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An Empirical Analysis of the Relationship between Fertility Rate, Mortality Rate and Income in Nigeria

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Abstract

This study investigates the relationship between fertility, under-five mortality rate and income in Nigeria from 1964 to 2017 using annual time series data. ARDL Bound-Co-integration and Granger causality Tests were used to analyze the data. Results from Bound-Co-integration Tests have revealed the existence of long run stable equilibrium relationship amongst fertility rate, under-five mortality rate and income in the country. The Long run coefficients estimate have shown that fertility rate has a positive and statistically significant influence on under-five mortality rate and fertility rate is negative and statistically significant in its impact on income at 5% level of significance in the long run. Also the error correction model (ECM) terms which are the speed of adjustment have the correct negative signs and statistically significant in adjusting for the short run disequilibrium in the stable long run equilibrium relationship amongst fertility rate, under-five mortality rate and income. Whereas the Granger causality results has shown that there is bidirectional causality between under-five mortality rate and fertility rate, a unidirectional causality from fertility rate to income and a unidirectional causality from under-five mortality rate to income. The study recommends among others improving maternal and child health care and nutrition services by increasing access to universal health care services; and improving girls' education and women empowerment programmes through provision of reproductive health care services such as access to family planning programmes, access to employment opportunities to women, which can go a long way in reducing fertility and child mortality in the country.

Keywords: *ARDL*, Fertility, *Income, Nigeria, Mortality.*
JEL Classification: I12, I31, J13, O15, P34

Contribution to/Originality Knowledge: This study contributes to the debate on relationship between fertility, mortality and income in many ways. First, it improve the existing literature on relationship between fertility, mortality and income in particular and demographic transition theory in general, with empirical evidences from Nigeria. second, it used Autoregressive Distributed Lag (ARDL) bounds cointegration testing technique on more recent data on fertility, mortality and income which to the best of our knowledge, has not previously been considered in the country. Third, this is a long study compared to others, as the number of years used are much larger than in previous related studies. Four, it examined some of the key factors behind the country's high population growth and the slow demographic transition using up to date data. Hence, this study contributes to filling the missing gap.

1.0 Introduction

Nigeria is one of the countries with highest rate of fertility in the world with a total fertility rate that is still higher in the country, having increased from 6.354 in 1960 to the highest level of 6.772 in 1978, but later declined to 5.457 per woman in 2017and under-five mortality rate of 100.2 per 1,000 live births in 2017, though there are decline in both the fertility and mortality rates, the declines were very slow over the years (See World Bank, 2019). With the slow

declines in fertility and mortality rates, it is feared that the country may continue to be experiencing rapid population growth. This implies that Nigeria has a long way to in terms of benefit from the demographic dividend. Demographic dividend refers to an economic benefit that a country can derive when it experienced rapid mortality decline which is trailed by a rapid fertility decline, thereby producing smaller, healthier families and youth cohort who can be educated and invested to enter the labour market (Hasan *et al.* nd).

It is not only Nigeria, but sub-Saharan African countries in general have been experiencing persistently high level of fertility rate despite the decline in mortality rate and this has been one of key reasons behind its high population growth and the slow demographic transition (Bloom, Canning & Sevilla, 2001). Where demographic transition theory posited that there is established relationship between fertility and mortality. When there is high fertility, mortality tends to be high (Shen & Williamson, 1999). This tends to suggest that, a decline in fertility rate would likely lead to a decline in mortality rate (Johnson, Abderrahim, & Rutstein, 2011). The demographic transition was initiated by the decline in mortality which was later flourished into correspondingly vivid decrease in fertility (Bloom, Canning & Sevilla, 2001). It has been argued by Poy (n.d.) demographic transition which determines the development trajectory of country can be harnessed and enhanced by the reduction in the fertility rate and mortality rate. For example the economic development of the growth of the Asian Tigers (South Korea, Taiwan, Hong Kong and Singapore) was significantly engineered and stimulated by the demographic advantage of fertility and mortality rates decline witnessed by the countries. The demographic dividend is very important for high population growth country like Nigeria, as the country is one of the top 10 countries that have the largest absolute and projected increases in the population of adolescent and children from 2010-2050.

In addition, the relationship between fertility and mortality rates as advanced by Liu, Yamada and Yamada (1996) are that infant mortality can affect fertility through two main avenues, inform of biological effect and replacement effect(response effect). The biological effect took effect when there is biological linkage between infant mortality and fertility, where recurrent infant deaths shorten breastfeeding of the child, curtail the sterile period, hence leading to likelihood of another pregnancy/conception. While the replacement effect which is retroactive in nature, has to do with the urge/want of the parents of the dead infant to have additional children in their attempt to replace the dead children. Therefore the higher the infant mortality rate, the higher the replacement births leading to increase in fertility. On the other hand, the lower the rate of infant mortality, the lower the number of replacement births, resulting to decrease in fertility rate. There is also the hoarding effect which is a precautionary demand for children is an insurance mechanism where parents may decide to have more children in the expectation of the likelihood of increase in the death of children in the future that may render them having zero or negligible surviving children, in that way increasing fertility. Although it has been argued by United Nations Population Fund (UNFPA, 2018) that sometimes fertility has to be high enough to compensate for high mortality rates and continued high demand for children.

Furthermore, the relationship between fertility and mortality can be situated on the argument by Bloom, Canning and Sevilla (2001) that "fertility decisions seem to respond strongly to changes in child mortality as parents realize that if fewer children are likely to die in childhood, they can give birth to fewer children to attain their desired number of offspring" (p.17). By implications, the continued high level of fertility rate exceeding five children per woman has increased risks for maternal mortality and morbidity. With economic development which is accompanied by high standard of living and up to date technological advancement, there tend to be lower fertility and mortality rates. Under-five mortality is one of the background variables that influence fertility via changes in the proximate determinants. Also reduction in under-five mortality rate signals improvement in a country's development (Johnson, Abderrahim, & Rutstein, 2011). It has been documented that, in the absence of high mortality or emigration rates, high fertility rate implies faster population growth rate which leads to challenges for governments in meeting the education and health care services needs of their citizens, and to sustain development goals. And rapid population growth rate can also hinder progress towards Sustainable Development Goals (UNFPA, 2018).

While on the relationship between fertility and income, Bloom, Kuhn, and Prettner (2015) have established that healthier women have higher probability of participating in the formal labor market, and therefore facing higher opportunity costs of bearing many children. Hence, improve investments in women's health can lead to leading to lower fertility rate because of the switching away from bearing many children toward having fewer, better-educated and healthier children. However, it has been argued that a reduction in mortality rates, if not accompanied or preceded by a resultant decline in fertility rate, tends to heighten population growth and may result to lower production per capita (Rocco, Fumagalli, Mirelman & Suhrcke, 2021)

Despite the concerns on the level of high fertility and mortality, and their relationship with income in a country (Norville, Gomez & Brown, nd; World Health Organization, 2019; UNFPA, 2018) and the established relationship as posited by the demographic transition theory (Shen & Williamson, 1999) coupled with the possible demographic advantage of declining fertility and mortality rates as witnessed in Nigeria over the years, very little is known about the relationship between fertility rate, mortality rate and income in the country. Although there are previous studies on fertility rate, mortality rate and income (Dauda, et al., 2021); Odior & Alenoghena, 2018; Aidi, Emecheta & Ngwudiobu, 2016; Anyamele, et al., 2015; Dahiru, 2015; Odusanya & Adegboyega, 2015; Wheatley, 2015;Ezeh,et al., 2014; Herzer, Strulik & Vollmer, 2010) all these studies are limited in scope compared to this present study and none of them studies have examined the relationship between fertility rate, mortality rate and income in the Nigeria from 1960 to 2017 using ARDL. Furthermore, there are lack of agreement in the findings of the relationship between fertility, mortality and income in literature. Therefore, this study has contributed to the debate on relationship between fertility, mortality and income. First, it used Autoregressive Distributed Lag (ARDL) bounds cointegration testing technique on more recent data on fertility, mortality and income which to the best of our knowledge, has not previously been considered in the country. Second, this is a long study compared to others,

as the number of years used are much larger than in previous related studies. Hence, this study contributes to filling the missing links.

Therefore, the objectives of this study are to examine the dynamic relationship between fertility rate mortality rate and income in Nigeria from 1964 to 2017 using Autoregressive Distributed Lag (ARDL) bounds cointegration testing method.

The remaining parts of this paper are as follows. Section 2 centred on literature review. Section 3 focused on methodology of the study. Section 4 presented results and discussions and section 5 highlighted the conclusion and recommendations.

2.0 Literature Review and Theoretical Framework

Fertility rate or Total fertility rate denotes the number of children that would be born to a woman if she were to live to the end of her childbearing years and bear children in accordance with age-specific fertility rates of the specified year (World Bank, 2019). Apart from fertility rate, there is also adolescent fertility rate which is the number of births per 1,000 women ages 15-19. More to that there is wanted fertility rate which is an estimate of what the total fertility rate would be if all unwanted births were avoided, (World Bank, 2019).There are also unwanted fertility or birth and a mistimed births; where unwanted fertility/birth which according to Rutstein and Rojas (2006) refers to birth/fertility that arises after a woman has reached her desired family size. While mistimed births denotes a wanted birth that takes place earlier than intended (United Nations Population Fund, UNFPA, 2018).

On the other hand under-five mortality rate is the probability per 1,000 that a newborn baby will die before reaching age five, if subject to age-specific mortality rates of the specified year (World Bank, 2019). This is different from infant mortality rate which is the number of infants dying before reaching one year of age, per 1,000 live births in a given year or neonatal mortality rate is the number of neonates dying before reaching 28 days of age, per 1,000 live births in a given year (World Bank, 2019).

There are myriad of empirical studies on the fertility, mortality rate and income over the decades, some of which are as follows: Dauda, Donga, Yaro, Saleh and Bello (2021) examined the long run determinants of adolescent fertility rate in Nigeria from 1960 to 2017 using annual time series data. Impulse response functions and variance decomposition were used to analyze the data. The study revealed that the impulse response functions indicate that adolescent fertility rate is self-generating and an increase in income reduces adolescent fertility rate. While the variance decomposition has shown that income has relative more distinct impact on adolescent fertility rate in the long term than in the short or medium term.

Rocco, Fumagalli, Mirelman and Suhrcke, (2021) investigated how mortality and morbidity determined economic growth in 135 countries using data from 1990 to 2014. Ordinary least squares (OLS) and instrumental variables (IV) techniques were used to analyzed the data. They find out that both mortality and morbidity rates have a negative effect on GDP per capita growth, that is decreasing mortality and morbidity rates have favourable impact on long run economic growth; where reducing mortality by 10 percent increases the GDP per capita growth

rate in over a quarter century by *at least* 9.6 percent. The effects of mortality and morbidity rates are heterogeneous across countries studied, with the low and the high income countries exhibiting a stronger effect compared to the middle income. The results of simulating the expected effect of the net present value of investing more or less resources on health policies in reducing mortality and morbidity rates in four representative countries, signifying high income (the US), upper-middle income (China), lower-middle income (India) and low-income countries (Niger) have found a non-negligible benefits (costs) in consolidating (dwindling) health policies, most specially in Niger and the United States, where the economic benefit of the positive action scenario and the economic cost of the negative action scenario are essentially symmetric and becomes higher in the US and Niger (10 percent and 5.1 percent of their 2014 per-capita GDP) and lower in China and India (2 percent and 0.3 percent of the 2014 per capita GDP respectively).

United Nations Inter-agency Group for Child Mortality Estimation (2020) have reported that though in 2019, 122 countries has already attained an under-five mortality rate lower than the Sustainable Development Goal (SDG) mark of 25 or fewer deaths per 1,000 live births, neonatal deaths had accounted for 47 percent of under-five mortality. And sub-Saharan African region have the highest under-five mortality rates in the world. Also five countries comprising of Nigeria, India, Pakistan, The Democratic Republic of the Congo and Ethiopia have accounted for 49 percent of all under-five deaths in 2019 across the world.

In a study by World Health Organization (2019) it was revealed that in 2017 under-five mortality rates are higher in low-income and lower-middle-income countries, where in low-income countries the risk of death is more than 13 times higher comparable to high-income countries. Also children in low-income countries are 100 times more likely to die from infectious diseases than children in high-income countries. In addition, the risk of under-five mortality is higher in male children than female children in all income groups, where male children are 11% more likely to die before reaching age 5 years than female children. Decline in under-five mortality rate was accompanied by declines in fertility rate from 2000 to 2017. But in societies where they have preference for male children, decreases in the under-five mortality rate have been accompanied by sex-selective abortion which is a female disadvantage-the disadvantage in natality via selective abortion of female fetuses thereby leading to more male births.

Odior and Alenoghena (2018) examined effects of socioeconomic variables on fertility rate in Nigeria from 1980 to 2016, using Engle-Granger single equation and Generalized Liner Model to analyze the data. Their study indicated an existence of long run relationship between fertility rate, education expenditure, health expenditure, per capita income, life expectancy at birth and infant mortality rate in the country. In addition, per capita income, life expectancy at birth and infant mortality rate have positive impact on total fertility rate in Nigeria, where 0.46%, 19.52% and 4.34% variations in fertility rate are accounted for by the income and infant mortality respectively. But education expenditure has a negative impact on fertility rate.

Aidi, Emecheta, and Ngwudiobu (2016), studied the relationship between population dynamics (in form of fertility, mortality and net-migration) and economic growth in Nigeria with time

series data from 1970 to 2014 using ordinary least square estimation technique in analyzing the data. Their result has shown an evidence of existence of a long-run equilibrium relationship between the economic growth and the population dynamics proxied by fertility, mortality, net-migration and the other control variables. In addition, fertility rate and mortality proxied by life expectancy at birth are found to have negative and statistically significant effect on economic growth. Also net-migration and savings each has a negative and statistically significant effect on economic growth. But capital stock proxied by gross fixed capital formation is positively and statistically significant in triggering economic growth However, both openness to trade and government expenditure have a positive and but not statistically significant relationship with economic growth.

Wheatley (2015) examines factors influencing child mortality using 2011 cross sectional data from 74 low and middle income Countries (Nigeria inclusive). Utilizing linear regression in analysing the data, he find out that fertility rate and HIV prevalence rates have a positive and statistical significant influence on child mortality proxied by under-five mortality rate at 5% level of significant. But literacy rate has a negative and statistical significant impact on the child mortality. However, access to improved water sources has a negative and statistically significant effect on child mortality at 10% level of significance. But national income proxied by GDP per capita, tuberculosis immunization and female labour force participation rate (a proxy for women's economic activity) is not statistical significant in influencing child mortality proxied by under-five mortality rate at 5% level of significance.

Dahiru (2015) investigates determinants of early neonatal mortality in Nigeria using 2013 demographic and health survey (DHS) data which captured representative sample of 38,948 women aged 15-49 years and 17,359 men aged 15-59 years living in 38,904 households. Cox proportional hazards regression model comprising of unadjusted and adjusted hazard ratios were used to analysed the data. Results from the study, in the unadjusted hazard model indicating the hazard rations and 95% confidence interval, revealed that, women aged 35 years and above, rural location, high parity of five and more, polygamous marriages, working, large babies, belonging to traditional religion, and birth order of four and above have significantly increased hazard of early neonatal mortality in the Nigeria. But complication during pregnancy has a marginal significant impact in increasing the hazard of early neonatal mortality. On the other hand, residence in southern part of the country, educational qualification of at least primary education and more, being in the middle and rich wealth index, delivery in the health care centres have significantly reduced the hazard of early neonatal mortality. While the adjusted hazard ratios indicate that new-borns born to mothers residing in the rural areas, babies who were large at birth, belonging to traditional religion, have significant association with increased hazard of early neonatal mortality. Dahiru (2015) uses demographic and health survey data that covers only a sample of 38,904 households which is far from being a true representative of the Nigerian population. More to that it used Cox proportional hazards regression which different from the present study.

Odusanya and Adegboyega (2015) utilizing ARDL Bounds cointegration test examined the effects of income, mortality rates and schooling on fertility rate in Nigeria from 1975 to 2015

using annual time series data. They established a long run equilibrium relationship amongst fertility, income and mortality rate. Also both income and schooling have a negative and statistically significant effect on total fertility where a one percent increase in income and schooling respectively lead to 0.12 percent and 0.11 percent decline in fertility rate in the country in the long run. But infant mortality rate has a positive and not statistically significant in influencing fertility rate in both the short run and long run.

Ezeh, Agho, Dibley, Hall and Page (2014) examined the risk factors associated with neonatal mortality in Nigeria using 2008 demographic and health survey (DHS). Cox proportional hazards and multivariate regression were used to analyze the data. The crude hazard ratios (HRs) indicates there are higher neonatal mortality rate among neonates born to mothers in the rural areas relative to those born to mothers in the urban areas (NMR:38.9 vs 31.3), there are also higher neonatal mortality rate among neonates born to mothers in poor households than those born to mothers in the middle-class households (NMR: 39.3 vs 35.6) and smaller size neonates have higher mortality rate than larger size neonates (NMR: 57.0 vs 30.0), there are higher neonatal mortality rates among neonates delivered through caesarean section than neonates born vaginally (NMR: 89.9 vs 35.8), and higher mortality rate was reported for male neonates than female neonates (NMR: 41.4 vs 31.7). While the multivariate analysis showed that there was a significantly higher risk of neonatal mortality rate among neonates born whose mothers dwelled in rural areas than neonates born to mothers in the urban areas, significantly higher of neonatal mortality rate to neonates born to mothers less than twenty years (young mothers) than neonates born to mothers aged 30 to 39 years. Furthermore, significantly higher of neonatal mortality rate among male neonates relative to female neonates, significantly higher of neonatal mortality rate to neonates born through caesarean than neonates born vaginally; significantly higher of neonatal mortality rate among children of birth order born with shorter birth interval relative to children with longer birth interval. Ezeh, at al (2014) used demographic and health survey data which depends on interview with surviving women within the 5-year period preceding the survey, the data were cross-sectional in nature and Cox proportional hazards and multivariate regression were used to analyzed the data since most of the variables were binary. In addition, their study did not consider causal effects among the variables since they used cross-sectional data, which is retrospective in nature. But the present study used ARDL to analyze the time series data.

Anyamele, Akanegbu and Ukawuilulu (2015) investigate the trends of infant and under-five mortality in Nigeria using demographic and health survey data for 2003 and 2008, They used descriptive and logistic regression analysis results revealed that though infant and under-five mortality rates has been decreasing from 2003 to 2008, There is a higher positive association of higher birth order with infant and under-five mortality rate in Nigeria, where reading birth order lower than have an odds of infant mortality decrease by 83. 67percent.

Herzer, Strulik and Vollmer (2010) studied the long-run relationship between fertility, mortality and income in 20 countries over a 100-year period from 1900 to 1999 using the dynamic ordinary least squares (DOLS) estimator and long-run Granger causality test to analyzed the data. Their study revealed that declining mortality rate triggered fertility rate to

declined, growth of income causes fertility rate to declined, decreasing mortality rate is not sufficient in influencing the decline in population growth rate over the period of the study and changes in fertility rate are both source and result of economic development. The statistical long-run Granger causality test showed that there is causality from mortality rate and income to fertility rate, from fertility rate to income, and from fertility rate to mortality rate.

Lorentzen, McMillan, and Wacziarg (2008) has established that that reducing mortality most especially adult mortality leads to less risky behavior, lower fertility, better investments in physical capital, and eventually improved economic growth.

Summarily, most of the studies reviewed were limited in scope compared to this present study and none of these studies have examined the relationship between fertility rate, mortality rate and income in the Nigeria from 1960 to 2017 using ARDL. Furthermore, there are lack of agreement in the results of the relationship between fertility, mortality and income in literature. For examples, there are contradicting results/findings from the studies of Dauda, et al., (2021); Anyamele, et al., (2015); Dahiru (2015); Odusanya and Adegboyega (2015); Wheatley (2015) and Ezeh,et al., (2014). Hence the need for this present studyto fill the missing links/gaps. By this, it is thought that the findings of this study on the relationship between health and economic growth will contribute to the improvement of the related literature.

2.1 Theoretical framework

Although there are myriad of fertility theories that describes the causes of changes in fertility rates such as Easterlin theory of fertility by Richard Easterlin in 1987, The Macunovich theory articulated by Diane Macunovich (1996), Ermisch's theory propounded by John Ermisch in 1983; Butz and Ward model/theory (1977) ; The fertility decline or Caldwell theory which was formulated by J.C. Caldwell in 1982, the New Home Economics theory or Becker's model (see Suset, 2005 for details; Norville, Gomez & Brown, ND).This study used fertility decline or Caldwell theory as a rider since it captures fertility, mortality and economic growth the variables of interest in the work.

The fertility decline or Caldwell theory was formulated by J.C. Caldwell in 1982 hypothesized a model of the African culture, in coming up with ideas about variations in sexual behaviour, explaining the pattern of population and fertility rate. In African structure polygamy and divorce are common. Also the African culture system is centered on mortality and theology, as individuals does not trace the aspects of sexual behavior in the center of their moral and social systems, most of sub-Saharan cultures do not consider premarital or extramarital sex as an immoral activity. The fundamental argument of the Caldwell theory is the transfer of goods, money, and services between groups. Fertility rate decline is not influenced by the level of country's economic development or the level of industrialization. And that economic growth is enhanced by the decline in fertility rate. According to Caldwell there are two types of society in connection with the level of fertility rate changes. First, a society with signs of decline in fertility rate and second a society without signs of decline fertility rate. Economic and social remunerations influenced the level of fertility rate and family size (see Suset, 2005 for details).

3.0 Methodology

3.1 Nature and Sources of data

This study used annual time series data from 1964 to 2017 on Fertility rate (FTR), Under-five mortality rate (U5MR) and income proxied by per capita gross domestic product (GDP_P) retrieved from the World Development Indicators (World Bank, 2019).

3.1.3 Model Specification

Autoregressive Distributed lag (ARDL) Bounds Cointegration testing approach. Since this study is using Autoregressive Distributed lag (ARDL) bounds testing method to cointegration test, the unrestricted/unconstrained empirical model of is as follows:-

$$\Delta FTR_t = \beta_{0t} + \beta_{1j} FTR_{t-j} + \beta_2 U5MR_{t-j} + \beta_3 LOG(GDP\_P_{t-j}) + \sum_{t=0}^{m} \delta_k \Delta FTR_{t-j} + \sum_{l=0}^{n} \xi_p \Delta U5MR_{t-j} + \sum_{w=0}^{o} \vartheta_\varpi \Delta LOG(GDP\_P_{t-j}) + \mu_{1t} \quad (1)$$

$$\Delta U5MR_t = \alpha_{0t} + \alpha_{1j} U5MR_{t-j} + \alpha_2 FTR_{t-j} + \alpha_3 LOG(GDP\_P_{t-j}) + \sum_{t=0}^{m} \chi_k \Delta U5MR_{t-j} + \sum_{l=0}^{n} \kappa_p \Delta FTR_{t-j} + \sum_{w=0}^{o} \rho_\varpi \Delta LOG(GDP\_P_{t-j}) + \mu_{1t} \quad (2)$$

$$\Delta LOG(GDP\_P)_t = \psi_0 + \psi_1 LOG(GDP\_P_{t-j}) + \psi_2 FTR_{t-j} + \psi_3 U5MR_{t-j} + \sum_{t=0}^{m} \psi_k \Delta LOG(GDP\_P_{t-j}) + \sum_{l=0}^{n} \pi_p \Delta FTR_{t-j} + \sum_{w=0}^{o} \varphi_\varpi \Delta U5MR_{t-j} + \mu_{1t} \quad (3)$$

We tested the null hypothesis of no cointegration of the ARDL model is H_0: $\beta_1 = \beta_2 = \beta_3 = 0$; $\alpha_1 = \alpha_2 = \alpha_3 = 0$ and $\psi_1 = \psi_2 = \psi_3 = 0$ denoting no cointegration. While the alternative hypothesis of the ARDL cointegration among the variables is H_1: $\beta_1 \neq \beta_2 \neq \beta_3 \neq 0$; $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq 0$ and $\psi_1 \neq \psi_2 \neq \psi_3 \neq 0$ implying presence of cointegration. To confirm the existence or otherwise of cointegration (long run equilibrium) relationships among the variables, the F- test statistic calculated was compared with the critical value which comprises of lower critical bound and upper critical bound values of Pesaran and Pesaran (1997) and Pesaran, Shin and Smith (2001). If it is established that none of the variables is I(2), the lower bound shall be based on the assumption that all the variables in the study are I(0), and the upper bound shall be based on the assumption that all the variables are I(1). The null hypothesis of no cointegrating relationship among the variables will be rejected if the computed F- test statistic falls above the upper bound. But if the calculated F- test statistic falls below the lower bound, the null hypothesis of no cointegration among the variables cannot be rejected. However, if the calculated F- test statistic falls between the lower and the upper bounds, the result of the cointegration test is inconclusive.

FTR = Fertility Rate is "total fertility rate represents the number of children that would be born to a woman if she were to live to the end of her childbearing years and bear children in accordance with age-specific fertility rates of the specified year (World Bank, 2019).

U5MR = "Under-five mortality rate is the probability per 1,000 that a new-born baby will die before reaching age five, if subject to age-specific mortality rates of the specified year" (World Bank, 2019)..

GDP_P= Income proxied by GDP per capita which is "GDP per capita is gross domestic product divided by midyear population. GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant local currency" (World Bank, 2019).

Δ= is the first difference

$\beta_1, \beta_2, \beta_3; \alpha_1, \alpha_2, \alpha_3; \psi_1, \psi_2, \psi_3$= are coefficients of the respective variables.

μ= is an error term

If the cointegration is established, the long run models for FTR, U5MR and GDP_P that shall be estimated are as follows:

$$FTR_t = C_0 + \sum_{t=0}^{m} \delta_k FTR_{t-j} + \sum_{l=0}^{n} \xi_p U5MR_{t-j} + \sum_{w=0}^{o} \vartheta_\varpi LOG(GDP\_P_{t-j}) + \mu_{1t} \quad (4)$$

$$U5MR_t = \varpi_0 + \sum_{t=0}^{m} \chi_k U5MR_{t-j} + \sum_{l=0}^{n} \kappa_p FTR_{t-j} + \sum_{w=0}^{o} \rho_\varpi LOG(GDP\_P_{t-j}) + \mu_{1t} \quad (5)$$

$$LOG(GDP\_P)_t = \delta_0 + \sum_{t=0}^{m} \psi_k LOG(GDP\_P_{t-j}) + \sum_{l=0}^{n} \pi_p FTR_{t-j} + \sum_{w=0}^{o} \varphi_\varpi U5MR_{t-j} + \mu_{1t} \quad (6)$$

The short run dynamics estimate using error correction model (ECM) associated with the long run estimates have the following representations

$$\begin{aligned} \Delta FTR_t = \beta_{0t} &+ \sum_{t=0}^{m} \delta_k \Delta FTR_{t-j} + \sum_{l=0}^{n} \xi_p \Delta U5MR_{t-j} \\ &+ \sum_{w=0}^{o} \vartheta_\varpi \Delta LOG(GDP\_P_{t-j}) + \rho ECM_{t-j} + \varepsilon_{1t} \end{aligned} \quad (7)$$

$$\begin{aligned} \Delta U5MR_t = \alpha_{0t} &+ \sum_{t=0}^{m} \chi_k \Delta U5MR_{t-j} + \sum_{l=0}^{n} \kappa_p \Delta FTR_{t-j} \\ &+ \sum_{w=0}^{o} \sigma_\varpi \Delta LOG(GDP\_P_{t-j}) + \gamma ECM_{t-j} + \varepsilon_{1t} \end{aligned} \quad (8)$$

$$\Delta LOG(GDP\_P)_t = \psi_{01t} + \sum_{t=0}^{m} \psi_k \Delta LOG(GDP\_P_{t-j}) + \sum_{l=0}^{n} \pi_p \Delta FTR_{t-j} + \sum_{w=0}^{o} \varphi_{\varpi} \Delta U5MR_{t-j} + \theta ECM_{t-j} + \varepsilon_{1t} \quad (9)$$

And

$$ECM_t = y_t - \sum_{i=1}^{k} \hat{\theta}_i x_{it} - \psi' w_t \quad (10)$$

Where δ, ξ, ϑ, χ, κ, σ, ψ, π, and ϕ are the short run dynamic coefficients of the models convergence to equilibrium and ρ, γ, and θ are the speeds of adjustment in the respective models. ECM_t reflects extent to any short run disequilibrium in the previous period is being corrected or adjusted in y_t

Granger Causality Equations

Since cointegration and long run relationship does not indicate direction of causality between or amongst variables, Granger causality was carried so as dictate the causal relationship between the variables. Granger causality equations for the pairwise causal relationship between the variables are as spelled-out below from equations (1) to (15).

$$FTR_t = \sum \alpha_i FTR_{t-1} + \sum \beta_i U5MR_{t-1} + \mu_{t-1} \quad (11)$$

$$U5MR_t = \sum \alpha_i FTR_{t-1} + \sum \beta_i U5MR_{t-1} + \mu_{t-1} \quad (12)$$

$$U5MR_t = \sum \alpha_i FTR_{t-1} + \sum \beta_i U5MR_{t-1} + \mu_{t-1} \quad (13)$$

$$FTR_t = \sum \alpha_i LOG(GDP\_P)_{t-1} + \sum \beta_i FTR_{t-1} + \mu_{t-1} \quad (14)$$

$$LOG(GDP\_P)_t = \sum \alpha_i LOG(GDP\_P)_{t-1} + \sum \beta_i FTR_{t-1} + \mu_{t-1} \quad (15)$$

$$U5MR_t = \sum \alpha_i LOG(GDP\_P)_{t-1} + \sum \beta_i U5MR_{t-1} + \mu_{t-1} \quad (16)$$

$$LOG(GDP\_P)_t = \sum \alpha_i LOG(GDP\_P)_{t-1} + \sum \beta_i U5MR_{t-1} + \mu_{t-1} \quad (17)$$

FTR_t = current value of fertility rate

FTR_{t-1} = past value of fertility rate

$U5MR_t$ = current value of under-five mortality rate.

$U5MR_{tt-1}$ = past value of under-five mortality rate.

$LOG(GDP\_P)_t$ = current value of income

$LOG(GDP\_P)_{t-1}$ = past value of income

Equation (10) postulates that current fertility rate is related to past value of itself as well as that of under-five mortality rate.

Equation (11) postulates that current under-five mortality rate is related to past value of itself as well as that of fertility rate.

Equation (12) postulates that current fertility rate is related to past value of itself as well as that of income.

Equation (13) postulates that current income is related to past value of itself as well as that of fertility rate.

Equation (14) postulates that current under-five mortality is related to past value of itself as well as that of income.

Equation (15) postulates that current income is related to past value of itself as well as that of under-five mortality.

4.0 Results and Discussion

Unit Root tests

Test of stationarity properties of the variables was carried out using Augmented Dickey-Fuller (ADF) unit root test, in order to test the null hypothesis of the unit root against the alternative hypothesis.

The results of the Augmented Dickey-Fuller (ADF) unit root test in table 1 shows that Under-five mortality rate (U5MR) is stationary at levels at 5 % level of significance, therefore it is integrated of order zero [I(0)]. However, fertility rate (FTR) and income proxied by GDP per capita [LOG(GDP_P)] are not stationary at levels, but becomes stationary at first difference at 5 % level of significance, hence they are integrated of order one [I(1)].

Table 1: An Augmented Dickey-Fuller (ADF) Unit Root test Results

Variables	*Augmented Dickey Fuller (ADF) test*		*5 % Critical values*		*Order of Integration*
	Level	1st Diff.	Level	1st Diff.	
FTR	-1.651853	-4.505140	-3.502373	-3.502373	I(1)
U5MR	-4.138321	-3.730004	-3.502373	-3.502373	I(0)
LOG(GDP_P)	-0.951684	-4.713681	-3.496960	-3.498692	I(1)

Source**:** Authors computation using EViews 10

Having established mixture of integration of order zero [I(0)] and order one [I(1)] variables, there is justification for the computation of ARDL long run form and bounds test of

cointegration to investigate the possible long run equilibrium relationship among the fertility rate (FTR), under-five mortality rate (U5MR) and income proxied by GDP per capita [LOG(GDP_P)]. Prior to bound cointegration test, lag length selection criteria were carried out and the study settled for optimal lag length of three based on Schwarz information criterion (SIC**).**

Results of ARDL Bound-Cointegration Test

The results of the model one bound test with fertility rate (FTR) as dependent variable as reflected in table 2 depicted that the null hypothesis of no cointegrating relationship amongst fertility rate, under-five mortality rate and income is rejected, since the computed F- test statistic value of 9.806697 is greater than the theoretical critical value bounds for the upper bound I(1) critical values of 4.61 at 5% level of significance.

Also the results of the model two bound test with under-five mortality rate with as dependent variable as shown in table 2 revealed that the null hypothesis of no cointegrating relationship amongst under-five mortality rate, fertility rate and income is rejected, since the computed F-test statistic value of 6.582284 is greater than the theoretical critical value bounds for the upper bound I(1) critical values of 4.61 at 5% level of significance. More to that the model three bound test with income proxied by GDP per capita [LOG(GDP_P)] as dependent variable as shown in table 2 revealed that the null hypothesis of no cointegrating relationship amongst under-five mortality rate, fertility rate and income is rejected, since the computed F- test statistic value of 6.772013 is greater than the theoretical critical value bounds for the upper bound I(1) critical values of 4.61 at 5% level of significance. Hence, all the three models have suggested the existence of long run dynamic equilibrium relationship amongst fertility rate, under-five mortality rate and income proxied by log of GDP per capita in Nigeria from 1964 to 2017. This is in agreement with the study Odusanya and Adegboyega (2015) that have established a long run equilibrium relationship amongst fertility, income and mortality rate in Nigeria. Also it is in accord with the findings of Odior and Alenoghena (2018) that revealed existence of long run relationship between fertility rate, education expenditure, health expenditure, per capita income, life expectancy at birth and infant mortality rate in Nigeria.

Table 2: Results of the ARDL F- Bounds Cointegration tests

S/NO	***Model***	***Dependent Variable***	***Independent Variable***	***F-Statistic***	***Lower Bound I(0)***	***Upper Bound I(1)***
1.	One	Fertility rate(FTR)	Under-Five Mortality Rate (U5MR), Income (GDP_P)	9.806697	3.88	4.61
2.	Two	Under-Five Mortality Rate(U5MR)	Fertility Rate (FTR), Income (GDP_P)	6.582284	3.88	4.61
3.	Three	Income [LOG(GDP_P)]	Under-Five Mortality rate	6.772013	3.88	4.61

	(U5MR), Fertility Rate (FTR)

Source**:** Author's computation using EViews 10

Having established the existence of cointegration relationship, the estimation of the long run dynamics follow-suit; Table 3 presents the results of the long run coefficient estimate, where estimate of long run in model one indicates that both the coefficients of the under-five mortality rate and income proxied by GDP per capita turn-out negative and not statistically significance in influencing fertility rate in the long run in the country during the period under review. The lack statistical significance of income on fertility rate inthis study is contrary to the findings of Dauda, Donga, Yaro, Saleh and Bello (2021) that income has negative impact on adolescent fertility rate in Nigeria most especially in the medium to long term. The findings is also contrary to the study by Odusanya and Adegboyega (2015) where income has a negative and statistically significant effect on total fertility, but infant mortality rate has a positive and not statistically significant in in influencing fertility rate in both the short and long run in Nigeria.

However, the results from model two has shown that the coefficient of fertility rate (FTR) is positive and statistically significant in influencing under-five mortality rate at 5% level of significance. This suggests that an increase in fertility rate by one percent led to increase in under-five mortality rate by 35 percent. Therefore, this suggests that the high level of fertility rate may be one of the factors behind the high level of under-five mortality rate in the country. But the coefficient of income [LOG(GDP_P)] is positive and not statistically significant in influencing under-five mortality rate. This findings that high level of fertility rate may be one of the factors behind the high level of under-five mortality rate in the country is in accord with the findings by Anyamele, et al. (2015) there is a higher positive association of higher birth order with infant and under-five mortality rate in Nigeria.

While the result from the model three portrayed that the coefficient under-five mortality rate though negative, but is not statistically significant in its impact on income. The coefficient of fertility rate (FTR) has the expected negative sign and is statistically significant in its effect on income [LOG(GDP_P)] at 5% level of significance, which tends to implies that an increase in total fertility rate will lead to reduction in income in the long run. This may be due to the high level of fertility rate which may be behind the rapid population growth with its attendant demographic implications on income.

Table 3: Results of Long Run Coefficients Estimate

Model One

Dependent Variable : Fertility rate (FTR)				
Independent Variables	Coefficients	Std. Error	t-Statistic	Prob.
U5MR	-0.044030	0.082859	-0.531386	0.5980
LOG(GDP_P)	-2.731781	3.706128	-0.737099	0.4653

Model Two

Dependent Variable : Under-Five Mortality Rate (U5MR)				
FTR	35.43656	18.93036	1.871943	0.0687
LOG(GDP_P)	-9.927145	11.58419	-0.856956	0.3967

Model Three

Dependent Variable : Income [LOG(GDP_P)				
U5MR	-0.003881	0.003291	-1.179364	0.2446
FTR	-0.538967	0.158020	-3.410761	0.0014

Source: Author's computation using EViews 10

Results of the short run coefficients indicate that when fertility rate is the dependent variable, under-five mortality rate turn out negative and statistically significant at 5 % level of significance, which is contrary to the a priori expectations. It implies that an increase in under-five mortality rate leads to a decrease in fertility rate in the country. This is in contrast with the findings that infant mortality rate has a positive and not statistically significant in influencing fertility rate in both the short and long run (Odusanya & Adegboyega, 2015) and also in divergence with the reports of World Health Organization (2019) that declines in under-five mortality rate was accompanied by declines in fertility rate from 2000 to 2017. The coefficient of Error Correction Model (ECM) term has the expected and correct sign which is -0.001452 (with its standard error and t-statistic of 0.000224 and -6.488 respectively) that measures the speed of adjustment to the equilibrium relationship has turn-out negative and statistically significant in adjusting for the short run disequilibrium in the stable long run relationship amongst fertility rate, under-five mortality rate and income.

But when under-five mortality rate is the dependent variable level period lag of fertility rate is negative and not statistically significant at 5% level of significance. Though at one period lag the fertility rate is positive and it is still not statistically significant. However, at lag two periods the fertility rate is negative and statistically significant at 10% level of significance. Meaning that as fertility rate increases it tends to decrease in under-five mortality rate in the country. This is in disagreement with the findings that high fertility leads to high mortality rate (Shen & Williamson, 1999) and that a decline in fertility rate would likely lead to a decline in mortality rate (Johnson, Abderrahim, & Rutstein, 2011). The coefficient of Error Correction Model (ECM) of -0.025714 is correctly signed (with its standard error and t-statistic of 0.004829 and -5.324890 respectively) has turn-out negative and statistically significant in correcting for the short run disequilibrium in the stable long run relationship amongst under-five mortality rate, fertility rate and income in the country.

Table 4: Results of Short Run and Error Correction Mechanism Coefficients

A. Dependent Variable: D(FTR)

Variables	Coefficients	Standard Error	t-statistic
C	0.077406	0.011940	6.483016
D(FTR(-1))	1.345680	0.138166	9.739580
D(FTR(-2))	-0.225394	0.235333	-0.957767
D(FTR(-3))	-0.299387	0.116784	-2.563595
D(U5MR)	-0.001076	0.000203	-5.299239
ECM (-1)*	-0.001452	0.000224	-6.488223
R-squared=	**0.999185;**	**F-statistic=**	**10782.77**

B. Dependent Variable: D(U5MR)

Variables	Coefficients	Standard Error	t-statistic
C	4.004486	0.803197	4.985680
D(U5MR(-1))	0.938784	0.125206	7.497883
D(U5MR(-2))	0.180835	0.188531	0.959179
D(U5MR(-3))	-0.306265	0.097399	-3.144443
D(FTR)	-20.06965	16.82782	-1.192647
D(FTR(-1))	43.39842	34.37082	1.262653
D(FTR(-2))	-39.18503	20.43358	-1.917678
CointEq(-1)*	-0.025714	0.004829	-5.324890
R-squared=	**0.997243;**	**F-statistic=**	**2170.604**

C. Dependent Variable: DLOG(GDP_P)

Variables	Coefficients	Standard Error	t-statistic
C	6.946882	1.289756	5.386199
DLOG(GDP_P(-1))	0.431986	0.104187	4.146253
D(FTR)	-7.693459	2.318575	-3.318185
D(FTR(-1))	9.440573	2.575850	3.665032
ECM(-1)*	-0.408940	0.076024	-5.379123
R-squared=	**0.503025;**	**F-statistic=**	**11.89304**

Source: Authors' computation using Eviews 10

Furthermore, when income is the dependent variable, at level period fertility rate turned out negative and statistically significant, signifying that that fertility rate increases has adverse consequences on income level in the country in the short run. But at lag one period the fertility

rate has positive and statistically significant impact on income. The statistically significant impact of fertility rate has tallied with results of a study by Herzer, Strulik and Vollmer (2010) that there is causality from fertility rate to income. The coefficient of Error Correction Model (ECM) term has the correct value of -0.408940, standard error of 0.076024 and t-statistic of -5.379123 is negative and statistically significant at 5% level of significance in correcting for the short run deviations or disequilibrium in the established long run equilibrium relationship path between income, under-five mortality rate and fertility rate in Nigeria from 1964 to 2017.

Granger Causality Test Results

The pair-wise granger causality test was used to measure the causal relationship between fertility rate (FTR) and under-five mortality rate (U5MR), fertility rate and income[LOG(GDP_P)], under-five mortality rate and income in Nigeria from 1964 to 2017. The Granger causality results in table 5 reflects that we reject the null hypothesis that under-five mortality rate does not granger cause fertility rate and so also we reject the null hypothesis that fertility rate granger causes under-five mortality rate at 5 percent level of significance. Therefore, this suggests that under-five mortality rate granger causes fertility rate and so also fertility rate granger causes under-five mortality rate. Hence, there is bidirectional causality between under-five mortality rate and fertility rate. This is in line with Herzer, Strulik and Vollmer (2010) which showed bidirectional causality between fertility rate and mortality rate. The findings of this study have justified the two channels of *biological effect* and *replacement effect* of the relationship between infant mortality and fertility rates (Liu, Yamada & Yamada, 1996).

Also the study tends to be in line with the demographic transition theory which posited a relationship between fertility and mortality. When there is high fertility, mortality tends to be high (Shen & Williamson, 1999).However, we accept the null hypothesis that indicates that income proxied by GDP per capita LOG (GDP_P) does not granger causes fertility rate, while fertility rate granger causes income. Therefore, there is a unidirectional causality from fertility rate to income. This is in contrast with the findings of Herzer, Strulik and Vollmer (2010) that finds a bidirectional causality between fertility rate and income. But in agreement with long in run coefficients estimate results table 5 above, but in disagreement with the study by Odior and Alenoghena (2018) per capita income has positive impact on total fertility rate in Nigeria. Furthermore, we accept the null hypothesis that indicates that income does not granger causes under-five mortality rate, while under-five mortality rate granger causes income. Therefore, there is a unidirectional causality from under-five mortality rate to income.

Table 5: Granger Causality Test Results

Null Hypothesis:	***Obs***	***F-Statistic***	***Prob.***	***Decision***
U5MR does not Granger Cause FTR		11.5473	1.E-05	Reject
FTR does not Granger Cause U5MR	51	5.20914	0.0036	Reject
LOG(GDP_P) does not Granger Cause FTR		1.21917	0.3140	Accept
FTR does not Granger Cause LOG(GDP_P)	51	4.57822	0.0071	Reject

LOG(GDP_P) does not Granger Cause U5MR		1.17118	0.3315	Accept
U5MR does not Granger Cause LOG(GDP_P)	51	3.08961	0.0367	Reject

Source: Authors' computation using Eviews 10

Diagnostic Tests

Evidences from the statistical diagnostic tests carried out using white Heteroscedasticity Test (Breusch-Pagan-Godfrey), Breusch-Godfrey Serial Correlation LM Test and Normality (Jacque-Bera) test indicates that the model has passed all the diagnostic tests, as it is free from heteroscedasticity, there are no evidence of serial correlation and the residual/error term are normally distributed at 5% level of significance.

Table 6: Results of diagnostic tests

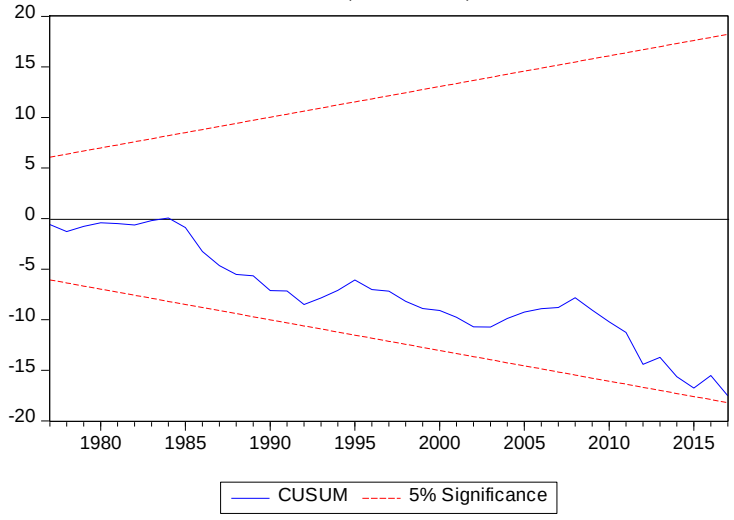
Test	F-Statistic	Probability
Heteroskedasticity Test: Breusch-Pagan-Godfrey	1.4035	0.2241
Breusch-Godfrey Serial Correlation LM Test:	0.9177	0.4640
Normality (Jacque-Bera) test	0.5698	0.7521

Source: Authors' computation using EViews 10

Model Stability Test

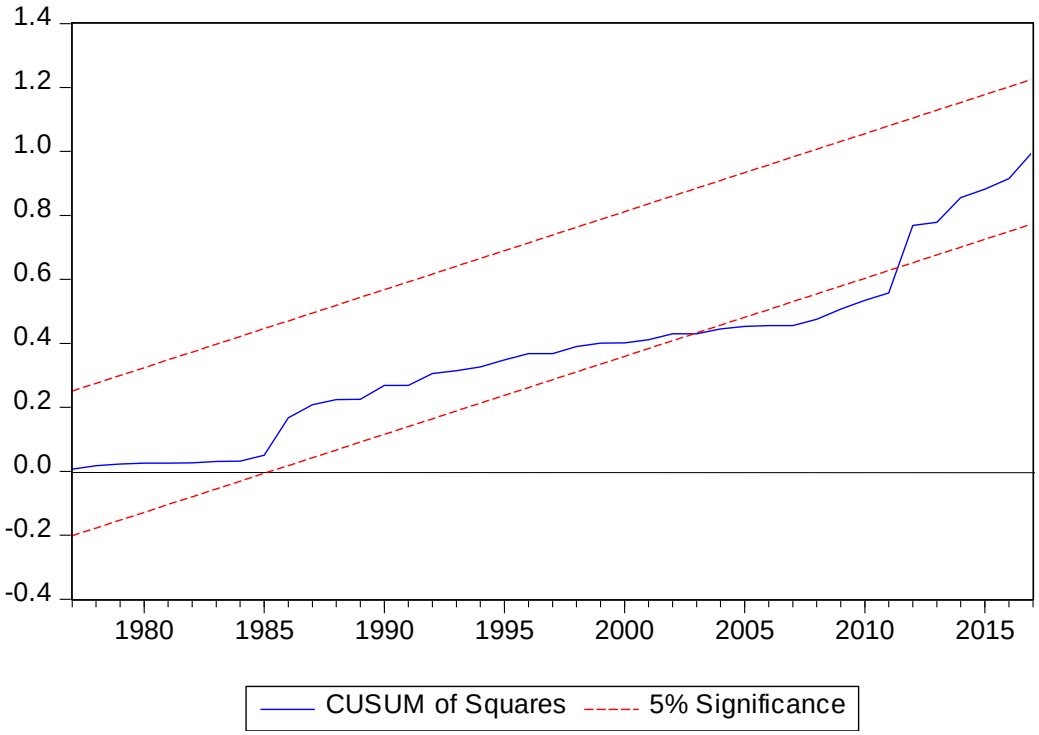
The stability of the long run coefficients of the model of the long run equilibrium relationship between fertility rate, under-five mortality rate and income was examined using both the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests as reflected in figures one and two respectively, where both the plots of the CUSUM and CUSUMSQ statistics are well within the 5% critical bound which revealed the stability, appropriateness and suitability of the coefficients in the long run model at 5% levels of significance.

Figure 1: Plot of cumulative sum (CUSUM) of the Recursive Residuals



NB: The straight line represent critical bounds at 5% level of significance.
Source: Authors' computation using EViews 10

Figure 2: Plot of Cumulative Sum of squares (CUSUMSQ) of the Recursive Residuals



NB: The straight line represent critical bounds at 5% level of significance.
Source: Authors' computation using EViews 10

5.0 Conclusion and Recommendations

This study investigates the nexus between fertility rate, under-five mortality rate and income from 1964 to 2017 using annual time series data sourced from World Bank's World Development Indicators 2019 database. Results from Bound-Cointegration Tests has indicated that all the three models have suggested the existence of long run equilibrium relationship amongst fertility rate, under-five mortality rate and income proxied by log of GDP per capita in Nigeria from 1964 to 2017. The Long run coefficients estimate has shown that fertility rate has a positive and statistically significant influence on under-five mortality rate at 5% level of significance and also fertility rate is negative and statistically significant in its effect on income at 5% level of significance in the long run. While the error correction models (ECMs) that measured the speed of adjustment in the all the three estimated models each has the correct sign by turning-out negative and statistically significant in adjusting for the short run disequilibrium in the stable long run equilibrium relationship amongst fertility rate, under-five mortality rate and income in Nigeria. Whereas the pair-wise Granger causality results has shown that there is bidirectional causality between under-five mortality rate and fertility rate, a unidirectional causality from fertility rate to income and a unidirectional causality from under-five mortality rate to income.

The implications of this findings of the established relationship between fertility, under-five mortality and income is that Nigeria can utilized the demographic advantage of the declined

in fertility and mortality rates as witnessed over the period for improvement in income and economic development of the country.

Since it has established that fertility and mortality rates are declining in Nigeria and the demographic transition can be harnessed and enhanced by the reduction in the fertility rate and mortality rate, there is the need to empower women by increasing their income level through conditional cash transfers or other financial incentives to poor vulnerable households; improving maternal and child health care and nutrition services access by increasing access to universal health care services; improving girls' education and women empowerment programmes through provision of reproductive health care services such as access to family planning programmes, improving girls child access to school, access to employment opportunities to women, which can go a long way in reducing fertility, discouraging adolescent marriage, decreasing adolescent/unwanted pregnancy, diminishing child mortality, improving maternal and child health and nutrition.

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