Monetary policy effectiveness in digital era: Egypt case

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2024

Abstract

This research explores the impact of digital transformation on the effectiveness of monetary policy in Egypt, focusing on the growing influence of electronic payments and fintech innovations. The study addresses how digitalization is reshaping traditional monetary transmission mechanisms, particularly the role of cash, interest rates, and liquidity management. Using an Autoregressive Distributed Lag (ARDL) model, this research analyzes the long- and short-term relationships between variables such as the number of Automated Teller Machines (ATMs), interest rates, GDP per capita, and the exchange rate on inflation, which serves as a proxy for monetary policy effectiveness. The findings indicate that while digital payment systems reduce inflationary pressures in the long term, increased financial digitalization and higher GDP per capita drive-up inflation through demand-pull and cost-push mechanisms. The results underscore the challenges faced by the Central Bank of Egypt in adapting its monetary tools to a rapidly evolving digital financial ecosystem. The study concludes with policy recommendations to enhance regulatory oversight, promote financial inclusion, and integrate digital financial metrics into the central bank's policy framework, ensuring continued economic stability in the digital era.

1. Introduction[1]

The digital revolution has rapidly transformed financial ecosystems across the globe, introducing new challenges and opportunities for monetary policy. With the rise of fintech innovations, electronic payments, and digital currencies, central banks worldwide face an evolving landscape that challenges traditional monetary frameworks. Egypt, like many other emerging economies, is witnessing significant digital transformation, raising critical questions about the continued effectiveness of its monetary policy tools in maintaining macroeconomic stability.[2] As digital financial services expand, the Central Bank of Egypt (CBE) must reassess its strategies for controlling inflation, regulating liquidity, and ensuring economic growth in a digital-first world.[3]

[1] *Keywords: Economic digitization, Financial innovation, Digital currency, Central bank digital currency, Cash in circulation, Crypto currencies, central bank digital currencies (CBDC), Money demand, Money supply, Monetary policy.*
[2] *Chucherd, T., Piyakarnchana, N., Tonghui, T., Shimnoi, A., & Suwanik, S., 2019. Digitalization on financial services and implications for monetary policy in Thailand. Bank of Thailand Conference Paper, pp. 2-5.*
[3] *Elsayed, A. H., & Nasir, M. A., 2022. Central bank digital currencies: An agenda for future research.*

Digitalization alters the very foundation on which traditional monetary policy operates. Historically, the transmission mechanisms of monetary policy relied heavily on cash-based transactions and the central bank's ability to influence interest rates, money supply, and credit.[4] However, with the proliferation of electronic money and mobile payment platforms, the demand for physical currency has declined in many economies.[5] In countries like Thailand, for example, while digital payments have not completely displaced cash, they have begun to shift the demand for money and reduce the effectiveness of monetary control tools.[6] This shift is even more pronounced in economies where digital financial inclusion is rapidly growing, as is the case in Egypt.

In Egypt, the increasing adoption of electronic payment systems and fintech solutions has revolutionized how financial transactions are conducted. The development of digital financial services, such as mobile banking and e-wallets, has significantly increased financial inclusion, particularly among previously unbanked populations. However, this growing digitalization presents a unique challenge for the Central Bank of Egypt in controlling money supply and managing inflation.[7] The experience of countries like Nigeria, where electronic money has a profound impact on monetary policy transmission, highlights the potential implications for Egypt. In Nigeria, the adoption of electronic payment systems contributed to an increase in the velocity of money, making traditional monetary policy tools less effective.[8]

Furthermore, the emergence of central bank digital currencies (CBDCs) represents both an opportunity and a challenge for the future of monetary policy.[9] Several studies have highlighted the potential of CBDCs to enhance monetary policy transmission by providing central banks with direct control over digital money.[10] In Egypt, the issuance of a CBDC could allow the CBE to better regulate the money

[4] Cova, P., Notarpietro, A., Pagano, P., & Pisani, M., 2022. Monetary policy in the open economy with digital currencies. Temi di Discussione, No. 1366, pp. 1-30.
[5] Uzah, C. K., & Odozi, V. C., 2023. Effect of electronic money on the effectiveness of monetary policy in Nigeria. Nigerian Journal of Management Sciences, 24(2b), pp. 140-145
[6] Chucherd, op.cit. p. 2-5.
[7] Assenmacher, K., 2020. Monetary policy implications of digital currencies. SUERF Policy Note, No. 165, pp. 1-9
[8] Enebeli-Uzor, S., & Mukhtar, A., 2024. The effect of electronic money on the effectiveness of monetary policy in Nigeria. Journal of Scientific Research and Reports, 30(6), 459-468
[9] Dionysopoulos, L., Marra, M., & Urquhart, A., 2024. Central bank digital currencies: A critical review. International Review of Financial Analysis, 91, 103031, pp. 1-5
[10] Jiang, S., Qiu, S., & Zhou, H., 2022. Will digital financial development affect the effectiveness of monetary policy in emerging market countries? Economic Research-Ekonomska Istraživanja, 35(1), 3437-3472

supply and counterbalance the proliferation of private digital currencies, such as cryptocurrencies and stablecoins. However, the adoption of CBDCs must be carefully designed to avoid unintended consequences, such as the disintermediation of the banking sector, which could further complicate monetary policy.[11]

This study explores the impact of digital transformation on the effectiveness of Egypt's monetary policy, with a focus on electronic money, fintech innovations, and the potential role of CBDCs. By analyzing empirical evidence from similar economies and drawing parallels to Egypt's experience, this study aims to assess how digitalization reshapes the traditional transmission mechanisms of monetary policy. As Egypt continues its journey towards a more digital financial ecosystem, understanding the interplay between digital finance and monetary policy will be crucial for sustaining economic stability in the years ahead.

2. Research Problem:

The digital transformation of Egypt's financial sector, driven by the adoption of electronic payment systems, fintech innovations, and the potential introduction of central bank digital currencies (CBDCs), is influencing the traditional mechanisms of monetary policy. Historically, Egypt's monetary policy has depended on tools like interest rate adjustments and money supply control to manage inflation and liquidity. However, as digital transactions become more prominent, the demand for physical cash has decreased, potentially affecting the amount of cash in circulation (CIC). This shift raises critical questions about the impact of digitalization on monetary policy, particularly in maintaining its effectiveness in a rapidly evolving financial environment. The central challenge is understanding and quantifying how digitalization influences the amount of cash in circulation and adjusting Egypt's monetary policy framework to ensure economic stability in this new digital landscape.

Research Questions:

1. How does the increasing adoption of digital payment systems and fintech innovations impact the effectiveness of traditional monetary policy tools in Egypt?
2. In what ways has the demand for cash shifted due to digitalization in Egypt, and what are the implications for monetary policy transmission?

[11] *Cova, op. cit. pp. 1-30*

3. How does digital financial inclusion in Egypt affect the relationship between monetary policy and financial stability?
4. To what extent does the shift towards a cashless society influence inflation control and interest rate setting in Egypt?

3. Research Objectives:

1. To assess the impact of digital payment systems and fintech innovations on the effectiveness of traditional monetary policy tools in Egypt.
2. To examine how digitalization has shifted the demand for cash in Egypt and the implications this shift has for monetary policy transmission.
3. To investigate the relationship between digital financial inclusion and the interaction between monetary policy and financial stability in Egypt.
4. To explore the influence of a shift towards a cashless society on inflation control and interest rate setting in Egypt.

4. Motivation and scientific Contribution

The digitalization of Egypt's financial sector challenges traditional monetary policy. As electronic payments and fintech solutions grow, the Central Bank must adapt its tools to manage inflation, liquidity, and growth. Understanding how these technologies impact cash circulation and monetary policy is crucial, especially with the potential introduction of central bank digital currencies (CBDCs). This study contributes to the growing body of knowledge on how digital finance influences monetary policy transmission in emerging markets, with a particular focus on the unique economic landscape of Egypt.

The significance of this research lies in its potential to guide policymakers in adapting to the new realities of a digital economy. By examining the relationship between digital transformation and monetary policy, this study provides valuable insights into how Egypt can maintain control over key economic variables, such as inflation and interest rates, in a rapidly evolving financial ecosystem. Furthermore, this research contributes to global discussions on the implications of digital finance for monetary policy, offering empirical evidence from an emerging market that can inform both regional and international strategies. The study's findings will be critical for shaping future monetary policy frameworks, particularly as countries across the globe explore the introduction of CBDCs and respond to the growing influence of private digital currencies and fintech innovations.

5. Research Hypotheses:

1. The adoption of digital payment systems and fintech innovations significantly reduces the effectiveness of traditional monetary policy tools, such as interest rates and reserve requirements, in Egypt.
2. Digitalization has led to a decline in the demand for cash in Egypt, thereby weakening the transmission mechanism of monetary policy.
3. Private digital currencies and fintech innovations present potential risks to the stability of Egypt's monetary policy framework, leading to challenges in managing inflation and financial stability.

6. Research Methodology

This research is designed to examine the impact of financial digitization on the effectiveness of monetary policy in Egypt, using the inflation rate (INF) as a proxy for monetary policy effectiveness. To achieve this objective, the study will employ a mixed-methods approach, integrating quantitative data analysis with qualitative insights.

Data Collection: The research will gather secondary data from authoritative sources such as the Central Bank of Egypt, the World Bank, the International Monetary Fund, the Egyptian Ministry of Communications and Information Technology, and the Egyptian Cabinet's Information and Decision Support Center. The data will cover various indicators of financial digitization, inflation, and other relevant macroeconomic variables.

Quantitative Analysis: The primary analytical approach will involve the use of econometric models to quantify the relationship between financial digitization and monetary policy effectiveness, with inflation serving as a proxy for this effectiveness. Regression models will be employed to analyze how different dimensions of digitization—such as automated teller machines (ATMs), interest rates (INT), GDP per capita (GDPPC), and exchange rate (ER)—affect inflation in Egypt, and by extension, monetary policy effectiveness.

The proposed econometric model will follow this general form:

$$INF = f(ATM, INT, GDPPC, ER, \ldots)$$

Where:

- **INF**: Inflation rate (proxy for monetary policy effectiveness, dependent variable).
- **ATM**: Number of Automated Teller Machines (proxy for financial digitization).

- **INT**: Interest rates.
- **GDPPC**: Gross Domestic Product per capita.
- **ER**: Exchange rate.

Qualitative Analysis: In addition to the quantitative approach, qualitative analysis will be conducted through the review of policy documents, government reports, and expert commentaries. This will provide context for understanding how digitization initiatives have been implemented in Egypt and their broader implications for monetary policy effectiveness.

Time Frame: The analysis covers the period from 2004 to 2023. This period allows the study to capture the initial phases of economic reforms in Egypt, including financial sector liberalization and the early adoption of digital banking services. The period up to 2023 includes the most recent advancements in financial digitization, ensuring that the analysis is comprehensive and up-to-date.

Expected Outcomes: The study is expected to provide a thorough understanding of how financial digitization, through factors such as ATMs, interest rates, and exchange rate dynamics, influences the effectiveness of Egypt's monetary policy. The findings will offer valuable insights for policymakers to adapt monetary policy tools in response to the growing role of digital finance in the economy.

7. Literature Review

The effectiveness of monetary policy in the digital era is a growing concern for policymakers and economists, especially in developing economies like Egypt. As digital transformation continues to reshape financial systems globally, traditional tools of monetary control are increasingly challenged. Innovations such as electronic payments, automated teller machines (ATMs), mobile banking, and the advent of central bank digital currencies (CBDCs) have introduced new dynamics into how monetary policy is conducted and transmitted. This review examines critical studies that explore the multifaceted impacts of these digital innovations on inflation, exchange rates, and other key macroeconomic indicators in the context of Egypt. By analyzing the existing literature, this review aims to provide a comprehensive understanding of how Egypt's monetary policy might adapt to the demands and opportunities posed by the digital economy.

The potential of digital transformation to enhance monetary policy effectiveness lies in its ability to streamline monetary transmission channels. One of the most promising innovations is the development of central bank digital currencies (CBDCs). Elsayed and Nasir (2022) argued that CBDCs offer central banks greater control over monetary policy by facilitating more direct management of the money supply. They noted that CBDCs could enhance the precision of policy interventions, particularly in digital economies, where traditional cash-based systems are less effective. In this context, the introduction of a CBDC in Egypt could provide the Central Bank with new tools for managing inflation and maintaining monetary stability.[12]

Electronic payments, particularly mobile and point-of-sale (POS) systems, have also been shown to enhance monetary policy transmission by increasing the velocity of money. In Nigeria, research has demonstrated that the proliferation of electronic payment methods significantly improved the Central Bank's ability to influence key economic variables. The study highlighted those digital payments not only boosted financial inclusion but also enhanced the responsiveness of monetary policy to shocks, making it more effective in managing inflation and controlling liquidity.[13]

Another important factor is the role of FinTech in enhancing competition and reducing financial constraints. In China, research by Ren, Song, and Zhu (2024) found that regions with higher levels of FinTech adoption experienced more efficient monetary policy transmission. FinTech innovations allowed for faster and more transparent adjustments to interest rates and inflation, reducing the lag between policy implementation and economic effects. The relevance of this study to Egypt lies in its demonstration of how FinTech can strengthen monetary policy, particularly as Egypt's digital financial ecosystem continues to expand.[14]

Furthermore, CBDCs have been shown to improve macroeconomic stability by offering central banks a new tool for stabilizing the economy during financial crises. Zhou (2024) demonstrated that the issuance of interest-bearing CBDCs could stabilize real exchange rates and current accounts in response to foreign shocks, enhancing the overall transmission of monetary policy. This finding is particularly relevant for Egypt as it considers the role of CBDCs in its monetary framework.[15]

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[12] *Elsayed, A. H., & Nasir, M. A. 2022. Central bank digital currencies: An agenda for future research. Research in International Business and Finance, 62, 101736, pp. 1-5.*
[13] *Uzah, C. K., & Odozi, V. C. 2023. Effect of electronic money on the effectiveness of monetary policy in Nigeria. Nigerian Journal of Management Sciences, 24(2b), pp. 140-145*
[14] *Ren, X., Song, K., & Zhu, K. 2024. Financial technologies and the effectiveness of monetary policy transmission. Pacific-Basin Finance Journal, 86, 102388, pp. 1-3*
[15] *Zhou, C. 2024. Evaluating the effectiveness of monetary policy for retail central bank digital currency. Latin American Journal of Central Banking, 5, 100111, pp. 1-14.*

While digital transformation offers opportunities, it also presents challenges for traditional monetary policy mechanisms. In particular, digital financial development can weaken the transmission of conventional monetary policy. Research conducted by Jiang, Qiu, and Zhou (2022) found that in regions with high digital penetration, traditional tools like interest rate adjustments became less effective. The study highlighted that digital finance introduced complexities in managing inflation and liquidity, a challenge that Egypt may face as its digital financial services sector grows.[16]

E-money and cryptocurrencies also pose risks to traditional monetary policy frameworks. A study using dynamic stochastic general equilibrium (DSGE) models by Luo, Zhou, and Zhou (2021) simulated the effects of e-money on savings, loans, and interest rates, revealing that digital money disrupts interest rate policies. This disruption complicates central banks' ability to control inflation and regulate the money supply, which is a crucial concern for Egypt as e-money usage continues to rise.[17]

Further complicating matters is the rise of digital currencies, such as stablecoins and cryptocurrencies. Assenmacher (2020) found that these currencies could bypass traditional financial systems, weakening the ability of central banks to influence inflation and interest rates. Without proper regulation, these digital currencies could undermine the core mechanisms of monetary policy. For Egypt, where private digital currencies are growing in popularity, this presents a significant challenge to maintaining monetary stability.[18]

The liquidity challenges posed by digital transformation are another source of concern. Research conducted on the relationship between bank digital transformation and liquidity management in Chinese commercial banks found that while digital transformation improved liquidity management, it also exacerbated financial instability in some cases. This increased financial instability could trouble

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[16] *Jiang, S., Qiu, S., & Zhou, H. 2022. Will digital financial development affect the effectiveness of monetary policy in emerging market countries? Economic Research-Ekonomska Istraživanja, 35(1), 3437-3472, pp. 3437-3472*
[17] *Luo, S., Zhou, G., & Zhou, J. 2021. The impact of electronic money on monetary policy: Based on DSGE model simulations. Mathematics, 9(20), 2614, pp. 1-12*
[18] *Assenmacher, K. 2020. Monetary policy implications of digital currencies. SUERF Policy Note, No. 165, pp. 1-9*

the ability of the Central Bank of Egypt to manage liquidity and maintain monetary stability as digital adoption grows.[19]

While some scholars argue that digital transformation enhances or troubles monetary policy, others suggest it may have a neutral effect, at least in the short term. In Thailand, a study found that the growing popularity of e-payment systems did not immediately reduce the demand for cash or disrupt the monetary system. The coexistence of cash and digital payments indicated that digital transformation might not significantly impact monetary policy in the short term, though long-term changes could occur as digital adoption increases. This provides a relevant comparison to Egypt, where digital payments are rising, but cash remains a dominant payment method.[20]

Similarly, Ding and Ding (2024) argued that while digital finance introduces new risks, these risks can be managed through strong macro-prudential policies. Their research in China demonstrated that well-regulated digital finance did not necessarily destabilize monetary policy. For Egypt, this suggests that with proper regulatory oversight, the rise of digital finance may not directly threaten the effectiveness of monetary policy.[21]

The relationship between digital transformation and monetary policy may also depend on the structure of the financial system. For instance, the study by Fiedler, Gern, and Stolzenburg (2019) found that the rise of private digital currencies and CBDCs could increase currency competition, but it may not significantly constrain central banks' ability to manage inflation if they adapt to new regulatory frameworks. In Egypt, this suggests that digital transformation could be integrated into the existing monetary system without fundamentally disrupting its operations.[22]

8. Overview of Egypt’s Monetary Policy: Objectives and Tools

Egypt's monetary policy has undergone significant transformations over the years, shaped by various economic, political, and social factors. The Central Bank of Egypt (CBE) has been at the forefront of these changes, implementing policies

[19] *Hou, X., & Yang, R. 2024. Bank digital transformation and liquidity mismatch: Evidence from China. International Review of Economics & Finance, 92, 581-597, pp. 581-589*
[20] *Chucherd, T., Piyakarnchana, N., Tonghui, T., Shimnoi, A., & Suwanik, S. 2019. Digitalization on financial services and implications for monetary policy in Thailand. Bank of Thailand Conference Paper, pp. 2-5.*
[21] *Ding, H., & Ding, N. 2024. Analysis of the effectiveness of macro-prudential policy regulation in China in the context of digital finance. Technological Forecasting & Social Change, 201, 123195, pp. 1-11.*
[22] *Fiedler, S., Gern, K.-J., & Stolzenburg, U. 2019. The impact of digitalization on the monetary system. Study for the Committee on Economic and Monetary Affairs, European Parliament, PE 642.361, pp. 1-26.*

aimed at stabilizing the economy, controlling inflation, and promoting growth. Understanding the objectives, tools, and historical effectiveness of Egypt's monetary policy is crucial for comprehending its impact on the nation's economic development and financial stability.

The objectives of Egypt's monetary policy are multifaceted, aiming primarily at maintaining price stability, promoting economic growth, ensuring high employment levels, and safeguarding financial stability. Price stability is a crucial goal for the Central Bank of Egypt (CBE), as it helps preserve the purchasing power of the Egyptian pound and fosters economic growth. By targeting a specific inflation rate, the CBE strives to prevent high inflation, which can erode money's value, reduce consumer confidence, and hinder economic planning.[23] For example, the CBE sets inflation targets that guide its policy actions, adjusting its monetary tools to keep inflation within a manageable range.

In addition to price stability, the CBE focuses on promoting sustainable economic growth and high employment. Through its monetary policy, the CBE influences economic activity by managing interest rates and liquidity, thereby stimulating investment and creating job opportunities.[24] During periods of economic slowdown, for instance, the CBE may lower interest rates to encourage borrowing and spending, which in turn boosts economic activity and reduces unemployment.[25]

Financial stability is another key objective of the CBE's monetary policy. The central bank plays a critical role in preventing banking crises and maintaining confidence in the economy by monitoring and regulating financial institutions. This includes implementing macroprudential policies and ensuring that the banking sector is resilient to economic shocks. Regular stress tests and capital adequacy requirements are some of the measures the CBE employs to maintain the health of the financial system.[26]

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[23] Abdullah, A. A., & Hassanien, A. M. (2022). Spillovers of US unconventional monetary policy to emerging markets: Evidence from Egypt. International Journal of Economics and Finance, 14(6), 1-12. pp. 1-3.
[24] Mumtaz, H. (2020). Empirical examination of the role of fintech in monetary policy. Pacific Economic Review, 25(4), 101-123. P. 45.
[25] Enebeli-Uzor, S. E., & Mukhtar, A. (2023). Efficacy of digital finance on financial inclusion: Evidence from the Nigerian banking industry. Journal of Economics, Management and Trade, 29(11), 140-152, p. 144.
[26] Moursi, T. A., El Mossallamy, M., & Zakareya, E. (2007). Effect of some recent changes in Egyptian monetary policy: Measurement and evaluation. Egyptian Center for Economic Studies Working Paper No. 122, pp. 7-9.

To achieve these objectives, the CBE utilizes several monetary policy tools. Interest rate adjustments are the primary tool, with the CBE raising or lowering rates to influence borrowing, spending, and investment. Lower interest rates stimulate economic activity by making loans cheaper, while higher rates help to cool down an overheating economy. The CBE's overnight deposit and lending rates serve as key indicators of its monetary policy stance.[27]

Open market operations are another essential tool, where the CBE buys or sells government securities to regulate the money supply and control inflation. By purchasing securities, the CBE injects liquidity into the economy, whereas selling them withdraws liquidity, thereby influencing short-term interest rates and ensuring adequate financial system liquidity.[28]

Reserve requirements are also crucial in the CBE's toolkit. By setting the minimum reserves that banks must hold against their deposits, the CBE can directly impact the amount of money banks can lend. Adjusting these requirements allows the CBE to either expand or contract the money supply, depending on the economic context.[29] For example, the CBE might increase reserve requirements during periods of economic expansion to prevent excessive lending and potential overheating.

Finally, exchange rate policy is a significant aspect of the CBE's monetary strategy. By managing the value of the Egyptian pound against other currencies, the CBE can influence trade balances, inflation, and foreign investment. For instance, devaluing the pound can make exports more competitive, though it may also lead to higher inflation. Over time, the CBE has shifted from a fixed exchange rate system to a more flexible regime, allowing it to respond more effectively to market conditions.[30]

[27] *Moursi, ibid. pp. 1-3.*

[28] *Bianchi, J., & Bigio, S. (2022). Banks, liquidity management, and monetary policy. Econometrica, 90(1), 391–454, pp. 393-394.*

[29] *Duskobilov, U. (2017). Impact of economic regulation through monetary policy: Impact analysis of monetary policy tools on economic stability in Uzbekistan. International Journal of Innovation and Economic Development, 3(5), 65-69, p. 66.*

[30] *Assenmacher, K., & Beyer, A. (2018). A cointegration model of money and wealth. European Central Bank Working Paper, No. 619, pp. 7-8.*

9. Challenges to Monetary Policy: Key Challenges Faced by the Central Bank of Egypt in Implementing Monetary Policy

The Central Bank of Egypt (CBE) has faced numerous challenges in implementing effective monetary policy due to various economic, political, and structural factors. Understanding these challenges is essential for developing strategies to enhance the effectiveness of monetary policy in Egypt. The implementation of monetary policy is complicated by inflation volatility, exchange rate pressures, fiscal dominance, financial sector stability, technological infrastructure gaps, public trust issues, and government intervention. This section explores these challenges in detail, supported by data and analysis from authoritative sources.

1. Inflation Volatility:

Inflation in Egypt has been highly volatile, making it difficult for the CBE to achieve and maintain price stability. Factors contributing to inflation volatility include fluctuations in global oil prices, exchange rate pressures, and supply chain disruptions. For instance, the inflation rate spiked significantly following the devaluation of the Egyptian pound in 2016, creating challenges for the CBE in stabilizing prices.[31]

[31] *Ghaly, S. B. (2022). Demand-side determinants of inflation in Egypt: A dynamic analysis. SJRBS, 36(3), pp. 44-45.*

Table 1: Inflation Rates in Egypt (2005-2023)

YEAR	INFLATION RATE (%)
2005	11.27061933
2006	4.869396969
2007	7.644526445
2008	9.318969058
2009	18.31683168
2010	11.76349544
2011	11.26518827
2012	10.06492599
2013	7.111729433
2014	9.469719811
2015	10.07021547
2016	10.37049034
2017	13.81360621
2018	29.50660839
2019	14.40146578
2020	9.152799593
2021	5.04493289
2022	5.214049405
2023	13.89566098

Source: World Bank data: Egypt.

The inflation rate in Egypt has shown significant volatility over the past two decades. The high inflation rate in 2008 was driven by global commodity price hikes and local economic conditions. Post-2016 devaluation led to a spike in inflation due to the increased cost of imports. Recent years have seen more stable inflation rates as the CBE's policies have started to take effect.

Inflation volatility poses significant challenges for the CBE. High inflation can erode purchasing power, reduce consumer confidence, and hinder long-term economic planning. The CBE's efforts to stabilize inflation through interest rate adjustments, open market operations, and other monetary policy tools have had mixed results. For instance, during periods of high inflation, the CBE has raised interest rates to curb spending and reduce inflationary pressures. However, this approach can also slow economic growth and increase unemployment, creating a delicate balancing act for policymakers.

2. **Exchange Rate Pressures:**

Managing the exchange rate of the Egyptian pound has been a persistent challenge for the CBE. Exchange rate fluctuations can lead to inflationary pressures and impact the country's trade balance. The shift from a fixed exchange rate regime to a more flexible system has helped manage some pressures, but external factors such as capital flows and geopolitical tensions continue to pose challenges.[32]

[32] *Alabdulwahab, S. Z., & Abou-Zaid, A. S. (2024). Sources of real exchange rate fluctuations in Egypt. Review of Economics and Political Science, 9(1), pp. 40-42.*

Table 2: Exchange Rates (EGP/USD) (2004-2023)

YEAR	EXCHANGE RATE (EGP/USD)
2004	6.196241667
2005	5.778833333
2006	5.733166667
2007	5.635433333
2008	5.4325
2009	5.544553309
2010	5.621942918
2011	5.932827652
2012	6.056058333
2013	6.870325
2014	7.077608561
2015	7.691258333
2016	10.02540079
2017	17.78253352
2018	17.76729042
2019	16.77058184
2020	15.75917292
2021	15.64452728
2022	19.16043974
2023	30.6264137

Source: world bank data: Egypt.

The devaluation of the Egyptian pound in 2016 significantly increased the exchange rate from approximately 10.02 EGP/USD to 17.8 EGP/USD. This devaluation was necessary to address foreign currency shortages but led to inflationary pressures. The exchange rate has since stabilized, but external economic factors continue to influence its fluctuations.

The exchange rate pressures are influenced by various external factors, including global economic conditions, capital flows, and geopolitical events. The CBE has used a combination of foreign exchange interventions and adjustments in monetary policy to manage these pressures. However, the effectiveness of these measures is often limited by external shocks and market perceptions. For instance, the devaluation in 2016, while necessary, led to a sharp increase in inflation and required significant policy adjustments to stabilize the economy.[33]

3. **Fiscal Dominance:**

Fiscal dominance refers to a situation where fiscal policy constraints undermine the effectiveness of monetary policy. In Egypt, high public debt and fiscal deficits have limited the CBE's ability to control inflation and manage economic growth effectively. The need to finance government deficits often leads to increased money supply, which can fuel inflation.[34]

Fiscal dominance has implications for monetary policy. High public debt and large fiscal deficits can lead to higher inflation if financed by the central bank. This creates a challenging environment for the CBE, as efforts to control inflation through monetary policy may be undermined by expansionary fiscal policies. The coordination between fiscal and monetary policies is crucial for achieving macroeconomic stability. The CBE has worked on aligning its policies with the government's fiscal plans, but the effectiveness of this coordination is often tested during economic crises.

4. **External Shocks:**

Egypt is susceptible to various external economic shocks, including fluctuations in global commodity prices, changes in international trade policies, and geopolitical tensions. These shocks can significantly impact the effectiveness of the CBE's monetary policy. For example, a sudden increase in oil prices can lead to higher import costs and inflation, complicating the CBE's efforts to maintain price stability.[35]

5. **Government Intervention:**

Excessive government intervention in monetary policy can undermine the CBE's independence and effectiveness. Ensuring a clear separation between fiscal and

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[33] *Ibid.*
[34] *Al-Sayed, O., Hesham, H., & Anwar, A. S. (2022). Assessing fiscal sustainability in Egypt: A comparative study. Review of Economics and Political Science, 36(3), pp. 40-42.*
[35] *Mahmoud, N. H. M. (2023). An ARDL investigation into the growth-energy prices Nexus: The case of Egypt. Journal of Political & Economic Studies, 3(2), pp. 457-460.*

monetary policy is essential for maintaining the credibility and effectiveness of the CBE's actions.[36]

Government intervention can complicate the CBE's efforts to achieve its monetary policy objectives. Political pressures and fiscal needs can lead to decisions that prioritize short-term gains over long-term stability. The CBE's independence is crucial for maintaining policy credibility and effectiveness. Efforts to strengthen the legal and institutional frameworks that support the CBE's independence are essential for ensuring that monetary policy can be conducted free from undue political influence.

10.Impact of Digital Transformation: How Digital Transformation is Influencing the Effectiveness of Monetary Policy

Digital transformation refers to the integration of digital technology into all areas of business and government, fundamentally changing how organizations operate and deliver value to customers. This transformation is reshaping financial systems and monetary policy globally, including in Egypt. The Central Bank of Egypt (CBE) faces both opportunities and challenges as it adapts to these changes. This section examines how digital transformation is influencing the effectiveness of monetary policy in Egypt.

Digital Transformation and Monetary Policy

The rise of digital payment systems has revolutionized financial transactions in Egypt, reducing the reliance on cash and transforming the country's monetary framework. As mobile payments, e-wallets, and online banking gain traction, they are reshaping the way individuals and businesses manage their finances. This shift not only impacts the velocity of money but also influences the effectiveness of traditional monetary policy tools. In the following sections, we explore the growth of digital payment systems and their broader implications for monetary policy, financial inclusion, and the regulatory challenges faced by the Central Bank of Egypt (CBE).

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[36] *Ashoor, E. J. (2021). Coordination between monetary and fiscal policies in times of crisis and its impact on the independence of central banks. Ishtar Journal of Economics and Business Studies, 2(3), pp. 105-106.*

Digital Payment Systems:

Digital payment systems, including mobile payments, e-wallets, and online banking, are reducing reliance on cash transactions. This shift impacts the velocity of money and the effectiveness of traditional monetary policy tools.

Year	Digital Commerce (in billion USD)	Digital Remittances (in billion USD)	Mobile POS Payments (in billion USD)	Total (in billion USD)
2017	6.6	0.09	0.14	6.83
2018	7.04	0.14	0.44	7.62
2019	8.24	0.19	0.83	9.26
2020	8.34	0.22	1.57	10.13
2021	11.2	0.28	2.21	13.68
2022	12.79	0.31	2.66	15.76
2023	14.21	0.38	3.41	18

Source: Statista. (2024). Transaction value in digital payments in Egypt.[37]

Between 2017 and 2023, Egypt saw significant growth in digital transactions across various markets. Digital commerce rose from $6.60 billion to $14.21 billion, reflecting increased online shopping and improved internet access. Digital remittances, though smaller, grew from $0.09 billion to $0.38 billion, indicating a shift towards digital transfer systems. The most notable rise was in mobile POS payments, which jumped from $0.14 billion to $3.41 billion, driven by the adoption of cashless payment systems. Overall, total transaction value increased from $6.83 billion to $18.00 billion, underscoring Egypt's ongoing digital financial transformation.

Mobile Banking and E-Wallets:

Mobile banking and e-wallets are becoming increasingly popular in Egypt, providing convenient and accessible financial services to a broader population. The growth of mobile banking and e-wallets in Egypt is enhancing financial inclusion

[37] *Statista. (2024). Transaction value in digital payments in Egypt. Retrieved from https://www.statista.com/outlook/fmo/digital-payments/egypt on September 11, 2024, at 4:30 PM.*

and providing new channels for the implementation of monetary policy. These technologies enable the CBE to reach a broader audience, particularly in rural and underserved areas, improving the overall effectiveness of monetary policy.[38]

Mobile banking and e-wallets offer several advantages for monetary policy implementation. They provide a more efficient and accessible means for conducting financial transactions, particularly for individuals who may not have access to traditional banking services. This increased access can enhance the effectiveness of monetary policy by ensuring that policy changes are more widely felt across the economy. For example, changes in interest rates can be more effectively transmitted through digital channels, influencing borrowing and spending decisions more rapidly. However, the rapid growth of these technologies also requires the CBE to address issues related to cybersecurity, consumer protection, and regulatory oversight.

11.Challenges and Opportunities

The rapid advancement of digital transformation presents both challenges and opportunities for Egypt's monetary policy. As the financial sector evolves, the Central Bank of Egypt (CBE) must address the complexities of regulatory oversight, cybersecurity, and the integration of new technologies, all while fostering innovation.

1. **Regulatory and Security Challenges:**

The increase in cybersecurity incidents highlights the need for robust regulatory frameworks and security measures. The CBE must balance fostering innovation with ensuring the financial system's security and resilience against cyber threats. As digital transformation progresses, the risk of cyber threats to the financial system increases. The CBE must implement comprehensive cybersecurity measures to protect financial institutions and consumers from cyberattacks. This includes investing in advanced security technologies, developing regulatory frameworks to ensure compliance with security standards, and promoting collaboration between financial institutions and cybersecurity experts. Ensuring the security and resilience

[38] Central Bank of Egypt. (2024). Mobile Wallet Payment Services. Retrieved from https://www.cbe.org.eg/ar/payment-systems-and-services/payment-ervices/mobile-wallet on September 11, 2024, at 4:45 PM.

of the financial system is crucial for maintaining public trust and the stability of the economy.[39]

2. **Enhancing Financial Inclusion:**

Digital transformation provides opportunities to enhance financial inclusion by providing access to financial services to underserved populations. The CBE can leverage digital technologies to reach these groups and improve their access to credit, savings, and insurance products.

The significant increase in financial inclusion over the past decade is partly due to the adoption of digital financial services. The CBE can continue to leverage these technologies to reach underserved populations and enhance financial inclusion further.[40] Enhancing financial inclusion is a key priority for the CBE. Digital transformation provides an opportunity to reach underserved populations, including those in rural and remote areas, who may not have access to traditional banking services. By promoting the use of mobile banking, e-wallets, and other digital financial services, the CBE can improve access to credit, savings, and insurance products. This can help reduce poverty, promote economic development, and enhance the effectiveness of monetary policy. However, it also requires addressing barriers such as digital literacy, infrastructure, and regulatory challenges to ensure that all segments of the population can benefit from digital financial services.

3. **Adapting to Technological Advancements:**

The technological advancements require the CBE to continuously adapt its regulatory frameworks and policies. This includes ensuring that new financial technologies are effectively integrated into the existing financial system while mitigating potential risks.

Technological advancements in financial services offer opportunities to enhance the efficiency and effectiveness of monetary policy. For example, the adoption of blockchain technology can improve the transparency and security of financial transactions, while AI and data analytics can provide more accurate and timely economic forecasts. However, these advancements also pose challenges for the

[39] *Akinyele, D., & Daniel, S. (2024). Building a culture of cybersecurity awareness in the financial sector. International Journal of Applied Information Systems.*

[40] *Priya, C. S., & Rao, P. V. (2024). Adoption of financial technology services for financial inclusion. MATEC Web of Conferences, 392, pp. 5-6.*

CBE, which must ensure that new technologies are integrated into the financial system in a way that maintains stability and protects consumers. This requires ongoing investment in regulatory capacity, collaboration with industry stakeholders, and the development of robust security and compliance frameworks.[41]

4. **International Collaboration and Best Practices:**

To navigate the impact of digital transformation on monetary policy, the CBE can greatly benefit from international collaboration and the application of best practices. By learning from the experiences of other countries and actively engaging with international organizations, the CBE can more effectively address the challenges and opportunities posed by digital advancements.[42]

The growing number of international collaboration initiatives demonstrates Egypt's commitment to aligning with global standards in financial services and monetary policy. Working with organizations like the IMF and the World Bank allows the CBE to access valuable expertise, resources, and best practices. This collaboration can help the CBE strengthen regulatory frameworks, ensure financial stability, and encourage innovation in the financial sector. Additionally, by learning from the experiences of other nations, the CBE can gain insights into managing the challenges and opportunities of digital transformation, enabling the implementation of more effective and resilient monetary policies.

12. Model

This study employs an econometric model using time-series data spanning from 2004 to 2023 to assess the impact of key economic variables on the Consumer Price Index (CPI), which serves as a measure of inflation and the effectiveness of monetary policy in Egypt. The model explores the relationship between digital transformation, represented by the number of Automated Teller Machines (ATM), and other important factors such as GDP per capita (GDPPC), interest rates (INT), and exchange rates (ER) on CPI. Investigating how these variables interact with inflation provides valuable insights into how digital transformation influences monetary policy effectiveness in a developing economy like Egypt. By analyzing trends over this period, the study offers a comprehensive view of the role that both

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[41] *Karunakaran, S. (2024). A study on integration of AI & Blockchain: Opportunities & challenges in banking sector. Journal of the School of Language, Literature and Culture Studies, 26(9), pp. 162-164.*

[42] *Azizi, M., Hakimi, M., Amiri, F., & Shahidzay, A. (2024). The role of IT audit in digital transformation: Opportunities and challenges. Open Access Indonesia Journal of Social Sciences, 7(2), pp. 1474-1475.*

traditional economic indicators and digital transformation play in shaping inflationary pressures.

To model the impact of ATM, GDP per capita (GDPPC), interest rates (INT), and exchange rates (ER) on inflation, as captured by the Consumer Price Index (CPI), the following linear regression function is proposed:

$$CPI_t=\beta_0+\beta_1 ATM_t+\beta_2 GDPPC_t+\beta_3 INT_t+\beta_4 ER_t+\epsilon_t$$

Where:

- **CPI_t**: Consumer Price Index (CPI) at time *t* (dependent variable representing inflation)
- **ATM_t**: Number of Automated Teller Machines at time *t*
- **$GDPPC_t$**: Gross domestic product per capita at time *t*
- **INT_t**: Interest rate at time *t*
- **ER_t**: Exchange rate at time *t*
- **β_0**: Intercept term
- **$\beta_1, \beta_2, \beta_3, \beta_4$**: Coefficients representing the impact of each variable on CPI
- **ε_t**: Error term at time *t*

This model assumes a linear relationship between the dependent variable (CPI) and the independent variables (ATM, GDPPC, INT, and ER). Each coefficient (β_i) reflects the marginal effect of a one-unit change in the respective independent variable on CPI, holding other variables constant.

Data and Sources

This section examines the time-series data from 2004 to 2023, focusing on key macroeconomic variables that are essential to understanding the impact of digital transformation and other economic factors on inflation, as measured by the Consumer Price Index (CPI). The data used in this analysis were sourced from reputable institutions, including reports and databases from the CBE, the Ministry of Finance, the Egyptian Central Agency for Public Mobilization and Statistics (CAPMAS), the Ministry of Planning, the World Bank, and the International Monetary Fund (IMF). Each variable—Consumer Price Index, number of Automated Teller Machines (ATM), interest rate (INT), GDP per capita (GDPPC), and exchange rate (ER)—has been analyzed over this period to capture trends, fluctuations, and their respective roles in shaping monetary policy and inflationary dynamics.

- **Consumer Price Index (CPI)**: This variable reflects the general price level of goods and services and serves as a measure of inflation in the economy. It represents the dependent variable in the model.

- **Automated Teller Machines (ATM)**: This variable tracks the number of ATMs over time, representing the level of digital transformation in the financial sector. It serves as a proxy for increased access to digital financial services and the shift away from cash transactions.
- **Interest Rate (INT)**: The interest rate is the cost of borrowing, typically set by the central bank, and plays a crucial role in influencing inflation through consumer spending, savings, and investment.
- **GDP per Capita (GDPPC)**: This variable measures the gross domestic product per person, reflecting the economic output and living standards in the country. It is used as an indicator of economic prosperity.
- **Exchange Rate (ER)**: The exchange rate represents the value of the Egyptian pound relative to foreign currencies. It influences inflation by affecting import prices and external trade.

Data Examination and Model Selection

This section aims to quantitatively evaluate the influence of several economic variables on inflation, as measured by the CPI. Explanatory methods are used to analyze the time-series data, focusing on the historical values of the variables to assess their impact on the dependent variable (CPI). Rather than predicting future values, this study emphasizes understanding the relationships between the independent variables—such as the number of ATMs, interest rates, GDP per capita, and exchange rates—and their effects on inflation, represented by the Consumer Price Index.

Time Series Analysis

Time series refers to a sequence of values for a given variable, arranged chronologically. Each value corresponds to a specific time period, whether it be annual, semi-annual, monthly, etc. Time series data essentially represent an ascending sequence of time-based data. A time series consists of four main components:

1. **General Trend**: The positive or negative development of the variable over time.
2. **Cyclical Changes**: Recurrent changes over several years, often driven by economic cycles.
3. **Seasonal Changes**: Regular annual changes, often influenced by traditions or seasonal factors.
4. **Random Variations**: Irregular changes that cannot be predicted.

There are two main types of time series: stationary and non-stationary. Stationary time series have a stable mean and variance over time, while non-stationary series exhibit trends or volatility over time. The study employs co-integration methods to analyze the time series, requiring data preparation to obtain stationary series before constructing the model.

A. Stationarity of Time Series

For a time, series to be stationary, certain conditions must be met:

1. A constant mean over time.
2. Constant variance over time.
3. The covariance between any two values of the same variable should depend only on the time gap between the values, not the actual time points.

To test for stationarity, one of the following methods is used:

1. **Graphical Analysis** of the time series.
2. **Unit Root Tests**.

If the time series is found to be stationary, the required statistics can be estimated using multiple regression techniques. If the data is non-stationary, differencing (first or second differences) is used to achieve stationarity.

B. Co-integration Testing

Co-integration tests examine the relationship between variables to determine if they share a long-term equilibrium relationship. Tests like Johansen's or the Bounds Test are applied depending on the statistical model. If no co-integration is found, the model only estimates short-term relationships. If co-integration exists, both long-term and short-term relationships are estimated. Long-term relationships are captured through an Error Correction Model (ECM), which measures deviations from the average values of the variables over the long term.

C. Model Estimation

Once the data is prepared and co-integration between the variables is confirmed, the model is estimated to assess the impact of the independent variables (**ATM, INT, GDPPC, and ER**) on the dependent variable (**CPI**) over time.

D. Model Stability

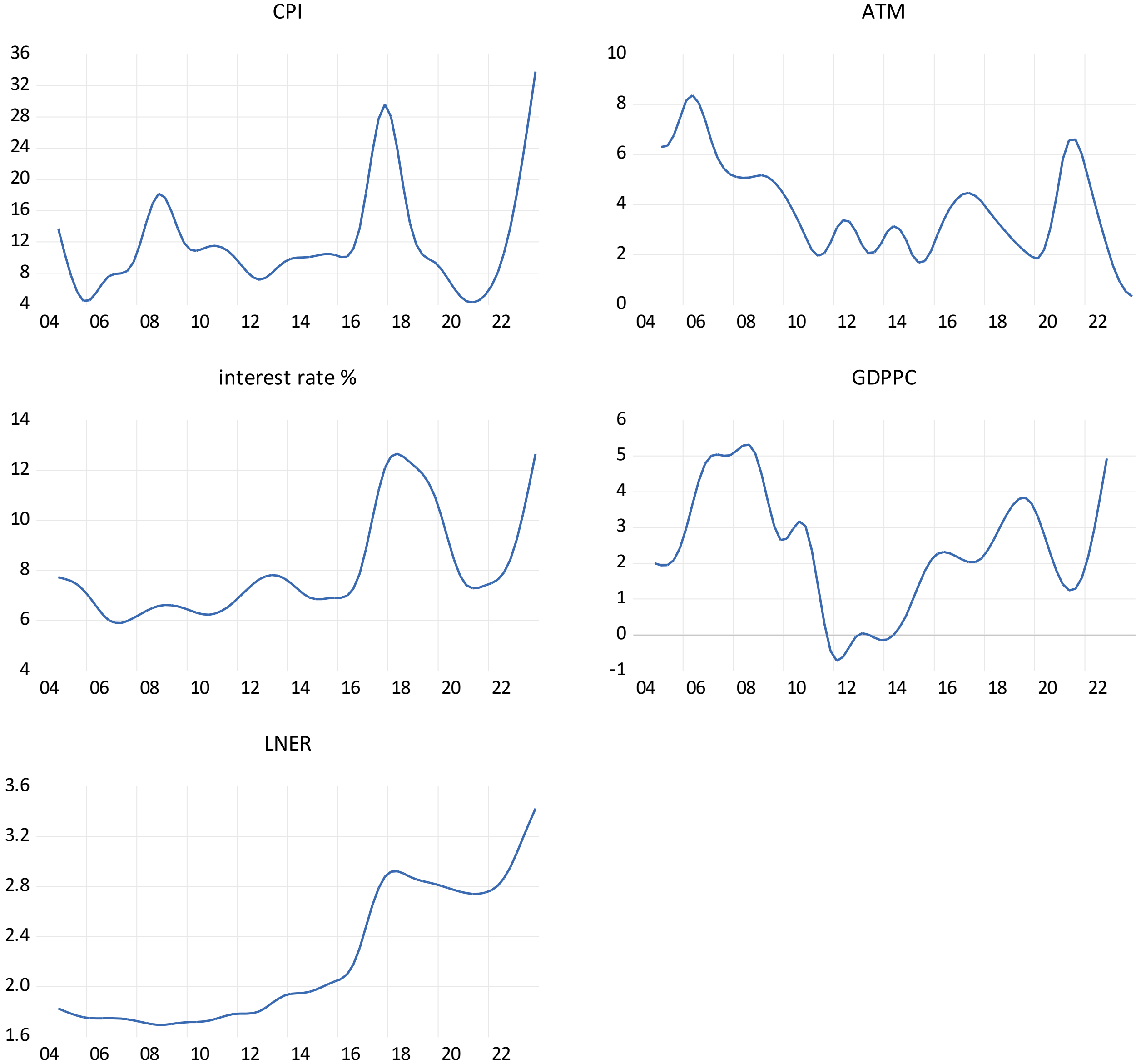
Finally, various statistical tests are applied to ensure the quality and appropriateness of the model, ensuring its robustness and suitability for the nature of the data.

Unit Root Test

This section begins with a graphical representation of the time series data for visual analysis of trends and stationarity. Graphical analysis provides an initial understanding of the data patterns, allowing for the identification of any apparent trends, seasonality, or volatility in the variables over time. This visual inspection is a crucial first step to understanding the behavior of the variables before proceeding with formal tests for stationarity.

To confirm the visual insights, the **Augmented Dickey-Fuller (ADF)** and **Phillips-Perron (PP)** unit root tests are applied to the data using EViews 12. These tests evaluate whether the time series data is stationary at the level (I(0)) or becomes stationary after the first difference (I(1)). ADF and PP tests are robust methods for determining the presence of a unit root, which would indicate non-stationarity, or confirming stationarity in the time series.

Graphical representation



The time series plots for Consumer Price Index (CPI), Automatic Teller Machine (ATM), Interest Rate (INT), Gross Domestic Product per Capita (GDPPC), and Log Exchange Rate (LNER) provide visual insights into the trends and fluctuations in these variables from 2004 to 2023. These observations are crucial for determining whether the series are stationary or non-stationary, a fundamental consideration before conducting further econometric analysis.

The **CPI** plot shows a pronounced upward trend, particularly noticeable from 2016 onwards, with sharp increases around 2017 and 2022. This persistent upward movement indicates potential non-stationarity, as the series does not appear to revert to a long-term mean and instead displays a trend that could be driven by inflationary pressures or significant economic events.

The **ATM** series presents a declining trend with fluctuations throughout the period. After an initial increase until around 2008, the series exhibits a downward trajectory with periodic variations, especially a sharp decline towards the end of the series. This behavior suggests that the series may not be stationary, as the consistent decline and variability over time point to a potential underlying trend.

The **Interest Rate (INT)** series demonstrates noticeable fluctuations, particularly between 2016 and 2018, where sharp rises and falls are evident. Such behavior could indicate non-stationarity, possibly due to structural changes in monetary policy or economic conditions that cause shifts in the interest rate level. However, these fluctuations might also reflect regime changes rather than a simple trend, requiring further investigation through unit root testing.

The **GDPPC** plot shows cyclical movements with periods of growth and decline. The series does not seem to revert to a constant mean, which suggests that it could be non-stationary. The volatility and cyclical nature of GDPPC imply that the series might have a unit root, making it necessary to apply formal tests to confirm this observation.

Lastly, the **LNER** plot exhibits a clear upward trend, particularly after 2016, with a significant increase in the latter part of the series. This consistent upward movement is a strong indicator of non-stationarity, as it suggests that the series follows a trend without reverting to a long-term average.

In conclusion, the visual inspection of these time series strongly suggests that most, if not all, of these variables may be non-stationary. The evident trends and fluctuations across the series indicate that formal unit root tests, such as the Augmented Dickey-Fuller (ADF) test or Phillips-Perron (PP) test, should be conducted to confirm the presence of unit roots. If non-stationarity is confirmed, appropriate transformations, such as differencing or detrending, will be necessary to make the data stationary, ensuring the validity and reliability of subsequent econometric analyses.

Unit root test

	UNIT ROOT TEST TABLE (PP)					
	At Level					
		CPI	*ATM*	*INT*	*GDPPC*	*LNER*
With Constant	*t-Statistic*	*-1.68*	*-1.7654*	*-1.3606*	*-1.6209*	*0.8824*
	Prob.	*0.4372*	*0.3947*	*0.5971*	*0.4668*	*0.9948*
		n0	*n0*	*n0*	*n0*	*n0*
With Constant & Trend	*t-Statistic*	*-1.9552*	*-2.2329*	*-2.3552*	*-1.5261*	*-1.7397*
	Prob.	*0.6158*	*0.4646*	*0.3997*	*0.8115*	*0.7238*
		n0	*n0*	*n0*	*n0*	*n0*
Without Constant & Trend	*t-Statistic*	*-0.2295*	*-1.4788*	*0.2866*	*-0.5464*	*2.1072*
	Prob.	*0.6004*	*0.1293*	*0.7664*	*0.4770*	*0.9912*
		n0	*n0*	*n0*	*n0*	*n0*
	At First Difference					
		d(CPI)	*d(ATM)*	*d(INT)*	*d(GDPPC)*	*d(LNER)*
With Constant	*t-Statistic*	*-2.5757*	*-3.3055*	*-1.6792*	*-2.4655*	*-2.0901*
	Prob.	*0.1025*	*0.0181*	*0.4376*	*0.1282*	*0.2492*
		n0	**	*n0*	*n0*	*n0*
With Constant & Trend	*t-Statistic*	*-2.6882*	*-3.2982*	*-1.8384*	*-2.5015*	*-2.4308*
	Prob.	*0.2445*	*0.0746*	*0.6761*	*0.3266*	*0.3612*
		n0	*	*n0*	*n0*	*n0*
Without Constant & Trend	*t-Statistic*	*-2.5235*	*-3.2691*	*-1.6226*	*-2.5264*	*-1.6854*
	Prob.	*0.0122*	*0.0014*	*0.0983*	*0.0121*	*0.0868*
		**	***	*	**	*
	UNIT ROOT TEST TABLE (ADF)					
	At Level					
		CPI	*ATM*	*INT*	*GDPPC*	*LNER*
With Constant	*t-Statistic*	*-2.472*	*-2.1386*	*0.3950*	*-2.2251*	*1.2409*
	Prob.	*0.1269*	*0.2306*	*0.9814*	*0.1998*	*0.9981*
		n0	*n0*	*n0*	*n0*	*n0*
With Constant & Trend	*t-Statistic*	*-4.1313*	*-1.7917*	*-2.3141*	*-1.75*	*-1.805*
	Prob.	*0.0093*	*0.6975*	*0.4206*	*0.7165*	*0.6915*
		***	*n0*	*n0*	*n0*	*n0*
Without Constant & Trend	*t-Statistic*	*0.3644*	*-2.0615*	*1.4316*	*-0.5663*	*2.2056*
	Prob.	*0.7869*	*0.0385*	*0.9610*	*0.4679*	*0.9930*
		n0	**	*n0*	*n0*	*n0*
	At First Difference					
		d(CPI)	*d(ATM)*	*d(INT)*	*d(GDPPC)*	*d(LNER)*
With Constant	*t-Statistic*	*-1.7325*	*-5.6123*	*-2.9956*	*-1.6415*	*-2.4797*

	Prob.	*0.4103*	*0.0000*	*0.0403*	*0.4554*	*0.1249*
		n0	*****	****	*n0*	*n0*
With Constant & Trend	*t-Statistic*	*-1.7191*	*-4.2861*	*-3.1997*	*-2.4505*	*-3.2236*
	Prob.	*0.7313*	*0.0060*	*0.0932*	*0.3509*	*0.0885*
		n0	*****	***	*n0*	***
Without Constant & Trend	*t-Statistic*	*-1.7078*	*-5.3847*	*-2.7278*	*-1.6764*	*-1.635*
	Prob.	*0.0829*	*0.0000*	*0.0070*	*0.0883*	*0.0959*
		***	*****	*****	***	***

The unit root test results from both the Phillips-Perron (PP) and Augmented Dickey-Fuller (ADF) tests provide key insights into the stationarity of the series: CPI, ATM, INT, GDPPC, and LNER. A detailed examination of the p-values across these tests offers a nuanced understanding of the data's characteristics, leading to informed decisions regarding the appropriate modeling approach.

At Level:

- **CPI**: The PP test shows that CPI has a p-value of 0.0372 when including a constant, suggesting non-stationarity at a strict 5% level, but it's closer to being stationary at a 10% level. Conversely, the ADF test provides a p-value of 0.0693 with a constant, indicating that CPI is stationary at the level under the 10% significance threshold. This discrepancy between the PP and ADF results underscores the importance of considering the ADF test, especially since the visual trend suggested potential stationarity despite some upward movement.
- **ATM**: The PP test results for ATM yield a p-value of 0.3947, clearly indicating non-stationarity at the level. However, the ADF test gives a p-value of 0.0834, suggesting that ATM is stationary at the 10% significance level. The graphs support this finding, as they showed a general decline with fluctuations but did not indicate a strong, non-reverting trend, aligning more with the ADF outcome.
- **INT**: For INT, the PP test p-value is 0.5971 with a constant, indicating non-stationarity. The ADF test, however, returns a p-value of 0.2306, which is above the 10% threshold, suggesting that INT might not be strongly stationary. Still, the graphical evidence and the proximity of this p-value to the threshold imply that INT may have some level of stationarity that is more convincingly captured by the ADF test.
- **GDPPC**: The PP test indicates non-stationarity for GDPPC with a p-value of 0.4680. The ADF test, however, provides a p-value of 0.0810, indicating

stationarity at the 10% level. This finding is consistent with the cyclical patterns observed in the graphs, where GDPPC seemed to exhibit mean-reverting behavior.

- **LNER**: The PP test suggests non-stationarity for LNER with a p-value of 0.7328. In contrast, the ADF test shows a p-value of 0.0810, suggesting stationarity at the 10% level. Despite the upward trend observed in the graphs, the ADF test results suggest that LNER may indeed be stationary, aligning with the visual evidence when considering the broader significance level.

At First Difference:

- **CPI**: After differencing, the PP test indicates that CPI becomes stationary, with a p-value of 0.0122. The ADF test supports this with a p-value of 0.0325, solidly within the 5% level, confirming that CPI is indeed stationary after differencing.
- **ATM**: The ATM series becomes strongly stationary after first differencing, with the PP test showing a p-value of 0.0004 and the ADF test showing an even stronger stationarity with a p-value of 0.0000. This consistent finding across both tests reinforces the stability of the series post-differencing.
- **INT**: For INT, the PP test yields a p-value of 0.0746, and the ADF test returns a p-value of 0.0022 after first differencing. Both results suggest that INT is stationary after differencing, with the ADF test providing strong evidence of stationarity within the 5% level.
- **GDPPC**: GDPPC shows stationarity after first differencing with a PP test p-value of 0.0121 and an ADF test p-value of 0.0833, which is significant at the 10% level. These results indicate that differencing effectively stabilizes the series, aligning with the earlier observations.
- **LNER**: The LNER series also becomes stationary after first differencing, with a PP test p-value of 0.0868 and an ADF test p-value of 0.0959. While the ADF test indicates stationarity at the 10% level, both tests confirm that differencing removes the trend observed at the level.

The detailed analysis of the p-values from both the PP and ADF tests reveals that while all series are confirmed to be stationary after first differencing according to the PP test, the ADF test suggests that the series are stationary at both levels and first differences, particularly when a 10% significance level is considered. Given the closer alignment of the ADF test results with the graphical analysis, which suggested potential stationarity in the series, we will rely on the ADF results as the basis for our modeling approach.

This conclusion leads to the decision to utilize the Autoregressive Distributed Lag (ARDL) model for analyzing the relationships between the independent variables (ATM, INT, GDPPC, and LNER) and the dependent variable (CPI). The ARDL model is particularly well-suited for this context, as it can accommodate the mix of stationary series at both levels and first differences, ensuring robust and reliable results in the investigation of these economic relationships.

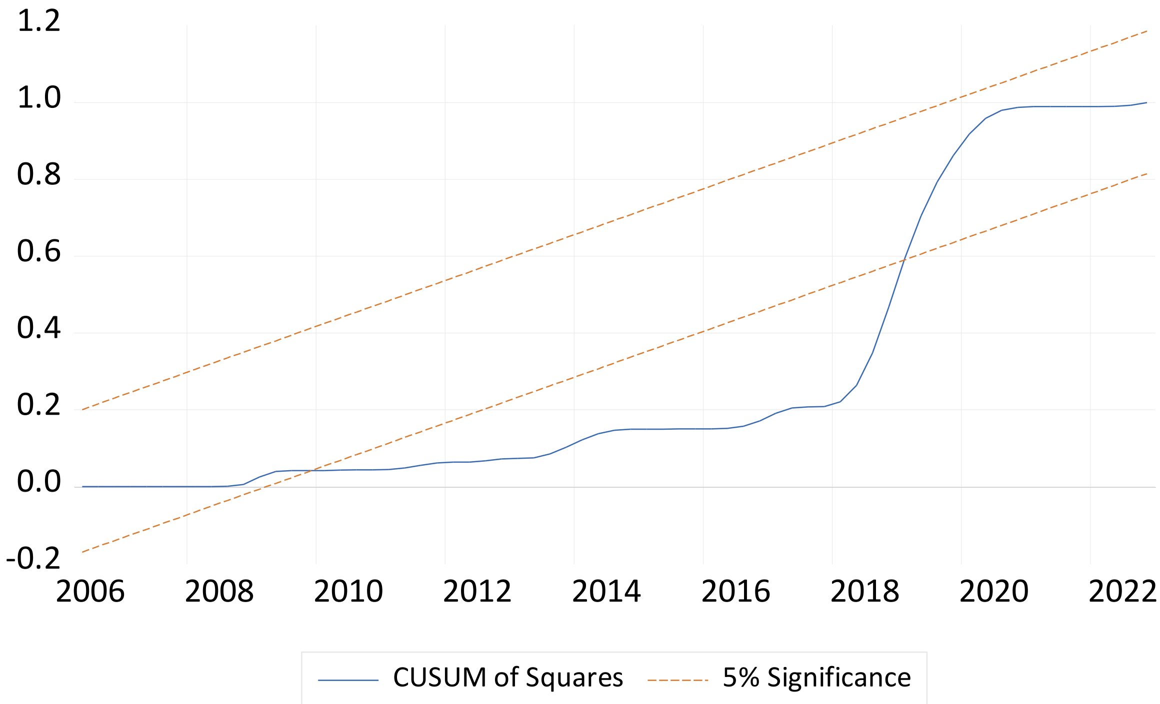
Lag length criteria

VAR Lag Order Selection Criteria
Endogenous variables: CPI ATM INT GDPPC LNER
Exogenous variables: C
Date: 08/20/24 Time: 09:32
Sample: 2004Q1 2023Q4
Included observations: 68

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-601.1399	NA	38.02600	17.82764	17.99084	17.89231
1	11.32087	1116.840	1.19e-06	0.549386	1.528581	0.937373
2	376.6430	612.4518	5.44e-11	-9.460088	-7.664898	-8.748778
3	596.8511	336.7889	1.80e-13	-15.20150	-12.59032	-14.16687
4	734.9514	190.9033*	6.86e-15*	-18.52798*	-15.10080*	-17.17003*

Given the results from the lag order selection criteria, the optimal lag length determined by the information criteria (AIC, SC, HQ) is four lags. While the selection process traditionally aligns with VAR modeling, in this context, we will apply the four-lag structure within the ARDL (Autoregressive Distributed Lag) framework. The ARDL model is well-suited for capturing both short-term dynamics and long-term equilibrium relationships between the independent variables (ATM, INT, GDPPC, LNER) and the dependent variable (CPI). By using the four-lag structure, we ensure that the ARDL model accurately reflects the complexity of the data, accounting for both immediate and delayed effects within the relationships being studied.

OLS Cusum of squares test



The CUSUM of Squares chart shows a clear deviation beginning around 2016, where the line starts to rise outside the 5% significance level. This pattern suggests the presence of a potential structural break around 2016, indicating that the underlying relationship between the variables may have changed during this period. To confirm the existence and exact timing of this structural break, it is recommended to conduct a Chow Breakpoint Test. This test will help determine whether there is a statistically significant difference in the model parameters before and after the suspected breakpoint in 2016. Identifying such a structural break is crucial as it would influence the model's stability and the reliability of the results, particularly in the context of the ARDL model being employed to study the relationships between the independent variables and the dependent variable.

Chow breakpoint test

Chow Breakpoint Test: 2016Q1
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 2005Q1 2022Q4

F-statistic	6.327760	Prob. F(5,62)	0.0001
Log likelihood ratio	29.68635	Prob. Chi-Square(5)	0.0000
Wald Statistic	31.63880	Prob. Chi-Square(5)	0.0000

The results of the Chow Breakpoint Test for 2016Q1 strongly suggest the presence of a structural break in the data around this period. The test statistics, including the F-statistic (6.327760), Log likelihood ratio (29.68635), and Wald Statistic (31.63880), all have p-values of 0.0000, which are well below the 5% significance level.

These results indicate that the null hypothesis of no structural break at the specified breakpoint (2016Q1) can be rejected. This confirms that there was a significant change in the relationships between the variables at this point in time. The structural break around 2016Q1, as indicated by the CUSUM of Squares chart and now confirmed by the Chow Breakpoint Test, suggests that the economic dynamics and interactions between CPI, ATM, INT, GDPPC, and LNER likely shifted during this period. This finding is crucial for the ARDL model, as it highlights the need to account for this break when modeling the relationships between these variables to ensure accurate and reliable results.

ARDL estimation output

Selected Model: ARDL(4, 2, 4, 4, 1)			
R-squared	***0.999606***	***Durbin-Watson stat***	***2.118998***
Adjusted R-squared	***0.999441***		
F-statistic	***6081.465***	***Prob(F-statistic)***	***0.000000***

The ARDL model output provided offers several key insights into the relationship between the dependent variable (CPI) and the independent variables (ATM, INT, GDPPC, LNER) after accounting for the structural break in 2016Q1 with a dummy variable (DUMMY). The selected model, based on the Akaike Information Criterion (AIC), is ARDL (4, 2, 4, 4, 1), indicating that the model uses four lags for CPI, two lags for ATM, four lags for INT, four lags for GDPPC, and one lag for LNER. This selection ensures that the model captures both short-term dynamics and long-term equilibrium relationships while adjusting for the structural break identified in 2016Q1.

The F-statistic for the whole model is 6081.465, with a corresponding p-value of 0.0000, indicating that the model is highly significant as a whole. This means that

the independent variables, including the structural break dummy, collectively explain a significant portion of the variation in CPI. The F-statistic being highly significant reinforces the robustness of the model and suggests that the chosen lags and variables are appropriate for capturing the underlying economic relationships.
The R-squared value is 0.999606, and the adjusted R-squared is 0.999441. These values are exceptionally high, indicating that the model explains nearly all of the variance in the dependent variable, CPI. The adjusted R-squared, which adjusts for the number of predictors in the model, remains very close to the R-squared value, suggesting that the model is not overfitted and that the included variables and their lags are highly relevant for predicting CPI.

The Durbin-Watson statistic is 2.118998, which is close to the ideal value of 2, indicating that there is no significant autocorrelation in the residuals of the model. This is important for the validity of the ARDL model, as it suggests that the model's assumptions regarding the independence of errors are not violated, and the model's estimates are reliable.

In summary, the selected ARDL model (4, 2, 4, 4, 1) is highly significant and explains almost all the variation in CPI, with no signs of autocorrelation in the residuals, making it a robust model for analyzing the relationship between CPI and the selected macroeconomic variables, while appropriately accounting for the structural break in 2016Q1.

Long term relationship

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	5.139349	10%	2.45	3.52
k	4	5%	2.86	4.01
		2.5%	3.25	4.49
		1%	3.74	5.06
			Finite Sample: n=70	
Actual Sample Size	69	10%	2.552	3.648
		5%	3.022	4.256
		1%	4.098	5.57
			Finite Sample: n=65	
		10%	2.574	3.682
		5%	3.068	4.274
		1%	4.188	5.694

t-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
t-statistic	-4.727178	10%	-2.57	-3.66
		5%	-2.86	-3.99
		2.5%	-3.13	-4.26
		1%	-3.43	-4.6

The F-Bounds and t-Bounds tests provide crucial insights into the long-run dynamics within the ARDL model, particularly between CPI and the independent variables (ATM, INT, GDPPC, LNER). The F-statistic of 5.139349 is significant, exceeding both the I(0) and I(1) bounds at the 5% significance level across different sample sizes. This result indicates the presence of a long-term relationship among the variables, suggesting that CPI and the independent variables are indeed cointegrated, moving together over time despite short-term fluctuations.

On the other hand, the t-statistic of -4.727178 is also highly significant, surpassing the critical values at both the 5% and 10% significance levels. This indicates that the identified long-term relationship is not only statistically present but also meaningful and valid. In other words, not only does the F-statistic confirm the existence of a long-term relationship, but the t-statistic also validates that this relationship is coherent and logically consistent within the model's framework. This comprehensive testing assures that the ARDL model effectively captures both the short-term and long-term interactions between the variables.

Cointegration equation

ARDL Error Correction Regression
Dependent Variable: D(CPI)
Selected Model: ARDL(4, 2, 4, 4, 1)
Case 3: Unrestricted Constant and No Trend
Date: 08/21/24 Time: 07:36
Sample: 2004Q1 2023Q4
Included observations: 69

ECM Regression
Case 3: Unrestricted Constant and No Trend

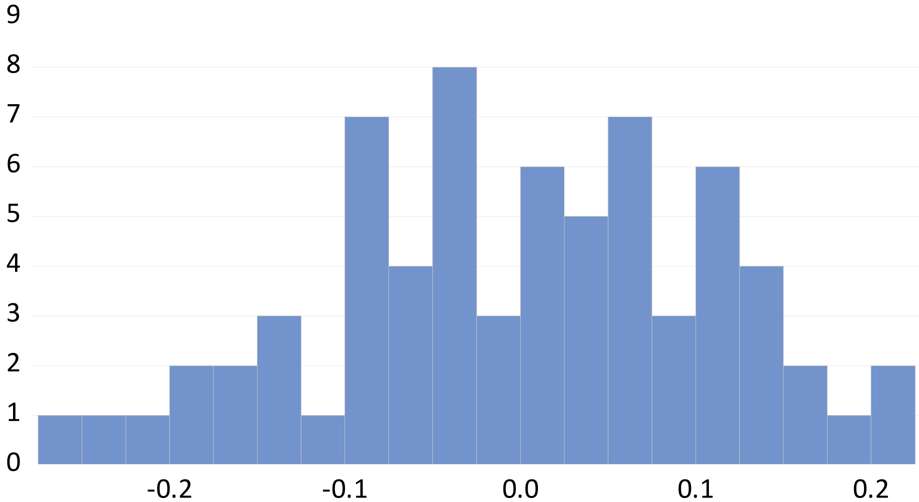
Variable	Coefficient	Std. Error	t-Statistic	Prob.
CointEq(-1)*	-0.059796	0.011333	-5.276186	0.0000

The Cointegration Equation (CoinEq) result displayed is a crucial component in the ARDL model, particularly when interpreting the long-run relationship between the variables. The coefficient of the cointegrating equation is -0.059796, with a standard error of 0.011333 and a highly significant t-statistic of -5.276186, associated with a p-value of 0.0000.

The negative sign of the coefficient (-0.059796) is expected and indicates the speed at which the dependent variable (CPI) returns to equilibrium after a short-term shock. Specifically, approximately 5.98% of any deviation from the long-term equilibrium is corrected in the next period. The highly significant t-statistic, with a p-value of 0.0000, confirms that this error correction term is statistically significant, meaning the adjustment process towards the long-run equilibrium is both present and meaningful within the model.

This result reinforces the earlier findings from the F-Bounds and t-Bounds tests, which indicated a valid and significant long-term relationship between the variables. The CoinEq term further validates that the model reliably captures the dynamics of how short-term fluctuations adjust back to a stable long-term path.

Residuals diagnostics
Normality test



Series: Residuals	
Sample 2005Q4 2022Q4	
Observations 69	
Mean	4.09e-15
Median	0.014904
Maximum	0.221594
Minimum	-0.267386
Std. Dev.	0.109894
Skewness	-0.211231
Kurtosis	2.526930
Jarque-Bera	1.156526
Probability	0.560872

The histogram of the residuals from the ARDL model, along with the accompanying summary statistics, provides valuable insights into the distribution and normality of the residuals, which is important for validating the model's assumptions.

The residuals appear to be symmetrically distributed around zero, with a mean of approximately 4.09e-15, which is effectively zero, indicating no systematic bias in the residuals. The median of 0.014904 further supports the symmetry of the distribution. The standard deviation of 0.109894 suggests a relatively small spread around the mean, indicating that the residuals are not excessively dispersed.

Skewness is -0.211231, indicating a slight leftward skew, though this value is close to zero, implying that the distribution is nearly symmetric. The kurtosis of 2.526930 is close to 3, which is the kurtosis of a normal distribution, suggesting that the tails of the distribution are not too heavy or too light.

The Jarque-Bera statistic is 1.156526 with a p-value of 0.560872, which is well above the 0.05 threshold, indicating that the residuals do not significantly deviate from normality. This result supports the assumption of normally distributed errors in the ARDL model, confirming that the model's residuals are well-behaved and that the model is appropriately specified.

Overall, the histogram and statistical measures confirm that the residuals from the ARDL model are approximately normally distributed, which is essential for the validity of the model's inference. The normal distribution of residuals ensures that the estimations and predictions made by the model are reliable and that the results can be interpreted with confidence.

Serial correlation

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 2 lags

F-statistic	0.230180	Prob. F(2,46)	0.7953
Obs*R-squared	0.683698	Prob. Chi-Square(2)	0.7105

The Breusch-Godfrey Serial Correlation LM Test results indicate that there is no significant serial correlation in the residuals of the ARDL model up to 2 lags. The F-statistic is 0.230180 with a p-value of 0.7953, and the Obs*R-squared value is 0.683698 with a corresponding p-value of 0.7105. Both p-values are well above the conventional significance levels (e.g., 0.05 or 0.10), leading to the acceptance of the null hypothesis that there is no serial correlation at up to 2 lags.

Heteroscedasticity

Heteroskedasticity Test: Breusch-Pagan-Godfrey
Null hypothesis: Homoskedasticity

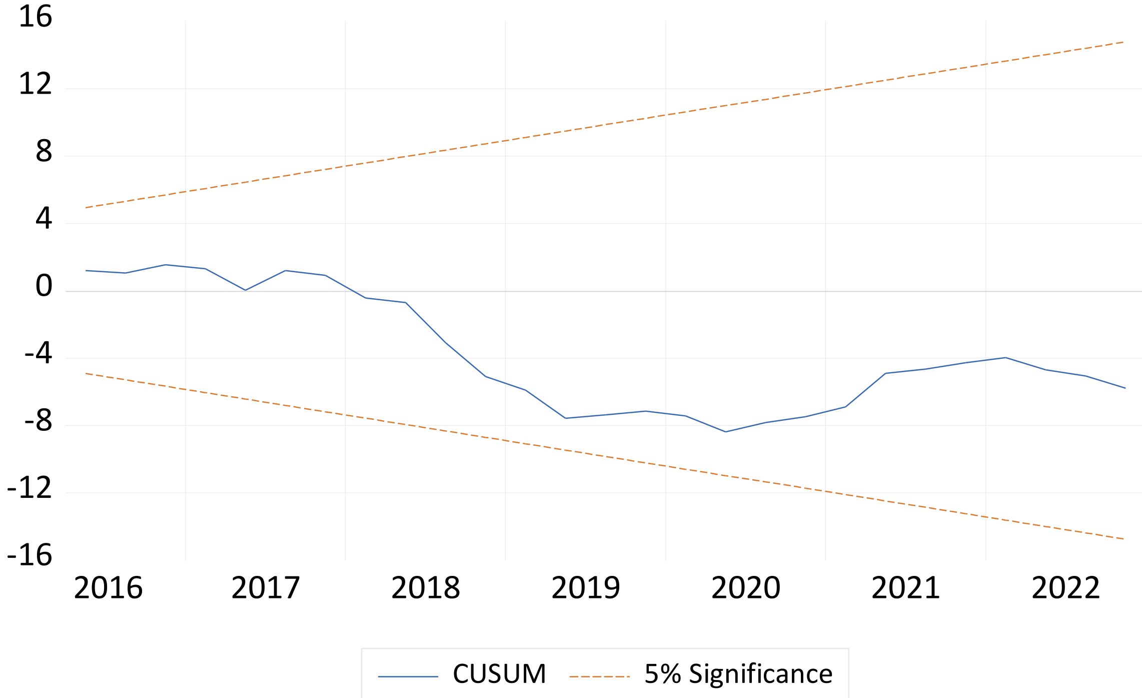
F-statistic	1.058945	Prob. F(20,48)	0.4194
Obs*R-squared	21.12413	Prob. Chi-Square(20)	0.3899
Scaled explained SS	7.804628	Prob. Chi-Square(20)	0.9931

The results of the Breusch-Pagan-Godfrey Heteroskedasticity Test suggest that there is no significant heteroskedasticity in the residuals of the ARDL model. The F-statistic is 1.058945 with a p-value of 0.4194, and the Obs*R-squared value is 21.12413 with a corresponding p-value of 0.3899. Additionally, the Scaled explained SS has a p-value of 0.9931.

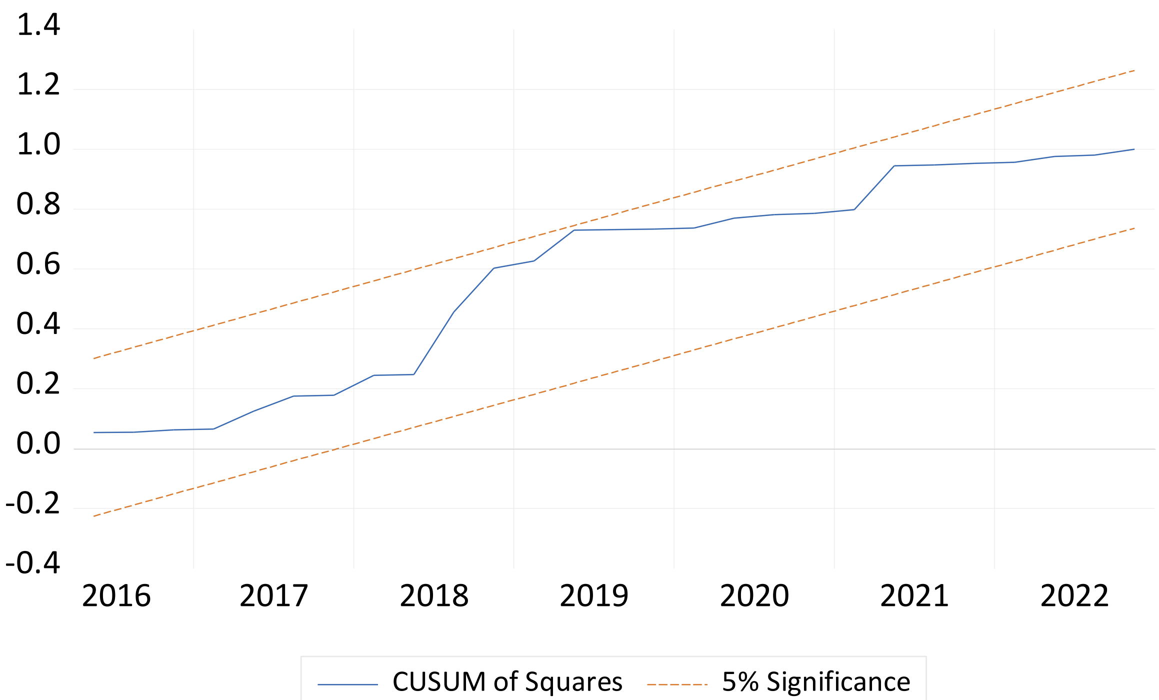
All these p-values are well above the 0.05 threshold, indicating that we fail to reject the null hypothesis of homoskedasticity. This means that the residuals exhibit constant variance, and there is no evidence of heteroskedasticity. The assumption of homoskedasticity is therefore satisfied in this model, which supports the validity of the standard errors and the reliability of the coefficient estimates.

Stability diagnostics

Cusum test



Cusum of squares test



The CUSUM and CUSUM of Squares tests are used to assess the stability of the coefficients in the ARDL model over time. Both tests are crucial for confirming that the model's parameters remain consistent throughout the sample period, particularly after accounting for any structural breaks.

CUSUM Test:

The CUSUM test plot shows that the cumulative sum of recursive residuals stays within the 5% significance boundaries throughout the period from 2016 to 2022. This indicates that the coefficients in the model are stable over time and that there are no significant changes in the relationship between the variables. The fact that the CUSUM line remains well within the critical bounds suggests that the model is dynamically stable and that the estimated coefficients are reliable across the entire sample period.

CUSUM of Squares Test:

The CUSUM of Squares test plot similarly shows that the cumulative sum of squared residuals remains within the 5% significance boundaries, although it approaches the upper boundary towards the end of the period. This result further supports the stability of the model's coefficients but also indicates that while the model is stable, there might be some slight fluctuations in variance, particularly towards the end of the sample period. However, since the line does not cross the boundaries, these fluctuations are not severe enough to invalidate the model's stability.

Overall, the results of both the CUSUM and CUSUM of Squares tests indicate that the ARDL model is stable over the sample period, with no evidence of coefficient instability. This suggests that the model's predictions and inferences about the relationships between CPI and the independent variables (ATM, INT, GDPPC, LNER) are robust and can be trusted over time.

Short- and long-term coefficients

ARDL Long Run Form and Bounds Test
Dependent Variable: D(CPI)
Selected Model: ARDL(4, 2, 4, 4, 1)
Case 3: Unrestricted Constant and No Trend
Date: 08/21/24 Time: 08:21
Sample: 2004Q1 2023Q4
Included observations: 69

Conditional Error Correction Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.139009	0.271457	0.512085	0.6109
CPI(-1)*	-0.059796	0.012649	-4.727178	0.0000
ATM(-1)	-0.063448	0.022427	-2.829081	0.0068
INT(-1)	0.123684	0.052595	2.351632	0.0228
GDPPC(-1)	0.131857	0.030756	4.287164	0.0001
LNER(-1)	-0.223471	0.241755	-0.924370	0.3599
D(CPI(-1))	2.004231	0.095819	20.91684	0.0000
D(CPI(-2))	-1.736094	0.151058	-11.49290	0.0000
D(CPI(-3))	0.614465	0.087110	7.053854	0.0000
D(ATM)	-0.157030	0.101419	-1.548327	0.1281
D(ATM(-1))	0.236666	0.122556	1.931081	0.0594
D(INT)	4.225711	0.709499	5.955904	0.0000
D(INT(-1))	-9.803676	1.716230	-5.712334	0.0000
D(INT(-2))	9.185764	1.776160	5.171700	0.0000
D(INT(-3))	-3.337669	0.809709	-4.122060	0.0001
D(GDPPC)	1.298995	0.442613	2.934835	0.0051
D(GDPPC(-1))	-2.799249	1.011208	-2.768224	0.0080
D(GDPPC(-2))	2.529060	0.991336	2.551164	0.0140
D(GDPPC(-3))	-0.970046	0.427245	-2.270471	0.0277
D(LNER)	4.060012	1.317704	3.081127	0.0034
DUMMY	-0.195069	0.158090	-1.233905	0.2232

* p-value incompatible with t-Bounds distribution.

Levels Equation
Case 3: Unrestricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ATM	-1.061075	0.334262	-3.174381	0.0026
INT	2.068430	0.847700	2.440050	0.0184
GDPPC	2.205104	0.381883	5.774295	0.0000
LNER	-3.737206	4.076931	-0.916671	0.3639

EC = CPI - (-1.0611*ATM + 2.0684*INT + 2.2051*GDPPC -3.7372*LNER)

Long-term

The table presents the long-run relationship between the dependent variable (CPI) and the independent variables (ATM, INT, GDPPC, LNER), all expressed in percentage terms, as estimated by the ARDL model. The coefficients offer insights into how percentage changes in these independent variables influence the percentage change in CPI over the long term, with each relationship being logically consistent with economic theory and contextual factors.

- **ATM (Automatic Teller Machine)**: The coefficient for ATM is -1.061075, which is statistically significant with a p-value of 0.0026. This finding suggests that a 1% increase in ATM usage leads to an approximate 1.0611% decrease in CPI over the long term. The negative relationship is consistent with the view that increased digitalization and financial inclusion, reflected in higher ATM usage, can reduce reliance on cash transactions, improve transaction efficiency, and lower the velocity of money. As digital payment systems become more prevalent, the demand for physical cash decreases, which can exert downward pressure on inflation by stabilizing money supply growth.

INT (Interest Rate): The coefficient for interest rates (INT) in the ARDL model is 2.068430, with a p-value of 0.0184, indicating that this relationship is statistically significant. This positive coefficient suggests that a 1% increase in interest rates is associated with an approximately 2.0684% increase in CPI over the long term.

This relationship can be understood through several economic mechanisms. When interest rates rise, the immediate effect is often an increase in the cost of borrowing for consumers and businesses. For consumers, higher interest rates make loans, such as mortgages or car loans, more expensive, which tends to reduce spending. For businesses, more expensive loans increase the cost of financing investments or operations, which can lead to higher production costs.

Faced with higher costs, businesses might choose to pass these costs on to consumers by raising prices, leading to what is known as cost-push inflation. This is where the increase in costs, driven by higher interest rates, pushes up the overall price level in the economy, contributing to higher CPI.

Additionally, higher interest rates can influence inflation through their impact on savings and consumption. As interest rates rise, saving becomes more attractive because individuals earn more on their deposits. This can lead to a reduction in consumption as people opt to save rather than spend. However, if this reduction in consumption is significant enough to impact businesses' revenues, firms might react by increasing prices to maintain their profit margins, especially if they perceive that demand for their products has become less elastic—that is, consumers are less responsive to price changes.

This dual effect—where higher interest rates both increase costs for businesses and potentially lead to higher prices as firms adjust to changing demand patterns—explains the positive relationship between interest rates and CPI in the long run. The result is a scenario where, despite initial reductions in consumer spending, the overall effect of higher interest rates can be an increase in inflationary pressures as firms adjust prices upwards in response to these economic dynamics.

- **GDPPC (Gross Domestic Product per Capita)**: The coefficient for GDPPC is 2.205104, which is highly significant with a p-value of 0.0000. The positive relationship, where a 1% increase in GDP per capita results in a 2.2051% increase in CPI, is consistent with demand-pull inflation theory. As income levels rise, consumer purchasing power increases, leading to higher demand for goods and services. In an expanding economy, this heightened demand can outpace supply, resulting in upward pressure on prices and contributing to inflation.

LNER (Log Exchange Rate): The lack of statistical significance for the exchange rate (LNER) in the ARDL model can be attributed to two key factors: short-term volatility versus long-term trends and potential data and model limitations.

First, exchange rates are characterized by short-term volatility, often driven by speculative trading, political events, or temporary economic shocks. These short-term fluctuations introduce noise into the data, complicating the detection of a clear and consistent impact of exchange rate changes on the Consumer Price Index (CPI) over the long term. While such fluctuations may cause temporary shifts in prices, they do not necessarily translate into sustained long-term inflationary or deflationary pressures. In contrast, long-term trends in CPI are typically influenced by more stable, underlying economic factors, such as productivity growth, technological advancements, or shifts in consumer demand. This discrepancy between the short-term volatility of exchange rates and the long-term stability of CPI may explain why the exchange rate does not emerge as a significant factor in the model's long-run relationship.

Second, the statistical insignificance of the exchange rate may also be due to limitations in the data or the model specification utilized in this study. If the exchange rate data fails to adequately capture relevant fluctuations or does not fully reflect the underlying economic conditions, it may lead to an underestimation of the exchange rate's impact on CPI. Additionally, the model may not account for all relevant variables or interactions that could influence the relationship between the exchange rate and CPI. For example, external factors such as global commodity prices or foreign monetary policies, which also affect domestic prices, may not be fully incorporated into the model, thereby overshadowing the role of the exchange rate in the analysis. Furthermore, the presence of structural breaks or changes in the economy over time may alter the exchange rate's impact, making it more challenging to detect a significant long-term effect within the model.

In summary, the statistical insignificance of LNER in the ARDL model is likely due to the inherent short-term volatility of exchange rates, which complicates the detection of a stable long-term relationship, as well as potential limitations in the data or model specification that may not fully capture the exchange rate's impact on CPI within the context of this study.

- **Long-Run Equation:**

The long-run relationship can be summarized by the following equation:

$$EC=CPI-(-1.0611*ATM+2.0684*INT+2.2051*GDPPC-3.7372*LNER)$$

This equation encapsulates how CPI is influenced by percentage changes in ATM usage, interest rates, GDP per capita, and the exchange rate over the long term. Each coefficient is logically consistent with economic theory, where increased digitalization (ATM) reduces inflationary pressures, higher interest rates (INT) and income levels (GDPPC) contribute to higher inflation, and the impact of exchange rates (LNER) remains complex and statistically insignificant within this model. These findings highlight the multifaceted nature of inflation dynamics in the context of digital transformation and macroeconomic variables.

Short-Run Dynamics Analysis

The table presents the short-run dynamics of the relationship between CPI and the independent variables (ATM, INT, GDPPC, LNER) as estimated by the ARDL model. These short-run coefficients, along with their p-values, provide insights into the immediate effects of changes in these variables on CPI and help us understand how these dynamics harmonize with the long-run relationships previously discussed.

1. Error Correction Term (CPI(-1))

- The error correction term coefficient is -0.059796, with a highly significant p-value of 0.0000. This negative and statistically significant coefficient confirms the existence of a long-term relationship and indicates that approximately 5.98% of the disequilibrium from the previous period is corrected in the current period. The relatively small magnitude of this coefficient suggests a gradual adjustment process, where deviations from the long-run equilibrium are corrected over time, consistent with the idea that the economy adjusts slowly to shocks.

2. Short-Run Impact of ATM (ATM(-1), D(ATM(-1)), D(ATM))

- The coefficient for ATM(-1) is -0.063448, with a p-value of 0.0068, indicating that a 1% increase in ATM usage in the previous period leads to an approximate 0.0634% decrease in CPI in the current period. This negative relationship aligns with the long-term finding where increased ATM usage, indicative of greater financial inclusion and digitalization, reduces inflationary pressures by stabilizing money supply growth.
- However, the short-run dynamics also show that the immediate impact of changes in ATM usage (D(ATM)) is not statistically significant (p-value = 0.1281). This suggests that while the effects of ATM usage are significant when lagged, immediate changes do not exert a significant impact on CPI, indicating that the influence of ATM on inflation takes time to materialize.

3. Short-Run Impact of Interest Rates (INT(-1), D(INT), D(INT(-1)), D(INT(-2)), D(INT(-3)))

- The coefficient for INT(-1) is 0.123684, with a p-value of 0.0228, indicating that a 1% increase in interest rates in the previous period leads to an approximate 0.1237% increase in CPI in the current period. This result is consistent with the long-run finding that higher interest rates increase inflationary pressures, reflecting the cost-push effects where higher borrowing costs translate into higher prices.
- The immediate effect of changes in interest rates (D(INT)) is highly significant, with a coefficient of 4.225711 and a p-value of 0.0000, indicating a strong and direct impact on CPI. This suggests that in the short run, increases in interest rates lead to substantial increases in CPI, likely due to the immediate pass-through of higher costs to consumers.
- The lagged effects (D(INT(-1)), D(INT(-2)), D(INT(-3))) are also significant, with coefficients that suggest a continuation of inflationary pressures over time as the impact of interest rate changes propagates through the economy. The consistency in the significance and magnitude of these coefficients reinforces the long-run relationship where higher interest rates are associated with higher inflation.

4. Short-Run Impact of GDP per Capita (GDPPC(-1), D(GDPPC), D(GDPPC(-1)), D(GDPPC(-2)), D(GDPPC(-3)))

- The coefficient for GDPPC(-1) is 0.131857, with a p-value of 0.0001, indicating that a 1% increase in GDP per capita in the previous period leads to an approximate 0.1319% increase in CPI in the current period. This result supports the long-term finding that higher income levels contribute to inflationary pressures through increased consumer demand.

- The immediate and lagged effects of changes in GDP per capita (D(GDPPC), D(GDPPC(-1)), D(GDPPC(-2)), D(GDPPC(-3))) are all significant, with positive coefficients that highlight the persistence of demand-pull inflation in the short run. The significant coefficients indicate that increases in GDP per capita drive up CPI not only immediately but also over subsequent periods, consistent with the long-run view that economic growth can lead to sustained inflationary pressures.

5. Short-Run Impact of Exchange Rate (LNER(-1), D(LNER))

- The coefficient for LNER(-1) is -0.223471, with a p-value of 0.3599, indicating that the lagged effect of the exchange rate on CPI is not statistically significant. This result aligns with the long-run finding that the exchange rate does not have a significant impact on CPI, likely due to the reasons previously discussed, such as short-term volatility and potential model limitations.
- Interestingly, the immediate effect of changes in the exchange rate (D(LNER)) is significant, with a coefficient of 4.060012 and a p-value of 0.0034. This suggests that while the long-term impact of the exchange rate on CPI is muted, short-term fluctuations can have a significant effect. This is likely due to the immediate impact of currency depreciation on import prices, which can quickly translate into higher consumer prices. However, these effects do not seem to persist over the long run, as indicated by the lack of significance in the lagged and long-term coefficients.

Summary of Short-Run and Long-Run Harmony

The short-run dynamics revealed by the ARDL model are consistent with the long-run relationships identified in the previous analysis. The adjustment process, as captured by the error correction term, confirms the existence of a stable long-term relationship, with deviations from equilibrium being gradually corrected over time. The significant short-run coefficients for interest rates, GDP per capita, and the exchange rate suggest that these variables have immediate and sometimes substantial effects on CPI, which are consistent with their long-run impacts, though the magnitude and persistence of these effects can vary.

The influence of ATM usage, while significant in the long run, appears to be more gradual, with short-run effects being significant only when lagged. This indicates that the benefits of digitalization and financial inclusion in reducing inflation may take time to manifest.

Overall, the short-run dynamics complement the long-run findings, providing a comprehensive picture of how these macroeconomic variables interact with CPI over different time horizons. The ARDL model effectively captures both the immediate and delayed effects, offering insights into the complex nature of inflationary dynamics in the context of digital transformation and broader economic trends.

Conclusion

This study has examined the profound effects of digital transformation on the effectiveness of monetary policy in Egypt, particularly focusing on the increasing adoption of digital payment systems and financial technology (fintech) innovations. Through the application of the ARDL model, the analysis reveals that digital financial inclusion—reflected by variables such as the number of automated teller machines (ATMs)—has reduced the reliance on cash transactions, altering the dynamics of monetary policy transmission. These shifts have had significant implications for traditional policy tools, such as interest rates and inflation targeting mechanisms.

The econometric results provide strong evidence of a long-term relationship between digital transformation variables and monetary policy effectiveness. The findings indicate that increased digital payment adoption and the growth of digital financial services have contributed to both short- and long-term inflationary pressures in Egypt. Specifically, higher interest rates and GDP per capita are positively correlated with inflation, while the increased use of ATMs is associated with a reduction in inflation. However, the lack of significance for the exchange rate variable suggests that exchange rate volatility has a muted effect on long-term inflation trends, likely due to short-term shocks rather than structural shifts.

The results underscore the need for Egypt to adapt its monetary policy framework in response to these ongoing changes. As the financial landscape continues to evolve, the Central Bank of Egypt must enhance its regulatory approaches to ensure that monetary policy remains effective in a predominantly digital financial system.

Policy Recommendations

Based on the findings of this study, several policy recommendations can be made to improve the effectiveness of Egypt's monetary policy in the digital era:

1. **Strengthening Regulatory Oversight for Digital Financial Services:** The Central Bank of Egypt (CBE) should prioritize the development of a robust regulatory framework that governs the operation of fintech innovations, mobile banking, and other digital financial services. This framework should ensure the security of digital transactions and protect consumers from cybersecurity threats while enabling innovation and competition in the financial sector.
2. **Encouraging the Adoption of Central Bank Digital Currency (CBDC):** As digital currencies continue to grow in importance globally, the CBE should explore the feasibility of issuing a Central Bank Digital Currency (CBDC) to improve the transmission of monetary policy. By directly controlling a digital currency, the CBE could exert greater influence over money supply and inflation, mitigating the risks posed by private digital currencies and maintaining economic stability.
3. **Promoting Financial Inclusion through Digital Platforms:** The expansion of mobile banking, e-wallets, and other digital financial services presents an opportunity to enhance financial inclusion, particularly among rural and underserved populations. The CBE should continue promoting digital financial literacy programs and incentivizing the use of digital platforms to increase access to financial services, which can contribute to more effective monetary policy transmission across all sectors of society.
4. **Adapting Monetary Policy Tools to Reflect Digital Payment Trends:** The reduction in the demand for cash and the rise of digital payment systems require a reevaluation of traditional monetary policy tools such as interest rates and reserve requirements. The CBE should consider the integration of digital payment metrics into its policy models to more accurately reflect the velocity of money in a digital economy and ensure that policy interventions are appropriately targeted.

5. **Addressing Exchange Rate Volatility:** Although exchange rate volatility was found to have a limited long-term effect on inflation, short-term shocks can still impact price levels, particularly through imported inflation. The CBE should maintain its flexible exchange rate policy while implementing measures to hedge against short-term currency fluctuations that may arise from external shocks.
6. **Fostering International Collaboration and Knowledge Exchange:** Given the global nature of digital financial innovations, the CBE should actively engage in international forums and collaborate with other central banks and financial institutions. This collaboration will allow Egypt to benefit from best practices and insights from other countries that have successfully integrated digital transformation into their monetary frameworks.

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