




ECONOMIC GROWTH IMPACT OF TECHNOLOGY AND TRADE IN NIGERIA



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ABSTRACT

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Trade generally has been linked to high economic growth and technology diffusion across and within economies. This study thus sets out to investigate, in the context of Nigeria, the economic growth impacts of technology and trade using three proxies of trade openness- the ratio of total exports and imports to the gross domestic product (GDP); the total volume of exports; and imports. Fixed telephone plus mobile cellular subscriptions were used as a proxy for technology. With data extracted from the World Development Indicators, three models were estimated using the autoregressive distributed lag (ARDL) framework for cointegration and determination of long-run coefficients of parameters. Granger causality tests were performed to determine the direction of causalities. The results of all the tests were interpreted to arrive at the inferences and conclusions drawn for this work. Trade openness and exports were found to be detrimental to growth, while the positive impact of imports was not significant. Technology was found to significantly promote growth and Granger caused exports, imports, capital, and labor. All the diagnostics supported the validity of the assumptions of the regression errors and the specification of our models. We concluded that the growth impact of trade on Nigeria's economy is largely dependent on the technology intensity of its trade.

Contribution/ Originality: This study is the original work of the authors. The innovative contribution of the study is the finding that the net growth effect of trade in Nigeria is a function of the technology intensity of trade. Thus, technology both contributes to growth as a product and as an input to traded goods.

1. INTRODUCTION

In his theory of comparative advantage, David Ricardo identified the basis for and gain from international trade as differences in relative labor productivity. In a two-good, two-country model where labor is the only factor of production, Ricardo advanced that countries gain from trade by exporting those goods they can produce at the lowest relative costs under autarky. The Heckscher-Ohlin-Samuelson (H-O-S) factor proportions theory, as a subsequent extension, proposed that comparative advantage results from differences in relative factor endowments. In a two-good, two-country, and two factors of production (labor and capital) model, the theory predicts that countries gain from trade by exporting those goods which most intensively use their more abundant factors. Thus, a relatively more labor-abundant country like Nigeria will benefit from trade by producing and exporting labor-intensive goods. The comparative advantage theory since the H-O-S theory has witnessed several refinements and empirical testing.

Leontief (1953) in what is popularly known as the Leontief paradox, triggered a search for alternative explanations of the basis for trade, finding no empirical support for the H-O-S theory. Strands of theoretical explanations have included human capital as distinct from the supply of skilled labor. Others have considered knowledge as a factor of production, particularly knowledge generated through investments in research and development (R & D). The latter strand provided a channel for the introduction of technology as a variable in the factor proportions model, thus bringing to the fore the role of innovation in the comparative advantage of countries. Early empirical tests of the US economy, which include Gruber, Mehta, and Vernon (1967); Stern and Maskus (1981), and Sveikauskas (1983) found technology as the basis of the United States (US) comparative advantage. Posner (1961) technology gap theory and Vernon (1966) product cycle theory attempts to position technology as the main determinant of trade. In both theories, countries with high technological capacity can be considered to have a comparative advantage in the export of technology-intensive and innovative goods.

While technology has become a basis for the explanation of trade, the trade-technology nexus has been generally accepted as a prime mover of global and national economic growth. Not only has the world witnessed striking growth in the volume of trade in technology, but global trade in goods and services has also been greatly deepened by advancements in technology. Gains from international trade are almost always measured in terms of economic growth, yet models of economic growth do not establish a clear relationship between trade and the rate of economic growth. In the early growth models, such as the Harrod-Domar model with capital as the only factor of production, openness to trade has positive effects on growth under the assumption that the marginal product of capital is bounded by a positive number (Srinivasan, 1999). In closed-economy neoclassical growth models, such as the Solow (1957), growth is exogenously determined. Solow's model and its various augmentations when adapted to an open economy in what is now called the endogenous growth theories allow the analysis of the effect of trade and technology on long-run economic growth through endogenous technological change.

In this paper, we appropriate the Solow (1956) growth model into a Cobb-Douglas production function to investigate the effect of trade and technology on the economic growth of Nigeria. Our objective is to provide further evidence on the trade-growth relation in Nigeria and, more importantly, the impact of technology on Nigeria's economic growth. We will also, via a causality test, determine the existence of any intersection between trade and technology in Nigeria. This paper is ordered into five sections. A brief literature review is presented in section two, while the third section presents the data, methodology, and model specification. The fourth section presents our empirical results and discussions. We conclude with recommendations in the last section

2. REVIEW OF LITERATURE

2.1. Trade in Theory

Various theories have been undertaken to explain why nations trade and the advantages associated with international trade since Adam Smith first promoted the quest for absolute cost advantage and division of labor as the cause for international exchanges. Abstracting from the notion of absolute advantage, Ricardo's comparative advantage theory asserts that the grounds for international trade are disparities in the relative values of products across nations, not their absolute values. One key source of comparative advantage is technological differences that lead to differences in product specialization, labor productivity, and resource reallocation between industries (Markusen, Melvin, Kaempfer, & Maskus, 1995; Ruffin, 2002). The Heckscher (1919) – Ohlin (1933) theorem expanded the comparative advantage theory by including capital as a factor of production. According to Heckscher-Ohlin, international trade is motivated by factor endowments and use intensity. Under the assumption of differences in the relative factor endowments among the countries, countries specialize in the production and export of goods that most intensively utilize their abundant factors. Accordingly, the gain from trade for a labor-abundant country will come from the production and export of labor-intensive goods.

The Heckscher-Ohlin model served as the foundation for the Stolper and Samuelson (1941) theorem. Real wages and real returns to capital are examined with respect to the relationship between relative prices of goods and relative factor returns. According to the theory, under the assumptions of constant returns and perfect competition, an increase in the relative price of a good will result in an increase in the returns to the factor used most intensively to produce the good and, conversely, a decrease in the returns to the other factor. Going by the Stolper-Samuelson theory, opening up to free trade may lead to the most intensively used factor reaping the benefits of increased factor income relative to the other factor. As a result, the theory implicitly demonstrates how trade may affect income distribution through changes in the prices of goods. Afterward, Samuelson (2004) proposed the factor price equalization theorem to clarify how the equalization of factor prices influences international trade's impact on the economy. According to the theorem, factor prices must be the same if product prices are the same across countries manufacturing the same combination of commodities using the same technology (Leamer, 1995). The factors of production, however, are thought to be immobile between countries, while the goods produced are perfectly mobile between the countries. Bhagwati (1958) immiserizing growth hypothesizes the possibility of a negative association between trade and economic growth for developing countries exporting primary goods when it faces unfavorable international demand conditions as it increases the export of its traditional goods. Immiserizing growth is a long-term phenomenon that occurs when the gain in a country's social welfare arising from economic growth is more than offset by a welfare loss arising from an adverse shift in the country's terms of trade (Pryor, 2007). Immiserizing growth can also occur in a growing industrialized country when the trading partners implement import-substituting growth policies and as a result shift the terms of trade against the exporting growing industrialized country (Samuelson, 2004).

Balassa (1964) and Samuelson (1964) identified productivity growth disparities between the tradable and non-tradable goods sectors as a factor introducing systematic differentials between relative prices and real exchange rates. By the law of one price, the prices of tradables tend to get equalized across countries, while the prices of non-tradables do not. Given that productivity grows faster in the tradable goods sector than in the non-tradeable goods sector, higher productivity in the tradable goods sector tends to increase wages in that sector, and with labor being mobile, wages in the entire economy will rise. Producers of non-tradables will be able to pay the resulting higher wages only if the relative price of non-tradables rise. This will generally lead to an increase in the overall price level in the economy, resulting in real exchange rate appreciation (Mihaljek & Klau, 2003).

Numerous studies have investigated how trade policy affects economic growth. Generally, complicated regulatory environments that discourage investments and the anti-competitive behavior of major market players stifle growth, whereas stronger open trade policies promote economic growth (WBG, 2018). Notwithstanding, there are no definitive theoretical explanations for how trade policy affects economic growth as empirical findings are conflicting (Silajdzic & Mehic, 2018). Contrary to the widely held belief that trade barriers are distortionary and harmful to growth, Rodriguez and Rodrik (1999) and Yanikkaya (2003) found that trade-related taxes and tariffs enhance economic growth and are positively correlated with the total productivity factor. Contrarily, Bernanke and Rogoff (2000) expressed support for the studies of the many scholars who, despite employing diverse approaches, have all come to the same conclusion that openness produces predictable and beneficial effects for growth. But by what channels do trade policies affect economic growth? Wacziarg (2001) identified channels of government policy, allocation and distribution, and technology transmission, with enhanced technology transmission and improvements in macroeconomic policy exerting a lesser positive effect on growth in comparison to the rapid accumulation of physical capital. Institutional quality, for instance, determines the ease of trading and doing business and the setting and negotiation of trade-related policies, which bears on transaction costs (Were, 2015). According to Grossman and Helpman (2015) some potential integrations provide incentives for new knowledge creation and diffusion, with implications for productivity growth. These integrations include the integration of people and cultures, which facilitates the flow of ideas across borders for the development of new products, improvement of existing products,

or lower production costs; the integration of product markets; and the integration of world markets with general equilibrium implications for input prices and products' relative prices.

2.2. Technology and Trade

Technology and trade are closely intertwined. Technological progress, which allows for the more efficient production of more and better goods and services, is widely accepted as the key driver of economic growth in countries, regions, and cities. From the development of steamships to blockchain technology, each wave of technological progress has had significant impacts on global trade. The cost of international trade is declining as a result of technological developments. According to the [WTO \(2018\)](#) falling trade costs will boost global trade by 1.8–2% per year, or 31.34% over 15 years. This is crucial as trade costs have been estimated to be a more significant obstacle to trade than tariff-related policy barriers. Thus, any change in trade costs is likely to affect trade significantly ([Anderson & Van Wincoop, 2004](#)). Falling trade costs are beneficial to micro, small and medium-scale enterprises and companies in developing countries, and if tempered with appropriate correlative policy measures, may serve to increase the share of emerging countries in international trade. Furthermore, the increasing adoption of digital technologies is redefining both intellectual property rights in trade and significantly changing the structure of trade in goods and services. In particular, knowledge-intensive business services are emerging as key drivers of knowledge accumulation. This, together with reduced productivity growth in manufacturing may point to a potential shift from manufacturing to services as the engine of global innovation ([WTO, 2013](#)).

In the traditional model of vertically integrated firms, technological spillovers from the affiliate company to the domestic firms do not exist. However, the evidence supports that technological spillovers exist. Since technology spillovers are greater among firms located in close proximity to one another, spillovers indirectly create agglomeration forces that shape trade. To benefit from technology spillovers, industries will tend to be concentrated in certain places, especially in a country with a large domestic market for the goods being produced. Locating in a large market will also benefit firms by reducing transport and trade costs. Resultantly, a country will export the product for which it has the largest home market rather than the relative factor abundance advantage. Thus, technology diffusion has an impact on production and trade patterns ([Head & Mayer, 2004](#); [Wolfgang Keller & Yeaple, 2009](#); [Keller & Yeaple, 2013](#)).

2.3. Empirical Literature

Empirical literature supports the beneficial effect of trade on growth. [Hendrik and Lewer \(2007\)](#) in their review of empirical studies found no convincing statistical evidence suggesting that trade and economic growth are negatively correlated. [Grossman and Helpman \(1990\)](#) hypothesized that both casual observations and empirical research supports that countries that are more trade-open have grown faster and achieved a higher level of economic well-being than those that adopted a more inward-orientation development strategy, and developing countries potentially stand the most to gain from free trade since they can draw upon the large stock of knowledge capital already accumulated in developed economies. [Frankel and Romer \(1999\)](#) estimated that trade had a moderately statistically significant but substantial impact on growth. Time series studies of South Africa by [Ogbokor and Meyer \(2017\)](#) and [Malefane and Odhiambo \(2018\)](#) concluded that trade is a key driver of economic growth. In the first study, exports contributed more to economic growth than trade openness and the exchange rate. The latter study, which investigated the dynamic impact of trade openness on economic growth, showed that in the long run, trade openness has a positive and significant impact on economic growth when the total trade-GDP ratio is used as a proxy of trade openness. Their short-run results showed three different proxies having a positive impact on growth. [Keho \(2017\)](#) study of Cote d'Ivoire confirmed that trade openness has positive effects on economic growth both in the short and long run, as well as a positive and strong complementary relationship between trade openness and capital formation in promoting economic growth. [Kong, Peng, Ni, Jiang, and Wang \(2021\)](#) using ARDL revealed a long-run stable co-

integration relationship between trade openness and the quality of economic growth in China with significant regional heterogeneity and non-linear threshold characteristics. A panel of 25 African countries studied by Akadiri, Gungor, Akadiri, and Bamidele-Sadiq (2020) using bootstrapping cointegration techniques established the presence of a long-run equilibrium association between foreign direct investment, trade openness, and economic growth as well as a bidirectional causality.

Nwadike, Johnmary, and Alamba (2020) using the total trade-GDP ratio conclude that trade openness has a significantly positive impact on Nigeria's economic growth for the period 1970–2011, whereas in Lawal, Nwanji, Asaleye, and Ahmed (2016) a significant and positive relationship was found only in the short-run. In an ARDL regression covering 1984 to 2017, Omoke and Opuala-Charles (2021) indicated that in Nigeria, export trade has a significant positive impact on economic growth while imports present a significant negative effect on growth, with the negative long-run effects decreasing as institutional quality improves. The reported long-run positive export-growth relationship is consistent with Olubiyi (2014). Also, Iyoha and Okim (2017) in a dynamic panel data of 15 Economic Community of West African States (ECOWAS) countries estimated four regression equations and found that exports were consistently positively related to growth. Ijirshar (2019) in another study of ECOWAS confirmed this result. The pooled ordinary least squares (POLS) model of Bunje, Abendin, and Wang (2022) in a panel of 52 African countries supported a long-run significant negative effect of imports on economic growth. These studies thus advance the differential effects of exports and imports on economic growth.

The growth effect of trade has not always been positive, as many empirical results have indicated a significant negative impact. Lawal et al. (2016) using the ARDL approach found that trade negatively impacts Nigeria's economic growth in the long run. Rasoanomenjanahary, Cao, and Xi (2022) found a significant negative effect of trade on growth in Madagascar. Kwegyir-Aggrey (2019) obtained similar results for Ghana. At a low level of human capital accumulation, Fatima, Chen, Ramzan, and Abbas (2020) found a negative impact of trade on trade for a panel of 80 countries. Vlastou (2010) finds a negative effect of openness on growth for some African countries, and in a panel of 42 sub-Saharan African countries, Zohonogo (2016) concluded that openness has a positive and significant effect on economic growth only up to a certain threshold, above which the beneficial effect diminishes.

3. DATA AND METHODOLOGY

3.1. Data and Variable Selection and Definition

The data used in this study is composed of annual time series extracted from the World Bank's World Development Indicators covering 1981 to 2022. Variables are selected based on robust empirical support for their influence on economic growth in developing economies. Table 1 summarizes the variables and their definitions.

Table 1. Definition of variables.

Variable	Definition
Dependent variable	
Y	Real Gross Domestic Product per capita (constant LCU) as a proxy for economic growth
Independent variables	
T	Fixed telephone subscriptions plus Mobile Cellular subscriptions as a proxy for technology
D	Ratio of total exports and imports to the real GDP as a proxy for openness to trade
E	Total exports of goods and services (constant LCU) as a proxy for openness to trade
M	Total imports of goods and services (constant LCU) as a proxy for openness to trade
K	Gross fixed capital formation (constant LCU) as a proxy for stock of physical capital
L	Labor force, total (total population ages 15-64) as a proxy for the input of labour
P	Inflation, consumer prices (annual %) as a measure of economic stability
G	General government final consumption expenditure (constant LCU)

The summary statistics for each of the variables that will be used in the models are provided in Table 2. Since their means are substantially closer to the minimum end of the data's range of values, almost all the variables appear to be somehow skewed to the right.

Table 2. Summary statistics for the variables.

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis
E	29.763	29.570	30.753	29.027	0.561	0.367	1.550
G	27.417	26.441	29.526	26.112	1.334	0.389	1.270
K	29.751	29.736	30.188	29.366	0.196	0.051	2.369
L	22.079	22.087	22.601	21.577	0.309	-0.002	1.791
M	29.401	29.416	30.443	28.303	0.526	-0.043	2.351
P	2.677	2.543	4.288	1.684	0.684	0.684	2.950
D	0.471	0.443	0.925	0.312	0.132	1.471	5.188
T	15.133	13.475	19.135	11.929	2.829	0.287	1.283
Y	12.469	12.387	12.862	12.862	0.239	0.399	1.536

3.2. Model Specification

To structure the empirical model testing the effect of trade and technology on the economic growth of Nigeria we adapted the Solow (1956) growth model in a Cobb-Douglas production function. The production function is expressed as:

$$Y_t = A_t K_t^\gamma L_t^{\beta} \quad 0 < \gamma + \beta < 1 \tag{1}$$

Where Y_t is real per capita income, K is the stock of physical capital, and L is the labour force. γ and β respectively are the share of stock of capital and the labour force. A denotes a function of productivity parameter determined as:

$$A_t = f(T_t D_t G_t P_t) = T_t^\varphi D_t^\psi G_t^\theta P_t^\lambda \tag{2}$$

Where A is technology, D is a measure of trade openness, G is government expenditure and P_t is the rate of inflation. Combining Equations 1 and 2, the empirical model is written as:

$$Y_t = T_t^\varphi D_t^\psi G_t^\theta P_t^\lambda K_t^\gamma L_t^\beta \tag{3}$$

Where φ , ψ , θ , λ , γ and β represent the elasticities of the production function for technology (T), trade (D), government expenditure (G), inflation (P), stock of physical capital (K) and the labour force (L). Taking the natural logarithm of both sides of Equation 3 we obtain the linear form of the model as Equation 4:

$$\ln Y_t = \alpha + \varphi \ln T_t + \psi \ln D_t + \theta \ln G_t + \lambda \ln P_t + \gamma \ln K_t + \beta \ln L_t + \varepsilon_t \tag{4}$$

Where α is the intercept, φ , ψ , θ , λ , γ and β are elasticities, and ε is the error term.

Additional two measures of trade will be successively introduced into Equation 4 to fully capture the effect of international trade on growth, thus exports (E_t) and imports (M_t) will in turn substitute D_t . By implementing the substitutions the model specification is complete with Equations 5 and 6

$$\ln Y_t = \alpha + \varphi \ln T_t + \beta \ln E_t + \theta \ln G_t + \lambda \ln P_t + \gamma \ln K_t + \beta \ln L_t + \varepsilon_t \tag{5}$$

$$\ln Y_t = \alpha + \varphi \ln T_t + \kappa \ln M_t + \theta \ln G_t + \lambda \ln P_t + \gamma \ln K_t + \beta \ln L_t + \varepsilon_t \tag{6}$$

Where β and κ respectively are the elasticities of exports and imports.

Equations 4, 5, and 6 will be estimated in section 4 as models (1), (2), and (3) respectively.

3.3. Estimation Techniques

Estimations of the specified models will proceed in four stages comprising tests for units root, tests of the co-integration of variables, the estimate of parameter coefficients, and the determination of causal direction.

3.3.1. Unit Root Tests

An economic time series may follow a stochastic or deterministic trend. Distinguishing between the two is an important task in econometric analysis as the two statistical specifications differ in terms of their statistical and

economic implications. Unit root tests can be used to discriminate between the two trends and conclude whether a time series should first be differenced to make it stationary or regressed against deterministic functions of time. Hence, we pretest each variable in this study for unit root and stationarity using Elliott, Rothenberg, and Stock (1996) DF-GLS test and the Kwiatkowski, Phillips, Schmidt, and Shin (1992) test (KPSS) tests. In choosing the DF-GLS unit root test, we consider that Lopez (1997) showed that the power of the augmented Dickey-Fuller (ADF) test of Dickley and Fuller (1981) relates positively to sample size and negatively to the lag length required in the testing regression. But when the Dickey-Fuller test is applied to a locally detrended time series using a data-dependent lag length selection procedure as proposed by Elliott et al. (1996) the DF-GLS provides better small-sample size and power performance than the ADF (Enders & Liu, 2014). The KPSS test is widely used in empirical studies as a complement to the standard unit root tests. KPSS reverses the null of the standard unit root tests by testing the null hypothesis that a series is a level or trend stationary. It tends to provide a more stringent test of the existence of unit roots as it too often rejects the null hypothesis. If both the results of KPSS and DF-GLS suggest that a series is stationary we accept the stationarity of the variable as is the practice in most empirical studies. Where further tests are required to make informed decisions on the properties of a series the Dickley and Fuller (1981) ADF test method and Perron and Phillips (1987) test will be deployed. The testing procedure for each variable include in the equations intercept only (a) or trend and intercept (b) or none (c). If the trend is insignificant we estimate and report the equation with intercept only (a). The result of the equation with trend and intercept is estimated and reported if both are significant (b). Where neither equation with intercept nor trend and intercept is significant, we estimate the equation without intercept and trend (c). Table 3 reports the results of the DF-GLS and KPSS tests.

Table 3. Unit root tests.

Variables	DF-GLS tests				KPSS tests				Order of Integration
	Levels		First difference		Levels		First difference		
	t-Stat	C V at 5%	t-Stat	C V at 5%	t-Stat	C V at 5%	t-Stat	C V at 5%	
In(Y)	-1.656	-1.950	-1.047	-1.950	0.564	0.460	0.377 ^a	0.460	I(2), I(1)
In(T)	-1.474	-1.944	-5.90 ^a	-1.950	0.626	0.460	0.221	0.460	I(1), I(1)
In(D)	-2.651	-3.194	-6.931 ^b	-3.194	0.293 ^a	0.460	-	-	I(1), I(0)
In(E)	-3.24 ^b	-3.194	-	-	0.722	0.460	0.124 ^a	0.460	I(0), I(1)
In(M)	-2.041	-3.194	-5.032 ^b	-3.194	0.292 ^a	0.460	-	-	I(1), I(0)
In(K)	-2.822	-3.194	-5.872 ^b	-3.194	0.563	0.460	0.276 ^a	0.460	I(1), I(1)
In(L)	-1.706	-3.194	-4.463 ^b	-3.194	0.774	0.460	0.242 ^a	0.460	I(1), I(1)
In(P)	-3.383 ^a	-1.942	-	-	0.286 ^a	0.460	-	-	I(0), I(0)
In(G)	-1.764	-3.194	-6.396 ^b	-3.194	0.662	0.460	0.113 ^a	0.460	I(1), I(1)

Note: a. Model with intercept only.
 b. Model with intercept and trend.

Both the DF-GLS and KPSS reported the first difference stationarity for the logs of T, K, L, and G and returned P as level stationary. The results were a mix of level and first difference stationary for the logs of D, E, and M. The stationarity status of these variables was thus accepted as reported by the two methods. However, the log of (Y) was not stationary at first difference with DF-GLS, thus we recourse to supplementary tests to aid our acceptance or otherwise of the I(1) presented by KPSS. The results of the supplementary tests with ADF and Phillips-Perron were reported in Table 4. On the evidence of KPSS and ADF tests, we accept (Y) as stationary at first difference. Phillips-Perron tests further allay any fear of (Y) being not stationary at first difference. The series altogether present a commixture of level and first difference stationary variables.

Table 4. Unit root tests.

Variable	ADF tests				Phillips-Perron tests				Order of Integration
	Levels		First difference		Levels		First difference		
	t-Stat	C V at 5%	t-Stat	C V at 5%	t-Stat	C V at 5%	t-Stat	C V at 5%	
In(Y)	-2.291	-3.532	-4.052 ^b	-3.532	-3.960	-3.522	-	-	I(1), I(0)

Note: b. Model with intercept and trend

3.3.2. Co-Integration Test

The Bounds testing procedure of ARDL modeling of Pesaran., Shin, and Smith (1996) and Pesaran and Smith (1995) provide a powerful and most appropriate tool for the estimation of long-run level relationships when the underlying property of time series is entirely I(0), entirely I(1), or jointly co-integrated. The procedure uses F and t-statistics to test the significance of lagged levels of variables in a univariate equilibrium correction system (Bhattacharyya, 2021). Bounds of critical values for the F-statistic supplied by Pesaran., Shin, and Smith (2001) are then used to determine co-integration. Evidence of co-integration is suggested if the value of the F-statistic goes above the upper bound. Additionally, co-integration is admitted if the coefficient of the co-integration equation of ARDL error correction regression is negative and significant. Results displayed in Tables 3 and 4 show that the series in this study present a mixture of I(0) and I(1) (jointly co-integrated), hence the bounds testing procedure is used to test the equilibrium relationship of the variables. Table 5 reports the outcomes of the bounds tests and coefficients of the error correction regressions with their associated probabilities. The F-statistic relation to the critical value upper bound at 5% for each model satisfies (Pesaran et al., 2001) condition for co-integration. Also, the coefficients of the co-integration equations are negative and very significant. We, therefore, reject the null hypothesis of no co-integration and conclude that each of the three models converges to long-run equilibrium.

Table 5. F-Bounds tests for co-integration.

Test Statistic	Model 1	Model 2	Model 3
F-Stat	6.661	6.934	4.193
Significance	5%	5%	5%
I(0)	2.27	2.27	2.27
I(1)	3.28	3.28	3.28
CointEq(-1)	-0.436 (0.000)	-1.005 (0.000)	-0.494 (0.000)

Table 6. ARDL long run coefficients.

Variables	Model 1			Model 2			Model 3		
	Coeff.	t-Stat	Prob.	Coeff.	t-Stat	Prob.	Coeff.	t-Stat	Prob.
C	20.057	3.939	0.000	9.087	1.937	0.094	28.274	4.882	0.000
In(T)	0.144	3.069	0.006	0.154	5.849	0.000	0.27	5.558	0.000
In(D)	-0.043	-0.246	0.808	-	-	-	-	-	-
In(K)	0.338	2.174	0.043	1.094	7.680	0.000	0.183	1.382	0.182
In(L)	-0.974	-3.568	0.002	-1.077	-8.798	0.00	-0.981	-3.312	0.003
In(P)	-0.053	-1.905	0.072	-0.091	-3.871	0.006	-0.032	-1.347	0.192
In(G)	0.039	0.433	0.669	0.082	2.005	0.085	-0.20	-3.31	0.00
In(E)	-	-	-	-0.334	-4.217	0.004	-	-	-
In(M)	-	-	-	-	-	-	0.057	1.183	0.250
R-squared	0.824			0.912			0.752		
DW Stat.	1.969			2.757			1.903		

Note: Model selection:

Model 1, ARDL(2, 2, 1, 3, 1, 0, 2).

Model 2, ARDL(1, 4, 3, 4, 4, 2, 4).

Model 3, ARDL(3, 2, 0, 1, 1, 0, 2).

We now proceed to estimate the long-run parameters of the models using the ARDL framework and perform the Granger causality test to determine the direction of causation of variables of interest.

4. PARAMETERS ESTIMATES AND DISCUSSIONS

The results presented in Table 6 for the three models provide sufficient evidence in the R-squared (0.824, 0.912, and 0.752) to conclude that the regressions fit the data, and the variability in economic growth (Y) is sufficiently explained by the regressors. In discussing the results, we will focus attention more on the growth impacts of technology, openness to trade, exports, and imports, and the corresponding direction of causality. Tests of residuals for the three models reported in Table 8 demonstrate that the errors are normally distributed and reject their autocorrelation and heteroscedasticity. Furthermore, it is confirmed that the regression equations' functional form is appropriate. The diagnostics thus confirm the statistical adequacy of our models for valid inference.

Table 7. Granger causality tests.

Null Hypothesis	F-Statistic	Prob.
K does not Granger cause E	1.119	0.297
E does not Granger cause K	19.817	8.E-05
L does not Granger cause E	11.019	0.002
E does not Granger cause L	1.736	0.195
T does not Granger cause E	36.001	7.E-07
E does not Granger cause T	5.159	0.029
T does not Granger cause M	3.052	0.089
M does not Granger cause T	5.232	0.028
T does not Granger cause K	17.380	0.000
K does not Granger cause T	0.766	0.387
T does not Granger cause D	0.252	0.619
D does not Granger cause T	0.303	0.586
Y does not Granger cause T	10.659	0.002
T does not Granger cause Y	83.224	7.E-11
Y does not Granger cause E	0.956	0.335
E does not Granger cause Y	25.948	1.E-05
Y does not Granger cause D	1.089	0.304
D does not Granger cause Y	9.485	0.004

4.1. Trade and Economic Growth

Openness to trade specified as the ratio of total exports and imports to the real GDP (Model 1) negatively impacts economic growth but is statistically insignificant. The volume of exports as a measure of trade openness (Model 2) is significantly negative in its effect on growth. Openness in terms of the volume of exports (Model 3) returned a positive but insignificant effect on growth. Though the results appear mixed, the combined effect points to economic growth as not being significantly promoted by trade and largely detrimental. Lawal et al. (2016) similarly have found that trade negatively impacts economic growth in Nigeria, as Rasoanomenjanahary et al. (2022) and Kwegyir-Aggrey (2019) discovered for Madagascar and Ghana respectively. Panel studies such as Vlastou (2010) and Zahonogo (2016) have also found a negative effect of trade on growth in sub-Shara Africa. Exports have also been reported to have negative impacts on economic growth according to Kim and Lin (2009); Kalaitzi and Cleve (2018) and Kalaitzi and Chamberlain (2020).

The causality tests reported in Table 7 reveal that trade openness and exports do cause growth in Nigeria. There is unidirectional causality from each to economic growth and bidirectional causality between exports and technology. The negative correlation of trade to economic trade, therefore, reinforces the fact that the benefits of trade openness do not automatically occur. Quality of governance and institutions are important determinants of how trade openness impacts economic growth (Akinlo & Okunlola, 2021). While higher trade volumes enhance economic growth, the product composition of exports is important for the net effect of trade on growth. Calderon, Cantu, and Zeufack (2020)

estimated that doubling the primary goods trade share in GDP lowers economic growth per year by more than half the percentage point of doubling the manufacturing trade share in GDP will increase economic growth. For this reason, an oil export-dependent country like Nigeria would experience a negative effect of trade on economic growth. With macroeconomic stability, a favorable investment climate (Newfarmer & Sztajerowska, 2012) export product diversification in favor of manufacturing, and a lowering of natural resource export dependence, greater trade openness will affect growth positively through the diffusion of technology and managerial know-how as well as enhanced allocative efficiency (Calderon et al., 2020).

4.2. Technology and Economic Growth

Results obtained in this study support technology as a motive force of economic growth but not as a basis for the explanation of trade, as there is no causality between trade openness and technology. In all three models, technology is robustly statistically significant for economic growth. This is supported by bidirectional causality between economic growth and technology, implying that economic growth and technological advancement mutually reinforce each other. The two-way causality between exports and technology suggests to us that the significant negative relationship between exports and economic growth may be reversed with the exports of increasingly technology-intensive goods. A one-way causality running from imports to technology similarly suggests that imports will foster economic growth in Nigeria if the product composition of imports tilts towards more technology-embodied goods. We may therefore conclude that the technology intensity of Nigeria's trade is a key determinant of the net effect of trade on economic growth.

Table 8. Results of diagnostic tests.

Diagnostic tests	Model 1		Model 2		Model 3	
	Test statistic	Prob.	Test statistic	Prob.	Test statistic	Prob.
Breusch-Godfrey Serial Correlation LM Test:	F = 2.032	0.162	F = 4.986	0.109	F = 0.045	0.956
Heteroskedasticity Test: Breusch-Pagan-Godfrey	F = 0.358	0.981	F = 1.495	0.271	F = 0.639	0.811
Jarque-Berra	JB = 4.751	0.093	JB = 0.123	0.940	JB = 1.912	0.385
Ramsey RESET	F = 0.197	0.662	F = 0.299	0.604	F = 0.093	0.763

Note: F = F-Statistic, JB = Jarque-Berra.

Capital accumulation exerts a positive and significant impact on economic growth in Model 1 and Model 2, while the positive impact is insignificant in Model 3. Accumulation of new technology-embodied capital as suggested by the one-way causality running from technology to capital accumulation will, ceteris paribus, accelerate economic growth in Nigeria. A similar one-way causality from technology to labour shows that labour-augmenting technology progress, which catalyzes labour productivity, is key to Nigeria's economic growth.

5. CONCLUSION AND POLICY RECOMMENDATION

This study examined the growth impacts of trade and technology in Nigeria using three measures of trade openness: the ratio of total exports and imports to the GDP, the volume of exports, and imports. The study concluded that the impact of trade on Nigeria's economic growth hinges on the technology intensity of trade. The increasing technological sophistication of imports and exports will individually and collectively positively impact economic growth. Hence, technology was found to be a prime mover of economic growth and, through exports, imports, capital accumulation, and the labour force positively promote growth. Neo-classical growth theorists recognized the role of technology-enhanced labor and capital inputs in long-term economic growth, which some have explained endogenously and others as a function of the dynamic capabilities of firms constrained or enabled by the quality and integration of institutions responsible for the development and diffusion of technologies and skills. The matrix of

these institutions (firms, government, universities, research institutes, finance, etc.), referred to as the national innovation system (NIS) may constrain or enhance the ability of firms to import, develop, use, or diffuse technologies which spur growth through trade. The effectiveness of the NIS in turn is premised on the focus and connectedness of the policies (industrial; science, technology, and innovation; education and research; fiscal and monetary; trade, etc.) that affect its constituents. This study recommends the urgent review of policies related to the NIS with a view to promoting technology-intensive production and trade.

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