                         Estimate Std. Error t value Pr(>|t|)
FAOFoodP_log.l1         -0.179654   0.214083  -0.839  0.40243
NbAffwDDum1.l1           0.020896   0.012421   1.682  0.09414 .
Infl_food_log.l1         0.209563   0.076809   2.728  0.00697 **
PolicyRateSpread_log.l1  0.923523   0.072580  12.724  < 2e-16 ***
EXR_log.l1               0.127864   0.216861   0.590  0.55615
FXRes_log.l1             0.059030   0.177373   0.333  0.73965
FAOFoodP_log.l2          0.278010   0.215895   1.288  0.19942
NbAffwDDum1.l2           0.007920   0.012567   0.630  0.52930
Infl_food_log.l2        -0.211328   0.075554  -2.797  0.00569 **
PolicyRateSpread_log.l2  0.003664   0.071046   0.052  0.95893
EXR_log.l2              -0.122537   0.217112  -0.564  0.57315
FXRes_log.l2            -0.113643   0.176408  -0.644  0.52022
const                    0.971087   0.765768   1.268  0.20631
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1


Residual standard error: 0.07485 on 189 degrees of freedom
Multiple R-Squared: 0.9551,     Adjusted R-squared: 0.9523
F-statistic: 335.2 on 12 and 189 DF,  p-value: < 2.2e-16


Estimation results for equation EXR_log:
========================================
EXR_log = FAOFoodP_log.l1 + NbAffwDDum1.l1 + Infl_food_log.l1 + PolicyRateSpread_log.l1 + EXR_log.l1 +
FXRes_log.l1 + FAOFoodP_log.l2 + NbAffwDDum1.l2 + Infl_food_log.l2 + PolicyRateSpread_log.l2 +
EXR_log.l2 + FXRes_log.l2 + const

                         Estimate Std. Error t value Pr(>|t|)
FAOFoodP_log.l1         -0.042600   0.065355  -0.652    0.515
NbAffwDDum1.l1           0.003884   0.003792   1.024    0.307
```

```
Infl_food_log.l1         0.033919   0.023448   1.447    0.150
PolicyRateSpread_log.l1 -0.007893   0.022157  -0.356    0.722
EXR_log.l1               1.451659   0.066203  21.927  < 2e-16 ***
FXRes_log.l1            -0.069767   0.054148  -1.288    0.199
FAOFoodP_log.l2          0.038341   0.065908   0.582    0.561
NbAffwDDum1.l2           0.002828   0.003836   0.737    0.462
Infl_food_log.l2        -0.033040   0.023065  -1.432    0.154
PolicyRateSpread_log.l2  0.010439   0.021689   0.481    0.631
EXR_log.l2              -0.455886   0.066280  -6.878 8.62e-11 ***
FXRes_log.l2             0.061730   0.053854   1.146    0.253
const                    0.223118   0.233773   0.954    0.341
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1


Residual standard error: 0.02285 on 189 degrees of freedom
Multiple R-Squared: 0.9974,     Adjusted R-squared: 0.9972
F-statistic:  5995 on 12 and 189 DF,  p-value: < 2.2e-16


Estimation results for equation FXRes_log:
==========================================
FXRes_log = FAOFoodP_log.l1 + NbAffwDDum1.l1 + Infl_food_log.l1 + PolicyRateSpread_log.l1 + EXR_log.l1
+ FXRes_log.l1 + FAOFoodP_log.l2 + NbAffwDDum1.l2 + Infl_food_log.l2 + PolicyRateSpread_log.l2 +
EXR_log.l2 + FXRes_log.l2 + const

                          Estimate Std. Error t value Pr(>|t|)
FAOFoodP_log.l1          0.0953798  0.0705045   1.353   0.1777
NbAffwDDum1.l1           0.0003885  0.0040905   0.095   0.9244
Infl_food_log.l1         0.0162701  0.0252958   0.643   0.5209
PolicyRateSpread_log.l1  0.0117350  0.0239030   0.491   0.6240
EXR_log.l1              -0.0698483  0.0714195  -0.978   0.3293
FXRes_log.l1             1.5850126  0.0584147  27.134   <2e-16 ***
FAOFoodP_log.l2         -0.0964089  0.0711014  -1.356   0.1767
NbAffwDDum1.l2          -0.0026658  0.0041387  -0.644   0.5203
Infl_food_log.l2        -0.0210390  0.0248823  -0.846   0.3989
PolicyRateSpread_log.l2 -0.0117528  0.0233978  -0.502   0.6160
EXR_log.l2               0.0719709  0.0715021   1.007   0.3154
FXRes_log.l2            -0.6102110  0.0580971 -10.503   <2e-16 ***
const                    0.6225651  0.2521927   2.469   0.0145 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1


Residual standard error: 0.02465 on 189 degrees of freedom
Multiple R-Squared: 0.985,      Adjusted R-squared: 0.984
F-statistic:  1033 on 12 and 189 DF,  p-value: < 2.2e-16



Covariance matrix of residuals:
                     FAOFoodP_log NbAffwDDum1 Infl_food_log PolicyRateSpread_log
FAOFoodP_log            5.309e-04  -0.0010183    -9.107e-06           -1.914e-04
NbAffwDDum1            -1.018e-03   0.1940306    -3.253e-04            1.136e-03
Infl_food_log          -9.107e-06  -0.0003253     2.197e-03           -1.635e-04
PolicyRateSpread_log   -1.914e-04   0.0011358    -1.635e-04            5.603e-03
EXR_log                -1.755e-06   0.0003473     2.266e-05            1.410e-04
FXRes_log              -6.253e-06  -0.0001321    -5.216e-05           -4.953e-06
                        EXR_log  FXRes_log
FAOFoodP_log         -1.755e-06 -6.253e-06
NbAffwDDum1           3.473e-04 -1.321e-04
Infl_food_log         2.266e-05 -5.216e-05
PolicyRateSpread_log  1.410e-04 -4.953e-06
EXR_log               5.222e-04 -1.057e-04
FXRes_log            -1.057e-04  6.077e-04
```

```
Correlation matrix of residuals:
                    FAOFoodP_log NbAffwDDum1 Infl_food_log PolicyRateSpread_log
FAOFoodP_log            1.000000    -0.10032     -0.008432            -0.110946
NbAffwDDum1            -0.100323     1.00000     -0.015755             0.034446
Infl_food_log          -0.008432    -0.01576      1.000000            -0.046595
PolicyRateSpread_log   -0.110946     0.03445     -0.046595             1.000000
EXR_log                -0.003334     0.03450      0.021159             0.082432
FXRes_log              -0.011008    -0.01217     -0.045139            -0.002684
                      EXR_log FXRes_log
FAOFoodP_log        -0.003334 -0.011008
NbAffwDDum1          0.034504 -0.012166
Infl_food_log        0.021159 -0.045139
PolicyRateSpread_log  0.082432 -0.002684
EXR_log              1.000000 -0.187670
FXRes_log           -0.187670  1.000000
```