Vulnerable Group Theory of Financial Inclusion

Ozili, Peterson K

2024

Central bank digital currency, economic growth and inflation

Peterson K. Ozili

Abstract

This study investigates the effect of CBDC issuance on economic growth rate and inflation rate in Nigeria. We are interested in determining whether the rate of economic growth and inflation changed significantly after the issuance of a non-interest bearing CBDC in Nigeria. Two-stage least square regression and granger causality test were used to analyse the data. Inflation significantly increased in the CBDC period, implying that CBDC issuance did not decrease the rate of inflation in Nigeria. Economic growth rate significantly increased in the CBDC period, implying that CBDC issuance improved economic growth in Nigeria. The financial sector, agricultural sector and the manufacturing sector witnessed a much stronger contribution to gross domestic product (GDP) after CBDC issuance. There is one-way granger causality between CBDC issuance and monthly inflation, implying that CBDC issuance causes a significant change in monthly inflation in Nigeria. The implication of the result is that the non-interest bearing eNaira CBDC is not able to solve the twin economic problem of "controlling inflation which stifles economic growth" and "stimulating economic growth which leads to more inflation." Policy makers should therefore use the eNaira CBDC alongside other monetary policy tools at their disposal to control inflation while stimulating growth in the economy. There are no empirical studies on the effect of CBDC issuance on economic growth or inflation using real-world data. We add to the monetary economics literature by analyzing the effect of CBDC issuance on economic growth and inflation.

Keywords: central bank digital currency, CBDC, inflation, economic growth, Nigeria.

JEL code: E31, E58, O47, O55.

To cite: Ozili, P. K. (2024). Central bank digital currency, economic growth and inflation. *Journal of Money and Business.* (early-cite)

1. Introduction

This study investigates the effect of CBDC issuance on economic growth rate and inflation rate in Nigeria.

A central bank digital currency (CBDC) is the digital equivalent of cash or paper currency and is a liability of the issuing central bank (Williamson, 2022). A CBDC, just like every other innovation, can be used to support productive activities depending on the objective the central bank wants to achieve with it and depending on its design features. Central banks around the world are increasingly interested in issuing a CBDC. The COVID-19 pandemic and the rise in private digital currencies, such as cryptocurrencies, motivated many central banks to consider the possibility of issuing a CBDC as a digital alternative to fiat paper money.

The Central Bank of Nigeria issued a non-interest-bearing central bank digital currency in October 2021. As a result, Nigeria became the first African country to issue an official central bank digital currency called the eNaira. The eNaira central bank digital currency has been well-received by corporations and wholesale merchants in Nigeria. It has recorded transactions worth ₦8 billion (or US$18.2 million) and the eNaira CBDC wallet has received over 800,000 downloads in 2022. These indicators are signs of progress within one year of the launch of the eNaira CBDC. While the Nigeria CBDC holds much promise for better economic welfare for citizens and economic growth in Nigeria, many questions have been raised about its effect on macroeconomic stability particularly with regard to economic growth and inflation. Therefore, it remains to be seen whether Nigeria's economic growth rate and inflation rate improved or worsened after the issuance of the eNaira central bank digital currency.

Economic growth and inflation are highly debated topics in the macroeconomics literature. The determinants of economic growth and inflation are diverse. Several studies have identified several factors affecting economic growth and inflation (see, for example, Rani and Kumar, 2019; Sheremirov, 2020; Rudd, 2022; Ozili et al, 2023). But such studies have not considered a central bank digital currency to be a potential factor contributing to economic growth and inflation. This study presents CBDC as a modern innovation and a potential factor that might explain the dynamics or changes in economic growth and inflation. Also, a pioneering work on the

innovation–growth nexus by Romer (1986), Lucas (1988), Grossman and Helpman (1994) emphasizes the role of innovation and technological advancement as inputs to production which leads to economic growth. Empirical studies also document evidence that innovation make a significant contribution to economic growth and price stability (Chu, 2022; Evers et al, 2020). But the literature has not considered the case of a central bank digital currency as a potential contributor to economic growth or inflation. Presently, there is little knowledge about the effect of a central bank digital currency on economic growth and inflation. There are no empirical studies on the effect of CBDC issuance on economic growth or inflation using real-world data and in African countries. This study contributes to the literature by analyzing the effect of CBDC issuance on economic growth and inflation in a non-interest-bearing central bank digital currency environment.

In this paper, we are interested in investigating whether the rate of economic growth and inflation changed significantly in the period after the eNaira CBDC was issued in Nigeria. In terms of the transmission mechanism, we predict that CBDC will improve economic growth by ensuring faster, cheaper and transparent cross-border payment services, ensuring the continued provision of public money to support production, offering a cheaper and efficient payment option for financial transactions, improving the functioning of the payment system and supporting economic digitalization which ultimately lead to positive economic growth (Auer et al, 2022; Ozili, 2022b). Regarding inflation, CBDC can reduce inflation by increasing the CBDC deposit rate which will lead to the migration of bank deposits to CBDC deposits, it will mop up excess liquidity in the banking sector, it will reduce money supply and decrease the rate of inflation (Minesso et al, 2022; Bhowmik, 2022; Keister and Sanches, 2023).

In the empirical analysis, we make use of the official inflation and GDP growth statistics obtained from the National Bureau of Statistics (NBS). We construct year dummies to capture the pre-CBDC period and the post-CBDC issuance period. Our empirical results indicate that inflation significantly increased after the issuance of the non-interest bearing CBDC in Nigeria. It was also found that CBDC issuance has a significant positive effect on economic growth in Nigeria especially on the financial sector, the agricultural sector and the manufacturing sector.

The study contributes to the literature that examines the role of innovation for economic growth. It contributes to this literature by examining whether the CBDC innovation led to improvement in economic growth and price stability. The study also contributes to the literature that examines the effect of a central bank digital currency on the economy. We focus on economic growth and inflation after the central bank digital currency was issued to determine if the two macroeconomic variables performed better or worse. The study also contributes to ongoing debates about the benefits and risks of a central bank digital currency. The analysis in the study will provide useful insight on the consequences and benefits of a central bank digital currency for macroeconomic stability.

The rest of the paper is organized in the following way. Section 2 presents the conceptual framework and the literature review. Section 3 presents the research methodology. Section 4 presents the empirical results and section 5 presents the conclusion of the study.

2. Conceptual Framework and Literature Review

2.1. CBDC, technology acceptance model and the Nigerian use case

A central bank digital currency (CBDC) is the digital equivalent of cash or paper currency and is a liability of the issuing central bank (Ward and Rochemont, 2019). A CBDC has cash-like properties and can be designed and redesigned to have extended functionalities to meet central bank objectives. Many central banks are motivated to study or issue a central bank digital currency because of the need for central banks to innovate in the 21st century and the need for central banks to counter the proliferation of private digital currencies which offer unlicensed digital money in the domestic economy (; Ozili, 2022a; Wang et al 2022; Ozili, 2023). A CBDC offers enormous benefits. It can enhance the conduct of monetary policy, increase financial inclusion, increase payment efficiency, facilitate government welfare transfers, offer cheaper cross-border payment, and eliminate tax evasion (Ozili, 2023). CBDCs also present some risks such as lack of interest in CBDC adoption by majority of the population, cyber security risks, disorderly bank

disintermediation and financial stability risks (Bindseil, 2020). While the benefits and risks of issuing a CBDC are well-known in the literature, there has been much focus on CBDC design. The design of a CBDC is crucial for it to achieve its intended purpose. A CBDC must be designed to have features that support the realization of the specific objectives that the central bank has set out to achieve (Kumhof and Noone, 2018). While CBDC design is important, it is equally important for the central bank to ensure that the central bank digital currency is widely accepted in society (Söilen and Benhayoun, 2021). If a central bank digital currency is not accepted in society, the CBDC will not achieve its objectives. The issue of CBDC acceptance leads us to discuss the technology acceptance model.

The technology acceptance model was formulated by Davis (1989). The model is used to explain an individual's acceptance and use of a technology or innovation (Lee et al, 2003). The model proposes that the perceived ease of use and perceived usefulness of a technology or innovation are determinants of whether an individual will accept and use the technology or innovation (Chau, 1996). The implication of the technology acceptance model for a CBDC is that the determinant of whether people will use CBDC is whether the CBDC is easy to use and whether people find it very useful to them compared to existing alternatives, and whether they feel that using CBDC in their daily lives will have a positive impact on their lives, as argued by the technology impact model which states that people assess whether an innovation will have a positive impact on them before reaching a decision to use the innovation (Ozili, 2024).

Furthermore, after issuing the eNaira CBDC, many people raised concerns about the usefulness of the eNaira CBDC for citizens since the existing payment channels owned by banks are working well. There were also concerns that the eNaira CBDC would compete with banks and that the central bank will have a superior advantage by being both a regulator and a player in the payment system. Economists also raised some concern about the effect of the eNaira CBDC on macroeconomic stability and its consequence for economic growth and inflation. Therefore, it is important to understand how the issuance of a CBDC affects economic growth and inflation. The literature has not examined this issue.

2.2. The innovation and economic growth literature

The innovation and economic growth literature explains the impact of innovation on economic growth. Verspagen (2006) argues that technological innovation is responsible for extended periods of sustained economic growth in developed economies. The major argument has been that innovative activity is the single most important determinant of long-term economic growth; and without it, long-term growth is not possible. Also, Arora et al (2020) show that modern economic growth is caused by the systematic application of science to advance technology which supports productive activities in the economy. Several studies test this argument by investigating the relationship between innovation and economic growth. For example, Gyedu et al (2021) examine the impact of innovation on economic growth among the G7 and [1]BRICS countries from 2000 to 2017. They focus on how innovation, which was measured by R&D, patents, and trademarks, affects GDP per capita which is the measure of economic growth. They found that the three types of innovation have a significant effect on GDP per capita and the impact is stronger in G7 countries than in BRICS countries. Mtar and Belazreg (2021) examine the causal relationship between innovation, financial development, and economic growth for 27 Organization for Economic Cooperation and Development (OECD) from 2001 to 2016. They find a unidirectional causality from innovation to economic growth. They conclude that country-specific characteristics play an important role in fostering innovation and economic growth. Farinha et al (2018) examine the relationship between innovation and economic growth in 148 countries with different levels of development. They use structural equation modelling and hierarchical cluster analysis and find that innovation is an important driver of growth and competitiveness in several economies. Ahlstrom (2010) shows that innovation leads to the development and production of innovative goods and services that lead to economic growth and higher per capita income. Rosenberg (2006) argues that innovation can lead to long-term economic growth especially if: (1) innovation is used to increase the number of inputs that go into the productive process, or (2) innovation can devise new ways in which more output can be derived from the same number of inputs. Pece et al (2015) also argue that innovation can support

[1] Brazil, Russia, India, China, and South Africa (BRICs)

the sustainable development of the private and public sectors, which will improve living standards and welfare in the form of positive economic growth and development. Maradana et al (2017) point out that innovation could lead to economic growth through other macroeconomic factors, and innovation is also affected by economic growth and other macroeconomic factors, implying that both innovative activities and economic growth can cause each other and therefore, there is the possibility of feedback relationship between the two (Maradana et al, 2017).

Collectively, these studies document a positive effect of innovation on economic growth. And since a central bank digital currency is a type of innovation, CBDC should have a positive effect on economic growth. This is because a CBDC is the sort of innovation that would foster more innovations and a long-term higher trend growth as in the Romer growth model, and arguably, CBDC as a financial innovation tool may have a different effect on the economy from CBDC as a technological innovation tool. Also, there may be a need to separate the transitionary impact of CBDC issuance from the long-term impact of having a CBDC circulating in the economy. Considering the fact that the eNaira CBDC has only being issued for a short period of time, it may be difficult to determine its long-term impact on growth at this time. We now proceed to review the existing studies that link CBDC to economic growth and inflation.

2.3. Potential effect of CBDC on economic growth and inflation

Few studies in the literature attempt to link CBDC to economic growth or inflation. For instance, Auer et al (2022) emphasize that CBDCs may support economic growth by ensuring faster, cheaper and transparent cross-border payment services that would deliver widespread benefits for citizens, improve welfare and support economic growth. Clemens et al (2021) argue that CBDC can improve economic growth because it would ensure the continued provision of public money, improve the functioning of the payment system, support economic digitalization and lead to less reliance on dominant foreign-based payment providers, thereby saving national resources which could be channeled towards economic growth. Ozili (2022b) shows that CBDC can stimulate growth in the circular economy in three ways: (i) by making CBDC accessible to all merchants, (ii) by incorporating design features into the CBDC that support circular economy goals, and (iii) by

offering a better payment option for circular economy financial transactions. Cukierman (2019) argues that CBDCs will allow central banks to become actively involved in allocating credit to the economy, thereby supporting economic growth. However, Cukierman (2019) points out that such move by central banks is undesirable since it is disadvantageous to private banks who are better equipped to allocate credit towards growth in the economy. Cukierman (2019) further argues that central banks should limit their activities to the area in which they have a comparative advantage, and they should not participate in the allocation of credit which private banks are able to do better since private banks have a comparative advantage in evaluating the risk involved in granting loans for various projects and to individual and corporate borrowers.

Regarding inflation, Minesso et al (2022) suggest that CBDC is a potent monetary policy tool that could be used to dampen inflation risk especially when the CBDC is interest-bearing. Bhowmik (2022) and Keister and Sanches (2023) argue that interest-bearing CBDC can help to control inflation by increasing deposit rates on CBDC which will mop up the excess liquidity in the banking sector, thereby reducing money supply and inflation. Beniak (2019) argues that when both cash and CBDC are available to the general public, monetary policy will be more constrained and ineffective in controlling inflation; as a result, it will yield higher inflation and lower welfare. Beniak (2019) further argues that the only way for monetary policy to work effectively to control inflation is if the CBDC is interest-bearing, and a much better outcome will be achieved if CBDC is the only legal tender. Chen and Siklos (2022) also argue that CBDC will not produce higher inflation; rather, the introduction of a CBDC, and at the same time eliminating large denominations of paper currency, will help to keep inflation under control. Overall, the literature suggests that an interest-bearing CBDC can reduce inflation.

However, the CBDC in Nigeria is non-interest bearing and there is no empirical evidence on the effect of non-interest bearing CBDC on inflation or economic growth. This paper extends the literature by examining the effect of CBDC issuance on economic growth and inflation in a non-interest bearing CBDC environment, focusing on the Nigeria context.

3. Research methodology

Economic growth and inflation data for Nigeria were obtained from the National Bureau of Statistics of Nigeria. For the economic growth analysis, quarterly real GDP growth data for Nigeria were obtained for the period 2019 to 2022. We omitted the year 2020 to isolate the adverse effect of the COVID-19 pandemic on real GDP growth in 2020.

The economic growth data were divided into the pre-CBDC period and the CBDC period to enable comparison using a dummy variable. The Nigeria eNaira CBDC was launched in October 2021 which is in the third quarter of 2021. A quarterly binary variable "CBDC1" was constructed to capture the CBDC period (i.e., a value of 1 is assigned to 2021-Q4, 2022-Q1 and 2022Q2, and zero otherwise, reflecting the CBDC period in Nigeria). In the analysis, we also divided the real GDP growth variable into its oil and non-oil components because Nigeria is a major oil producing country and Nigeria's GDP is usually reported in terms of oil GDP and non-oil GDP. Thereafter, we assess how the non-oil components affect real GDP growth in the CBDC period. For the inflation analysis, monthly (year-on-year) data were obtained from October 2020 to September 2022. The inflation data were divided into the pre-CBDC period and the CBDC period to enable comparison using a dummy variable. A monthly binary variable "CBDC2" was constructed to capture the CBDC period (i.e., a value of 1 is assigned to months from October 2021 to September 2022 and zero otherwise, representing the CBDC period in Nigeria). See table 1 for variable description.

Table 1. Variable description and source

Variable	Sector	Source
GDPR	Real GDP growth rate measuring economic growth	National Bureau of Statistics (NBS)
INFH	Headline or annual inflation (year-on-year) (%)	NBS
INFF	Food inflation (year-on-year) (%)	NBS
INFC	Core inflation (year-on-year) (%)	NBS
INFM	Monthly inflation (month-on-month) (%)	NBS

CBDC1	A quarterly binary variable that takes the value 1 from the quarter of CBDC issuance and zero otherwise, representing the CBDC period.	Authors' construct
CBDC2	A monthly binary variable that takes the value 1 from the month of CBDC issuance and zero otherwise, representing the CBDC period.	Authors' construct
ICT	Information and communication sector (ICT) contribution to real GDP (%)	NBS
FIN	Finance and insurance sector contribution to real GDP (%)	NBS
AGR	Agriculture sector contribution to real GDP (%)	NBS
MAN	Manufacturing sector contribution to real GDP (%)	NBS
EN	Energy contribution sector to real GDP comprising of electricity, gas, steam and air conditioning supply (%)	NBS
PR	Professional, scientific, and technical services contribution to real GDP (%)	NBS

Source: Nigeria Bureau of Statistics (NBS)

4. Empirical Result

The results were derived using descriptive statistics, correlation analysis, two-stage least squares regression and the granger causality methods. The descriptive statistics are reported to show the behaviour of the data. Correlation analysis is used to show the correlation between the variables. Thereafter, the two-stage least squares regression method is used to estimate the effect of CBDC issuance on economic growth and inflation in Nigeria. The two-stage least squares regression method controls for potential endogeneity issues in the data. The granger causality method is used to determine the directional causality between CBDC issuance, economic growth, and inflation.

4.1. Economic growth analysis

Nigeria operates both an oil economy and a non-oil economy. This classification is reflected in the official real GDP growth statistics of the NBS. It divides Nigeria's real GDP growth into oil GDP

growth rate and non-oil GDP growth rate. We take this peculiarity into account in our analysis of the effect of CBDC issuance on economic growth in Nigeria.

4.1.1. Comparison of mean

We begin the analysis by comparing the mean of real GDP growth in the quarters before CBDC issuance and the quarters after CBDC issuance. We omit the year 2020 from the analysis because of the adverse effect of the COVID-19 pandemic on real GDP growth and so that it will not contaminate the empirical results.

As shown in table 2, the mean real GDP growth in the pre-CBDC period (from the first quarter of 2019 to the fourth quarter of 2019) was 2.26 percent. We also use an alternative pre-CBDC period (from the first quarter of 2021 to the third quarter of 2021). During this period, the average real GDP growth was 3.18 percent. Meanwhile, the average real GDP growth during the CBDC period was 3.54 percent which is higher than the real GDP growth in the two pre-CBDC periods. This suggests that real GDP growth was relatively higher in the CBDC period than in the pre-CBDC period.

Table 3 reports the pre-CBDC and CBDC period means for oil GDP growth and non-oil GDP growth. It shows that the average non-oil GDP growth was 5.19 percent in the CBDC period which is higher than the average pre-CBDC non-oil GDP growth of 2.06 and 3.91 percent respectively. This indicates that non-oil GDP growth was higher after CBDC issuance in Nigeria. Similarly, the average non-oil sector contribution to real GDP was 92.85 percent in the CBDC period which is higher than the average non-oil sector contribution to real GDP in the pre-CBDC period which was 91.31 and 91.95 percent, respectively. This indicates that the non-oil sector's contribution to real GDP was higher after CBDC issuance in Nigeria. In contrast, the average oil sector contribution to real GDP was 6.73 percent in the CBDC period which is lower than the pre-CBDC average oil sector contribution to real GDP of 8.76 and 8.05 percent, respectively. This indicates that oil sector contribution to real GDP did not improve after CBDC issuance in Nigeria.

Table 4 reports the pre-CBDC and CBDC means for the sectors contributing to non-oil GDP in Nigeria. It shows that, on average, the agricultural sector, the financial sector, and the professional services sector had a higher contribution to non-oil GDP after CBDC issuance.

Meanwhile, the energy sector, the ICT sector and the manufacturing sector have a lower contribution to non-oil GDP after CBDC issuance.

Table 2. Comparing means of real GDP growth in the pre-CBDC and the CBDC quarters

	Mean (Pre-CBDC period)	*Mean Pre-CBDC period*	*Mean (CBDC period)*
	(2019-Q1 to 2019-Q4)	(2021-Q1 to 2021-Q3)	(2021-Q4 to 2022-Q2)
Average real GDP growth (%)	2.26	3.18	3.54

*Year 2020 quarters were excluded from the analysis to avoid the adverse effects of the pandemic on the real GDP of Nigeria. Including the 2020 quarters would bias the mean comparison.

Source: Nigeria Bureau of Statistics (NBS)

Table 3. Comparing means of oil vs non-oil contribution to real GDP growth in the pre-CBDC and CBDC quarters

	Mean (Pre-CBDC period)	*Mean Pre-CBDC period*	*Mean (CBDC period)*
	(2019-Q1 to 2019-Q4)	(2021-Q1 to 2021-Q3)	(2021-Q4 to 2022-Q2)
Oil GDP growth (%) in real terms	3.9	-8.53	-8.06
Non-oil GDP sector (%) in real terms	2.06	3.91	5.19
Oil sector contribution to real GDP (%)	8.76	8.05	6.73
Non-oil sector contribution to real GDP (%)	91.31	91.95	92.85

*Year 2020 quarters were excluded from the analysis to avoid the adverse effects of the pandemic on the GDP of Nigeria. Including the 2020 quarters would bias mean comparison.

Source: Nigeria Bureau of Statistics (NBS)

Table 4. Comparing means of the sectors contributing to non-oil GDP

	Mean (Pre-CBDC period)	*Mean Pre-CBDC period*	*Mean (CBDC period)*
Sector	(2019-Q1 to 2019-Q4)	(2021-Q1 to 2021-Q3)	(2021-Q4 to 2022-Q2)
Information and Communication (ICT) (%)	9.22	7.23	7.88
Financial and Insurance (FIN) (%)	2.85	6.76	21.95
Agriculture (AGR) (%)	2.39	1.60	2.65
Manufacturing (MAN) (%)	0.76	3.73	3.72
Energy (EN) (%)	-2.68	33.73	-6.63
Professional, scientific, and technical services (PR) (%)	0.22	-0.48	1.77

*Year 2020 quarters were excluded from the analysis to avoid the adverse effects of the pandemic on the GDP of Nigeria. Including the 2020 quarters would bias mean comparison.

Source: Nigeria Bureau of Statistics (NBS)

4.1.2. Correlation analysis

The Pearson correlation analysis is reported in table 5. The correlation of interest in table 5 is the correlation of the CBDC1 variable with all other growth variables. The correlation result shows that the CBDC1 variable is positively correlated with the GDPR variable. This indicates that the CBDC period is associated with greater economic growth. Also, the CBDC1 variable is positive and highly correlated with the FIN variable. This indicates that the CBDC period is associated with a higher contribution of the financial services sector to non-oil GDP. The CBDC1 variable is also positively correlated with the PR and AGR variable. This indicates that the CBDC period is associated with higher contribution of the agricultural sector and the professional services sector to non-oil GDP but to a lesser degree. In contrast, the CBDC period is associated with reduced contribution of the energy sector and ICT sector to non-oil GDP. The p-value of all the correlation

coefficients are insignificant; therefore, we did not report the p-value of the correlation coefficients.

Table 5. Pearson correlation of CBDC and economic growth variables

Variable	GDPR	CBDC1	AGR	FIN	EN	ICT	PR
GDPR	1.000						
CBDC1	0.334	1.000					
AGR	-0.269	0.334	1.000				
FIN	0.418	0.645	0.095	1.000			
EN	0.501	-0.353	-0.361	-0.381	1.000		
ICT	-0.242	-0.104	0.165	0.071	-0.458	1.000	
PR	0.661	0.444	0.0156	0.365	0.106	0.072	1.000

Source: Author computation

4.1.3. Effect of CBDC period on economic growth: 2SLS regression analysis

The two-stage least squares regression estimation is reported in table 6. The CBDC1 coefficient is positive and statistically significant. This indicates that the issuance of the eNaira CBDC had a significant positive effect on real GDP growth in Nigeria. This result implies that real GDP growth improved significantly in the quarters after CBDC was issued in Nigeria. Therefore, the authorities in Nigeria should encourage the continued use of the eNaira CBDC in Nigeria due to its positive effect on real GDP growth. This finding supports the literature that show evidence of a positive effect of digital innovations on economic growth such as Solomon and van Klyton (2020) and Liu et al (2021). Also, it was observed that the financial services sector, the energy sector and the information and communication technology sector have a significant positive effect on real GDP growth in Nigeria as shown by the significant and positive sign on the FIN, EN and ICT coefficients in table 6. The manufacturing sector had a negative effect on real GDP growth during the period examined.

We also analyze the effect of the CBDC period on the sectors that contribute to Nigeria's non-oil GDP. Table 7 reports the result. The result shows that the CBDC1 variable has a significant positive effect on the manufacturing sector, the agricultural sector, and the financial services sector in Nigeria. In contrast, the CBDC1 variable has an insignificant effect on the energy sector, the ICT and professional services sector. The implication of the result is that the CBDC issuance supports growth in the manufacturing, the financial services, and the agricultural sector in Nigeria. Therefore, the authorities in Nigeria should encourage the use of the eNaira CBDC in the agricultural sector, the manufacturing sector, and the financial sector to stimulate growth in these sectors toward greater economic growth.

Table 6. CBDC period as a determinant of economic growth
Two-Stage Least Squares (2SLS) regression

	Dependent variable: GDPR
Independent Variable	Coefficient (t-statistic)
CBDC1	2.596*
	(3.16)
MAN	-0.631*
	(-3.10)
AGR	-0.408
	(-1.59)
FIN	0.089**
	(3.89)
EN	0.076***
	(6.29)
ICT	0.402**
	(4.76)
PR	-0.147
	(-1.03)
R-Square	0.939
Adjusted R-square	0.82
J-statistic	0.01
P(J-statistic)	0.92

CBDC1 = A quarterly binary variable representing the quarters when CBDC was adopted. MAN = real growth in manufacturing

services. AGR = real growth in agricultural services. FIN = real growth in financial and insurance services. EN = real growth in energy services. ICT = real growth in information and communication technology. PR= real growth in professional services

Source: Author computation

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Table 7. Effect of CBDC period on the contributors to non-oil real GDP growth: Two-Stage Least Square (2SLS) regression

	MAN	AGR	FIN	EN	ICT	PR
Independent Variable	Coefficient (t-statistic)	Coefficient (t-statistic)	Coefficient (t-statistic)	Coefficient (t-statistic)	Coefficient (t-statistic)	Coefficient (t-statistic)
CBDC1	3.723** (2.66)	2.647** (2.31)	21.953*** (3.54)	-6.633 (-0.42)	7.883 (1.77)	1.770 (1.69)
J-statistic	4.904	7.48	1.248	1.548	8.25	0.015
P(J-statistic)	0.03	0.01	0.26	0.21	0.00	0.90

***, ** denote statistical significance at the 1% and 5% levels.

Source: Author computation

4.1.4. Granger causality test for CBDC period and economic growth

We also perform granger causality tests. An augmented Dickey-Fuller test was first conducted to determine whether each of the time series data has a unit root process. The result in table 8 shows that the CBDC1 and GDPR time series data have a unit root and are therefore non-stationary. This means that the CBDC1 and GDPR time series data will be first-differenced [i.e., d(GDPR) and d(CBDC1)] before performing the granger causality test.

The granger causality test result is reported in table 9. The result shows that there is no granger causality running from d(CBDC1) to d(GDPR) as the p-value is 0.727 which is greater than 0.05. Therefore, there is no causality between the CBDC period and economic growth. On the other

hand, there is a one-way granger causality running from d(GDPR) to d(CBDC1) as the p-value is 0.026 which is less than 0.05 in table 9. This indicates that real GDP growth causes the CBDC period. However, this result is not meaningful. Overall, the result suggests that the CBDC period does not granger cause economic growth.

Table 8. Augmented Dickey-Fuller test result for CBDC period and economic growth variables

Variable	T-Statistic	P-value	Remark
GDPR	-2.471	0.152	Has a unit root. GDPR is non-stationary. Should be first-differenced i.e. d(GDPR)
CBDC1	-0.509	0.846	Has a unit root. CBDC1 is non-stationary. Should be first-differenced i.e. d(CBDC1)

*** represents statistical significance at the 1% level

Source: Author computation

Table 9. Pairwise Granger Causality Tests

Period: October 2020 to September 2022

Lags: 2

Observation: 7

Null hypothesis	F-statistic	P-value
d(GDPR) does not granger cause d(CBDC1)	37.94**	0.026
d(CBDC1) does not granger cause d(GDPR)	0.376	0.727

*** represents statistical significance at the 1% level

Source: Author computation

4.2. Inflation analysis

We focus the analysis on four types of inflation in Nigeria which are headline inflation rate (INFH), food inflation rate (INFF), core inflation rate (INFC) and the monthly inflation rate or month-on-month inflation (INFM). The sample period is 24 months (12 months before CBDC issuance and 12 months after CBDC issuance).

4.2.1. Comparison of mean

Table 10 reports the pre-CBDC and CBDC means. It shows that the average headline inflation rate for the CBDC period was higher than the average headline inflation rate in the pre-CBDC period. Similarly, the average food inflation rate, core inflation rate and monthly inflation rate for the CBDC period are all higher than their pre-CBDC values. This indicates that inflation was much higher in the months after CBDC issuance. The inflation rates were also higher in November and December 2021 as well as in January of 2022 prior to the Russia-Ukraine war. The implication is that inflation did not decrease after the CBDC was issued in Nigeria.

Table 10. Comparing means of the pre-CBDC and CBDC period

	Mean (Pre-CBDC period)	*Mean (CBDC period)*
	(October 2020 to September 2021)	(October 2021 to September 2022)
Headline inflation rate (%)	16.81	17.36
Food inflation rate (%)	20.69	19.27
Core inflation (%)	12.53	14.89
Monthly inflation (%)	1.29	1.59

Source: Author computation

4.2.2. Correlation analysis

The Pearson correlation analysis is reported in table 11. The correlation of interest in the analysis is the correlation of the CBDC2 variable and the four inflation variables. The result shows that the CBDC2 variable is positive and highly correlated with the INFC variable at 0.705. This indicates that the CBDC period is associated with a much higher core inflation in Nigeria. The CBDC2 variable is also positively correlated with the INFH and INFM variables. This indicates that the CBDC period is correlated with higher headline inflation and higher monthly inflation but to a lesser degree. In contrast, the CBDC2 variable is negative and correlated with the INFF variable at -0.331. This suggests that the CBDC period is associated with reduced food inflation in Nigeria. The p-value of all correlation coefficients in insignificant; therefore, we did not report the p-value of the correlation coefficients.

Table 11. Pearson correlation of CBDC period and inflation variables

Variables	INFH	INFF	INFC	INFM	CBDC2
INFH	1.000				
INFF	0.859	1.000			
INFC	0.752	0.322	1.000		
INFM	0.046	-0.195	0.245	1.000	
CBDC2	0.167	-0.331	0.705	0.468	1.000

Source: Author computation

4.2.3. Effect of CBDC period on inflation: 2SLS regression analysis

We also analyze the effect of the CBDC period on the four types of inflation: headline inflation (INFH), food inflation (INFF), core inflation (INFC) and monthly inflation (INFM). The two-stage least square regression estimation is reported in table 12. The INFH, INFC, INFF and INFM coefficients are positive and significant at the 1% level. This indicates that the CBDC period has a significant positive effect on the four types of inflation and suggests that the four types of inflation increased after CBDC was issued. The significant positive effect implies that the CBDC period did not reduce inflation during the period examined. A possible explanation for this result could be that, despite issuing the eNaira CBDC, the CBDC was not designed to control inflation; rather, the CBDC was designed to achieve other objectives such as to achieve payment efficiency and financial inclusion objectives.

Table 12. Effect of CBDC period on the four inflation components: Two-stage Least Square 2SLS regression

	INFH	INFC	INFF	INFM
Independent Variable	Coefficient (t-statistic)	Coefficient (t-statistic)	Coefficient (t-statistic)	Coefficient (t-statistic)
CBDC2	17.955*** (4.91)	14.887*** (5.65)	19.276*** (4.43)	1.586*** (5.64)
J-statistic	22.58	22.59	22.57	21.03
P(J-statistic)	0.00	0.00	0.02	0.00

***, ** denote statistical significance at the 1% and 5% levels.

Source: Author computation

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4.2.4. Granger causality test

We also perform granger causality tests. An augmented Dickey-Fuller test was first conducted to determine whether each of the time series data has a unit root process. The result in table 13 shows that the CBDC2, INFH, INFC and INFM time series data have a unit root and is therefore non-stationary. Only the INFF time series data are stationary. As a result, the CBDC2, INFH, INFC and INFM time series data are first-differenced before performing the granger causality test. The granger causality test result is reported in table 14. The result shows that there is one-way granger causality running from d(CBDC2) to d(INFM) as the p-value is 0.004 which is less than 0.05. This indicates that there is uni-directional granger causality between the CBDC period and monthly inflation (INFM). This suggests that the CBDC period causes a significant change in monthly inflation. On the other hand, there is no granger causality running from d(CBDC2) to d(INFH), d(INFF) and d(INFC) variables.

Table 13. Augmented Dickey-Fuller test result for the CBDC period and inflation variables

Symbol	T-Statistic	P-value	Remark
INFH	-2.511	0.127	Has a unit root. INFH is non-stationary. Should be be first-differenced i.e. d(INFH)
INFF	-4.277***	0.004	Does not have unit root. INFF is stationary.
INFC	0.332	0.974	Has a unit root. INFC is non-stationary. Should be first-differenced i.e. d(INFC)
INFM	-1.852	0.348	Has a unit root. INFM is non-stationary. Should be first-differenced i.e. d(INFM)
CBDC2	-0.956	0.751	Has a unit root. CBDC2 is non-stationary. Should be first-differenced i.e. d(CBDC2)

*** represents significance at the 1% level

Source: Author computation

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Table 14. Pairwise Granger Causality Tests

Monthly Period: October 2020 to September 2022

Lags: 2

Observation: 21

Null hypothesis:	F-statistic	P-value
d(INFH) does not granger cause d(CBDC2)	1.104	0.356
d(CBDC2) does not granger cause d(INFH)	2.186	0.145
d(INFC) does not granger cause d(CBDC2)	1.950	0.175
d(CBDC2) does not granger cause d(INFC)	0.491	0.619
INFF does not granger cause d(CBDC2)	0.970	0.400
d(CBDC2) does not granger cause INFF	1.895	0.183
d(INFM) does not granger cause d(CBDC2)	0.191	0.828
d(CBDC2) does not granger cause d(INFM)	8.023***	0.004

*** represents statistical significance at the 1% level

Source: Author computation

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4.3. Further analysis: Cross country analysis

In this section, we compare Nigeria's economic benefit from CBDC with the economic performance of similar countries that have not yet issued a CBDC particularly Malaysia, Brazil, and Argentina.

4.3.1. Comparison of means

In this section, we compare the mean of real GDP growth of Nigeria with the mean of real GDP growth of Malaysia, Argentina, and Brazil. As shown in table 15, the mean real GDP growth is lowest in Nigeria compared to Malaysia, Argentina, and Brazil. This suggests that the gains of CBDC for economic growth in one country may not be comparable to the economic growth of other countries. We also compare the mean of the annual inflation rate of Nigeria with the mean of annual inflation rate of Malaysia, Argentina, and Brazil. As shown in table 15, the mean inflation rate remains high in Nigeria and is similar to the inflation rate in Brazil.

Table 15. Comparing the means of Nigeria's real GDP growth and inflation rate with similar countries that have not adopted CBDC

	Nigeria	*Malaysia*	*Brazil*	*Argentina*
Average Real GDP growth (%) (from 2021-Q1 to 2022-Q2)	3.36	4.73	4.45	9.17
Annual Inflation rate (%) (from November 2020 to September 2022)	17.48	3.21	61.4	10.31

Source: Author computation

4.3.2. Correlation analysis

Table 16 presents the correlation of Nigeria's economic growth with the economic growth data of three countries with similar economic characteristics, namely Malaysia, Brazil, and Argentina. The correlation shows that Nigeria's GDP growth in the CBDC period is highly correlated with the GDP growth of Brazil and Argentina which have not adopted a CBDC. The result suggests that some countries that did not issue a CBDC (e.g., Malaysia, Argentina and Brazil) also witness positive economic growth similar to the positive economic growth witnessed in Nigeria after CBDC issuance.

Meanwhile, in table 17, the correlation shows that Nigeria's annual inflation rate in the CBDC period is highly correlated with the inflation rate of Malaysia and Argentina which have not adopted a CBDC. An inverse correlation is observed between Brazil's inflation rate and Nigeria's inflation rate after CBDC adoption. The result suggests that some countries that did not issue a CBDC (e.g., Malaysia and Argentina) also witness high inflation similar to the high inflation witnessed in Nigeria after CBDC issuance and vice versa.

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Table 16. Pearson correlation of

GDP growth of Nigeria, Malaysia, Brazil and Argentina

Countries	Nigeria	Malaysia	Brazil	Argentina
Nigeria	1.000			
Malaysia	0.492	1.000		
Brazil	0.641	0.712	1.000	
Argentina	0.844	0.522	0.910	1.000

Source: Author computation

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Table 17. Pearson correlation of inflation rate Nigeria, Malaysia, Brazil and Argentina

Countries	Nigeria	Malaysia	Argentina	Brazil
Nigeria	1.000			
Malaysia	0.849	1.000		
Argentina	0.984	0.844	1.000	
Brazil	-0.567	-0.704	-0.661	1.000

Source: Author computation

4.3.3. Further regression results

In this section, we estimate the effect of CBDC issuance on economic growth using panel sample data which consists of Nigeria, Malaysia, Argentina, and Brazil over the 2021-Q4 to 2022-Q2 period. In the first instance, we pool the four countries together and use a binary variable to separate Nigeria's GDP growth from the GDP growth of the remaining three countries. We then introduce the CBDC3 binary variable that equals one for Nigeria's GDP growth from 2021-Q4 to 2022-Q2 and equal zero for Malaysia, Brazil, and Argentina's GDP growth rate during the same period. We then estimate the effect of CBDC3 on the GDPR variable and the result is reported in column 1 of table 18. We undertake another subsample analysis in which we pool only Nigeria and Malaysia together. We then introduce the CBDC4 binary variable that equals one for Nigeria's GDP growth from 2021-Q4 to 2022-Q2 and equal zero for Malaysia's GDP growth rate during the same period. We then estimate the effect of CBDC4 on the GDPR variable and the result is reported in column 2 of table 18. We undertake a further analysis in which we pool only Nigeria and Brazil together. We then introduce the CBDC5 binary variable that equals one for Nigeria's GDP growth from 2021-Q4 to 2022-Q2 and equal zero for Brazil's GDP growth rate during the same period. We then estimate the effect of CBDC5 on the GDPR variable and the result is reported in column 3 of table 18. Finally, we undertake another subsample analysis in which we pool only Nigeria and Argentina together. We then introduce the CBDC6 binary variable that equals one for Nigeria's GDP growth from 2021-Q4 to 2022-Q2 and equal zero for Argentina's

GDP growth rate during the same period. We then estimate the effect of CBDC6 on the GDPR variable and the result is reported in column 4 of table 18.

The 2SLS estimation results for the full sample in column 1 of table 18 show that the CBDC period has a significant positive effect on GDP growth in Nigeria relative to other countries. Also, the result in column 2 shows that the CBDC period has a significant positive effect on GDP growth in Nigeria relative to Malaysia. The result in column 3 shows that the CBDC period has a significant positive effect on GDP growth in Nigeria relative to Brazil. The result in column 4 shows that the CBDC period has a significant positive effect on GDP growth in Nigeria relative to Argentina.

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Table 18. Panel 2SLS regression estimation:
The effect of CBDC period on economic growth

	Full sample	Malaysia	Brazil	Argentina
	(1)	(2)	(3)	(4)
Independent Variable	Coefficient (t-statistic)	Coefficient (t-statistic)	Coefficient (t-statistic)	Coefficient (t-statistic)
CBDC3	21.712** (2.23)			
CBDC4		8.095* (2.01)		
CBDC5			7.812** (2.47)	
CBDC6				12.528* (2.12)
J-statistic	7.69	5.87	8.67	9.67
P(J-statistic)	0.13	0.21	0.19	0.23

**, * denote statistical significance at the 5% and 10% levels. CBDC3 = binary variable equals one for Nigeria's GDP growth rate from 2021-

Q4 to 2022-Q2 and equal zero for Malaysia, Brazil and Argentina's GDP growth rate during the same period. CBDC4 = binary variable equals one for Nigeria's GDP growth rate from 2021-Q4 to 2022-Q2 and equal zero for Malaysia's GDP growth rate during the same period. CBDC5 = binary variable equals one for Nigeria's GDP growth rate from 2021-Q4 to 2022-Q2 and equal zero for Brazil's GDP growth rate during the same period. CBDC6 = binary variable equals one for Nigeria's GDP growth rate from 2021-Q4 to 2022-Q2 and equal zero for Argentina's GDP growth rate during the same period.

Source: Author computation

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Regarding the inflation rate aspect, we estimate the effect of CBDC issuance on inflation using panel sample data which consists of Nigeria, Malaysia, Argentina, and Brazil over the November 2021 to September 2022 period. In the first instance, we pool the four countries together and use a binary variable to separate Nigeria's inflation rate from the inflation rate of the remaining three countries. We then introduce the CBDC7 binary variable that equals one for Nigeria's inflation rate from November 2021 to September 2022 and equal zero for Malaysia, Brazil, and Argentina's inflation rate during the same period. We then estimate the effect of CBDC7 on the INF variable and the result is reported in column 1 of table 19. We undertake another subsample analysis in which we pool only Nigeria and Malaysia together. We then introduce the CBDC8 binary variable that equals one for Nigeria's inflation rate from November 2021 to September 2022 and equal zero for Malaysia's inflation rate during the same period. We then estimate the effect of CBDC8 on the INF variable and the result is reported in column 2 of table 19. We undertake a further analysis in which we pool only Nigeria and Brazil together. We then introduce the CBDC9 binary variable that equals one for Nigeria's inflation rate from November 2021 to September 2022 and equal zero for Brazil's inflation rate during the same period. We then estimate the effect of CBDC9 on the INF variable and the result is reported in column 3 of table 19. Finally, we undertake another subsample analysis in which we pool only Nigeria and Argentina together. We then introduce the CBDC10 binary variable that equals one for Nigeria's inflation rate from November 2021 to September 2022 and equal zero for Argentina's inflation

rate during the same period. We then estimate the effect of CBDC10 on the INF variable and the result is reported in column 4 of table 19. The 2SLS estimation result for the full sample in column 1 of table 19 show that CBDC issuance has a significant positive effect on the inflation rate in Nigeria relative to other countries. Also, the result in column 2 shows that CBDC issuance has a significant positive effect on the inflation rate in Nigeria relative to Malaysia. The result in column 3 shows that CBDC issuance has a significant positive effect on inflation rate in Nigeria relative to Brazil. The result in column 4 shows that CBDC issuance has a significant positive effect on inflation rate in Nigeria relative to Argentina.

Table 19. Panel 2SLS regression estimation: The effect of CBDC period on the inflation rate

	Full sample	Malaysia	Brazil	Argentina
	(1)	(2)	(3)	(4)
Independent Variable	Coefficient (t-statistic)	Coefficient (t-statistic)	Coefficient (t-statistic)	Coefficient (t-statistic)
CBDC7	92.523*** (3.09)			
CBDC8		20.692* (13.31)		
CBDC9			27.914** (6.05)	
CBDC10				78.883* (2.92)
J-statistic	6.16	7.02	4.33	2.35
P(J-statistic)	0.25	0.87	0.34	0.01

**, * denote statistical significance at the 5% and 10% levels. CBDC7 = binary variable equals one for Nigeria's GDP growth rate from 2021-Q4 to 2022-Q2 and equal zero for Malaysia, Brazil and Argentina's GDP growth rate during the same period. CBDC8 = binary variable equals one for Nigeria's GDP growth rate from 2021-Q4 to 2022-Q2 and equal zero for Malaysia's GDP growth rate during the same period. CBDC9 = binary variable equals one for Nigeria's GDP growth rate from 2021-Q4 to 2022-Q2 and equal zero for Brazil's GDP growth rate during the same period. CBDC10 = binary variable equals one for

Nigeria's GDP growth rate from 2021-Q4 to 2022-Q2 and equal zero for Argentina's GDP growth rate during the same period.

Source: Author computation

5. Conclusion

This article examined the effect of CBDC issuance on economic growth and inflation in Nigeria using quarterly data from 2019 to 2022 and after isolating the 2020 period. The data were analyzed using descriptive statistics, correlation analysis, two-stage least squares regression and granger causality test methods.

The results revealed that inflation significantly increased in the CBDC period, implying that CBDC issuance did not decrease the rate of inflation in Nigeria. Also, GDP growth rate significantly increased in the CBDC period, implying that CBDC issuance improved economic growth in Nigeria. The financial sector, the agricultural sector and the manufacturing sectors witnessed much stronger contribution to GDP after CBDC issuance. There is one-way granger causality between the CBDC period and monthly inflation, implying that the CBDC period caused a significant change in monthly inflation in Nigeria.

The policy implication of the findings is that issuing a non-interest-bearing central bank digital currency presents a significant tradeoff for the central bank of Nigeria. This means that the central bank digital currency may have been designed to have features that support economic growth, but such features are ineffective in reducing inflation. This suggests that a growth-enhancing non-interest bearing CBDC can lead to higher inflation. Conversely, a CBDC that is designed to have features to control inflation may not be able to spur growth in the economy.

Given this tradeoff, policymakers in Nigeria must decide on which economic objective is paramount at a given period and the central bank digital currency should be designed to have features that help to achieve that objective. Once the objective has been achieved, the central bank digital currency can be redesigned with the features that are needed to achieve the next important objective.

The findings that a non-interest-bearing central bank digital currency improves economic growth but increases inflation in Nigeria suggests that CBDC innovation may not be able to solve the twin economic problem of "controlling inflation which stifles economic growth" and "stimulating economic growth which leads to rising inflation". Therefore, the central bank should use CBDC alongside other monetary policy tools at their disposal to control inflation while stimulating growth in the economy.

The study has one limitation. The study covers only a short period of time because CBDC is a recent innovation and there isn't much empirical data available about CBDC.

Future studies can extend the analysis in the study by exploring the relationship between economic growth and inflation in a CBDC context and using a longer time period when more data becomes available. Future studies can also investigate how CBDC issuance and adoption may affect the rate of unemployment. Future studies can assess how widespread adoption of CBDC would affect bank stability especially when widespread CBDC usage leads to bank disintermediation which also affect bank liquidity. Furthermore, Barrdear and Khumof (2016) show how introducing a CBDC will have an impact on real yields and affects growth and inflation through the usual monetary policy channel if it increases the size of money in circulation. Future studies can investigate how the issuance of the eNaira could affect real yields and affect growth and inflation through the usual monetary policy channel.

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Tables

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