



Available Online

Journal of Economic Impact

ISSN: 2664-9764 (Online), 2664-9756 (Print)

<https://www.scienceimpactpub.com/jei>

THE LONG RUN IMPACT OF EXCHANGE RATE AND INFLATION ON GDP: A PANEL DATA APPROACH CONSISTENT WITH DATA FROM BRAZIL, RUSSIA, INDIA, CHINA, AND SOUTH AFRICA (BRICS)

Sateesh Kumar ^{a,*}, Ajeet Kumar ^a, Ghulam Mustafa Shaikh ^b, Kamran Ali ^a, Mukaram Azhar ^a^a Department of Business Administration, SZABIST University, Larkana Campus, Sindh, Pakistan^b Department of Business Administration, University of Larkana, Sindh, Pakistan

ARTICLE INFO

Article history

Received: September 28, 2023

Revised: December 10, 2023

Accepted: December 19, 2023

Keywords

Gross domestic product

Panel data

BRICS

Inflation

Exchange rate

Long-run impact

ABSTRACT

The study seeks to address current discrepancies, providing valuable knowledge for decision-makers, fostering economic stability and expansion, informing global economic trends, assisting in business risk mitigation, and contributing to academic advancement through methodological innovation, with a focus on the changing nature of global economic dynamics. The purpose of this study is to assess how inflation and currency exchange rates affect the GDPs of the BRICS (Brazil, Russia, India, China, and South Africa) nations between 1998 and 2022. We employed a fixed-effect panel data model using EViews software to conduct a thorough regression analysis on the influence of exchange rates and inflation on the Gross Domestic Product (GDP) of the BRICS nations. The World Development Indicators website provides data that shows that, in contrast to predictions, exchange rates have no appreciable impact on GDP. Nonetheless, during the given time frame, inflation turns out to be a noteworthy and positively connected element impacting these countries' economic growth. This research contributes to the current understanding by uncovering the complex interconnections between exchange rates, inflation, and GDP in BRICS economies. Our findings highlight the necessity of customized economic strategies that recognise the distinct functions of inflation and currency rates in influencing the long-term growth patterns of individual countries.

* Email: sateeshkumarhotchandani@gmail.com<https://doi.org/10.52223/econimpact.2023.5318>

© The Author(s) 2023.

This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

INTRODUCTION

The longitudinal study examines the long-lasting effects of exchange rates and inflation on Gross Domestic Product (GDP) by employing a panel data methodology. The research is primarily concerned with the BRICS countries, namely Brazil, Russia, India, China, and South Africa. Its objective is to analyse the intricate relationship between currency exchange rates, inflation rates, and their long-term impact on economic growth. This project intends to analyze patterns and trends in the economic landscapes of varied nations over an extended period using a comprehensive panel data technique. The goal is to get insights into the complex mechanisms that shape these economies. Comprehending the lasting consequences of fluctuations in exchange rates and inflation on the Gross Domestic Product (GDP) within the framework of the BRICS nations is important for policymakers, economists, and investors. It provides essential insights for making well-informed decisions in the global economic sphere.

Gross Domestic Product (GDP)

The Gross Domestic Product (GDP) plays a significant function as a vital indicator that evaluates a nation's economic success throughout a defined timeframe (Duan et al., 2021). The study conversely, serves as a guiding force in influencing policy decisions and infrastructure planning. Gross Domestic Product (GDP) serves as a comprehensive measure to assess a country's entire economic power and capability (Wu and He, 2021). Moreover, advanced approaches, such as neural network models, are utilized to forecast

GDP. GDP is the total worth of all products and services produced inside a country's borders during a specific year. This indicator is a crucial benchmark for assessing the economic vitality and efficiency of a country (Shaker, 2022).

Exchange Rate

The exchange rate functions as a quantitative indicator of the worth of a currency, comprising both the rates at which it can be sold and purchased. In addition, the dynamic metric is subject to the influence of various factors, such as interest rates, inflation, and other significant economic variables (Rahayuningtyas et al., 2021). Moreover, Seputra et al. (2022) defined exchange rates as the complex network of connections within the realm of currency trading, wherein one currency is traded for another. The complicated choreography of this dance is directed by a multifaceted interaction of monetary, political, and psychological factors that collectively establish the comparative value of one currency in relation to another. The exchange rate is essentially the valuation of one nation's currency in relation to another nation's currency, stated and measured in terms of the latter's currency (Kartono et al., 2021).

Inflation

Inflation, a fundamental concept in economic analysis, denotes an ongoing and widespread increase in the prices of goods and services within an economy. This economic phenomenon is

characterized by a persistent and widespread increase in prices, which has a significant influence on the whole economic environment (Fadliani et al., 2021), Inflation, by causing a gradual increase in prices, can gradually diminish the buying power of a country's currency, therefore impacting the economic vitality of the nation (Lubis and Soemitra, 2022). The impacts of this phenomenon extend beyond theoretical economic measures and are tangibly felt by the general population as they observe the decline in the purchasing power of their currency. Inflation, characterized by the upward movement of prices, is closely linked to the interaction between demand and supply forces in an economy. When there is more demand than supply or other causes cause costs to rise, it leads to a gradual increase in inflation that affects the economic dynamics of a country (Lee, 2022).

Exchange Rate Significance in International Trade and Economic Stability

Exchange rates exhibit a significant influence on international economic interactions, affecting all facets of trade and economic stability. Various complex elements, including nominal and relative inflation, income levels, government actions, and unexpected events, all contribute to the formation of foreign currency rates, which in turn impact trade volumes and overall current account performance (Karakostas, 2021). Exchange rates in the area of international trade function as a standard for evaluating the costs of goods and services between countries, impacting competitive positioning and the movement of trade (Agarwal, 2021), moreover the lasting influence of the real exchange rate is demonstrated in the two-way trade connections between Indonesia and Japan, where it serves as a catalyst for more exports, lower imports, and a favorable surplus in the trade balance. Exchange rates are more than just numbers. They are a powerful and complex force that is closely linked to economic stability and trade dynamics. To make successful policies and navigate the global economy, it is important to have a detailed grasp of exchange rates (Agarwal, 2021).

Inflation Significance in International Trade and Economic Stability

The inflation rate has a substantial impact on both international commerce and macroeconomic stability. It affects the total exports and exchange rates with a delay of 1 and 2 periods, respectively, in various economic conditions. These dynamics play a vital role in maintaining both macroeconomic and social stability. They lead to changes in the structural composition and have a significant impact on the well-being of the population, particularly during times of crisis (Saygılı, 2020). In addition to its economic ramifications, inflation is intricately linked to both macroeconomic and social stability. Inflation targeting significantly amplifies the benefits derived from free trade agreements by highlighting the adaptability of trade facilitation without the need for a unified currency. Within the Nigerian economy, there is a direct relationship between inflation and trade openness, which leads to improved economic results. However, the exchange rate and money supply have a negative impact, affecting the nation's economic performance. Understanding the relevance of inflation in the context of international commerce and economic stability requires appreciating its complex effects on structural proportions, social well-being, and policy dynamics. As countries face difficulties, the significant influence of inflation highlights its crucial role in influencing the direction of the global economy (Haque et al., 2022).

BRICS Organization

The BRICS Development Organization was established with the goal of supporting and promoting countries that are on the verge of industrialization, including Brazil, Russia, India, China, and South Africa. The term was introduced by American economist Jim O'Neal in 2001 to describe a collective endeavor aimed at promoting growth and prosperity among these varied nations. An essential priority for BRICS nations is to strengthen their dispute resolution processes, which is a crucial measure to encourage investment and stimulate economic growth. The organization's cooperative attitude is highlighted by the shared goal of establishing a strong framework for resolving conflicts, which is crucial for promoting sustained growth. Member countries acknowledge the significance of this objective (Fatima, 2022). Although BRICS possesses significant economic influence, it does not present a legitimate challenge to the US-dominated post-war liberal global system. This can be due to the internal composition of the organization, which is characterized by a mix of political and ideological differences. Additionally, there is a noticeable lack of significant agreement on foreign policy objectives and preferences among its members. Therefore, although BRICS functions as a powerful economic alliance, its influence on the current global system is limited due to internal intricacies. BRICS has established investment protection agreements with Latin America and the Caribbean within the realm of international treaties. Significantly, these agreements closely resemble the traditional framework for safeguarding foreign investments, thus reinforcing the region's position as a major supplier of unprocessed resources. This facet of BRICS interactions exemplifies the organization's wider economic dynamics and its impact on global trade patterns (Nuruzzaman, 2020). Essentially, BRICS, as a collective, manages an intricate environment, maintaining an equilibrium between economic ambitions and internal heterogeneity. The joint efforts of the organization have a significant impact on regional development and economic cooperation. However, these efforts are influenced by the complex interplay of political, ideological, and economic factors inside its member nations (Garcia and Pereira, 2023).

Economic significance of BRICS in the Global Context

The BRICS nations have emerged as prominent players in the global economy, showcasing robust expansion and exerting a growing influence, particularly in times of global turmoil. The BRICS consortium, comprising Brazil, Russia, India, and China, has not only adeptly managed global economic challenges but has also made substantial contributions to the broader endeavors of recovery (Yadav, 2022). The collective impact of these nations extends beyond their individual capacities, as they collaborate across several domains and establish significant institutions such as the New Development Bank and Contingent Reserve Arrangement. This joint strategy enhances not just their economic resilience but also their collective ability to effectively tackle global economic risks (Iqbal, 2022). The economic importance of BRICS goes beyond just regional cooperation; it plays a crucial role in shaping global governance and promoting socio-economic development at the country level. As these nations establish more robust economic connections, they play a crucial role in guiding global economic discussions and policy. The BRICS nations are ensuring the protection of their own economic interests and promoting stability and progress in the global community by promoting collaboration and establishing mechanisms to manage financial risks. Essentially, the economic collaboration among BRICS countries is crucial for both worldwide economic expansion

and the maintenance of each nation's socio-economic welfare (Li and Pogodin, 2020).

Problem Statement

The intricate relationship among exchange rates, inflation, and economic growth has been extensively studied by scholars due to its crucial influence on the economic structure of countries. It is crucial to comprehend the long-term effects of exchange rates and inflation on Gross Domestic Product (GDP) within the cohort of Brazil, Russia, India, China, and South Africa (BRICS) as their economies gain increasing significance on the world stage. The current body of work has offered useful insights into the separate impacts of exchange rate fluctuations and inflation on economic performance. Nevertheless, there is a significant study gap in thoroughly examining the long-term consequences of these determinants on GDP in BRICS countries. An in-depth and context-specific study is required due to the intricate structure of these economies, which are characterized by varied structural intricacies, varying policy frameworks, and distinct stages of economic development.

This study seeks to close this disparity by utilizing a data panel methodology, enabling a comprehensive analysis that takes into account both the unique dynamics of individual countries and shared patterns within the BRICS group. This study aims to enhance the understanding of the long-term connections between exchange rates, inflation, and GDP in the BRICS nations by utilizing panel data analysis methodologies, such as the Fixed Effects or Random Effects models. The objective is to present a comprehensive and detailed analysis.

It is essential to recognize the changing nature of global economic dynamics, which includes changes in trade patterns, integration of financial markets, and geopolitical effects when doing this research. Moreover, with the most up-to-date data, this study seeks to provide timely and pertinent insights that can guide policy-making and strategic planning for both domestic governments and international organizations.

The results of this study are anticipated to enhance our comprehension of the complex interrelationships among exchange rates, inflation, and economic growth within the BRICS framework. Furthermore, this study has ramifications that go beyond academic discussions. It provides practical advice for politicians, economists, and business executives who are dealing with the intricacies of these ever-changing and powerful economies.

Significance of Study

The importance of my research on the "long-run effects of exchange rates and inflation on Gross Domestic Product (GDP) in BRICS countries: An analysis using panel data" rests in its capacity to provide significant insights to both academic and policy spheres.

Policy Implications: An in-depth comprehension of the impact of exchange rates and inflation on GDP in BRICS countries might furnish policymakers with invaluable insights. Authorities can utilize this information to develop efficient monetary and fiscal strategies to control inflation, stabilize currency exchange rates, and foster sustainable economic expansion.

Economic Stability and Growth: This study has the capacity to elucidate the elements that contribute to the stability and growth of the economies in BRICS countries. The research aims to provide recommendations for optimizing economic performance by analyzing the correlation between exchange rates, inflation, and GDP.

Global Economic Dynamics: Given the significant role that BRICS countries play in the global economy, this research has the potential to offer valuable insights into the interdependence of these nations and their influence on the international economic environment. This comprehension is crucial for politicians, enterprises, and investors globally.

Risk Management for Businesses: The results of this research can aid businesses in these countries and beyond in formulating efficient risk mitigation strategies. By comprehending the impact of currency rates and inflation on GDP, firms can make well-informed decisions regarding investment, production, and pricing strategies.

Academic Contribution: This study enhances the scholarly literature on the macroeconomic factors that influence the Gross Domestic Product (GDP) in developing nations. By utilizing a data panel technique, this study contributes to the current knowledge base and offers a detailed comprehension of the interconnected interactions.

Methodological Innovation: Employing a data panel methodology enhances the methodological rigor of the investigation. This methodology enables the examination of differences in exchange rates, inflation, and GDP across different countries and throughout time, resulting in a more comprehensive analysis of their dynamics.

Impact of Exchange Rate on GDP

Exchange rates have a tremendous impact on the economic growth of many countries, and each situation offers unique insights into this intricate relationship. In the context of Bangladesh, the impact of exchange rates on GDP growth is highly advantageous, suggesting a robust link between these two variables (Rahaman et al., 2022). In the context of Pakistan, the impact of the exchange rate on GDP is negatively associated (Shaikh et al., 2018). According to Adu-Gyamfi et al. (2020), the Real Exchange Rate (RER) has been identified as a significant factor contributing to GDP growth in nine nations of West African countries. Furthermore, a study of the Middle East, Iraq also observed a favorable and significant influence of exchange rates on GDP, emphasizing a reliable correlation between these economic indicators (Majee, 2023). However, the situation changes when we focus on South Africa, since the fluctuation in exchange rates brings about a negative aspect. The consequences in this particular situation are clearly seen in various aspects, such as Foreign Direct Investment (FDI), GDP, and trade openness. The negative effect of fluctuations in exchange rates on these factors highlights the complex difficulties that South Africa faces in preserving economic stability (Dagume, 2022). In contrast, Mexico offers a distinct tale. The Real Exchange Rate (RER) does not have a central role in affecting GDP growth in this country. On the contrary, the focus is on public spending, which has a notable and meaningful impact on the Mexican economy's long-term growth path. This variety highlights the range of ways in which countries are impacted by currency rates (Médici et al., 2021). Upon analyzing India's manufacturing sector, it is observed that exchange rate volatility has a detrimental effect, albeit it does not achieve statistical significance. However, there are additional global factors that have a positive and considerable impact on Indian manufacturing exports, such as world GDP and real effective exchange rates. The complex interaction of variables emphasizes the subtle nature of the correlation between exchange rates and GDP in various global contexts (Jyoti, 2021). Overall, the effect of exchange rates on GDP is a complex phenomenon that requires a detailed analysis, taking into account not just the direction but also the magnitude and importance of the interactions involved. The distinctive economic conditions of each

country contribute to the complexity of this interaction, highlighting the significance of conducting context-specific analysis to fully understand the actual dynamics involved.

H1: There is a significant/meaningful relationship between Exchange Rate and GDP.

Impact of Inflation on GDP

Inflation affects GDP through a dual process, exerting a major influence on both necessary products and non-essential commodities. Accordingly, it affects the ability of middle and lower-income groups to buy things, leading to broad effects such as increased costs in various areas (Kapoor, 2023). Inflation has a largely negative influence on the economy, particularly in the long term, leading to a noticeable decrease in GDP. Nevertheless, it is crucial to acknowledge the intricate character of its immediate consequences, in which the impact on GDP is evident in both positive and negative ways. The intricate interaction between inflation and economic growth highlights the intricacy of their relationship (Iqbal et al., 2022). Regional analysis provides specific evidence of the significant impact of inflation on GDP. Empirical evidence from nine West African countries consistently demonstrates a large and detrimental effect of inflation on the total growth of GDP. This discovery highlights the widespread nature of the negative effects that inflation can have on economic progress (Adu-Gyamfi et al., 2020). A nation's actual Gross Domestic Product (GDP) is especially susceptible to the adverse consequences of elevated inflation rates. The decline in the actual value of GDP can have significant consequences for economic expansion and overall inflation rates. The significance of preserving a stable inflation rate to promote continuous economic growth is emphasized by this interconnection (Radjamin et al., 2022). Furthermore, it is important to mention that although inflation has a detrimental influence on GDP growth, the extent of this impact is relatively smaller when compared to the impact of uncertainty around inflation. The complex interplay between inflation anxiety and GDP growth, which is mediated via its effect on inflation, underscores the intricate processes that shape the broader economic environment (Živkov et al., 2020). The correlation and regression studies reveal the complex relationship between inflation, population growth, and GDP in the Indian setting. These statistical tools unveil the complex network of connections in which inflation and population expansion together influence the path of GDP. This highlights the complex and diverse character of the factors involved, emphasizing the need for a thorough understanding of these dynamics in order to develop well-informed economic policies (Lagad et al., 2022).

H2: There is a significant/meaningful relationship between Inflation and GDP.

Purchasing Power Parity Theory

The Purchasing Power Parity (PPP) hypothesis provides a framework for predicting exchange rates between two countries, taking into account their individual inflation rates. PPP theory suggests that the nominal exchange rates in developed nations might fluctuate due to cross-sectional dependence, resulting in either depreciation or appreciation. This hypothesis essentially establishes a correlation between variations in inflation rates and fluctuations in exchange rates, offering valuable insights into the comparative vigor or fragility of currencies in the international market (Lim, 2021). The fundamental concept is that exchange rates should gradually adapt to mirror fluctuations in price levels, guaranteeing that comparable commodities possess equivalent costs in various currencies, thereby fostering equality in

purchasing power. Comprehending and forecasting the fluctuations of currency valuations in international trade and finance relies heavily on this fundamental idea (Choji and Sek, 2023).

Monetarist theory

The essence of the Monetarist theory is in the development of effective monetary policy rules within the existing monetary system, emphasizing a preference for government intervention, which sets it apart from the Austrian theory (Israel, 2022). The Monetarist perspective places great importance on the effectiveness of both fiscal and monetary policy as crucial instruments for accomplishing the ambitious objectives of strong and enduring economic development, complete employment, and stable prices. Monetarists argue that targeted government interventions, specifically through fiscal and monetary policies, can effectively help to achieve and sustain a stable and successful economic climate (Demissew and Kotosz, 2020).

METHODOLOGY

This study is conducted with a specific purpose or target in mind, and it is implemented using a descriptive-correlational approach. In this study, the variable of GDP is regarded as the dependent variable. We utilize the data panel methodology to measure the influence of exchange rates and inflation on GDP. This study was undertaken in five countries: Brazil, Russia, India, China, and South Africa. The statistical data of these countries has been acquired from the website World Development Indicators for the period from 1998 to 2022.

Statistical Model

Using the logarithmic transformation of exchange rate data, specifically through centered log ratios, is crucial for maintaining the reliability of statistical analysis (Gámez Velázquez and Coenders, 2020). This transformation not only simplifies the depiction of percentage changes but also allows for a more understandable identification of substantial increases and decreases in value. Using the logarithmic representation of inflation data in the model provides numerous benefits. This conversion is especially efficient in reflecting the subtleties of Taiwan's inflation patterns, save for the instances observed during the oil crises of 1973 and 1979-80 (Chow, 2012). The model utilizes a cointegration relation that is expressed as a linear function of the logarithm of a price index and the logarithm of the ratio of money supply to output. This approach guarantees a stronger and more reliable depiction of the fundamental economic connections. The logarithmic transformation enhances comprehension of proportional changes and mitigates scale-related problems, hence improving the model's ability to accommodate fluctuations in inflation patterns over time. The logarithm of GDP data is an essential stage in the analytical process, as it helps to achieve stationarity and enables the use of forecasting models in the context of Nigeria (Okereke and Bernard, 2014). The log transformation is effective in addressing problems associated with heteroscedasticity and non-constant variance, which are frequently observed in economic time series data.

$$ILGDP_{it} = B_0 + \text{BitLER}_{it} + \text{BitLINF}_{it} + \text{Eit} \quad (1)$$

Where:

LGDP= Log of Gross Domestic Product

LER= Exchange Rate

LINF=Inflation

I= country/entity

T= time

Panel Data Regression Model Choice

By including fixed effects, these models consider unobserved attributes that differ among individual entities within the panel over time, hence improving the strength and dependability of the study (Baltagi, 2021). By employing this approach, we not only guarantee a more precise depiction of the connections being studied, but also enhance our comprehension of the intricate interaction between variables in a panel dataset (Nwakuya and Ijomah, 2021).

Pooled/Panel ordinary least squared

Pooled Ordinary Least Squares (Pooled OLS) is a frequently employed technique in the analysis of panel data. Panel data regression analysis is most straightforward when using the simplest kind of regression. This methodology involves aggregating data from many cross-sectional units, such as countries, and time periods. Subsequently, a singular regression model is computed for the entire dataset (Zulfikar, 2018).

The test for this model fitness is Breusch-Pagan test.

Ho: Select POLS (if p-value is >0.05 Accept Ho otherwise reject H0)

H1: Select Random/Fixed Effect Model

Fixed/Random effect Model

The Random Effects (RE) model is a commonly employed method in the study of panel data. The architecture of this model accounts for unobserved variability by incorporating individual-specific effects that are considered to be random rather than constant (Zulfikar, 2018).

The test for this model fitness is Durbin-wu-Hausman Test

H0: Select Random Effect (if p-value is >0.05 Accept Ho otherwise reject H0)

H1: Select the Fixed Effect model

A Fixed Effects (FE) model is a regression model frequently employed in panel data analysis to accommodate individual-specific effects. Panel data refers to the collection of data that includes observations on several units, such as countries, firms, or individuals, spanning multiple time periods. The Fixed Effects model resolves the problem of unobserved heterogeneity among individual units by incorporating individual-specific fixed effects (Zulfikar, 2018).

RESULTS AND DISCUSSION

Exchange rate (LER)

On examining Table 1 and Figure 1, The exchange rate (LER) among BRICS members has demonstrated a consistent level of stability over the past 25 years, with an average value of 0.722. The distribution has a symmetrical pattern, but there are notable deviations ranging from -0.459 to 1.933, which indicate periods of extreme volatility. The data has a moderate level of variability, as indicated by a standard deviation of 0.315. Additionally, there is a slight skewness towards the left, with a skewness value of -0.172. The distribution of the data is characterized by heavy tails, as evidenced by a kurtosis value of 5.696. The findings of the Jarque-Bera test indicate a departure from a normal distribution ($p < 0.05$), indicating that assumptions of a Gaussian distribution should be approached with caution. The intricate economic landscape, as evidenced by these exchange rate trends, provides an opportunity to examine the enduring impact on GDP and inflation in BRICS nations.

Table 1. Descriptive statistics for the exchange rate, inflation and GDP of BRICS countries from 1998-2022.

Descriptive	LER	LGDP	LINF
Mean	0.722112	12.08002	1.108893
Median	0.732675	12.13465	0.984755
Maximum	1.933216	13.25438	1.895447
Minimum	-0.458656	11.11088	0.064651
Std. Dev.	0.314612	0.501490	0.509419
Skewness	-0.171694	0.324715	-0.060741
Kurtosis	5.696254	2.733106	1.815197
Jarque-Bera	36.63070	2.444417	7.033468
Probability	0.000000	0.294579	0.029696
Sum	85.93133	1437.522	131.9583
Sum Sq. Dev.	11.67969	29.67613	30.62187
Observations	119	119	119

Gross Domestic Product (GDP)

Upon analyzing Table 1 and Figure 2, the Gross Domestic Product (GDP) data of the BRICS countries over the last 25 years, some significant observations become apparent. The average GDP level is 12.08, representing the total economic output for the chosen period. The median, which is located around the mean, indicates a symmetrical distribution, indicating an equal representation of GDP levels among the countries analysed. A notable characteristic is the relatively narrow range of GDP statistics, indicating a restricted fluctuation in economic production throughout the investigated time. The standard deviation, which quantifies the extent of this fluctuation, supports this result with a relatively low value of 0.501. This discovery suggests that the GDP data exhibits a certain level of stability, as most of the numbers are concentrated around the average. The skewness coefficient of 0.325 provides a nuanced insight, indicating a little rightward skew in the distribution of GDP statistics. The near alignment between the mean and

median suggests that the data is mostly symmetrical. However, the positive skewness indicates that there is a somewhat longer tail on the right side of the distribution. This suggests that some countries have GDP numbers that are greater than the average.

Moreover, the kurtosis value of 2.733 provides insight into the form of the distribution. The modest kurtosis indicates that the GDP data deviates to some extent from a completely normal distribution, although it is not overly peaked or flattened. This discovery enhances our comprehension of the distributional attributes of GDP among BRICS countries. Significantly, the Jarque-Bera test, which assesses the normality of the data, produces a p-value that exceeds 0.05. This outcome offers statistical evidence to support the hypothesis that the GDP data conforms to a normal distribution. Therefore, readers may confidently analyse and interpret GDP patterns, knowing that the underlying distributional assumptions are reliable. In summary, the intricate relationship between these descriptive statistics

improves our understanding of the patterns and features present in the GDP data of the chosen BRICS countries.

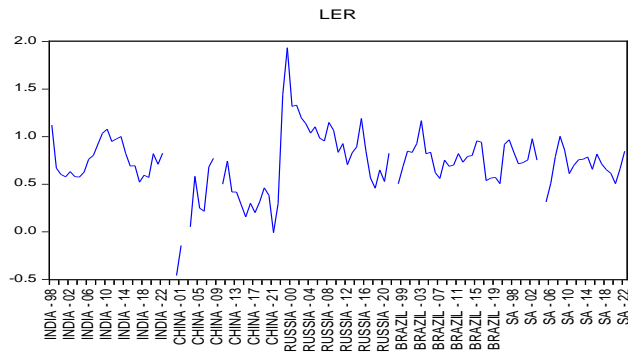


Figure 1. Exchange rate (LER).

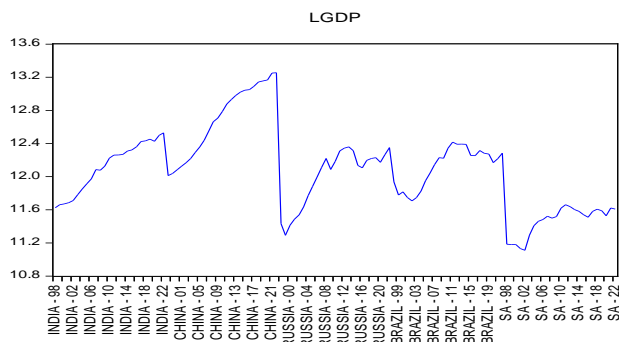


Figure 2. Gross Domestic Product (GDP).

Inflation rate (LINF)

An analysis of Table 1 and Figure 3, inflation rates in the BRICS nations over the past 25 years reveals a thorough understanding through the use of descriptive statistics. The average inflation rate, currently at 1.109, is a key indicator that represents the overall trend. Upon closer examination, one can observe fascinating subtleties within the distribution.

The median, being below the mean at 0.985, indicates a distribution that is positively skewed. The skewness is further accentuated by a somewhat negative skewness score of -0.061, suggesting a minor inclination towards lower inflation values. However, the apparent slant is offset by the extensive scope of the dataset. The inflation rates vary significantly, ranging from a minimum of 0.065 to a maximum of 1.895. The wide variation of

inflationary experiences among the BRICS members throughout the examined time is significant.

The standard deviation of 0.509 indicates a substantial amount of variability, highlighting the dynamic character of inflation rates within and between countries. In addition, the kurtosis value of 1.815 indicates a distribution that is relatively similar to the normal curve, albeit it has heavier tails. This implies that although there is a certain degree of resemblance to a normal distribution, the data displays a level of unpredictability.

The Jarque-Bera test reveals a significant departure from the normalcy assumption, as indicated by a p-value below 0.05. This deviation from normalcy suggests that the fundamental assumptions that form the basis of several statistical studies may not be applicable, emphasizing the need for careful consideration in the ensuing analytical procedures.

The unusual trends found in inflation rates frequently originate from an intricate interplay of several economic forces. Significant factors contributing to the inflationary landscape include the consequences of prevalent occurrences such as unemployment, globalization, outsourcing, migration, and terrorism, each exerting a unique impact (Goonatilake and Reyes, 2019). Commodity prices, world slack, exchange rates, and the dynamics of global value chains have significant influence on Consumer Price Index (CPI) inflation trends at a worldwide level (Forbes, 2019).

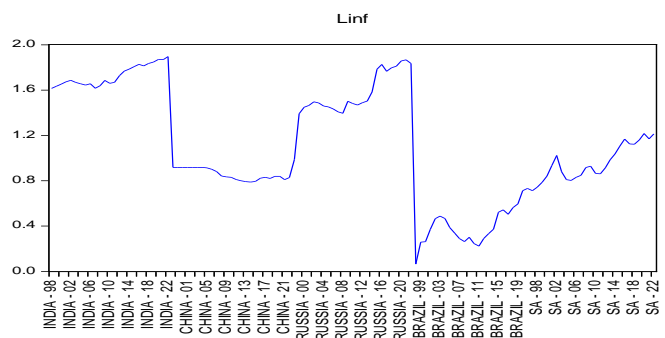


Figure 3. Inflation rate (LINF).

Pooled Ordinary least Squared output

As shown in Table 2 and 3, the P value of Breusch-Pagan is less than 0.05 so we reject the null hypothesis of the Breusch-Pagan LM test, and accept the alternative hypothesis of the Random effect model is best.

Table 2. Pooled OLS regression output.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	12.55345	0.126276	99.41290	0.0000
LINF	0.045237	0.083833	0.539610	0.5905
LER	-0.725087	0.135743	-5.341625	0.0000
Descriptive	Value			
R-squared	0.199800			
Adjusted R-squared	0.186003			
S.E. of regression	0.452454			
Sum squared resid	23.74685			
Log-likelihood	-72.95911			
F-statistic	14.48183			
Prob(F-statistic)	0.000002			
Mean dependent var	12.08002			
S.D. dependent var	0.501490			
Akaike info criterion	1.276624			
Schwarz criterion	1.346686			
Hannan-Quinn criter.	1.305074			
Durbin-Watson stat	0.106155			

Table 3. Model fitness of pooled OLS (POLS test for fitness of model).

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	140.3893	10	0.0000
Pesaran scaled LM	29.15593		0.0000
Pesaran CD	11.74916		0.0000

Random Effect Model Output

The value is <0.05 when looking at Table 4 and 5 accepting the null hypothesis of the random effect model is best but since R square and adjusted are very low 9% and 8% respectively, this model assumes that these 5 countries are sample from the total population in fact we have chosen whole population the BRICS for this analysis and assumes that other factors like more countries data would have enhanced it efficiency of model fitness. So, we will choose a fixed effect model for our final analysis.

Fixed Effect Model Output

The study used a fixed effect model to analyse the long-lasting impact of exchange rates on the Gross Domestic Product (GDP) of the BRICS nations (Brazil, Russia, China, India, and South Africa) from 1998 to 2022. The fixed effect model includes cross-sectional fixed effects in the analysis to consider the distinctive implications of each individual country. The results in Table 6 indicate that the constant term (C) is statistically significant, as indicated by a coefficient of 11.60787 and a t-statistic of 47.37828. This indicates a strong positive relationship between the intercept and the logarithm of GDP. The primary variables of interest, namely the lagged inflation rate (LINF) and the lagged exchange rate (LER), have coefficients of 0.539163 and -0.174110, respectively. The positive coefficient for LINF (with a t-statistic of 2.877632) indicates that an increase in the previous inflation rate is linked to a higher GDP. Conversely, the negative coefficient for LER (with a t-statistic of -1.479983) indicates that the prior exchange rate had an adverse impact on GDP. However, it is crucial to recognize that the correlation for LER does not achieve statistical significance at conventional criteria. (p-value = 0.1417). The fixed effects specification, indicated by the R-squared value of 0.699487, implies that more than 70% of the variation in the dependent variable (log GDP) can be explained by the model. The adjusted R-

squared score of 0.683388 incorporates the number of predictors in the model, leading to a more conservative evaluation of the model's capacity to account for the variability in the data. The results of the redundant fixed effects tests indicate that the inclusion of cross-sectional fixed effects greatly enhances the model's fit, as evidenced by the cross-section F-statistic of 46.557804 and the corresponding p-value of 0.0000. The chi-square test provides more evidence to confirm this conclusion, as indicated by a statistic of 116.545054 and a p-value of 0.0000.

The null hypothesis, which suggests that there is no substantial correlation between exchange rates and GDP, is not supported by the statistical analysis. Specifically, the coefficient for LER is not statistically significant at the 5% level. Thus, considering the existing evidence, we lack adequate justification to dismiss the null hypothesis. In the fixed effect model used, it can be concluded that there is no statistically significant or substantial correlation between exchange rates and Gross Domestic Product in the BRICS countries from 1998 to 2022.

Upon analyzing the coefficients of the variables, it is evident that the logarithm of GDP (LGDP) is positively impacted by the lagged inflation variable (LINF) with a value of 0.539. Furthermore, this relationship is statistically significant at a level of 0.0048. Conversely, the delayed exchange rate variable (LER) exhibits a negative effect on GDP, although this effect is not statistically significant. The coefficient for LER is -0.174, and the corresponding p-value is 0.1417. Utilizing multivariate skewness and kurtosis to describe GDP distributions is a reliable method, especially useful when working with sample sizes of 25 or more (Machado, 1983). By incorporating weighted skewness and kurtosis, which have been carefully adjusted to account for biases related to sample size, a valuable tool is provided to differentiate between valid observations and potentially deceptive outliers in data distributions (Rimoldini, 2014).

Table 4. Random effect model regression.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	11.76218	0.309961	37.94733	0.0000
LINF	0.438760	0.172146	2.548767	0.0121
LER	-0.210231	0.115712	-1.816845	0.0718
Descriptive	Value			
R-squared	0.095663			
Adjusted R-squared	0.080071			
S.E. of regression	0.283303			
Sum squared resid	9.310223			
F-statistic	6.135378			
Prob(F-statistic)	0.002932			
Mean dependent var	1.449289			
S.D. dependent var	0.303799			
Durbin-Watson stat	0.106155			

Table 5. Model fitness of random effect model (Durbin-wu-Husman test result).

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	2.908253	2	0.2336

Table 6. Fixed effect model regression output.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	11.60787	0.245004	47.37828	0.0000
LINF	0.539163	0.187363	2.877632	0.0048
LER	-0.174110	0.117643	-1.479983	0.1417
Descriptive		Value		
R-squared		0.699487		
Adjusted R-squared		0.683388		
S.E. of regression		0.282180		
Sum squared resid		8.918072		
Log-likelihood		-14.68658		
F-statistic		43.44927		
Prob(F-statistic)		0.000000		
Mean dependent var		12.08002		
S.D. dependent var		0.501490		
Akaike info criterion		0.364480		
Schwarz criterion		0.527958		
Hannan-Quinn criter.		0.430864		
Durbin-Watson stat		0.118446		

The findings indicate a substantial link between inflation and GDP, thereby rejecting the null hypothesis about this correlation. However, the existing data does not provide evidence of a significant relationship between exchange rates and GDP, suggesting that there is no reason to reject the null hypothesis on this variable.

H1: There is significant/meaningful relationship between Exchange Rate and GDP (Rejected).

H2: There is significant/meaningful relationship between Inflation and GDP (Accepted).

Discussion

The inquiry into the enduring consequences of currency exchange rates on Gross Domestic Product (GDP) within the BRICS states has produced enlightening findings. The first null hypothesis, which states that there is no substantial correlation between exchange rates and GDP, has been confirmed, despite initial predictions. Within the analyzed timeframe and context, it can be inferred that swings in exchange rates have no statistically significant impact on the aggregate economic production of Brazil, Russia, China, India, and South Africa.

An alternative explanation for this result is that the economic strategies and systems implemented in these BRICS nations would have lessened the potential influence of currency exchange rate variations on their individual gross domestic products. Additionally, this could suggest a degree of robustness in these economies, enabling them to endure the difficulties presented by fluctuations in currency value. Examining the particular policy measures and economic structures of each country in more detail could offer significant insights into the elements that contribute to this observed link.

Conversely, the failure of the second null hypothesis, which posited that there is no substantial correlation between inflation and GDP, reveals a more intricate component of the economic processes in action. This denial suggests that inflation does have an impact on the long-term development of the Gross Domestic Product (GDP) of the BRICS nations. The consequences of this discovery are extensive, encompassing topics like the efficacy of monetary policy, tactics for targeting inflation, and the overall stability of these economies.

CONCLUSIONS

Ultimately, this research has provided insight into the complex correlation among exchange rates, inflation, and Gross Domestic Product throughout the BRICS states. The basic hypothesis that there is little link between exchange rates and GDP has been confirmed. However, the recognition of a substantial correlation between inflation and GDP highlights the significance of taking into account many economic elements to comprehend long-term economic patterns. These findings have significant ramifications for policymakers and economists, underscoring the necessity for sophisticated strategies in economic governance among the BRICS nations. The study's findings can provide a basis for improving and adjusting economic policies to maintain long-term growth and stability in light of the changing global economic landscape. Additional investigation and examination could explore the precise mechanisms by which inflation impacts GDP in these countries, facilitating more focused and efficient policy actions. In summary, this work adds to the continuing discussion on the intricacies of economic interactions, providing significant insights for both academic and practical purposes.

Limitations

When examining the influence of exchange rates and inflation on gross domestic product (GDP) using a fixed effect model and panel data from BRICS countries, it is important to recognize certain constraints. These limitations include the use of logarithmic transformations for the variables. To begin with, the fixed effect model assumes that the impacts peculiar to each country remain constant throughout time, disregarding any potential dynamic changes. Furthermore, the study is based on the premise that there is no bias due to omitted variables and that all significant variables influencing GDP, exchange rates, and inflation are included. Moreover, the logarithmic modification can obscure the comprehensibility of the coefficients. The study's findings may be influenced by the selected econometric model, which could restrict the applicability of the results. Moreover, the utilization of panel data assumes uniformity among countries, which may fail to convey the diversity in economic structures and policy contexts among the BRICS nations. The study's time span may not adequately account for long-term structural changes, which could

restrict the capacity to make complete conclusions on the enduring influence of exchange rates and inflation on GDP in the context of BRICS.

Future Directions

In order to further the study on the influence of exchange rates and inflation on Gross Domestic Product (GDP) in the BRICS countries in the upcoming phase, it is crucial to thoroughly examine the intricate dynamics of these interactions. Future studies could investigate time-varying effects within the fixed effect model and log transformation of variables. Specifically, these studies could analyze how the link between exchange rates, inflation, and GDP changes across various economic stages or policy regimes. In addition, the inclusion of other pertinent macroeconomic factors, such as interest rates or trade openness, could yield a fuller comprehension of the complex interconnections. Moreover, conducting country-specific research within the BRICS nations may reveal distinct trends and factors that influence the situation, providing customized policy suggestions. In order to adapt to the changing global economic scene, it would be advantageous for this research to adopt a more flexible methodology, potentially integrating machine learning methods to accurately capture complex patterns and abrupt changes in the connections being studied. In summary, the future focus of this work should be on improving the accuracy of policy suggestions by further developing our understanding of the complex connections between exchange rates, inflation, and GDP in the context of the BRICS countries.

REFERENCES

- Adu-Gyamfi, G., Nketiah, E., Obuobi, B., Adjei, M., 2019. Trade openness, inflation and gdp growth: panel data evidence from nine (9) West Africa countries. *Open J. Bus. Manag.* 8, 314–328. <https://doi.org/10.4236/ojbm.2020.81019>.
- Agarwal, D.V., 2021. Foreign exchange market and the asset approach. *Int. J. Res. Appl. Sci. Eng. Technol.* 9, 351–356. <https://doi.org/10.22214/ijraset.2021.37956>.
- Baltagi, B.H., 2021. *Econometric analysis of panel data*. Springer International Publishing. <https://doi.org/10.1007/978-3-030-53953-5>.
- Choji, N.M., Sek, S.K., 2023. Purchasing power parity theory: a cross-sectional dependence panel data analysis of sixteen developed countries. *J. Comput. Innov. Anal.* 2, 89–106. <https://doi.org/10.32890/jcia2023.2.1.5>.
- Chow, G.C., 2012. A model of inflation in Taiwan. *Econ. Lett.* 117, 464–466. <https://doi.org/10.1016/j.econlet.2012.06.038>.
- Dagume, A.M., 2022. Exchange rate volatility and macroeconomic variables in South Africa. *Int. J. Econ. Financ. Issues* 12, 1–14. <https://doi.org/10.32479/ijefi.13446>.
- Demissew, S.D., Kotosc, B., 2020. Is fiscal or monetary policy more effective on economic growth? an empirical evidence in the case of Ethiopia. *J. Afr. Res. Bus. Technol.* 124855. <https://doi.org/10.5171/2020.124855>.
- Duan, L., Liu, Z., Yu, W., Chen, W., Jin, D., Liu, J., Zhou, H., Sun, S., Dai, R., 2021. Modeling and forecasting gross domestic product in different regions of china, in: 7th Annual International Conference on Social Science and Contemporary Humanity Development (SSCHD 2021). Atlantis Press, pp. 300–304. <https://doi.org/10.2991/assehr.k.211215.055>.
- Fadliani, I., Purnamasari, I., Wasono, W., 2021. Peramalan dengan metode sarima pada data inflasi dan identifikasi tipe outlier (Studi Kasus: Data Inflasi Indonesia Tahun 2008-2014). *J. Stat. Univ. Muhammadiyah Semarang* 9, 109–116. <https://doi.org/10.26714/jsunimus.9.2.2021.109-116>.
- Fatima, N., 2022. Future of dispute resolution and investment in BRICS. *Rev. Bras. Altern. Disput. Resolut. J. Altern. Disput. Resolut.* 4, 187–209. <https://doi.org/10.52028/rbadr.v4i8.9>.
- Forbes, K.J., 2019. Inflation dynamics: dead, dormant, or determined abroad? *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.3489524>.
- Gámez Velázquez Velázquez, D.G., Coenders, G., 2020. Identification of exchange rate shocks with compositional data and written press. *Financ. Mark. Valuat.* 6, 99–113. <https://doi.org/10.46503/LDAW9307>.
- Goonatilake, R., Reyes, O., 2019. Sustainability of economy: inflation vs interest rates. *J. Bus. Econ. Policy* 6. <https://doi.org/10.30845/jbep.v6n4a1>.
- Haque, M.A., Biqiong, Z., Arshad, M.U., Yasmin, N., 2022. Role of uncertainty for FDI inflow: Panel econometric analysis of selected high-income nations. *Cogent Econ. Financ.* 10, 2156677. <https://doi.org/10.1080/23322039.2022.2156677>.
- Iqbal, B.A., 2022. BRICS as a driver of global economic growth and development. *Glob. J. Emerg. Mark. Econ.* 14, 7–8. <https://doi.org/10.1177/09749101211067096>.
- Iqbal, M.A., Nadim, N., Akbar, Z., 2022. Determinants of recent inflation in Pakistan and its relation with economic growth: An econometric analysis. *Pakistan J. Humanit. Soc. Sci.* 10, 345–353. <https://doi.org/10.52131/pjhss.2022.1001.0202>.
- Israel, K.-F., 2023. On the complementarity of the Austrian and monetarist traditions. *Q. J. Austrian Econ.* 25, 318–324. <https://doi.org/10.35297/qjae.010145>.
- Jyoti, 2021. Impact of exchange rate fluctuations on india's manufacturing exports: an empirical investigation on long-run relation. *J. Asian Econ. Integr.* 3, 61–73. <https://doi.org/10.1177/2631684620982426>.
- Kapoor, S., 2023. Inflation: Direct Effect on Middle/Lower Income Group. *Int. J. Sci. Res. Eng. Manag.* 7. <https://doi.org/10.55041/IJSREM17681>.
- Karakostas, E., 2021. The significance of the exchange rates: a survey of the literature. *Mod. Econ.* 12, 1628–1647. <https://doi.org/10.4236/me.2021.1211082>.
- Kartono, A., Solekha, S., Sumaryada, T., 2021. Foreign currency exchange rate prediction using non-linear Schrödinger equations with economic fundamental parameters. *Chaos, Solitons & Fractals* 152, 111320. <https://doi.org/10.1016/j.chaos.2021.111320>.
- Lagad, S.J., Rodge, K.D., Gulave, M.R., 2022. GDP of indian economy and its impact on inflation. *Int. J. Res. Appl. Sci. Eng. Technol.* 10, 213–219. <https://doi.org/10.22214/ijraset.2022.42115>.
- Majee, H.L., 2023. Analyzing and measuring the impact of exchange rate fluctuations on economic growth in Iraq for the period (2004-2022). *J. Kurdistan Strateg. Stud.* 2. <https://doi.org/10.54809/jkss.vi2.225>.
- Lee, A., 2022. Predicting Whether Inflation Will Remain in the US after the Covid-19 Pandemic. *J. Student Res.* 11. <https://doi.org/10.47611/jsrhs.v11i2.3025>.
- Li, J., Pogodin, S., 2020. BRICS economic cooperation factors in global governance, in: *iop conference series: materials science and engineering*. IOP Publishing, p. 12029. <https://doi.org/10.1088/1757-899X/940/1/012029>.

- Lim, S., 2021. Testing purchasing power parity in Cambodia: Time-varying trade weights in constructing real effective exchange rate. *Int. J. Econ. Financ. Issues* 11, 146. <https://doi.org/10.32479/ijefi.10543>.
- Lubis, S.N., Soemitra, A., 2022. Evaluation of the regional inflation control team's (TPID) Performance on the medan city economy. *J. Ekon. Manajemen, Bisnis dan Akunt. Rev.* 2, 191–200. <https://doi.org/10.53697/emba.v2i1.561>.
- Machado, S.G., 1983. Two statistics for testing for multivariate normality. *Biometrika* 70, 713–718. <https://doi.org/10.1093/biomet/70.3.713>.
- Médici, F., Mario, A., Fiorito, A., 2021. Questioning the effect of the real exchange rate on growth: new evidence from Mexico. *Rev. Keynes. Econ.* 9, 253–269. <https://doi.org/10.4337/roke.2021.02.05>.
- Nuruzzaman, M., 2020. Why BRICS is no threat to the post-war liberal world order. *Int. Stud.* 57, 51–66. <https://doi.org/10.1177/0020881719884449>.
- Nwakuya, M.T., Ijomah, M.A., 2021. Study on fixed effect versus random effects modeling in a panel data analysis; a consideration of economic and political indicators in six African countries. *Recent Adv. Math. Res. Comput. Sci. Vol.* 4 42–49. <https://doi.org/10.9734/bpi/ramrcs/v4/11245D>.
- Okereke, O.E., Bernard, C.B., 2014. Forecasting gross domestic product in Nigeria using Box-Jenkins methodology. *J. Stat. Econom. Methods* 3, 33–46.
- Radjainin, I.P., Ramadhania, A.F., Laksmiana, P.E., Gunawan, M.F., Riadi, R.A., Istiqomah, S.N., 2022. The Relationsip between Population Ages 30-34 and Inflation of The Growth Domestic Bruto Inflator. *J. Ekon. dan Bisnis* 26, 107–111. <https://doi.org/10.24123/jeb.v26i2.5300>.
- Rahaman, M.M., Rahman, S.M.K., Ahmed, A., 2022. Effect of international trade, foreign investment, remittances, and exchange rate on the economic growth of Bangladesh. *Int. J. Sustain. Econ. Manag.* 11, 1–18. <https://doi.org/10.4018/IJSEM.309099>.
- Rahayuningtyas, E.F., Wicaksono, G.W., Chandranegara, D.R., 2021. Prediction of Yuan to IDR Exchange rate using general regression neural network, in: 2021 International Conference on Computer Science, Information Technology, and Electrical Engineering (ICOMITEE). IEEE, pp. 1–6. <https://doi.org/10.1109/ICOMITEE53461.2021.9650304>.
- Rimoldini, L., 2014. Weighted skewness and kurtosis unbiased by sample size and Gaussian uncertainties. *Astron. Comput.* 5, 1–8. <https://doi.org/10.1016/j.ascom.2014.02.001>.
- Garcia, S.A., Pereira, C.R., 2023. Political economy of South–South relations: an analysis of BRICS'investment protection agreements in Latin America and the Caribbean. *Third World Q.* 44, 57–75. <https://doi.org/10.1080/01436597.2022.2128328>.
- Saygılı, H., 2020. Sectoral inflationary dynamics: cross-country evidence on the open-economy New Keynesian Phillips Curve. *Rev. World Econ.* 156, 75–101. <https://doi.org/10.1007/s10290-019-00340-7>.
- Seputra, Y., Rodoni, A., Meirinaldi, M., 2022. Analysis of foreign exchange using neural network and adaptive neuro fuzzy inference system (ANFIS), in: Proceedings of the 2nd International Conference on Law, Social Science, Economics, and Education, ICLSSEE 2022, 16 April 2022, Semarang, Indonesia. <https://doi.org/10.4108/eai.16-4-2022.2319723>.
- Shaikh, G.M., Ghumro, N.H., Nawaz, A.D., 2018. Long run relationship among Gross Domestic Product (GDP), Foreign Direct Investment (FDI) and exchange rate of Pakistan: A case of Pakistan 1981-2016. *Int. Res. J. Soc. Sci.* 7, 24–31.
- Shaker, V., 2022. Modeling and forecasting Egyptian GDP: autoregressive-integrated moving-average model. *J. Agric. Econ. Soc. Sci.* 13, 279–283. <https://doi.org/10.21608/jaess.2022.147684.1060>.
- Wu, J., He, Y., 2021. Prediction of GDP in time series data based on neural network model, in: 2021 IEEE International Conference on Artificial Intelligence and Industrial Design (AIID). IEEE, pp. 20–23. <https://doi.org/10.1109/AIID51893.2021.9456509>.
- Yadav, A., 2022. BRICS and its growing influence at global stage. *Int. J. Res. Appl. Sci. Eng. Technol.* 10, 3536–3541. <https://doi.org/10.22214/ijraset.2022.45795>.
- Živkov, D., Kovačević, J., Papić-Bлагоjević, N., 2020. Measuring the effects of inflation and inflation uncertainty on output growth in the central and eastern European countries. *Balt. J. Econ.* 20, 218–242. <https://doi.org/10.1080/1406099X.2020.1846877>.
- Zulfikar, R., 2018. Estimation model and selection method of panel data regression: an overview of common effect, fixed effect, and random effect model. Universitas Islam Kalimantan MAB Banjarmasin. <https://doi.org/10.31227/osf.io/9qe2b>.

Publisher's note: Science Impact Publishers remain neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made. The images or other third-party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit <https://creativecommons.org/licenses/by/4.0/>.