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EVOLUTION OF ICT AT THE LEVEL OF BRICS ECONOMY

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Abstract:

This article provides an in-depth analysis of the impact of Information and communication technology (ICT) on the BRICS economies from 2000 to 2022. It employs quantitative data analysis by gathering secondary data from official sources to explore trade dynamics, high technology exports, and global challenges within the bloc. The research reveals that China's economic development has significantly impacted ASEAN economies, both in terms of trade volume and structural economic changes. Key findings include that ICT and high –technology exports play major roles in economic growth providing further evidence that technology intensive goods and services are critical in the new economy. On the other hand, the relationship between trade and GDP was less strong and in some cases negative which implies that for these countries technologies could offer more value than traditional trade or export traditional products. However, there are several limitations encountered when conducting the analysis including missing data in ICT goods export and high technology exports, not considering other variables which may affect the dependent variable. It is recommended that BRICS countries invest more on technology transfer and on exportation of ICT and high-tech goods since they experience a positive impact on the economic growth rates. Further study therefore needs to incorporate more comprehensive databases and consider other characteristics like education, infrastructure or institutional quality, which might help to better explain the factors behind GDP growth in these economies.

Keywords: Information and Communication Technology**,** GDP, BRICS bloc

Abbreviations: OECD, Organization for Economic Cooperation and Development; GDP, Gross Domestic Product; WB, World Bank; IMF, International Monetary Fund; UNCTAD, United Nations Conference on Trade and Development; OLS, Ordinary Least Squares; ICT, Information and Communications Technology; WDI, World Development Index; R&D, Research and Development; ITU, The International Telecommunication Union.

1. INTRODUCTION

ICT has turned out to be an influential tool toward the economic, social and political change in the contemporary society. ICT therefore involves all those technologies and structures that support information flow around the world today forming the basis of the global digital revolution. The evolution of these technologies has been very fast in the last two decades and has taken a new dimension impacting on the global economy, redesigning industries and improving productivity in many sectors (World Bank, 2020). This versatile invention began with the telecommunications system and data processing system, then, cloud computing system, artificial intelligence system continues to challenge and change the world societies. Communications technology in the emerging economies has played a critical role in development and in increasing access and participation. They have increasingly appreciated the role of ICT to address the effects of the digital divide, help internal constituents gain access to needed services and deliver the international competitiveness imperative (UNCTAD, 2021). Among these countries, BRICS - a coalition of five major emerging economies: So it becomes important to examine how Brazil, Russia, India, China and South Africa – collectively known as BRICS – is positioned in ICT industry. Altogether, the countries of BRICS have contributed to the formation of the

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postindustrial society, showing the dynamically growing rates of ICT usage and development that plays a key role in formation of a new technological basis for the continuation to build their economies and to consolidate their positions on the global level (ITU, 2022).

Since ICT is constantly changing at high speeds, economies and societies worldwide, including those of the BRICS countries, have not been left behind. It is against this backdrop that this article aims at analyze these challenges and also understand the extent to which ICT has been transformed in these emergent economies. Another issue to be discussed is the problems of digital divide – the unequal distribution of modern ICT in BRICS countries. Even though BRICS governments poured money into the establishment of ICT infrastructure, millions of people in the countryside and other hard-to-reach areas cannot access good internet connection, ICT gadgets, and skills to harness the benefits of the ICT revolution. More so, the survival of ICT driven growth amid geopolitical tensions as well as volatility within the global economy poses a concern to BRICS countries. These countries suffer from external shocks in the form of trade barriers, sanctions and political instabilities that would seasonally interrupt ICT value chains. For example, the conflict of interest between the United States and China has cascaded operations around the BRICS countries and impacted on the ICT industries by locking out key technologies that could have fostered cooperation. It also leads to doubt about the capability of the BRICS nations in maintaining ICT development in the context of an unstable world. These issues – from the communication divide to skill shortage, and geo political hazards – are an indication of the challenges involved in ICT development in emerging markets. Solving these issues can only occur in combination and with the active involvement of separate countries of the BRICS association and the region as a whole to provide the necessary ICT drive for the collective growth of the bloc.

The main purpose of this article is to discuss ICT development in BRICS countries and evaluate the role of ICT in the economic, social, and technological processes in these countries. Thus, the objectives of this research are the identification of the causes that have promoted the ICT growth and the identification of the obstacles that have arisen in front of development, as well as the definition of the consequences of such tendencies for the BRICS bloc. This article aims at presenting a view on the role of ICT that can advance the economic development, social integration, and innovation within the BRICS nations in order to understand how ICT has developed at BRICS level and a view on the possible difficulties that may hinder the further development of ICT. Firstly, the article will examine the general ICT readiness situational analysis. This will assist to find out the challenges that still face these countries in order to reduce the digital divide in their economy and society. Secondly, the research will also explore the extent to which ICT has boosted the economy in the BRICS countries. To this end, answering the above research questions will enable the article to contribute to an understanding of the BRICS nations' ICT evolution, factors that have influenced this evolution, and prospects for ICT advancement in these emerging economies. The results derived from this study are hoped to benefit the comprehension of the dynamics of how ICT can be utilized to support the BRICS nations' development with reference to the inclusive growth and development concept.

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2. LITERATURE REVIEW

The accelerating growth of ICT has attracted significant research and policy attention all over the world especially in the developing countries. A wide range of authors have focused on the governance role of ICT in terms of economic development, social integration, and technology development.

Country-Specific Insights

Analyzing the ICT development of the BRICS countries reveals different developmental paradigms due to varied social economic environments, policy inclinations and structures and infrastructures. Collectively, the BRICS nations have adopted ICT as one of the drivers for growth and the promotion of information society but the nations encounter regional circumstances. For example, despite possessing the best Digital Infrastructure & Technology Adoption index scores meaning that broad government-led investment and initiatives such as 'Digital India' & 'Made in China 2025', there are concerns regarding data privacy and regulation consistency (Xiao & Menon, 2022). Despite the intentions of the government of bridging the urban-rural divide through the National Broadband Plan still Brazil faces the issue of connectivity gap especially in the rural areas (dos Santos et al., 2021). Likewise, the developmental initiatives in ICT in operations in South Africa are however constrained by issues to do with literacy and specifically costs of infrastructure preventing equal use of ICT resources (Muthinja, 2021). The Russian approach has been highly centralized with government focusing on issues of cybersecurity and state control over digital assets hence the highly regulated ICT environment in Russia observed by Ivanov & Saifuddin, 2020. These aspirations have been realized by improving national security and cybersecurity but have drawn anxiety about data privilege and international interaction restrictions (Aliyev, 2022). Each country represents the BRICS, and the common problem of all is a gap in skills that hinder the development of ICT-based economic growth. Even though a lot of money has been poured into education, it is evident that the rates of growth of human capital in these nations cannot satisfy the skill demands of the dynamically growing ICT industries in the future, which should be an essential area for future policy concern (Jain & Wang, 2023). Taken together, these observations speak to the fact that ICT development in the context of BRICS has been defined by sets of linked but qualitatively distinct dynamics surrounding infrastructure, policy, security, and workforce preparedness. The promotion of ICT policies' further cooperation and integration among the BRICS member countries could further consolidate the bloc's digital economies and assist more in boosting the level of inclusiveness of economic growth.

Economic Growth and ICT

Studies centered on the ways technologies and innovation drive the economic development of BRICS countries where the mentioned countries have been drawn from. Aljneibi, R. S., Zervopoulos, P. D., and Kanas, A. (2024) proved that ICT, education, and R&D influence heterogeneous technology and economic efficiency through their effect on 52 industrialized and developing countries departing from 2011 to 2019 Through an approach which merges the Bayesian estimation with data envelopment methodology, the effectiveness of technology and its inefficiency gap is evaluated. The results show that R&D decreases the gap between technology growth and the economy whereas fixed broadband subscribers eliminate the unproductive situation of the economy. This is all in keeping with the Catch-Up theory where ICT-mediated knowledge spillovers from R&D cooperation help in closing the technology gap. As such, Akwetey, J., & Sene, I. (2018) investigated whether rich nations (high-income countries) or poor ones (middle-low-income nations) benefit more from the ICT revolution's impact on development. The authors of the recommended paper select a sample of 123 countries in the period from 2002 to 2017: 45 high-income, 58 middle-income, and 20 low-income ones, building an ICT index from 3 points, namely mobile, internet, and fixed broadband. They concluded that, in general, ICT gives additional GDP growth in all countries; however, another study, that is Cheng, C. Y., Chien, M. S., & Lee, C. C. (2021) looked into finances, ICT spread, and the relationship between them and growth. The findings according to which development of financial level mostly in high-income countries have a negative influence on the growth of the economy. In high-income countries, ICT diffusion would be the factor of the rise in economic growth, but as for middle-income and low-income countries, the impact is not as clear as that of, high-income countries.

Research Gap

As for previous explorations of the role of ICT in contributing to the overall economy of BRIC countries, these have mainly taken under consideration data up to the year 2000. Such studies do not take into account the developments that have occurred in the recent past, as well as emerging trends in ICT, which have gained more importance in the post-COVID-19 era where ICT has fueled the pace of adaptability and resilience of the economy. Moreover, the majority of previous studies does not include South Africa as a country that joined the bloc in 2010 as the last country to complete the BRICS formation and bring valuable insights to the ICT-led economy. This article fills these gaps by expanding the time horizon to the years 2021 and 2022, which are periods that depict changes in ICT policies and the use of products associated with the pandemic period. Including South Africa in this study also offers a deeper understanding of the ICT situation and contribution of the whole BRICS, covering post-pandemic ICT roles in promoting economic reform, digital integration, and technological advancement. This broader scope is not only relevant to fill this literature gap but also relevant to understand the emerging trends of ICT in the BRICS economies in contemporary and post COVID-19 world.

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3. METHODOLOGY

This article adopts a quantitative analysis method to study ICT changes in the BRICS countries and the effect of trade, export of ICT goods, and export of high technology on the economic growth. The data for these independent variables was conducted directly from reliable sources of data for the Brazil, Russia, India, China and South Africa for the period 2000 to 2022. Two methods of estimation were employed, namely OLS regression analysis and a Panel Data Model, analyzed using STATA 15.0. Using the method of OLS regression, the article explored the above interactions for each of the countries separated from the rest of the world in order to have a preliminary look at the manner in which trade, ICT goods exports and high-technology exports affected economic growth in a vacuum of the regional and international market systems. Since the research embraced different time and country, panel data model was used for capturing the difference across the BRICS nations. This model eliminates country- and time- specific biases factors, thereby improving the reliability of the results.

Theoretical background

The roles of economic performance are formed through the actions of internal and external factors with technological improvement being considered as a crucial driver. Based on endogenous growth theory this research aims at modeling the link between ICT and economic growth for BRICS nations. Endogenous Growth Theory specified by Economists such as Paul Romer is to the effect that growth is self-generated through technological change and improved quality of human's capital. From this theory, ICT is regarded as having an instrumental role in raising the efficiency through improving information flows, minimizing the transaction costs and promoting innovation. Within BRICS context, ICT can foster growth through reducing trade costs, raising export of ICT and ICT capital goods, and enhancing the international competitiveness of commodities. Through merging of these aspects, this study aligns with Endogenous Growth Theory to analyze the role played by ICT related variable like, trade, ICT goods exports, and high technology exports as a determinant of the economic growth of the BRICs nations.

Empirical background

Respected global associations such as the World Bank, IMF, and UNCTAD, as well as the national agencies of statistics and their central banks, will serve as providers of this data. For the database to prove accurate in the context of long-term vital constants and shifts of ICT within the BRICS group, which will take, at least, several years is necessary. The next important process in the sequence is data organization and cleaning. The next important step to ensure that study quality is not compromised by problems such as missing values, inconsistent values, outliers and other quality issues that might affect the validity of the research is addressing these issues.

Model Construction

The study's function form is described as follows:

$$GDP = f(ICT, TO, HT) \quad (1)$$

Furthermore, to build the model using the function form mentioned before as:

$$\boldsymbol{GDP = \beta_0 + \beta_1 ICT + \beta_2 TO + \beta_3 HT} \quad (2)$$

Looking at the details, GDP shows the gross domestic product, ICT shows information and communication technology, TO means trade openness, and HT indicates high technology export. The thesis analyses the interconnection of those dependent and independent variables over 22 years from 2000-2022 for BRICS countries, like Brazil, Russia, India, China, and South Africa.

Table 1. Variables Description and Data Source

Signs	Variables	Measuring Units	Sources
GDP	Economic growth	Current US	World Bank (WDI, 2022)
ICT	Information and Communication Technology	Percentage of the population that uses the Internet	World Bank (WDI, 2022)
TO	Trade Openness	Total trade as a percentage of GDP	World Bank (WDI, 2022)

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HT	High technology export	Percentage of the manufactured exports	World Bank (WDI, 2022)

Source: Author's estimation

4. EMPIRICAL RESULT

As the study aims to explore the role of ICT in the development of BRICS economies, several tests are done to find correlation between economic growth and ICT. Firstly, we discuss descriptive statistics of the selected variables. In there. Dependent variable is GDP growth, and trade, ICT goods export, and high technology export are all independent variables.

The results are Table 4 represent descriptive statistics of 1 dependent variable and 10 independent variables in 5 BRICS states, namely Brazil, Russia, India, China and South Africa. Countryname denotes 5 different countries and the number of observations is 115 starting from 2000 and ending with 2022. The data is balanced and distributed between 5 nations. In terms of GDP growth and trade, the mean is 58 with 33.34 in standard deviation for both. These factors, ICT goods export and high technology export, show that, on average, exports of ICT products are important parts of economies, with means of 31.898 and 22.372, respectively. The fact that ICT goods and high technology exports data are missing for 5 and 38 observations respectively should be seen as a flaw or reason to be careful in how the results are interpreted.

Table 2. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
countryname	115	3	1.42	1	5
year	115	2011	6.662	2000	2022
GDPgrowth	115	58	33.342	1	115
trade	115	58	33.342	1	115
ictgoodsexport	110	55.5	31.898	1	110
hightechnologyexport	77	39	22.372	1	77

According to Graph 1, the exports of ICT products fluctuated over 23 years. Among the observed countries China showed high ICT exports as a percentage of total goods exported throughout the period. China's share remained above 60% since 2000 and fluctuated around 80-90% between 2005 and 2020, indicating the country's significant focus on ICT exports. On the other hand, there was a downward trend in Brazil's ICT exports. Starting from around 2000, the percentage of ICT goods as a share of total exports decreased steadily, suggesting that the focus on ICT exports weakened over time. However, India's ICT exports show high initial rise around 2005-2010. But it is decreased significantly after that year and there might be a diversification towards the other sectors of exports or there might be some shift in the ICT export market of the world. Russia's average share of ICT exports was consistently low, ranging just above 10% or below throughout the period. This implies that ICT goods have not been main component of total exports in Russia. While South Africa has maintained a steady export outlook of the ICT products which vary between 20% and 50%. In terms of their contribution, there was significant rise between 2005-2010 and decreased afterwards which actually suggest growth up to a point in the ICT export sector of the respective countries.

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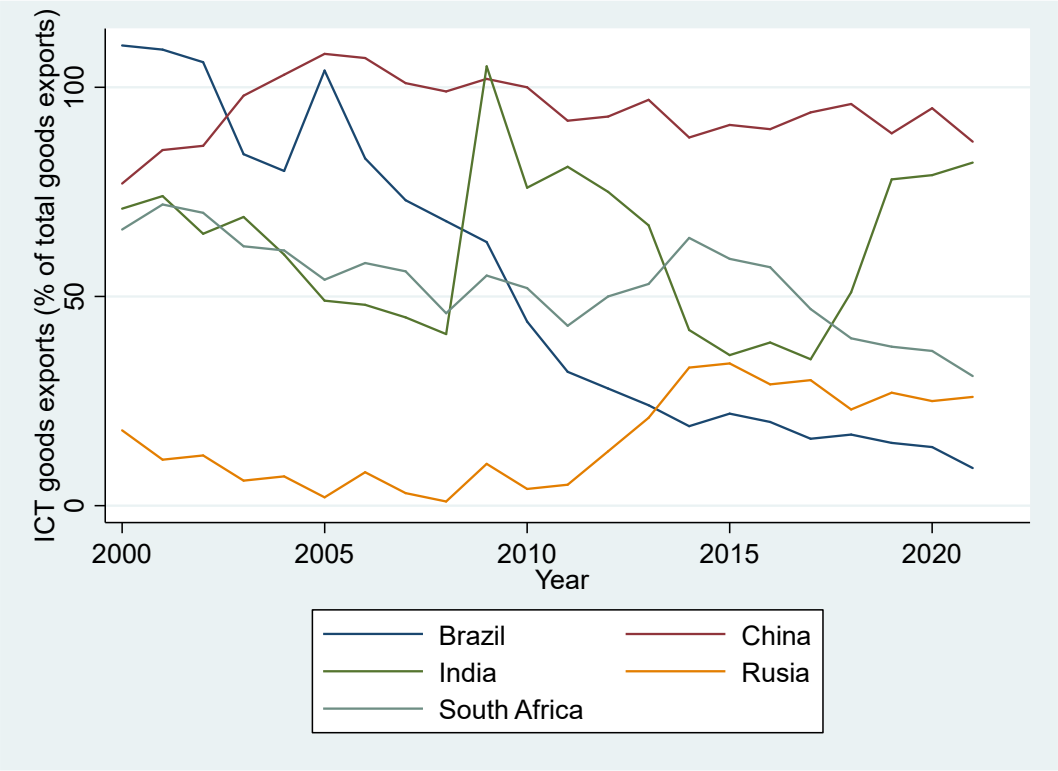

Graph 1. ICT goods exports

The first OLS and OLS robust regression methods are applied to provide in-depth analysis of the the variables influencing GDP growth annually, incorporating data from 115 observations. Table provides the results of OLS and OLS robust model while Appendix 1 provides both regression results separetly.

In the OLS model, F-Test= 10.605, and its p-value Prob > F = 0.0000 signifies that the model is statistically significant overall. This suggests that the variables included collectively have a moderately explanatory power on GDP growth. The R-squared value of 0.304 indicates that about 30.4 % of the variation in GDP growth is explained by the model, which is a substantial proportion for economic data, highlighting the model's relevance. The mean of the dependent variable, GDP growth, is 54.836 with a standard deviation of 35.643, reflecting considerable variability in growth rates across observations.

Based on the data, we constructed the following formula:

$$GDPgrowth = 15.819 - 0.233*trade + 0.567*IGE + 0.6*HTE \quad (3)$$

In the OLS robust regression, strong evidence was found F-Test (7, 105) = 16.503, Prob > F = 0.0000, R squared = 0.304. The mean of dependent variable is 54.836, and standart deiation is 35.643.This result is significant at the p > 0.05 level.

$$GDPgrowth = 15.819 - 0.233*trade + 0.567*IGE + 0.6*HTE \quad (4)$$

Table 3. OLS and OLS robust model

Variable	OLS		OLS robust	
	Coef.	Sig.	Coef.	Sig.
trade	-.233	*	-.233	*
ictgoodsexport	.567	***	.567	***
hightechnologyexport	.6	***	.6	***
constant	15.819		15.819	*
*** p<.01, ** p<.05, * p<.1				

Source: Author's estimation

The regression analysis reveals how various independent variables impact the dependent variable through their coefficients. The coefficient for "trade" is negative 0.233, which shows that one unit increase in trade results in negative

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0.233 change in the dependent variable GDP growth, if other variables are constant. This result is statistically insignificant at beyond 0.1 meaning that at most there is a negative relation, though it may not exactly be strong or consistent or reliable. On the other hand, ICT goods exports holds a great positive effect on economic growth coefficient of 0.567. Likewise with High technology exports which was seen to have a positive impact in the GDP growth rate. The coefficient is 0.6 and the p value is 0.02 which is statistically significant. In this model, F-Test= 10.065, where the Prob > F value of 0.0000 indicates that the total model is statistically significant. This implies that overall the variables have a reasonable measure of the capacity to explain the variability in GDP growth. For the overall fit of the model, the model explains a significance proportion of 30.4% for the GDP growth rate, the r-squared standard being 0.304 means that economic data is acceptable and confirming the model importance. From the above results we note that the mean of the dependent variable is 54.836 with standard deviation of 35.643 denoting large fluctuations from one observation to another.

Pooled regression, Fixed and Random effect

The regression analysis provides insights using three different models: Pooled Regression, Fixed Effect, and Random Effect. Each model gives a nuanced understanding of the impact of various economic indicators on a dependent variable, likely GDP growth. The main results of each regression models are represented in Tables in Appenix 2.

Table 4. Pooled regression, Fixed effect and Random effect models

Variable	**Pooled regression**		**Fixed effect**		**Random effect**	
	Coef.	Sig	Coef.	Sig	Coef.	Sig
trade	-.017		.125		-.017	
ictgoodsexport	.281		-.004		.281	
hightechnologyexport	.468	***	.387	**	.468	***
Constant	23.516		32.745	*	23.516	

There was a positive correlation between GDP growth and ICT goods export and high technology export. Only trade negatively affect GDP growth. The regression results, with an overall R-squared of 0.243, suggest that about two fifhs of the variation in GDP growth can be explained by these factors across the observations. This model's chi-square of 8.305 with a probability near zero further supports the model's statistical significance. The difference between the R-squared within (0.066) and R-squared between (0.568) values reveals a higher explanatory power for variations between groups compared to within groups, suggesting that the model better captures differences between different countries or groups than it does variations within them over time. Mean for GDP growth is 54.836 and SD = 35.643.

GDPgrowth= 23.516 – 0.017*trade + 0.281*IGE + 0.468*HTE *(5)*

The regression model in Fixed effect shows an average dependent variable value of 54.836 with a standard deviation of 35.643, indicating variability in the data. The R-squared value of 0.088 suggests that approximately 8.8% of the variation in the dependent variable can be explained by the model's independent variables. The F-test result of 2.094 with a p-value of 0.057 signifies that the model is statistically significant, meaning the independent variables collectively have a significant impact on the dependent variable. The low Akaike Information Criterion (AIC) of 689.108 and the Bayesian Information Criterion (BIC) of 698.270 further affirm the model's goodness of fit, suggesting that it adequately captures the data's underlying patterns while maintaining a balance between model complexity and performance.

GDPgrowth= 32.745 + 0.125*trade - 0.004*IGE + 0.387*HTE *(6)*

The Random effect anlysis results indicate that the mean of the dependent variable across the dataset is 54.836 with a standard deviation of 35.643, showing significant variability among the observations. The overall R-squared value is 0.243, suggesting that about 24.3% of the variation in the dependent variable is explained by the independent variables used in the model. The model's statistical significance is confirmed by a Chi-square statistic of 8.305 with a probability (Prob > chi2) of 0.040, indicating that the model as a whole fits the data well at a significant level. The R-squared within of 0.066 indicates that 6.6% of the variation is explained within individual entities, showing a slight level of explanation for changes over time within entities. Conversely, the R-squared between of 0.568 is moderate, suggesting that the model explains 56.8% of the variation between different entities, which is substantial. This high R-squared between indicates that the model is particularly effective at capturing differences across the entities rather than within them over time.

GDPgrowth= 23.516 – 0.017*trade + 0.281*IGE + 0.468*HTE *(7)*

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The Hausman test results provided with a Chi-square test value of 14.408 and a p-value of 0.044 suggest that the fixed effects model is more appropriate than the random effects model for your data. This result is statistically significant at the 5% level, indicating that there are systematic differences between entities that are correlated with the independent variables, thus justifying the use of fixed effects to control for potential omitted variable biases.

Hausman test

Table 5. Hausman (1978) specification test

	Coef.
Chi-square test value	14.408
P-value	.044

The Hausman specification test is used to determine whether a fixed effects or random effects model is more appropriate for panel data analysis. In this case the chi square test value comes to 4.963 while the p value is 0.175. As the p-value is larger than the conventional alpha levels (0.05 or 0.01), null hypotheses is approved. Since there is not very big difference between the fixed and random effects estimates, the random effects model is preferred for this analysis. This implies that the unique differences across entities (such as countries or firms) are not correlated with the explanatory variables, and a random effects model would provide consistent and efficient estimates.

The study of the development of ICT in BRICS economies has described in detail how different factors – exports of ICT goods, exports of high technologies, trade affect GDP growth. The regression analysis also supported the hypothesis that ICT goods exports and high-technology exports are the variables that are significantly associated with the GDP growth rate with high-technology exports showing a particularly strong positive impact. The weak impact of trade and ICT goods exports suggests complexities that merit further investigation, perhaps due to the varying levels of ICT infrastructure and capabilities within BRICS economies. This comprehensive analysis not only underscores the profound role of ICT in economic development but also highlights areas for potential policy enhancements to foster healthier economic relations and growth within the BRICS region.

5. DISCUSSION

This paper provides the statistical analysis of ICT goods exports, high technology exports , trade and their impact on the economic development of BRICS states. The descriptive statistics of the selected variables show that these variables have a significant impact on economic growth of the BRICS economies. The role of the ICT goods exports and the high technology exports is underlined by these economies of BRICS. These sectors are major factors of production and growth particularly in developing countries such as China and India, both of which are world's leading exporters of ICT and other technology related commodities. The finding of this study is in line with Pradhan et al. (2021) who highlighted the importance of ICT for economic growth by opening up new information and communication technologies. It also supports Mewes and Broekel (2022) view that technological infrastructure is paramount in the development of economy. The regression analysis offers valuable insights into the relationship between the independent variables—trade, ICT goods exports, and high-technology exports—and GDP growth in the context of the BRICS economies. OLS and OLS robust, Pooled, Fixed and Random models perfectly give details of how these factors affect the economic growth by giving more emphasis on their coefficients and statistical significance of each of them.

The estimated coefficients from the OLS model offer information about the correlation between the independent variables and the GDP growth. It also points out the strength of positive coefficients of ICT goods exports, high technology exports, and other technological variables that essentially emphasize the technological sectors as the key drivers of growth in GDP. This in turn suggests that despite having a negative coefficient, trade has a relatively small influence on the potential of the GDP growth in these economies. In order to reduce any possible problem arising from heteroscedasticity, the OLS robust regression is used for estimation. Similar to the OLS model, the use of the robust model also allows finding the positive effect of ICT goods and high-technology exports to GDP growth, which emphasizes the role of technology in determining the country's performance. The negative effect of trade is a long-run characteristic but its coefficient is insignificant which indicates that trade is not a robust variable correlated to GDP growth. Moreover, the standard error of the coefficients is found to be smaller in the robust regression model than the standard OLS model hence providing more reliable values of the coefficients to support the general findings of the model.

In the pooled regression model, the data obtained in different countries are calculated together without considering country-specific factors, all observations are considered from the same sample. In this model, it is believed that the direction of the variables' interaction is constant across countries. This model works well, but it may eliminate specific circumstances within the country that can affect the growth of GDP. Additionally, they may be less accurate, and the pooled model may not be advantageous wherever sharp disparities exist across nations. The second model is the fixed effects or the Generalized Method of Moments one that essentially controls for differences that are constant over time

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the between-country difference here as it isolates the effect of the independent variables on the GDP growth of each country at different points in time. Furthermore, the fixed effects model makes up for the fact of country-specific characteristics by showing how variations in ICT exports and trade affect GDP growth within a given country. This model is more appropriate when studying the dynamics of change in individual economic indicators within a country while excluding cross-country differences. On the other hand, the random effects model assumes that the characteristics of specific countries are unrelated to the other independent variables but enables variations at both within country and between-country levels. This model seems to be more appropriate as compared to fixed effects because it considers the idea that differences within the countries play a role in GDP growth. It takes into account within-country changes and cross-country differences regarding the impact of trade, ICT goods, and high-technology exports on the observed countries' GDP growth perspective.

The Hausman test is used to determine the best approach to use either fixed effects or random effects models. As stated, if the test result gives a non-significant result, then the random effects model is used since it is more efficient. In this case, the Hausman test indicated that random effects model was more appropriate, this means that difference across countries is not explained randomly or related with the independent variables. Therefore, random effects model is an appropriate approach for estimating the fixed effects and characterizing the factors that affect the GDP growth.

Among all the variables, the use of high-technology exports as a predictor of GDP growth rate has been highlighted continuously in all models. This implies that BRICS nations can gain more benefit from investing or exporting technological products. High-technology exports probably promote innovation, enhance efficiency, and stimulate growth through placing these countries at higher places in the global market (Navarro Zapata et al,2024). This result suggests that the economies driving by technology tend to have a faster and sustainable rate of growth.Similarly, exports of ICT goods have a positive correlation with the growth in GDP and but somehow complex (Appiah-Otoo and Song, 2021). While ICT goods exports contribute to economic growth, their impact appears to vary across countries and models, reflecting different levels of technological infrastructure, digital readiness, and policy frameworks within the BRICS nations. ICT exporter countries, including China, and India, can therefore have higher income improvement impacts from these exports than Russia and Brazil, which mainly focus on other sectors, like natural products.

There is a mixed pattern of the positive and negative effect of trade on the growth of GDP. There are circumstances where the impact of trade appears to lack importance or could be explicitly regressive even though trade mostly fosters income multiplication. This might be attributed to the fact that not all trade contributes positively in the same manner (Kong et al, 2021). For instance, depending on imports as a source of goods or when the ratios of exports to imports are unbalanced, there are adverse effect to an economy. The difference in the degree of trade openness in BRICS economies might also be attributed to the differences in structure of their economies, including China with a manufacturing base, Russia and Brazil being resource-based economies.

Overall, the results obtained in this research support the general conclusion that although trade cannot be considered as the key force of growth in this sense, ICT goods and high-technology exports plays the key role in the economic growth (Banday et al, 2021). This emphasises that countries should support technological development of their nations and export more hi-technology products for better future income. Furthermore, the model shows that a significant level of the variance observed in the growth of the GDP can be accounted for by these variables not least highlighting the centrality of technology in the determination of economic performance.

6. CONCLUSION

In conclusion, this study gives a detailed explanation on ICT goods exports, high-technology exports, and exports on how these exports affect GDP growth of the BRICS countries. These findings are useful in that they show conclusively that ICT and high –technology exports play major roles in economic growth providing further evidence of the fact that technology intensive goods and services are critical in the new economy. On the other hand, the relationship between trade and GDP was less strong and in some cases negative which implies that for these countries technologies could offer more value than traditional trade or export traditional products.

However, there are several limitations encountered when conducting the analysis. Firstly, there is missing values in ICT goods and high-technology exports for some of the observations that may bias the results. Missing data can lead to biases in the regression analysis, affecting the reliability of the coefficients and interpretations. Furthermore, due to the reliance on quantitative data, this study is limited in its ability to consider qualitative aspects of economic performance, potential determinants of GDP, including institutional quality, governance, and public policies effectiveness. Besides, although the paper investigates the variables concerning ICT and trade that are relevant for determining GDP growth, other factors that cause an impact on GDP growth have not been taken under consideration in this study; such as employment assertions, infrastructure advancements, and foreign investments. This reduces the reliability of the findings which would have been more comprehensive if provided in larger focus. The parameters set in

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the process of conducting a regression analysis do not allow proving the causal relationships between the independent variables and GDP growth..

Based on the findings, the following recommendations can be drawn. It is recommended that BRICS countries invest more on technology transfer and on exportation of ICT and high-tech goods since they experience a positive impact on the economic growth rates. In addition, the policymakers should be very cautious while incorporating the trade factor into their development of their economic frameworks, particularly considering this factor has a comparatively low correlation to growth in this regard. Further study therefore needs to incorporate more comprehensive databases and consider other characteristics like education, infrastructure or institutional quality, which might help to better explain the factors behind GDP growth in these economies. Also, there is a necessity of policy formation in which governments try to better coordinate technology with trade as they seek to maximize their export prospects in a competitive world economy.

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Appendixes

Table A1-1. OLS regression

GDPgrowth	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
trade	-.233	.131	-1.78	.079	-.494	.028	*
ictgoodsexport	.567	.118	4.81	0	.332	.802	***
hightechnologyexport	.6	.186	3.22	.002	.229	.971	***
Constant	15.819	10.046	1.57	.12	-4.222	35.86	
Mean dependent var		54.836	SD dependent var			35.643	
R-squared		0.304	Number of obs			73	

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F-test	10.065	Prob > F	0.000
Akaike crit. (AIC)	709.400	Bayesian crit. (BIC)	718.562

*** p<.01, ** p<.05, * p<.1

Table A1-2. OLS robust regression

GDPgrowth	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
trade	-.233	.134	-1.73	.087	-.501	.035	*
ictgoodsexport	.567	.119	4.78	0	.33	.804	***
hightechnologyexport	.6	.177	3.39	.001	.247	.953	***
Constant	15.819	8.275	1.91	.06	-.689	32.327	*

Mean dependent var	54.836	SD dependent var	35.643
R-squared	0.304	Number of obs	73
F-test	16.503	Prob > F	0.000
Akaike crit. (AIC)	709.400	Bayesian crit. (BIC)	718.562

*** p<.01, ** p<.05, * p<.1

Table A1-3. Pooled Regression results

GDPgrowth	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
trade	-.017	.169	-0.10	.922	-.347	.314	
ictgoodsexport	.281	.183	1.54	.125	-.078	.64	
hightechnologyexport	.468	.181	2.59	.01	.113	.823	***
Constant	23.516	15.941	1.48	.14	-7.729	54.76	

Mean dependent var	54.836	SD dependent var	35.643
Overall r-squared	0.243	Number of obs	73
Chi-square		Prob > chi2	0.040
R-squared within	0.066	R-squared between	0.568

*** p<.01, ** p<.05, * p<.1

Table A1-4. Fixed Regression results

GDPgrowth	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
trade	.125	.192	0.65	.518	-.259	.509	
ictgoodsexport	-.004	.231	-0.02	.987	-.465	.458	
hightechnologyexport	.387	.184	2.11	.039	.02	.753	**
Constant	32.745	17.329	1.89	.063	-1.864	67.354	*

Mean dependent var	54.836	SD dependent var	35.643
R-squared	0.088	Number of obs	73
F-test	2.094	Prob > F	0.057
Akaike crit. (AIC)	689.108	Bayesian crit. (BIC)	698.270

*** p<.01, ** p<.05, * p<.1

Table A1-5. Random Regression results

GDPgrowth	Coef.	St.Err.	t-	p-	[95%	Interval]	Sig

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			value	value	Conf		
trade	-.017	.169	-0.10	.922	-.347	.314	
ictgoodsexport	.281	.183	1.54	.125	-.078	.64	
hightechnologyexport	.468	.181	2.59	.01	.113	.823	***
Constant	23.516	15.941	1.48	.14	-7.729	54.76	

Mean dependent var	54.836	SD dependent var	35.643
Overall r-squared	0.243	Number of obs	73
Chi-square	8.305	Prob > chi2	0.040
R-squared within	0.066	R-squared between	0.568

**** p<.01, ** p<.05, * p<.1*