Economic growth and life expectancy: a panel analysis of the BRICS countries

OM Oche

orcid.org/ 0000-0001-7364-3697

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Promoter: Prof G Mah

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DECLARATION

I OCHE, Mary Onyemowo, declare that ***ECONOMIC GROWTH AND LIFE EXPECTANCY: A PANEL ANALYSIS OF THE BRICS COUNTRIES*** is entirely my work submitted at the North-West university for the award of Doctor of Philosophy in Economics. It has never been submitted by me or anyone else for a degree or exam at any other university. Complete references have been included to identify and recognise every source I used or quoted.

Full names..... Date.....

Signed.....

Signature..... Date.....
Supervisor

DEDICATION

I dedicate this work to my late mother **Regina Paul Oche**, whose life and prayers continue to inspire me each day. Although you are no longer here to witness this accomplishment, your influence and seed of prayer sown into my academic journey lives on in every part of me. I hope this makes you proud.

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ABSTRACT

With notable increases in GDP per capita and a disproportionate share of global output, the BRICS (Brazil, Russia, India, China, and South Africa) economies have become prominent actors in the global economy. However, these nations have continued to face several health issues, ranging from the prevalence of both communicable and non-communicable illnesses, and water and air pollution, as well as road traffic accidents. Thus, life expectancy, a crucial measure of population health, has not increased consistently across these countries despite significant economic progress. Hence, this current study sought to statistically investigate the link between life expectancy and economic growth of the BRICS nations. With data sourced from World Bank Development indicators for the period 2000-2023, a life expectancy model and a growth model are estimated in this study in cooperating variables such as life expectancy, GDP per capita, education, trade, physicians per 1000, CO_2 emissions, health expenditure per capita, and gross fixed capital formation. This study investigates the long-run relationship between life expectancy and economic growth in the BRICS countries using annual panel data and advanced econometric techniques. The panel cointegration approach was employed and the results confirm a stable long-term link between the variables. The Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) estimators as well as Granger causality test were applied to capture both long-term and short-term dynamics.

The empirical results of the Life Expectancy Model of this study showed that GDP per capita and education have significant positive effects on life expectancy in the BRICS countries, while carbon emissions have a significant negative relationship with life expectancy. The Granger causality analysis further reveals a bidirectional relationship between GDP per capita and life expectancy, indicating that economic growth and population health mutually reinforce each other. Additionally, carbon emissions unidirectionally Granger-cause life expectancy, highlighting the detrimental impact of environmental degradation on health outcomes.

These findings suggest that policies aimed at improving life expectancy should prioritize sustained economic growth, expansion of educational opportunities, and effective environmental management. More specifically, governments should invest in income-generating initiatives (micro- and small enterprise development, and Transport and Logistics Services among others) and social protection, to boost GDP per capita, enhance access to quality education to strengthen human capital, and also implement stringent carbon emission controls alongside renewable energy

adoption to mitigate health risks from pollution. Such integrated strategies can simultaneously improve population health and reinforce long-term economic development.

Furthermore, the empirical findings from the Economic Growth Model indicate that life expectancy and current health expenditure per capita have statistically significant positive effects on economic growth in the BRICS countries. The Granger causality analysis shows that life expectancy unidirectionally Granger-causes GDP per capita, and carbon emissions also exhibit a unidirectional causal influence on economic growth. These results highlight the central role of population health and healthcare investment in promoting economic performance, as well as the potential impact of environmental quality on growth outcomes.

Based on the significant long-run results, policymakers in the BRICS countries should prioritize interventions that improve population health and strengthen healthcare systems. Investments in healthcare infrastructure, preventive care, and public health programmes will enhance labour productivity and support sustainable economic growth. Given the causal influence of life expectancy on economic performance, integrating health improvements into national development strategies is crucial. Additionally, although carbon emissions are not significant in the long run, their unidirectional effect on economic growth underscores the importance of environmental management. Policies should include stricter emission controls, promotion of renewable energy, and cleaner industrial practices to protect both health and long-term economic performance.

Key terms: Life Expectancy, Economic Growth, FMOLS, DOLS, Granger causality, BRICS

JEL Classification: I15, I150, O40, C23, C33.

LIST OF ABBREVIATIONS

ADF = Augmented Dickey Fuller

ARDL = Autoregressive Distributed Lag

BRICS = Brazil, Russia, India, China and South Africa

CBN = Central Bank of Nigeria

CO2 = Carbon Emission

DOLS = Dynamic Ordinary Least Square

ECM =Error correction model

EsWACs =English-speaking West African Countries

EU =European Union

FDI = Foreign Direct Investment

FMOLS = Fully Modified Ordinary Least Square

GDP = Gross Domestic Product

GMM = Generalized method of moments

HIV/AIDS = Human immunodeficiency virus/ Acquired immunodeficiency syndrome

IPS = Im, Pesaran, and Shin (IPS test)

LLC =Levin-Lin-Chu

LSDV = Least Square dummy variable

MENA = Middle East and North Africa

OECD = Organisation for Economic Co-operation and Development

PCA = Principal component Analysis

PVAR = Panel vector autoregression

SEM = Structural equation modelling

SES = School enrolment secondary

SSA = Sub-Saharan Africa

VAR = Vector autoregression

VECM = Vector Error correction model

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CHAPTER ONE

INTRODUCTION TO STUDY

1.1 Introduction/Background/ Rationale

Economic growth and population health are widely recognized as fundamental indicators of national development and human wellbeing. Across developed and developing economies, policymakers and development scholars have consistently emphasized the need to improve both economic performance and health outcomes as essential components of sustainable development. Consequently, the relationship between economic growth and health has attracted considerable attention within the fields of development economics and health economics (Kuznets, 1955; Preston, 1975). The introduction of the Human Development Index by the United Nations Development Programme further reinforced the importance of integrating health outcomes into assessments of economic development (UNDP, 1990). Since then, debates have persisted regarding whether economic growth improves population health or whether improved health outcomes stimulate economic prosperity (Bloom & Canning, 2000; Weil, 2014). This debate remains important because health and economic prosperity are mutually reinforcing dimensions of sustainable development.

Life expectancy, defined as the average number of years an individual is expected to live under prevailing mortality conditions, has emerged as one of the most widely used indicators of population health and social welfare (Jen et al., 2010). Higher life expectancy generally reflects improved living conditions, better nutrition, improved healthcare systems, and higher standards of living (Jen et al., 2010). It is also regarded as an important proxy for measuring health outcomes and the development status of an economy (Halicioglu, 2010; Poças & Soukiazis, 2010). Beyond serving as a health indicator, life expectancy contributes significantly to labour productivity, human capital accumulation, and long-term economic growth because healthier populations are generally more productive and economically active (Bloom & Canning, 2000; Barro, 1996). Conversely, economic growth enables governments and households to invest more resources in healthcare delivery, education, infrastructure, and social welfare, thereby improving longevity and population health outcomes (Pritchett & Summers, 1996). This suggests the existence of a potentially bidirectional relationship between economic growth and life expectancy.

Although improvements in economic growth and health outcomes have been widely observed globally, the relationship between the two variables remains uneven across countries and regions. In many developed economies, sustained economic expansion has generally been accompanied by significant improvements in healthcare systems, living standards, and longevity (Preston, 1975; Deaton, 2003). However, several developing economies continue to experience persistent health inequalities despite periods of economic growth. Factors such as poverty, unemployment, weak healthcare infrastructure, environmental degradation, income inequality, and demographic pressures often constrain the extent to which economic growth translates into improved health outcomes (Bloom et al., 2004; Cutler et al., 2006; Weil, 2014). Similarly, poor health conditions may reduce labour productivity, weaken human capital accumulation, and constrain long-term economic performance (Barro, 1996; Bloom & Canning, 2000). Consequently, the nature, direction, and magnitude of the relationship between economic growth and life expectancy remain particularly important within the context of developing and emerging economies.

Among emerging economies, the BRICS countries particularly the founding members (Brazil, Russia, India, China, and South Africa which form the scope of this current study, provide a particularly important context for examining the relationship between economic growth and life expectancy. These BRICS countries collectively account for more than 40 percent of the world's population and contribute substantially to global economic output (World Bank, 2021). Over the past three decades, these economies have emerged as major drivers of global economic growth and international trade. According to the United Nations Conference on Trade and Development (UNCTAD, 2023), the BRICS economies accounted for approximately one-quarter of global economic output in 2023. They have experienced a remarkable economic progress from 1990 to 2015, with the shift in output from 5.85% to 21.6%, as their nominal GDP stood at $14.9 trillion. They are predicted to surpass the growth of the global community in the twenty-first century and contribute almost half of all the global GDP growth. They have the potential to outgrow the Group of the Seven (G7) wealthiest nations by 2050. Their increasing global economic relevance has been attributed to factors such as large domestic markets, abundant natural resources, demographic advantages, and ongoing economic reforms (Tamara, 2019; Chatterjee & Naka, 2022). Despite their rapid economic transformation, the BRICS countries continue to exhibit substantial disparities in healthcare

systems, institutional quality, and health outcomes, making them particularly suitable for analysing the growth–health nexus in emerging economies (Harttgen et al., 2013).

Despite their impressive economic growth, the BRICS countries continue to face considerable health challenges, including the growing burden of communicable and non-communicable diseases, environmental pollution, rising healthcare costs, and unequal access to healthcare services (Ivins, 2013; Sun et al., 2022). Although governments within the BRICS bloc have implemented reforms aimed at improving healthcare financing and achieving universal health coverage, significant disparities in healthcare access and health outcomes persist both within and across these economies (Rao et al., 2014). For instance, India continues to experience high burdens of infectious diseases alongside increasing non-communicable diseases, while South Africa remains heavily burdened by HIV/AIDS and tuberculosis, China witnessed increasing mortality associated with chronic non-communicable diseases such as cardiovascular conditions and diabetes and Brazil also faces significant pressures from non-communicable (Ivins, 2013; Jafrin et al., 2021). The coexistence of rapid economic growth and persistent health challenges makes the BRICS countries particularly suitable for analyzing whether economic growth and life expectancy maintain a consistent relationship within emerging economies. These disparities suggest that rapid economic growth alone may not automatically translate into proportional improvements in population health outcomes.

The variations in health outcomes across the BRICS countries are further reflected in their life expectancy trends. Although all BRICS countries have experienced improvements in life expectancy over time, the pace and magnitude of progress differ substantially across countries. The Russian Federation experienced periods of stagnation and fluctuation in life expectancy from 1960, resulting in relatively modest gains compared to the other BRICS countries. India and Brazil recorded gradual increases in life expectancy over time, whereas China experienced a relatively rapid improvement. South Africa, however, experienced a decline in life expectancy during the 1990s before recording gradual recovery in subsequent years (WHO, 2015; Dorrington et al., 2018).

The disparities in life expectancy among the BRICS countries remained evident between 2010 and 2017. India's life expectancy increased modestly from approximately 67.0 years in 2010 to 68.7 years in 2017, while South Africa improved from 58.5 years to approximately 64.0 years during the same period. Russia recorded an increase from approximately 68.9 years to

about 72 years, whereas Brazil improved from 73.9 years to 75.7 years. China consistently recorded the highest life expectancy levels among the BRICS countries, increasing from approximately 74.8 years in 2010 to about 76.3 years in 2017 (WHO, 2015; BRICS, 2018). This statistics are depicted in Figure 1.1 below:

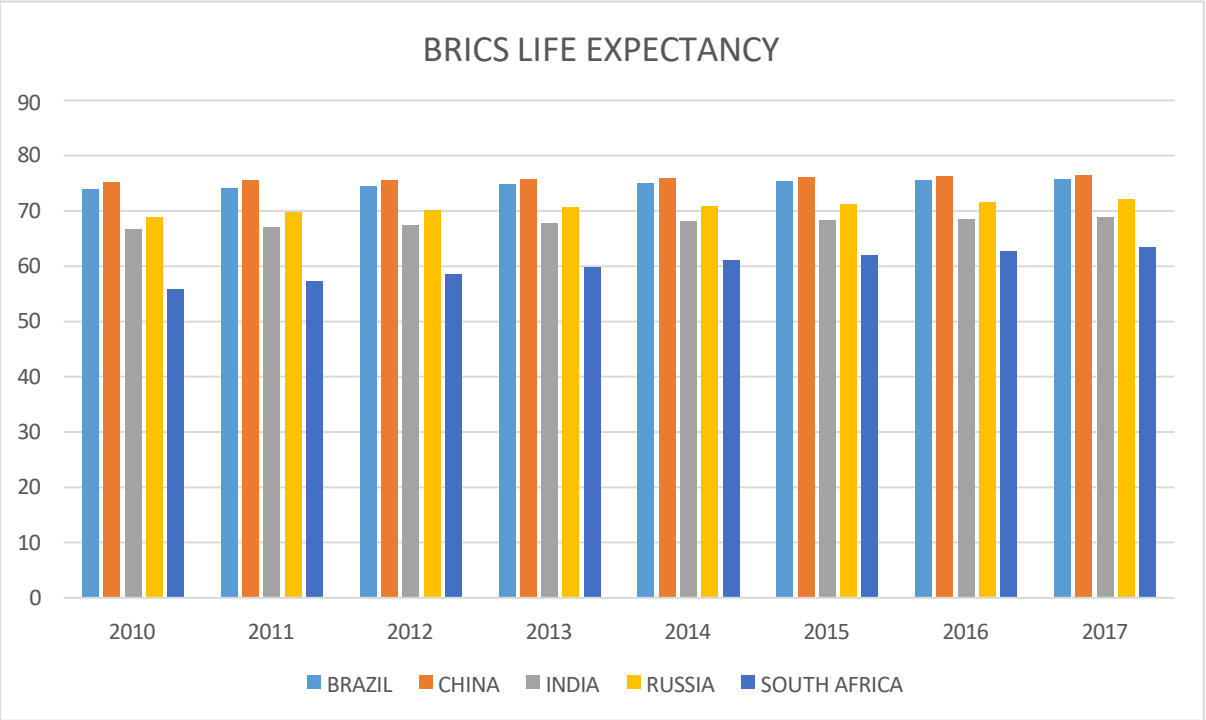


Figure 1.1: BRICS Life Expectancy from 2010-2017

Authors' Design, Data sourced from World Bank development indicators

From Fig.1.1 it is observed that among the BRICS countries, India and South Africa have had the lowest since the inception of the economic bloc while Brazil and China had higher life expectancies of about 70 years and above, but less than 80 years for the period 2010 to 2017. These are followed by Russia, which had 60 years, and slightly above 70 years in 2017. India has had over 60 years but below 70 years in all the years, and lastly South Africa is between 50.5 years and 64 years.

A further investigation of the period 2020 to 2024 indicates that the disparities in life expectancy across the BRICS countries persist, with South Africa and India continuing to record lower life expectancy levels compared to China and Brazil. In particular, a noticeable gap remains between countries with relatively high longevity outcomes and those with lower

health performance, suggesting persistent structural and institutional differences in health outcomes across the BRICS bloc. This is revealed clearly as depicted in Figure 1.2 below:

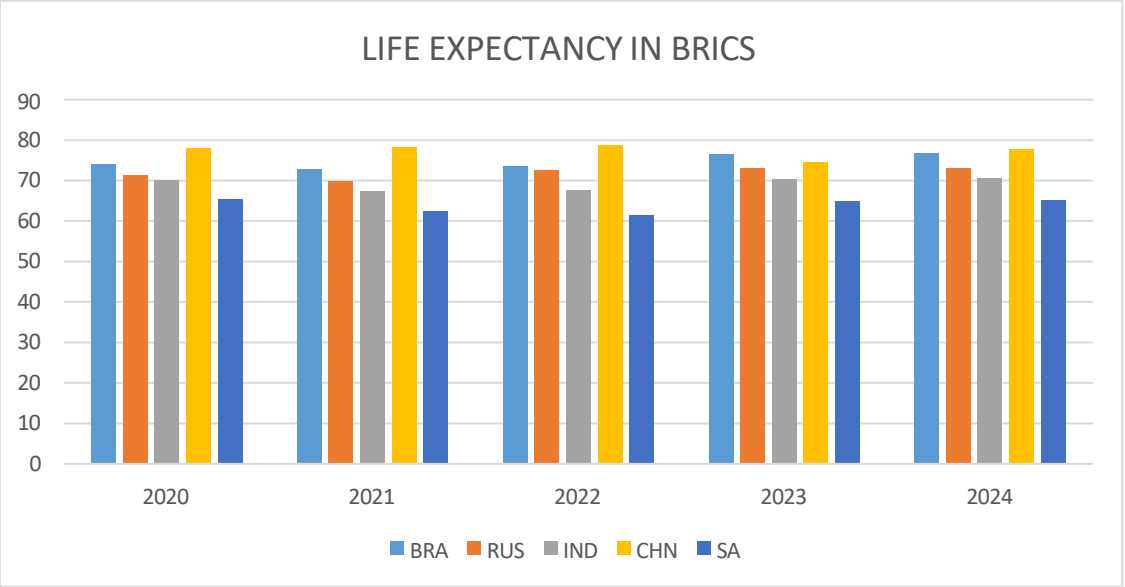


Figure 1.2: BRICS Life Expectancy from 2020-2024

Authors' Design, Data sourced from World Bank development indicator

From Fig 1.2 it is observed that the disparity has persisted over the period from 2020 to 2024. Equally it is noted that South Africa and India have continued to perform lower than the other BRICS countries, while Brazil and China have continued to top the chart in this period. It is important to note that in 2023, there is a huge gap of about 10 years between Brazil, which has the highest life expectancy, and South Africa with the lowest.

It is vital to note that health is a vital asset of an individual, and the need to improve health status has been a crucial social need and goal, as observed by Colantonio et al. (2010). This asset allows for full attainment of capability, but its absence will result in both emotional and physical breakdown, which will in turn pose restrictions on human lives. The health of citizens is both a prerequisite for sustained economic growth and a result of sustainable economic development. Thus, for many nations, improving the health status or health outcomes of the people is a major social and economic developmental objective. One key developmental and health indicator used for comparing one country to another is longevity, that is, life expectancy and mortality rate (Obrizan & Wehby, 2017)..

One major economic indicator commonly associated with life expectancy is Gross Domestic Product per capita (GDP per capita), which serves as a proxy for economic growth and living standards. The relationship between income and life expectancy was first systematically established by Samuel H. Preston (1975) through the Preston Curve, which demonstrates that countries with higher income levels generally exhibit higher life expectancy. However, Preston also observed that increases in income alone do not fully explain improvements in mortality trends over time, suggesting the influence of broader social and institutional factors. Similarly, Bloom et al. (2004) argued that life expectancy is not only an outcome of economic development but also an important determinant of long-term economic growth through its effects on productivity, labour efficiency, and human capital accumulation.

Despite extensive empirical research on the relationship between economic growth and life expectancy, existing studies have largely focused on unidirectional relationships. Many studies examine either the effect of economic growth on life expectancy or the effect of life expectancy on economic growth, but not both simultaneously (Bloom et al., 2004; Weil, 2014). Moreover, findings across studies remain inconsistent due to differences in methodology, model specification, and country context. Limited research has examined the bidirectional relationship between economic growth and life expectancy within the BRICS countries using panel econometric techniques. This creates both an empirical and methodological gap in the literature, particularly in emerging economies where structural conditions differ significantly from developed countries (Deaton, 2003; Cutler et al., 2006).

Against this backdrop, this study examines the bidirectional relationship between economic growth and life expectancy in BRICS countries using panel data analysis. Specifically, the study investigates both the effect of economic growth on life expectancy and the effect of life expectancy on economic growth within the BRICS economies. The study contributes to the literature by providing empirical evidence on the interdependence between health and economic performance in emerging economies and offers policy-relevant insights for improving both economic growth and population health outcomes.

1.2 Problem Statement

The BRICS economies comprising the founding members Brazil, Russia, India, China, and South Africa have experienced remarkable economic growth and increasing global relevance

over the past two decades. With significant increases in GDP per capita and growing contributions to global output, these economies have emerged as major actors within the international economic system (Agarwal, 2023). Despite these economic advancements, improvements in life expectancy across the BRICS countries have remained uneven and disproportionate. While countries such as China and Brazil have recorded substantial gains in longevity, South Africa and India continue to experience relatively lower life expectancy levels due to persistent public health challenges, inequality, poverty, and healthcare constraints (Romaniuk et al., 2020; WHO, 2023). This divergence raises important concerns regarding whether sustained economic growth alone is sufficient to improve population health outcomes within emerging economies.

The disparity in health outcomes across the BRICS countries is further influenced by differences in demographic structures and population-related policies adopted by member states. China, for instance, historically implemented the One-Child Policy and subsequently transitioned to more flexible population policies aimed at addressing ageing population concerns and declining fertility rates (Zhang, 2017). India, on the other hand, continues to grapple with rapid population growth and high population density, which exert pressure on healthcare systems, housing, sanitation, and public infrastructure (Bongaarts, 2016). Russia faces demographic decline and ageing population challenges, while Brazil and South Africa continue to experience urban population pressures, unemployment, and socio-economic inequality (UNDESA, 2022). These variations in demographic policies and population dynamics significantly affect healthcare demand, labour productivity, resource allocation, and ultimately life expectancy outcomes within the BRICS bloc.

In addition, substantial differences exist among the BRICS nations in terms of technological advancement and healthcare development. China and Russia have made considerable investments in digital healthcare systems, medical technologies, biomedical research, and healthcare infrastructure, while India has emerged as a major hub for pharmaceutical production and medical innovation (OECD, 2021; Chatterjee & Naka, 2022). Conversely, South Africa and parts of Brazil continue to face infrastructural deficiencies, unequal technological diffusion, and inadequate healthcare delivery systems, particularly in rural and marginalized communities (World Bank, 2021). These technological disparities influence the quality, efficiency, and accessibility of healthcare services and contribute to variations in health outcomes and longevity across member nations.

Access to healthcare facilities and qualified medical personnel also remains uneven within the BRICS countries. While some countries have expanded universal health coverage and strengthened healthcare financing mechanisms, significant inequalities persist in access to hospitals, primary healthcare centres, physicians, nurses, and specialized medical experts (Rao et al., 2014). Rural populations and low-income groups in several BRICS countries continue to face inadequate healthcare access, high out-of-pocket healthcare expenditure, and shortages of skilled healthcare professionals (WHO, 2023). South Africa, for example, continues to experience healthcare inequalities associated with poverty, HIV/AIDS, and under-resourced public health institutions, whereas China's substantial investments in healthcare infrastructure have contributed to notable improvements in life expectancy (Jafrin et al., 2021). These disparities suggest that economic growth may not automatically translate into equitable improvements in population health outcomes across the BRICS bloc.

Empirical evidence further reveals persistent disparities in life expectancy despite sustained economic expansion within the BRICS economies. Between 2019 and 2023, average life expectancy within the BRICS countries remained below the OECD benchmark and varied considerably among member states. China and Brazil consistently recorded higher life expectancy levels compared to South Africa and India (WHO, 2023). The persistence of these disparities has significant implications for labour productivity, human capital formation, healthcare expenditure, and long-term economic sustainability (Bloom & Canning, 2000). Where economic growth fails to produce commensurate improvements in health outcomes, the result may include rising inequality, reduced productivity, and weakened human development outcomes (Mújica et al., 2014).

Although BRICS countries have collectively implemented several health-related initiatives involving disease control, vaccine development, healthcare cooperation, and public health financing, major health challenges remain unresolved. Existing BRICS health programmes have largely focused on disease-specific interventions without adequately addressing broader structural determinants of health such as inequality, environmental degradation, healthcare accessibility, technological disparities, demographic pressures, and institutional weaknesses (Global Health Research and Policy, 2023). Furthermore, many BRICS health agreements remain largely non-binding and are weakened by inadequate monitoring and accountability mechanisms, thereby limiting their long-term effectiveness (International Journal for Equity in Health, 2021).

Despite extensive empirical studies on the relationship between economic growth and health outcomes, existing literature remains inconclusive regarding the direction and magnitude of the relationship between economic growth and life expectancy within the BRICS countries. Many previous studies have focused primarily on unidirectional relationships by examining either the effect of economic growth on health outcomes or the influence of health on economic growth separately, without adequately accounting for their potential interdependence (Bloom et al., 2004; Weil, 2014). In addition, limited studies have jointly incorporated critical structural factors such as population dynamics, technological disparities, healthcare accessibility, and cross-country heterogeneity within the BRICS context.

Consequently, an important empirical and methodological gap exists regarding the extent to which economic growth has translated into improved life expectancy within the BRICS economies. To address this gap, this study employs two multivariate panel regression models in order to capture the bidirectional nature of the relationship between economic growth and life expectancy. Specifically, the study utilizes Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) techniques to estimate the long-run relationship while controlling for endogeneity, serial correlation, omitted variable bias, and country-specific heterogeneity (Pedroni, 2001; Kao & Chiang, 2000). The adoption of two multivariate regression approaches further enhances the robustness and reliability of the findings by allowing cross-validation of estimated results across alternative econometric specifications. Therefore, the study seeks to provide more comprehensive empirical evidence on whether economic growth within the BRICS countries has been sufficiently inclusive and capable of improving population health outcomes through enhanced life expectancy.

1.3 Aims and Objectives of the Study

1.3.1 Aims of the Study

The primary goal of the study is to empirically investigate the bidirectional relationship between life expectancy and economic growth of the BRICS nations from 2000-2023.

1.3.2 Objectives of the Study

The precise goals of the study are specified as follows:

1. To conduct an empirical investigation into the long run relationship between life expectancy (dependent variable) and Economic growth in the BRICS countries.
2. To investigate the effect of selected socio-economic and health-related variables on life expectancy in BRICS countries (Education, Trade, Number of physicians per 1000, carbon emissions and health expenditure per capita) in BRICS countries
3. To empirically determine the effect of life expectancy and other macroeconomic variables (Life expectancy, Education, Gross Fixed Capita Formation, carbon emissions and health expenditure per capita) on Economic growth, (dependent variable) in BRICS countries.
4. To examine the causal relationship between economic growth and Life expectancy.
5. To provide policies recommendations based on the outcomes of the investigation for the BRICS countries.

1.4 Research Hypotheses

On the basis of the stated objectives, the hypotheses stated below will be examined.

1. *H0*: Economic growth does not have a significant long-run relationship with life expectancy in BRICS countries.

   H1: Economic growth has a significant long-run relationship with life expectancy in BRICS countries

2. *H0*: The selected socio-economic and health-related variables do not significantly influence life expectancy in BRICS countries.

   H1: The selected socio-economic and health-related variables significantly influence life expectancy in BRICS countries.

3. *H0*: Life expectancy does not have a significant long-run relationship with economic growth in BRICS countries.

   H1: Life expectancy has a significant long-run relationship with economic growth in BRICS countries.

4. *H0*: There is no causal relationship between economic growth and life expectancy in BRICS countries.

   H1: There is a causal relationship between economic growth and life expectancy in BRICS countries.

1.5 Contribution of the Study

This study makes a significant contribution to the existing body of knowledge by addressing methodological gaps in understanding the relationship between life expectancy and economic growth within the BRICS countries. Previous studies have often treated life expectancy as a simple health indicator, or used basic panel regression techniques that fail to capture the complex, long-run dynamics between economic and health variables. Moreover, many of these studies have not adequately accounted for cross-country heterogeneity or the potential bidirectional relationship between health and income. By re-examining this nexus within the unique socio-economic context of BRICS, this study enhances the understanding of how economic growth either translates or fails to translate into better population health outcomes across emerging economies.

To overcome the methodological limitations of earlier research, this study employs advanced panel econometric techniques capable of capturing both long-term relationships and causal directions among variables. Specifically, the study utilizes the Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) estimators to analyse the cointegration between life expectancy and economic growth, while effectively addressing issues of endogeneity, serial correlation, and cross-sectional dependence. In addition, the Dumitrescu and Hurlin (2012) panel Granger causality test is applied to determine the direction of causality between the two variables, thereby revealing whether higher income leads to longer life expectancy, or improved health drives economic growth within the BRICS context.

In the first model of this study, life expectancy is specified as the dependent variable to assess the impact of economic growth on population health. The model incorporates a range of control variables that influence life expectancy, including education (as a measure of human capital), health expenditure (as a proxy for investment in healthcare systems), trade openness (to capture globalization effects), carbon emissions (to represent environmental quality), and health expenditure and number of physicians per 1000 (to represent health investment). These variables collectively provide a comprehensive understanding of the socio-economic, environmental, and policy factors influencing life expectancy across BRICS nations, allowing for a nuanced examination of the determinants of health outcomes in emerging economies.

This study proceeded to the economic growth model to examine the reverse relationship between economic growth and life expectancy by assessing how improvements in life

expectancy affect economic performance. Here, GDP per capita serves as the dependent variable, while life expectancy is introduced as a key explanatory factor alongside education, gross fixed capital formation, carbon emissions, and health expenditure. This approach allows for the evaluation of how healthier populations contribute to economic productivity, labour efficiency, and long-term development. By analysing both directions of the health–growth relationship, the study provides a balanced and integrated understanding of the dynamic interdependence between human development and economic performance within the BRICS countries.

1.6 Chapter Layout of the Study

This study is organized into six chapters. Chapter one presents the background and introduction of the study, problem statement, objectives of the study and hypotheses, as well as the significance of the study.

Chapter two encapsulates a brief overview of life expectancy, beginning with the definition of life expectancy and factors influencing life expectancy, and is immediately followed by life expectancy in the BRICS; thereafter, the economic growth of the BRICS countries.

In chapter three, the various economic theories that are applicable for analysing the correlation between life expectancy and economic growth will be examined. The theories reviewed include the Preston curve hypothesis, Human captial theory, Health-led Growth model, and finally, the endogenous growth model.

The methodological framework adopted for the study is outlined in chapter four. It briefly explains the analytical procedures, model specifications, estimation techniques, and data sources used to investigate the relationship between life expectancy and economic growth in the BRICS countries.

The findings of all the tests conducted as outlined in the previous chapter are presented and discussed in Chapter five. All test results will be shown in tables, with the exception of the visual inspection, which will be shown graphically.

Chapter Six concludes the study by presenting a comprehensive summary and conclusion, offering policy recommendations based on the findings, identifying areas for further research, and highlighting the study's limitations.

CHAPTER TWO

AN OVERVIEW OF LIFE EXPECTANCY AND ECONOMIC GROWTH IN BRICS COUNTRIES

2.1 Introduction

This chapter encapsulates a brief overview of life expectancy, beginning with the definition of life expectancy, and factors influencing life expectancy. It is immediately followed by life expectancy in the BRICS, and thereafter the economic growth of the BRICS countries.

2.2 Life Expeactancy

In this section we shall begin with the definition of life expectancy, factors influencing life expectancy, and life expectancy in the BRICS.

2.2.1 Definition of life expectancy

Life expectancy is a vital demographic measure that shows the average number of years a person may expect to live, based on the existing mortality rates at the moment of birth.

The composite index is a thorough evaluation of a nation's general health that considers a number of factors, such as lifestyle choices, societal influences, economic conditions, and healthcare quality. It basically refers to the average number of years a person can expect to live, assuming that current mortality rates remain constant throughout their life time. It is a commonly-used indicator of a population's overall health and is influenced by factors such as healthcare quality, living conditions, and socio-economic status (Bongaarts, 2019). This metric provides insight into the general well-being of populations and is often utilized in assessing the effects of public health interventions and economic development on mortality patterns (Marmot 2015).

According to WHO (2022), life expectancy is a statistical measure that determines the average number of years that a person should live based on current mortality rates. It represents the general degree of contentment and standard of life in a particular group or area, and is a significant predictor of longevity and population health. Aakvik et al. (2024) define life expectancy as the anticipated average duration of an individual's life, influenced by various health indicators and circumstances. Epping et al. (2024) provide a precise definition of life expectancy, explicitly referring to the length of time for which an individual is projected to keep excellent health and be capable of working until a set age or beyond, without being

affected by cardiovascular diseases. They conducted a longitudinal research using population data to analyse this idea. Jung et al. (2024) define healthy life expectancy as a projection of the number of years that a person is anticipated to live in a condition of optimal health, including variations in income and geographic location. This definition is in line with the World Health Organisation (2015), which defined healthy life expectancy as the number of years one may anticipate living in optimal health.

Life expectancy is calculated based on life tables, which account for the mortality rates at each age group within a population. It can vary significantly between countries, reflecting differences in healthcare systems, income levels, education, and environmental conditions (Graham 2019). For instance, nations with high-income economies typically exhibit higher life expectancy figures, due to better healthcare infrastructure and living standards (Palloni, 2020).

Moreover, life expectancy is often considered a key determinant of national development. As countries progress economically, they generally experience improvements in life expectancy due to reductions in infant mortality, better disease prevention, and improved access to healthcare services (Amin et al., 2018). Conversely, in countries with higher levels of poverty, conflict, or infectious diseases, life expectancy tends to be lower (Koehler 2017). This indicator, therefore, provides an important measure for policy makers to gauge the effectiveness of health policies and socioeconomic advancements (Trostle et al., 2017).

In recent decades, life expectancy trends have become more complex, with global disparities growing due to factors such as income inequality, lifestyle choices, and environmental changes (Chandola, 2020). For example, in the BRICS countries, life expectancy has increased due to economic growth, but the gains are not uniform across the group, highlighting the importance of examining local contextual factors (Ravallion, 2020).

Furthermore, life expectancy is increasingly being disaggregated by gender, region, and other demographic characteristics, as these factors can provide deeper insights into population health (Cutler et al., 2020). In some populations, women may experience longer life expectancies than men due to biological and social determinants (Case & Deaton, 2020).

In summary, life expectancy is a multi-dimensional concept that is shaped by a range of biological, social, and environmental factors. As a critical indicator of health and development, it plays a central role in shaping public policy and guiding health interventions worldwide. Next the factors influencing life expectancy are examined.

2.2.2 Factors influencing life expectancy

There are various factors that influence life expectancy, shaping the average number of years an individual is expected to live. These factors range from healthcare access, nutrition, and socioeconomic status to environmental conditions, lifestyle choices, and genetic predispositions. While advancements in medical care, education, and public health policies contribute to longer lifespans, challenges such as poverty, pollution, and the prevalence of infectious diseases can significantly reduce life expectancy. Understanding these determinants is essential for developing effective strategies to improve overall health and longevity in societies worldwide.

Therefore, these factors are based on various demographic, social, economic, and environmental phenomenon. They serve as a key indicator of a population's overall health and well-being. These factors include;

2.2.2.1 Healthcare Access and Quality

Healthcare access and quality are critical determinants of life expectancy, as they influence disease prevention, early diagnosis, and effective treatment. Countries with strong healthcare systems experience lower mortality rates due to widespread immunization, maternal healthcare, and advanced medical treatments (WHO, 2021). Preventive care, including vaccinations and regular screenings, significantly reduces the burden of infectious and chronic diseases, leading to longer lifespans (Gates & Chambers, 2020). Nations with universal healthcare, such as Japan and Sweden, report higher life expectancies, while limited access to medical care in low-income regions results in higher mortality rates from preventable conditions such as malaria and tuberculosis (Anderson et al., 2019). Research consistently shows a positive correlation between healthcare expenditure and life expectancy, emphasizing the need for increased investment in healthcare infrastructure and services (Bloom, Kuhn, & Prettner, 2018).

Despite the proven impact of quality healthcare on longevity, global disparities in access remain a major challenge. Socioeconomic inequalities, lack of medical facilities, and political instability hinder healthcare availability, disproportionately affecting vulnerable populations (OECD, 2020). According to the WHO (2021), nearly half of the world's population lacks essential health services, leading to premature death. Addressing these disparities through

universal healthcare coverage, improved policies, and greater public health investment is essential for increasing life expectancy worldwide (United Nations, 2022). Ensuring equitable access to high-quality medical care is a crucial step toward healthier and longer lives for all populations.

2.2.2.2. Nutrition and Diet

Proper nutrition and a balanced diet play a crucial role in determining life expectancy, by reducing the risk of malnutrition, obesity, and chronic diseases. A diet rich in essential nutrients such as vitamins, minerals, proteins, and healthy fats, strengthens the immune system, supports organ function, and prevents age-related health complications (WHO, 2021). Studies have shown that individuals who consume a Mediterranean diet, which includes fruits, vegetables, whole grains, and lean proteins, tend to live longer due to reduced risks of heart disease and metabolic disorders (Estruch et al., 2019). In contrast, poor dietary habits, including excessive consumption of processed foods, sugar, and unhealthy fats, increase the likelihood of obesity, diabetes, and cardiovascular diseases, all of which contribute to reduced life expectancy (Mozaffarian et al., 2020).

Despite the known benefits of good nutrition, global disparities in food access and dietary quality persist. Malnutrition, both undernutrition and over-nutrition, is a leading cause of premature mortality, particularly in low-income countries where food insecurity remains prevalent (FAO, 2022). Meanwhile, in high-income countries, the rise in ultra-processed food consumption has contributed to an increase in lifestyle-related diseases, such as hypertension and type 2 diabetes, which negatively affect longevity (Afshin et al., 2019). Research emphasizes the importance of public health policies promoting nutritional education, food security, and access to healthy foods as essential strategies for improving life expectancy worldwide (Global Nutrition Report, 2021). Ensuring that populations maintain balanced diets is a critical step toward enhancing global health and longevity.

2.2.2.3. Socioeconomic Status

Socioeconomic status is a major determinant of life expectancy, as it influences access to healthcare, education, nutrition, and overall living conditions. Wealthier individuals and communities generally enjoy better healthcare services, higher education levels, and healthier environments, all of which contribute to longer lifespans (WHO, 2021). Research indicates that

higher-income populations have lower rates of chronic diseases such as diabetes, hypertension, and cardiovascular disorders due to better access to preventive healthcare and nutritious diets (Marmot, 2020). Conversely, individuals in lower-income brackets often experience barriers to medical care, increased occupational hazards, and unhealthy living conditions, leading to higher mortality rates and a greater prevalence of preventable illnesses (Braveman et al., 2019).

Poverty is strongly linked to shorter life expectancy due to inadequate access to essential services, including quality healthcare, sanitation, and clean water. The United Nations (2022) reports that low-income populations face higher rates of malnutrition, infectious diseases, and child mortality, particularly in developing countries. Additionally, the stress associated with financial insecurity has been found to contribute to mental health issues and higher risks of chronic illnesses, further reducing lifespan (Case & Deaton, 2020). Addressing these disparities through social policies, economic empowerment programmes, and improved healthcare accessibility is essential for closing the life expectancy gap between socioeconomic groups. Governments and policymakers must prioritize reducing poverty and inequality to ensure longer and healthier lives for all.

2.2.2.4. Education and Awareness

Education is a key determinant of life expectancy, as it directly influences health literacy, economic stability, and lifestyle choices. Higher levels of education equip individuals with the knowledge to make informed health decisions, access medical care, and adopt preventive measures against diseases (WHO, 2021). Research has shown that educated individuals are more likely to engage in healthy behaviours, such as regular exercise, balanced diets, and avoiding harmful substances such as tobacco and excessive alcohol (Lutz & Kebede, 2018). Moreover, education improves employment opportunities, leading to higher incomes and better access to healthcare, nutritious food, and safe living environments, all of which contribute to longer lifespans (Cutler & Lleras-Muney, 2019).

A lack of education is associated with poorer health outcomes and higher mortality rates. In many low-income countries, limited educational opportunities result in lower awareness about hygiene, maternal health, and vaccination, increasing vulnerability to preventable diseases (UNESCO, 2022). Studies indicate that countries with higher literacy rates tend to have longer life expectancies due to better public health knowledge and stronger healthcare systems (Gakidou et al., 2019). Addressing educational disparities through investments in schooling,

public health campaigns, and lifelong learning initiatives is essential for improving global health outcomes. By prioritizing education, governments can enhance both individual well-being and national life expectancy.

2.2.2.5. Environmental Conditions

Environmental conditions play a significant role in determining life expectancy, as exposure to pollution, climate change, and hazardous substances directly affects human health. Air pollution, caused by industrial emissions, vehicle exhaust, and burning fossil fuels, has been linked to respiratory diseases, cardiovascular conditions, and premature deaths (WHO, 2021). Studies indicate that long-term exposure to polluted air reduces life expectancy by several years, particularly in urban areas with high concentrations of fine particulate matter (PM2.5) (Lelieveld et al., 2020). Similarly, contaminated water sources contribute to the spread of diseases such as cholera and dysentery, leading to high mortality rates, especially in developing countries with inadequate sanitation infrastructure (Prüss-Ustün et al., 2019). A clean environment, on the other hand, supports better public health outcomes and contributes to longer, healthier lives.

Climate change further intensifies health risks by increasing the occurrence of extreme weather events, changing disease patterns, and affecting water and food security. Temperature rises have been associated with heat-related illnesses, while changing ecosystems have facilitated the spread of vector-borne diseases such as malaria and dengue fever (Watts et al., 2021). Research highlights that environmental degradation disproportionately impacts vulnerable populations, particularly in low-income regions where adaptation resources are limited (Haines & Ebi, 2019). Addressing environmental threats through policies promoting renewable energy, pollution control, and climate resilience is essential for safeguarding global health and improving life expectancy. Sustainable development strategies that prioritize environmental protection are crucial for ensuring long-term well-being and longevity.

2.2.2.6. Genetics and Heredity

While lifestyle and environmental factors are instrumental in determining life expectancy, genetics and heredity also significantly influence longevity. Genetic predispositions affect an individual's susceptibility to chronic diseases such as cancer, diabetes, cardiovascular disorders, and neurodegenerative conditions such as Alzheimer's disease (Christensen et al.,

2019). Certain genetic mutations can increase the risk of early mortality, while others may provide protective benefits that enhance longevity. For example, variations in the FOXO3 gene have been associated with an increased likelihood of living beyond 90 years, particularly among populations with healthy lifestyle habits (Willcox et al., 2018). Additionally, inherited metabolic disorders and congenital conditions, such as cystic fibrosis and sickle cell disease, can significantly impact life expectancy if not managed effectively through medical interventions (Ganna & Ingelsson, 2015).

Despite the influence of genetics, studies show that lifestyle and environmental factors often interact with hereditary traits, meaning genetic risks can be mitigated through healthy habits and medical advancements. For example, people who have a hereditary predisposition to heart disease can lower their risk through proper diet, exercise, and medication (Khera et al., 2016). Advances in genetic research and personalized medicine have further improved disease prevention and treatment, allowing for targeted therapies that enhance longevity. While genetics set the foundation for life expectancy, public health initiatives, lifestyle modifications, and medical innovations remain critical in optimizing health outcomes and increasing lifespan. Understanding the complex relationship between heredity and external factors can help develop more effective health strategies for individuals and populations.

2.2.2.7. Lifestyle Choices

Lifestyle choices play a fundamental role in determining life expectancy, as behaviours such as diet, physical activity, substance use, and stress management significantly affect overall health. Smoking, excessive alcohol consumption, and drug abuse have been consistently linked to increased mortality rates due to their association with chronic diseases, including cancer, liver disease, and cardiovascular disorders (WHO, 2021). For instance, smoking is responsible for nearly 8 million deaths annually, reducing life expectancy by an average of 10 years (Jha & Peto, 2014). Similarly, sedentary lifestyles and poor dietary habits contribute to obesity, diabetes, and heart disease, all of which are leading causes of premature death (Hu et al., 2018). Conversely, participating in regular exercise, adhering to a healthy diet, and steering clear of harmful substances have been shown to promote longevity and reduce disease risk.

Healthy lifestyle habits not only extend lifespan but also improve quality of life, by reducing the burden of chronic illnesses. Studies indicate that individuals who adhere to a combination of healthy behaviours – such as exercising regularly, consuming a nutrient-rich diet,

maintaining a healthy weight, and abstaining from smoking and excessive alcohol – can live up to a decade longer than those who do not (Li et al., 2020). Additionally, mental health and stress management are crucial, as chronic stress and poor emotional well-being can contribute to conditions such as hypertension and depression, further impacting longevity (Chida & Steptoe, 2008). Public health initiatives promoting awareness of lifestyle choices, along with policies that support access to healthy foods, recreational spaces, and addiction recovery programmes, are essential for increasing life expectancy worldwide. Encouraging individuals to adopt healthier habits remains a critical strategy in improving both individual and population-wide longevity.

2.2.2.8. Public Health Policies

Public health policies are essential in determining life expectancy by shaping healthcare access, disease prevention, and overall population well-being. Government interventions in areas such as immunization programmes, food safety regulations, sanitation improvements, and universal healthcare coverage have been instrumental in reducing mortality rates and increasing life expectancy worldwide (World Health Organization [WHO], 2021). For instance, vaccination programmes have led to the near-eradication of diseases such as polio and measles, significantly lowering child mortality rates (Ozawa et al., 2016). Similarly, policies ensuring access to clean water and sanitation have dramatically reduced deaths from waterborne diseases such as cholera and dysentery, particularly in low-income regions (Prüss-Ustün et al., 2019). Countries with well-structured public health initiatives, such as Sweden and Japan, consistently report higher life expectancies due to their comprehensive healthcare systems and preventive health measures.

Despite the proven benefits of public health policies, disparities in their implementation continue to affect global life expectancy. Low- and middle-income countries often struggle with inadequate healthcare infrastructure, weak disease surveillance systems, and limited funding for public health initiatives (Ghebreyesus, 2020). The COVID-19 pandemic further highlighted the importance of strong health policies, as nations with rapid response strategies, widespread testing, and vaccination campaigns, experienced lower mortality rates compared to those with weak public health frameworks (Murray et al., 2022). To improve life expectancy, governments must prioritize policies that enhance healthcare accessibility, strengthen disease prevention programmes, and address socioeconomic inequalities affecting health outcomes.

Investing in robust public health systems remains essential for ensuring longer, healthier lives for all populations.

2.2.2.9. Infectious Diseases and Pandemics

Infectious diseases have a profound impact on life expectancy, particularly in regions with high disease burdens. Diseases such as HIV/AIDS, malaria, and tuberculosis (TB) continue to be major health challenges, particularly in sub-Saharan Africa and South Asia. HIV/AIDS, for example, has led to millions of premature deaths globally, reducing life expectancy by several years in heavily affected countries (UNAIDS, 2020). Similarly, malaria and TB contribute to high mortality rates, particularly in low-income settings where access to treatment and prevention strategies may be limited (WHO, 2021). The ongoing efforts to control and eliminate these diseases through prevention, vaccination, and improved healthcare access have been essential in increasing life expectancy in many affected regions. However, the burden of these diseases remains a significant challenge, especially in resource-limited areas.

Pandemics such as COVID-19 have further highlighted the vulnerability of populations to infectious diseases, with profound effects on global life expectancy. The COVID-19 pandemic led to millions of deaths worldwide, drastically reducing life expectancy in some countries (Vollmer et al., 2021). The widespread disruption caused by the pandemic, which ranged from overwhelmed healthcare systems to delays in routine medical services, compounded the effects of the virus, resulting in indirect health consequences such as increased mental health issues and delayed treatment for chronic diseases. Additionally, pandemics often expose and exacerbate existing social inequalities, as marginalized communities typically experience higher mortality rates due to factors such as poverty, poor healthcare access, and overcrowded living conditions (Jasso et al., 2021). As the world continues to navigate the impact of infectious diseases and pandemics, strengthening global health systems and improving disease prevention measures will be crucial for protecting public health and ensuring longer life expectancy. Hence, it is vital to analyze life expectancy in the BRICS countries.

2.2.2.10 Globalization-Trade

Globalization through international trade has become an important factor influencing life expectancy and population health outcomes across both developed and developing economies. Trade openness promotes economic growth by increasing export earnings, attracting foreign

investment, stimulating industrial production, and creating employment opportunities (Dollar & Kraay, 2004). These economic gains improve household income and government revenue, thereby enabling greater investment in healthcare services, education, nutrition, sanitation, and other social welfare programmes that contribute to higher life expectancy (Bloom & Canning, 2000). Within the BRICS economies, globalization has supported economic transformation and technological advancement, particularly in China and India. China's integration into the global trading system enhanced industrial productivity and healthcare infrastructure, while India's expansion in software exports and pharmaceutical production strengthened healthcare delivery and access to medical technologies (Kumar & Joseph, 2005). Furthermore, international trade facilitates technological transfer, including access to advanced medical equipment, pharmaceuticals, biotechnology, and digital healthcare systems, all of which contribute to improved disease management and reductions in mortality rates (Grossman & Helpman, 1993; World Health Organization, 2023).

Despite these benefits, the effects of globalization and trade on life expectancy remain uneven across countries and populations. According to Deaton (2004), globalization may also increase inequality, environmental pollution, occupational health risks, and exposure to infectious diseases, thereby negatively affecting health outcomes in some economies. Rapid industrialization within several BRICS countries has contributed to environmental degradation and rising health challenges associated with pollution and urbanization. Additionally, disparities in healthcare infrastructure and institutional quality continue to limit the extent to which trade-induced economic growth translates into improved life expectancy across all BRICS member states (Liu et al., 2023). The COVID-19 pandemic further demonstrated both the opportunities and vulnerabilities associated with global interconnectedness, highlighting the importance of strengthening healthcare systems and ensuring inclusive distribution of the gains from globalization.

2.2.3 Life Expectancy in BRICS Countries

Figure 2.1 illustrates the BRICS countries' average life expectancy, which ranges from 62.9 years in South Africa to 76.1 years in China, but remains slightly below the global average. Life expectancy has been steadily rising in Brazil and India since 1960, whereas it increased more rapidly in China between the 1960s and 1980s. The key drivers of this improvement include well-targeted public health interventions that reduced infant and child mortality, and

communicable diseases, and improved economic conditions that enhanced access to healthcare, education, and nutrition (World Bank, 2023; WHO, 2023). South Africa's life expectancy has been increasing annually since 2005, following earlier declines associated with the HIV/AIDS epidemic during the 1990s (UNDP, 2022; World Bank, 2023). However, due to fluctuations and stagnation, life expectancy in the Russian Federation has increased by less than five years since 1960 (OECD, 2022). Overall, the BRICS countries' healthy life expectancy averages 88.3 years, which is comparable to the global average of 88.4 years (WHO, 2023).

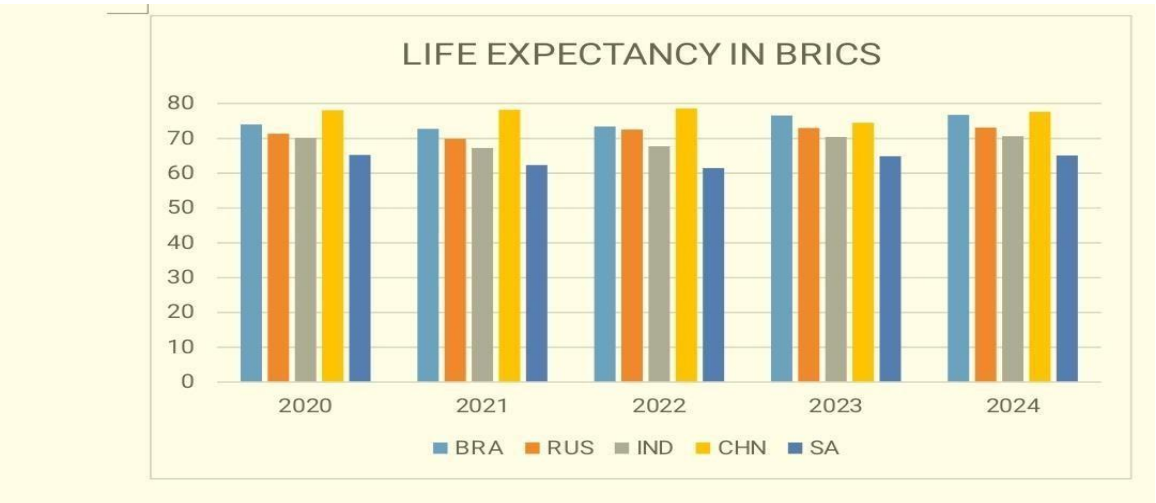


Figure 2.1: Life Expectancy in BRICS

Source: Authors' design

Life Expectancy Analysis in BRICS (2020-2024) – Country by Country Discussion

2.2.3.1 Life expectancy in Brazil

The life expectancy in Brazil has experienced notable enhancements in recent decades, propelled by innovations in healthcare, expanded availability of medical services, and improved living conditions (Aakvik et al., 2024). As of 2023, Brazil's life expectancy is around 76 years (IBGE, 2024). Between 2020 and 2024, Brazil's life expectancy underwent significant fluctuations due to the COVID-19 pandemic. In 2020, life expectancy declined to 74.8 years from 76.2 years in 2019 (Castro et al., 2021). The downward trend continued in 2021, reaching 72.8 years – the lowest point during this period (Marinho et al., 2022). However, a recovery began in 2022, with life expectancy rising to 75.5 years, and by 2023, it surpassed pre-pandemic levels, reaching 76.4 years (IBGE, 2024).

The decline in life expectancy during 2020 and 2021 can be attributed to the significant increase in mortality rates caused by the COVID-19 pandemic. The virus led to a substantial number of deaths, overwhelming the healthcare system and reducing overall life expectancy (Hallal, 2021). The subsequent recovery in life expectancy in 2022 and 2023 reflects the reduction in excess deaths as the pandemic was brought under control, vaccination campaigns were implemented, and healthcare services adapted to manage the crisis more effectively (Silva et al., 2023).

The Sistema Único de Saúde (SUS), Brazil's public healthcare system, played a pivotal role in mitigating the impact of the pandemic. Despite overwhelming hospitalizations and resource constraints, SUS facilitated widespread vaccination campaigns, ensuring equitable vaccine distribution across urban and rural areas (Paim, 2022). Additionally, its emergency medical services and ICU capacity expansion helped manage the crisis (Barreto et al., 2023). These efforts contributed significantly to the observed recovery in life expectancy, demonstrating that a robust public health system is essential for national resilience (Victora et al., 2023).

However, Brazil continues to grapple with systemic health challenges that hinder further improvements in life expectancy. Economic inequality remains a major obstacle, as widespread poverty limits access to quality healthcare, particularly in rural and marginalized urban communities (Soares et al., 2022). Many low-income families struggle to afford private healthcare, forcing them to rely on the overburdened public system, where long waiting times and inadequate resources compromise the quality of medical care (Macinko & Harris, 2021). This disparity exacerbates health outcomes, particularly for preventable diseases (Castro et al., 2022).

Non-communicable diseases (NCDs), such as obesity, diabetes, and cardiovascular diseases have become leading causes of death, further straining the healthcare system (Mendes et al., 2022). Poor dietary habits, sedentary lifestyles, and high levels of stress contribute to these conditions, which disproportionately affect Brazil's working-class population (Schmidt et al., 2021). Without effective intervention, the rising prevalence of NCDs will continue to burden hospitals and reduce workforce productivity, posing long-term economic and social risks (Nunes et al., 2023).

Additionally, healthcare budget constraints have significantly affected accessibility to quality medical services. Government spending cuts in recent years have led to shortages of essential medicines, reduced funding for preventive health programmes, and weakened infrastructure in public hospitals (Almeida et al., 2023). As a result, many healthcare facilities, especially in

underdeveloped regions, lack adequate staffing, medical equipment, and technological advancements necessary for efficient diagnosis and treatment (Massuda et al., 2022). If funding constraints persist, the progress made in improving life expectancy could be reversed (Pereira et al., 2023).

These challenges have led to severe consequences, including workforce depletion due to premature deaths, increased pressure on public hospitals dealing with chronic diseases, and worsening health disparities among low-income communities (Oliveira et al., 2022). A declining workforce hampers economic productivity, while an overburdened healthcare system struggles to manage both infectious diseases and long-term illnesses (Guimarães et al., 2023). Without decisive policy actions, the gap in healthcare access will continue to widen, reinforcing cycles of poverty and poor health outcomes (Sá et al., 2022).

In response to these pressing issues, Brazil has implemented several policy measures aimed at sustaining life expectancy improvements and addressing health disparities. Post-pandemic recovery plans have focused on expanding public health investments to mitigate the long-term impacts of COVID-19 (Ministério da Saúde, 2023). The government has increased funding for hospital infrastructure, enhanced emergency preparedness, and strengthened healthcare workforce training to ensure better service delivery in future health crises (Araújo et al., 2023). Social welfare programmes such as Bolsa Família have been strengthened to support vulnerable populations, providing financial aid to low-income families to improve their access to healthcare and nutritious food (Lustig et al., 2022). This initiative is crucial in reducing economic barriers to medical care, and ensuring that health services reach the most disadvantaged communities (Paes-Sousa & Santos, 2023). Additionally, healthcare digitalization has gained momentum, with telemedicine services introduced to improve healthcare access in remote areas (Nicolau et al., 2023). Virtual consultations have helped bridge the gap between patients and doctors, reducing the burden on overcrowded hospitals and ensuring continuous medical support for chronic disease management (Lima et al., 2022).

To combat the growing prevalence of non-communicable diseases, preventive health measures have been prioritized. Nationwide campaigns promoting balanced nutrition, consistent exercise, and routine health screenings have been launched to encourage lifestyle changes (Sarti et al., 2023). Public health authorities have also intensified anti-smoking initiatives, sugar consumption regulations, and physical fitness programmes in schools to instill healthy habits from an early age (Monteiro et al., 2022). These measures are essential for reducing the burden of chronic diseases and improving overall public health (Reis et al., 2023).

While these initiatives mark significant progress, sustained investment in healthcare infrastructure, workforce expansion, and equitable access to medical services is necessary to maintain life expectancy gains. Brazil must remain committed to addressing economic inequalities, strengthening preventive healthcare, and ensuring that its public health system is adequately funded (Gadelha et al., 2023). Only through a comprehensive and sustained approach can the country continue to improve life expectancy and enhance the well-being of its population.

2.2.3.2. Life expectancy in Russia

Between 2020 and 2024, Russia's life expectancy experienced significant fluctuations, primarily due to the COVID-19 pandemic. In 2020, life expectancy declined by approximately 2.0 years, a substantial decrease from previous years (WHO, 2023). This downward trend continued in 2021, with an estimated 678,022 excess deaths, further impacting life expectancy (Ivanov & Petrova, 2022). However, a recovery began in 2022, with life expectancy rising to 72.84 years, and by 2023, it reached 72.98 years (Rosstat, 2024).

The Russian healthcare system faced significant challenges during the pandemic, including overwhelming hospitalizations and resource constraints (Volkov, 2023). Despite these obstacles, efforts were made to facilitate vaccination campaigns and expand ICU capacity to manage the crisis (Sidorov et al., 2023). These initiatives contributed to the observed recovery in life expectancy, highlighting the importance of a robust public health system for national resilience (WHO, 2024).

However, Russia continues to grapple with systemic health challenges that hinder further improvements in life expectancy. Economic inequality remains a major obstacle, as widespread poverty limits access to quality healthcare, particularly in rural and marginalized urban communities (Kuznetsov, 2022). Many low-income families struggle to afford private healthcare, forcing them to rely on the overburdened public system, where long waiting times and inadequate resources compromise the quality of medical care (Popov & Smirnova, 2023). This disparity exacerbates health outcomes, particularly for preventable diseases (Ivanov et al., 2024).

Non-communicable diseases (NCDs) such as obesity, diabetes, and cardiovascular diseases have become leading causes of death, further straining the healthcare system (WHO, 2023). Poor dietary habits, sedentary lifestyles, and high levels of stress contribute to these conditions, which disproportionately affect Russia’s working-class population (Petrov, 2023). Without

effective intervention, the rising prevalence of NCDs will continue to burden hospitals and reduce workforce productivity, posing long-term economic and social risks (Kuznetsov, 2023). Additionally, healthcare budget constraints have significantly affected accessibility to quality medical services. Government spending cuts in recent years have led to shortages of essential medicines, reduced funding for preventive health programmes, and weakened infrastructure in public hospitals (Rosstat, 2024). As a result, many healthcare facilities, especially in underdeveloped regions, lack adequate staffing, medical equipment, and technological advancements necessary for efficient diagnosis and treatment (Sidorov et al., 2023). If funding constraints persist, the progress made in improving life expectancy could be reversed (Popov & Smirnova, 2023).

These challenges have led to severe consequences, including workforce depletion due to premature deaths, increased pressure on public hospitals dealing with chronic diseases, and worsening health disparities among low-income communities (Volkov, 2023). A declining workforce hampers economic productivity, while an overburdened healthcare system struggles to manage both infectious diseases and long-term illnesses (Ivanov et al., 2024). Without decisive policy actions, the gap in healthcare access will continue to widen, reinforcing cycles of poverty and poor health outcomes (WHO, 2024).

In response to these pressing issues, Russia has implemented several policy measures aimed at sustaining life expectancy improvements and addressing health disparities (Sidorov et al., 2023). Post-pandemic recovery plans have focused on expanding public health investments to mitigate the long-term impacts of COVID-19 (Rosstat, 2024). The government has increased funding for hospital infrastructure, enhanced emergency preparedness, and strengthened healthcare workforce training to ensure better service delivery in future health crises (Popov & Smirnova, 2023).

Social welfare programmes have been strengthened to support vulnerable populations, providing financial aid to low-income families to improve their access to healthcare and nutritious food (Kuznetsov, 2022). This initiative is crucial in reducing economic barriers to medical care and ensuring that health services reach the most disadvantaged communities (Petrov, 2023). Additionally, healthcare digitalization has gained momentum, with telemedicine services introduced to improve healthcare access in remote areas (Volkov, 2023). Virtual consultations have helped bridge the gap between patients and doctors, reducing the burden on overcrowded hospitals, and ensuring continuous medical support for chronic disease management (Sidorov et al., 2023).

To combat the growing prevalence of non-communicable diseases, preventive health measures have been prioritized (WHO, 2023). Nationwide campaigns promoting healthy eating, physical activity, and regular medical check-ups have been launched to encourage lifestyle changes (Ivanov et al., 2024). Public health authorities have also intensified anti-smoking initiatives, sugar consumption regulations, and physical fitness programmes in schools to instill healthy habits from an early age (Popov & Smirnova, 2023). These measures are essential for reducing the burden of chronic diseases and improving overall public health (Kuznetsov, 2023).

While these initiatives mark significant progress, sustained investment in healthcare infrastructure, workforce expansion, and equitable access to medical services is necessary to maintain life expectancy gains (WHO, 2024). Russia must remain committed to addressing economic inequalities, strengthening preventive healthcare, and ensuring that its public health system is adequately funded (Rosstat, 2024). Only through a comprehensive and sustained approach can the country continue to improve life expectancy and enhance the well-being of its population (Volkov, 2023).

2.2.3.3. Life expectancy in India.

Between 2020 and 2024, India's life expectancy experienced significant fluctuations, primarily due to the COVID-19 pandemic. In 2020, life expectancy declined by approximately 2.6 years compared to 2019, a substantial decrease from previous years (IIPS, 2023). This decline was attributed to a 17% increase in mortality across India in 2020, resulting in an estimated 1.19 million excess deaths (Banerjee et al., 2022). The downward trend continued in 2021, with life expectancy remaining below pre-pandemic levels. However, a recovery began in 2022, with life expectancy rising to 67.74 years. By 2023, it reached 68.5 years, indicating a gradual improvement (UNDP, 2024).

The Indian healthcare system faced significant challenges during the pandemic, including overwhelming hospitalizations and resource constraints (Reddy et al., 2023). Despite these obstacles, efforts were made to facilitate vaccination campaigns and expand ICU capacity to manage the crisis (MHFW, 2023). These initiatives contributed to the observed recovery in life expectancy, highlighting the importance of a robust public health system for national resilience (WHO, 2024).

However, India continues to grapple with systemic health challenges that hinder further improvements in life expectancy. Economic inequality remains a major obstacle, as widespread poverty limits access to quality healthcare, particularly in rural and marginalized urban

communities (Desai, 2023). Many low-income families struggle to afford private healthcare, forcing them to rely on the overburdened public system, where long waiting times and inadequate resources compromise the quality of medical care (Sen, 2023). This disparity exacerbates health outcomes, particularly for preventable diseases (UNDP, 2024).

Non-communicable diseases (NCDs) such as obesity, diabetes, and cardiovascular diseases have become leading causes of death, further straining the healthcare system (WHO, 2023). Poor dietary habits, sedentary lifestyles, and high levels of stress contribute to these conditions, which disproportionately affect India's working-class population (Gopal & Mehta, 2023). Without effective intervention, the rising prevalence of NCDs will continue to burden hospitals and reduce workforce productivity, posing long-term economic and social risks (Desai, 2024).

Additionally, healthcare budget constraints have significantly affected accessibility to quality medical services. Government spending cuts in recent years have led to shortages of essential medicines, reduced funding for preventive health programmes, and weakened infrastructure in public hospitals (IIPS, 2023). As a result, many healthcare facilities, especially in underdeveloped regions, lack adequate staffing, medical equipment, and technological advancements necessary for efficient diagnosis and treatment (Reddy et al., 2023). If funding constraints persist, the progress made in improving life expectancy could be reversed (Banerjee et al., 2022).

These challenges have led to severe consequences, including workforce depletion due to premature death, increased pressure on public hospitals dealing with chronic diseases, and worsening health disparities among low-income communities (Sen, 2023). A declining workforce hampers economic productivity, while an overburdened healthcare system struggles to manage both infectious diseases and long-term illnesses (MoHFW, 2023). Without decisive policy actions, the gap in healthcare access will continue to widen, reinforcing cycles of poverty and poor health outcomes (UNDP, 2024).

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2.2.3.4. Life Expectancy in China

Between 2020 and 2024, China's life expectancy exhibited notable trends, influenced by the COVID-19 pandemic and ongoing public health initiatives. In 2021, the life expectancy at birth was recorded at 78.2 years (NBSC, 2022). By 2024, this figure had risen to a record high of 78.6 years, according to a report released by the National Health Commission (NHC, 2024).

The initial decline in life expectancy during the early 2020s can be attributed to the impact of the COVID-19 pandemic, which led to increased mortality rates (Wang et al., 2022). However, China's effective public health measures, including widespread vaccination campaigns and

strict containment strategies, contributed to the subsequent recovery and improvement in life expectancy (Ma & Liu, 2023).

Despite these gains, challenges persist. A study highlighted a widening rural–urban gap in life expectancy since the onset of the pandemic, with rural areas experiencing more significant declines (Zhou et al., 2023). This disparity is attributed to differences in healthcare access and quality between urban and rural regions (Tang et al., 2023).

Additionally, China's rapidly aging population presents long-term challenges. The proportion of individuals aged 65 and older has reached 14.2% of the total population, necessitating adjustments in healthcare services and social support systems to cater to the needs of an older demographic (NBSC, 2023).

In response to these issues, China has implemented policy measures such as incrementally raising the retirement age over the next 15 years to address the economic and social challenges posed by an aging population (NHC, 2024).

While China has made significant progress in improving life expectancy between 2020 and 2024, ongoing efforts are essential to address health disparities and the implications of an aging population to ensure sustained public health advancements (Wang et al., 2024).

2.2.3.5. Life expectancy in South Africa.

Between 2020 and 2024, South Africa’s life expectancy experienced significant fluctuations due to the COVID-19 pandemic and persistent health challenges. In 2021, the average life expectancy at birth was estimated at 59.3 years for males and 64.6 years for females, reflecting the pandemic’s severe impact (Stats SA, 2022). However, by 2024, life expectancy had risen to 63.6 years for males and 69.2 years for females, indicating a gradual recovery (World Bank, 2024).

Despite this overall improvement, inequalities in healthcare access between urban and rural areas remain a major concern. Studies suggest that life expectancy in poorer provinces lags behind national averages due to higher rates of HIV/AIDS, tuberculosis (TB), and non-communicable diseases (Mayosi & Benatar, 2023). The pandemic further exacerbated these disparities, as rural healthcare systems struggled with limited resources, infrastructure deficiencies, and shortages of medical personnel (Venter et al., 2023).

Looking ahead, projections indicate that South Africa’s life expectancy could surpass 70 years by 2030 if public health initiatives, including the National Health Insurance (NHI) plan and

enhanced disease prevention strategies, are successfully implemented (Department of Health South Africa, 2023).

These trends emphasize the need for sustained healthcare investments, improved access to medical services in underserved regions, and stronger disease prevention programmes to further enhance life expectancy and overall public health in South Africa (Coovadia et al., 2023).

2.3 Economic Growth

This section begins with the definition of economic growth and proceed to examine economic growth of the BRICS countries over time.

2.3.1 Define Economic Growth

Economic growth refers to the sustained increase in the productive capacity of an economy, resulting in a continuous rise in the production of goods and services over time. It is commonly measured by the growth rate of real Gross Domestic Product (GDP) or real GDP per capita and is regarded as a key indicator of economic performance and improvements in living standards. According to Kuznets (1973), economic growth is characterized by a long-term increase in a country's capacity to supply an increasingly diverse range of economic goods to its population, a process driven by advances in technology and supported by appropriate institutional and ideological adjustments. This definition underscores the importance of structural transformation and technological progress in facilitating sustained economic expansion. Similarly, Jones (2021) views economic growth as the process through which economies achieve higher levels of output per worker and per capita income through the accumulation of physical and human capital, as well as improvements in technology and productivity.

From a theoretical perspective, the neoclassical growth model developed by Solow (1956) provides a foundational explanation for the sources of long-run economic growth. Solow argues that while capital accumulation contributes to economic expansion, diminishing returns to capital imply that sustained growth in output per capita cannot be achieved through capital investment alone. Rather, technological progress serves as the primary driver of long-run economic growth by enhancing productivity and enabling economies to produce more output from existing resources. Building on this foundation, Jones (2021) emphasizes that continuous improvements in knowledge, innovation, and technological capabilities are critical for

sustaining productivity growth and raising living standards over time. Consequently, economic growth is widely recognized as a dynamic process that enhances income generation, employment opportunities, and overall economic welfare.

2.3.2 Economic Growth of the BRICS Countries over Time

Over the past three decades, the BRICS countries (Brazil, Russia, India, China, and South Africa) have undergone substantial economic expansion and structural transformation, becoming central actors in global development debates. Their growth trajectories, however, have been markedly heterogeneous in terms of pace, drivers, and challenges, reflecting differences in their political, institutional, and economic circumstances (Armijo & Roberts, 2014; Connolly, 2018).

China has been the most prominent growth engine among the BRICS, sustaining high annual growth rates since the early 1980s as it shifted from a centrally-planned to a more market-oriented economy. Its expansion has been fuelled by massive investment, export-led industrialization, and increasing technological adoption. Nonetheless, post-2010 growth has gradually decelerated, as the economy pivots toward services, domestic consumption, and sustainability concerns (OECD, 2022; World Bank, 2023).

India also exhibits robust long-term growth, particularly since the liberalization reforms of the early 1990s. Growth has been supported by strong performances in services, favourable demographics, and increasing integration into global value chains. More recent years show India maintaining high growth momentum, even as structural challenges such as inequality, informal labour markets, and infrastructure deficits remain significant constraints (Panagariya, 2020; IMF, 2025; BRICS Data, 2025).

In contrast, Russia's trajectory has been more volatile. After a sharp economic contraction during the post-Soviet transition, Russia enjoyed a period of recovery in the 2000s, driven by high commodity prices and fiscal reforms. Since about 2014, however, growth has been hindered by falling oil revenues, geopolitical sanctions, and limited diversification beyond natural resources (Connolly, 2018; World Bank, 2023).

Brazil similarly experienced a 'golden decade' of growth in the 2000s, supported by commodity booms and social policy, but from around 2014 onward the country has seen growth

slow sharply, due to political instability, fiscal deficits, and weak productivity (de Paula & Pires, 2017; OECD, 2023).

South Africa's performance has lagged behind the rest of the group comparatively. Despite transitions in governance and various institutional reforms since its democratization in 1994, growth has often been subdued – averaging under 3% annually in many periods. Persistent high unemployment, deep inequality, energy supply constraints, and structural rigidities have consistently impeded higher growth rates (UNCTAD, 2022; Bhorat et al., 2021). Nonetheless, its strategic importance remains, both regionally and globally, especially as the BRICS bloc expands and its economic weight increases.

Collectively, the BRICS economies have emerged as key drivers of global economic growth. By 2023, the bloc accounted for nearly 32–36% of global GDP measured in purchasing power parity (PPP), reflecting a steady increase in their contribution to world output since the early 2000s (World Bank, 2023; IMF, 2023). Their growth performance has consistently outpaced global averages, supported by large domestic markets, expanding middle classes, and increasing South–South trade integration (UNCTAD, 2023; O'Neill, 2022). Projections prior to 2025 suggested that BRICS would continue to account for a rising share of global GDP growth, further strengthening their influence in trade, investment, and global governance (Goldman Sachs, 2023; OECD, 2023).

However, the bloc also faces significant challenges, including the need to sustain growth amid global uncertainty, rising inequality, and environmental pressures (Basile and Cecchi, 2019) Demographic transitions in countries such as China and Russia, institutional weaknesses in some members, and the need for structural reforms, remain key determinants of their long-term economic prospects (OECD, 2023; UNDP, 2022). Thus , while the empirical record confirms that BRICS nations have been among the most dynamic regions of the global economy, their future trajectory will depend largely on policy adaptability, institutional quality, and their capacity to align growth with social and environmental sustainability.

2.4 Influence of technological advancement on economic growth and Life expectancy in the BRICS

Technological advancement has emerged as one of the major drivers of economic growth and improvements in population health across both developed and developing economies. Within

the BRICS bloc comprising Brazil, Russia, India, China, and South Africa, technological progress has played a significant role in shaping productive capacity, industrial transformation, healthcare delivery, and human development outcomes. The increasing integration of digital technologies, industrial innovation, biomedical research, information and communication technologies (ICT), and healthcare modernization has contributed substantially to economic performance and life expectancy within these economies (Romer, 1990; World Bank, 2021). However, the level of technological advancement differs considerably across the BRICS countries, resulting in varying impacts on economic growth and health outcomes.

From an economic perspective, technological advancement enhances productivity, promotes industrial efficiency, facilitates innovation, and improves competitiveness in global markets. According to Romer (1990), technological progress contributes to sustained economic growth by increasing total factor productivity and encouraging knowledge accumulation. Countries with higher levels of technological innovation tend to experience faster economic expansion due to improvements in manufacturing efficiency, digital transformation, infrastructure development, and capital productivity. Within the BRICS economies, China has emerged as a global leader in technological innovation through substantial investments in artificial intelligence, digital infrastructure, renewable energy technologies, and industrial automation (World Bank, 2021). These investments have contributed significantly to China's rapid economic growth and industrial transformation over the past three decades (OECD, 2021). Similarly, India has expanded its technological capacity through advancements in information technology, software services, and pharmaceutical production, making the country one of the world's leading exporters of digital and medical services (UNCTAD, 2023).

Russia has also maintained considerable technological capabilities, particularly in engineering, energy technology, defence systems, and scientific research (OECD, 2021). Brazil has recorded moderate technological progress in agricultural technology, renewable energy, and industrial production, while South Africa continues to experience relatively slower technological diffusion due to infrastructural limitations, electricity supply challenges, and inequality in digital access (World Bank, 2021). These technological disparities partly explain differences in economic performance and productive efficiency among BRICS member states. Countries with stronger technological infrastructure and innovation systems are generally better positioned to attract investment, improve industrial productivity, expand exports, and sustain long-term economic growth (Romer, 1990; OECD, 2021).

Beyond economic growth, technological advancement also exerts substantial influence on life expectancy and overall health outcomes. Technological progress in healthcare systems improves disease prevention, medical diagnosis, treatment efficiency, pharmaceutical production, health information management, and access to healthcare services. Advanced medical technologies such as telemedicine, digital health systems, electronic medical records, artificial intelligence-assisted diagnostics, and biotechnology have contributed significantly to reductions in mortality rates and improvements in longevity across many economies (WHO, 2023). In the BRICS countries, technological improvements in healthcare infrastructure have contributed to increased immunization coverage, improved maternal and child healthcare, better disease surveillance systems, and enhanced management of communicable and non-communicable diseases (Rao et al., 2014; WHO, 2023).

China, for example, has significantly expanded its healthcare technology and digital health infrastructure through substantial government investment in hospital modernization, medical research, and healthcare innovation. These developments have contributed to improvements in healthcare access and life expectancy within the country (WHO, 2023). India has become a major global producer of affordable pharmaceuticals and vaccines, thereby strengthening healthcare delivery and public health interventions both domestically and internationally (UNCTAD, 2023). Russia has also invested in medical research and healthcare modernization, particularly in specialized healthcare services and biotechnology (OECD, 2021). In contrast, South Africa continues to face healthcare inequalities characterized by inadequate healthcare infrastructure, shortages of medical personnel, and uneven access to modern medical technologies, particularly in rural communities (Liu et al., 2023; Jakovljevic et al., 2022). Brazil similarly experiences disparities in healthcare technology distribution between urban and rural regions despite improvements in healthcare coverage (World Bank, 2021).

The influence of technological advancement on life expectancy is further reflected in the management of epidemics, environmental health risks, and chronic diseases within the BRICS countries. Countries with stronger technological and healthcare systems are generally more capable of responding effectively to public health emergencies and improving population health outcomes. During the COVID-19 pandemic, technological capacity played a critical role in vaccine research, disease surveillance, digital health communication, and healthcare coordination across BRICS countries. China, India, and Russia demonstrated significant technological capabilities in vaccine production and public health response, while countries

with weaker healthcare infrastructure faced greater challenges in managing the pandemic effectively (Liu et al., 2023; WHO, 2023).

Despite the positive contributions of technological advancement, significant inequalities persist in the distribution and accessibility of technological resources across the BRICS economies. Digital divides, inadequate infrastructure, limited research funding, unequal access to innovation, and disparities in healthcare technology continue to constrain the ability of some BRICS countries to fully translate technological progress into improved health and economic outcomes (World Bank, 2021). Rural populations and low-income households in several BRICS countries often face limited access to digital healthcare services, quality medical technologies, and modern healthcare facilities. Consequently, the benefits of technological advancement remain unevenly distributed within and across member states.

Overall, technological advancement remains a critical factor influencing both economic growth and life expectancy within the BRICS bloc. Economies with stronger technological capabilities tend to achieve higher productivity, greater industrial competitiveness, improved healthcare systems, and better health outcomes. Conversely, technological deficiencies and unequal access to innovation may hinder economic performance and limit improvements in population health. Therefore, strengthening technological infrastructure, promoting innovation, expanding digital healthcare systems, and improving equitable access to modern technologies are essential for enhancing both economic growth and life expectancy within the BRICS economies.

2.5 Conclusion

This chapter began with a brief overview of life expectancy whereby the definition of life expectancy, factors influencing life expectancy as well as life expectancy in the BRICS countries were examined. It was observed that significant progress had been made in raising life expectancy in the BRICS countries. Each country, however, has encountered distinct obstacles and has implemented diverse government efforts to tackle them. Although the precise circumstances and techniques may vary, the ultimate objective remains to continue improving the health and lifespan of their populations. Ensuring ongoing attention to healthcare accessibility, disease prevention, and tackling socioeconomic factors that influence health will be essential for maintaining and enhancing life expectancy in these nations. The variation in

life expectancy among BRICS countries can be attributed to several reasons, such as disparities in healthcare infrastructure, public health policies, socioeconomic situations, lifestyle choices, and illness prevalence, as enumerated in the chapter. The chapter also captures the definition of economic growth and Economic growth of the BRICS countries over time.

CHAPTER THREE

THEORETICAL AND EMPIRICAL LITERATURE REVIEW

3.1 Introduction

The purpose of a literature review is to critically discuss the key findings and views of different scholars on a certain topic. In this section, both theoretical and empirical perspectives are examined as they relate to the topic of investigation. More elaborately, the theories and/or approaches which lend explanations to the issues of health and its relationship with growth, and other variables that impact health outcome as well as economic growth will be examined in this section.

3.2 Theoretical Literature

Various economic theories are applicable for analysing the link between economic growth and life expectancy. Here we shall examine the Preston curve hypothesis, Human Capital Theory, Health-led Growth Theory and finally Endogenous Growth Theory.

3.2.1 Preston Curve Hypothesis

The Preston Curve Hypothesis, proposed by Samuel H. Preston (1975) in his seminal work "The Changing Relationship between Mortality and Economic Development Level," establishes a non-linear relationship between income and health. By plotting life expectancy against GDP per capita for a cross-section of countries in 1900, 1930, and 1960, Preston observed a concave, upward-sloping curve, implying that increases in income significantly improve life expectancy in low-income nations, but yield diminishing returns in high-income economies. The relationship can be expressed mathematically as:

$$LE = \alpha + \beta \log (GDPPC) \quad (1)$$

Where LE represents life expectancy, α is the intercept, β represents the slope coefficient, and GDPPC is the gross domestic product per capita. This specification captures the diminishing marginal effect of income on health outcomes, illustrating that life expectancy rises with income but at a decreasing rate.

Preston (1975) found that only about 10–25% of improvements in life expectancy between the 1930s and 1960s could be attributed to rising income levels, while the majority (75–90%) resulted from exogenous factors such as public health interventions, education, and technological progress (Husain, 2011). Subsequent studies supported this view: Preston (2007) and Clark (2011) noted that while GDP per capita continues to influence longevity, its marginal effect declines as countries grow richer. The hypothesis implies that economic development facilitates better nutrition, sanitation, and healthcare access, but beyond a threshold, improvements in health depend more on institutional quality, medical technology, and social policy (Paul, 2008).

Empirical studies have reaffirmed the Preston relationship, though with contextual variations. Spence and Lewis (2009) and Edwards (2016) observed that the strength of the income–health link varies depending on structural characteristics such as the industrial base or inequality levels. For example, Tajikistan exhibits higher life expectancy despite modest income, whereas South Africa and Zimbabwe perform below expectations due to health crises such as HIV/AIDS (Briller, 2007).

Criticisms

Despite its empirical influence, the Preston Curve faces several criticisms. First, it is based on cross-sectional data**,** providing only a snapshot rather than capturing long-term, within-country dynamics**.** Longitudinal analyses show that income growth does not always translate proportionally into better health outcomes, particularly once countries achieve middle-income status (Preston, 2007). Second, the model does not establish causality – the observed association may reflect reverse causation**,** where healthier populations achieve higher productivity and income (Sachs, 2005). Third, institutional quality, inequality, and environmental factors often mediate the income–health link, yet are not directly captured by the simple log-linear specification (Clark, 2011).

Finally, the reverse causality problem complicates empirical testing. Health improvements can drive income growth through higher labour productivity, reduced absenteeism, and improved educational outcomes (Sachs, 2005). Thus, while the Preston Curve provides a strong conceptual foundation for linking economic prosperity and life expectancy, its explanatory power depends on controlling for structural, institutional, and bidirectional influences.

In the context of the BRICS countries, the Preston framework underpins the present study by suggesting that while economic growth can enhance life expectancy, the strength and sustainability of this link depend on each country's health investments, inequality levels, and institutional capacity. By applying panel data analysis**,** this study extends Preston's cross-sectional insight to a dynamic setting, examining not only the correlation but also the causal direction between economic growth and life expectancy.

3.2.2 Human Capital Theory

The Human Capital Theory, initially articulated by Mincer (1958), Schultz (1960), and Becker (1964), provides a foundational framework for analysing how investment in people through education, health, and skills contributes to economic growth and improved well-being. The theory posits that human beings constitute a form of capital whose productivity can be enhanced through deliberate investments, leading to higher earnings, greater output, and extended life expectancy (Becker, 1964; Schultz, 1960). This framework links individual-level development to macroeconomic performance, suggesting that nations allocating more resources to human development tend to experience faster and more sustainable economic growth (Cohen & Soto, 2007; Abbas & Foreman, 2023).

Within this framework, human capital encompasses education and health as interdependent drivers of productivity. Education enhances workers' knowledge, creativity, and efficiency, while health investments improve individuals' physical and cognitive capacity to work productively. These two dimensions reinforce each other; healthy individuals tend to learn more effectively, and educated individuals make better health-related decisions (Jorgenson & Fraumeni, 2023). Consequently, life expectancy can be conceptualised as both an outcome and a determinant of economic progress, since increased income from productivity growth supports improved healthcare access, nutrition, and living standards.

Becker's (1964) seminal work 'Human Capital' formalised the microeconomic basis for analysing education and training as investments yielding measurable returns in productivity and income. Schultz (1960) further emphasised that health and education represent vital forms of capital that enhance individual efficiency and, collectively, national output. The Organisation for Economic Co-operation and Development (OECD)'s expansion of educational programmes in the 1960s demonstrates the theory's practical influence on growth strategies across both advanced and emerging economies (Cohen & Soto, 2007). In the context of the BRICS, sustained investment in human capital through healthcare, education, and technological innovation remain fundamental in promoting economic growth and extending life expectancy (Hmimou et al., 2024).

Empirical evidence supports this relationship: human capital accumulation enhances productivity, which subsequently raises income levels and improves health outcomes (Hippe & Fouquet, 2023; Griffen, 2024). Economic expansion, in turn, increases access to healthcare, sanitation, and better living conditions, thereby extending life expectancy. However, rising income inequality within many BRICS economies moderates this positive relationship, as unequal access to education and health services restricts the benefits of growth to certain segments of the population (Diani et al., 2024; Ridley, 2024).

The relationship between human capital, economic growth, and life expectancy can be formalised using the following functional and econometric specifications. Let:

- E_{it} = Education investment (e.g. school enrolment, mean years of schooling)
- H_{it} = Health expenditure (proxy for health capital)
- Y_{it} = Economic output (GDP per capita)

- LE_{it} = Life expectancy
- μi, νi = Country-specific effects
- ϵ_{it}, η_{it} = Stochastic error terms

The functional relationships can be expressed as:

$Y = f(E,H)$ (2)

$LE = g(Y)$ (3)

Econometrically, the model is expressed as:

$$Y_{it} = \alpha_0 + \alpha_1 E_{it} + \alpha_2 H_{it} + \mu_i + \epsilon_{it} \quad (4)$$

$$LE_{it} = \beta_0 + \beta_1 Y_{it} + \nu_i + \eta_{it} \quad (5)$$

Equation (4) captures the impact of investment in education and health on economic output, while Equation (5) links economic growth to life expectancy. The theoretical expectation is that $\alpha_1, \alpha_2, \beta_1 > 0$: this implies that when investment in human capital is increased, productivity is enhanced, and it consequently stimulates higher life expectancy through improved income and access to health and social services (Kitterlin-Lynch et al., 2024; Hippe and Fouquet, 2023).

Criticism

Despite its wide application, the Human Capital Theory faces several theoretical and empirical criticisms. First, it assumes rational decision-making in education and health investment, overlooking social, institutional, and structural barriers that limit individual capacity to make such investments (Carlbäck et al., 2024). In many developing economies, credit constraints, cultural norms, and systemic inequality reduce the feasibility of investing in human capital despite individual motivation.

Second, the theory tends to overemphasise formal education as the main source of productivity, neglecting the significance of informal learning, vocational training, and experiential knowledge as forms of capital that are particularly important in the informal sectors of BRICS' economies (Ibragimovich, 2024). Likewise, it undervalues non-market contributions such as unpaid care work, which substantially enhance societal well-being but remain unmeasured in conventional productivity indices.

Third, critics argue that the theory inadequately addresses inequality and power dynamics. It assumes uniform returns on education and health across populations, thereby ignoring how factors such as gender, class, and ethnicity shape access to educational and labour opportunities (Griffen, 2024). In BRICS countries, for example, regional and income disparities often hinder equitable human capital accumulation and its associated welfare benefits (Hmimou et al., 2024).

Finally, the Human Capital Theory's static assumptions have been challenged in light of globalisation, technological change, and environmental disruption. The theory presumes stable returns from knowledge and skills, yet the rapid pace of automation and climate shocks continually alters the types of skills in demand (Goldin, 2024; Jorgenson & Fraumeni, 2023). Furthermore, its narrow focus on market returns neglects broader human development dimensions such as environmental sustainability, social inclusion, and resilience to public health crises.

In summary, the Human Capital Theory remains a cornerstone of modern economic growth analysis, particularly for explaining the linkages among education, health, productivity, and life expectancy. However, its assumptions require contextual adaptation to contemporary realities – especially in developing and transitional economies such as the BRICS. Integrating institutional, technological, and equity considerations within the human capital framework provides a more comprehensive understanding of how human development drives economic growth and long-term improvements in life expectancy.

3.2.3 Health-Led Growth Hypothesis.

This hypothesis suggests that economic growth is improved when population health is improved. This was popularized by Bloom et al. (2004)**.** This theory is a build-up on the larger frame work of the human capital theory, as it identified health as a vital factor of productive capacity. It maintains that spending on public health improves worker output, physical stamina and cognitive function aside, enhancing the well-being of individual. These factors jointly fuel continued economic growth (Bloom et al., 2004; Weil, 2014).

At the core of the hypothesis is the idea that healthier individuals can work longer hours, learn more effectively, and engage more productively in economic activities. Improved health outcomes, such as higher life expectancy and lower disease burden, reduce absenteeism,

enhance labour participation, and foster innovation (Acemoglu & Johnson, 2007). As such, public spending on healthcare is not merely a social expenditure but an economic investment that yields long-term developmental dividends. In developing and emerging economies – such as the BRICS countries – where health disparities remain wide, the HLGH provides a compelling explanation for why sustained health improvement can catalyse inclusive growth (Hmimou et al., 2024).

Bloom et al. (2004) incorporated health as an essential element of human capital within an augmented production function. In their model, economic output depends not only on traditional inputs (labour and physical capital) but also on the quality of human capital, which comprises education, experience, and health. The model assumes that improvements in health contribute to both the quantity and quality of labour by extending working life and enhancing productivity per worker. Accordingly, total factor productivity (TFP) reflects not just technological progress but also the efficiency gains associated with better health conditions (Weil, 2014; Gyimah-Brempong & Wilson, 2021).

The functional relationship can be expressed as:

$$Y = AK^{\propto}L^{\beta}e^{\emptyset 1s+\emptyset_2 exp+\emptyset_3 exp^2+\emptyset_4} \quad (6)$$

Where:

Y= output or gross domestic product (GDP);

A= Total Factor Productivity;

K= is physical capital;

L = is the labour force;

and human capital consists of three components,

S = average years of schooling,

Exp = average work experience of the work force,

Exp^2= average square of work experience, and

H= health (which we proxy with life expectancy).

This model indicates that health, alongside education and experience, enhances human capital through exponential effects on output. Health improvements thus operate as both a direct input in production and an indirect catalyst that raises the marginal productivity of other factors such as labour and capital (Bloom et al., 2004; Chakraborty, 2021).

Empirical evidence supports the theory. For instance, Bloom and Canning (2008) found that a one-year increase in life expectancy raises GDP per capita by 4%. Similarly, Arora (2017) demonstrated that better health outcomes in emerging economies contribute to faster productivity growth through demographic dividends. These findings suggest that health-led policies can foster virtuous cycles of growth, whereby improved health leads to higher income, which in turn finances further health investments.

Criticisms.

Firstly, critics have argued that the relationship between health and growth is bidirectional**,** implying that while improved health stimulates growth, increases in income equally promote improvement in health by enhancing sanitation, nutrition and medical access (Acemoglu & Johnson, 2007). Thus, causality may run both ways, complicating empirical estimation. Second, the hypothesis tends to assume uniform benefits of health investment across countries, overlooking differences in institutional quality, inequality, and governance that mediate health's impact on productivity (Bhargava et al., 2014). Third, overemphasis on health-led policies may underplay complementary factors such as education, innovation, and infrastructure, which are equally vital for sustained growth (Weil, 2014). Finally, some scholars note that the health–growth nexus may exhibit diminishing returns beyond a certain threshold, additional health spending yields limited productivity gains (Gyimah-Brempong & Wilson, 2021).

Nonetheless, the Health-Led Growth Hypothesis remains a valuable framework for understanding how human development contributes to economic performance. In the context of the BRICS economies, where both health challenges and growth potential are significant, the hypothesis underscores the strategic importance of health investment as a foundation for long-term, inclusive development.

3.2.4 Endogenous Growth Model

The Endogenous Growth Theory (EGT) emerged in the 1980s as a response to the limitations of the neoclassical growth model, particularly its assumptions of diminishing returns to capital and the exogenous treatment of technological progress (Romer, 1994; Lucas, 1988). While the Solow-Swan model attributes long-run growth to external technological shocks, EGT posits that economic growth is determined internally through mechanisms such as innovation, knowledge spillovers, and human capital accumulation (Aghion & Howitt, 1998). Thus, the theory provides a dynamic explanation of how policy interventions, education, and research investments can generate sustained increases in productivity and income levels.

According to Romer (1990, 1994), technological change arises from intentional decisions by firms and individuals seeking to maximize profits and utility. Knowledge creation, learning-by-doing, and innovation yield positive externalities that sustain productivity over time. Consequently, government policies that encourage research and development (R&D) protect intellectual property, and subsidized education can enhance the incentives for innovation, and so prevent the diminishing returns to capital predicted by neoclassical models (Jones, 2019).

Frankel (1962) and Rebelo (1991) formalized this idea through the AK model**,** which assumes a linear relationship between output and capital, expressed as:

$$Y = AK \qquad (7)$$

Where Y represents total output (GDP), A is total factor productivity (TFP), and K denotes total capital (physical and human). The model implies constant marginal productivity of capital, suggesting that sustained investments in capital, particularly knowledge-intensive capital, can drive perpetual growth (Barro & Sala-i-Martin, 2004).

Lucas (1988) extended the endogenous growth framework by explicitly incorporating human capital as a key driver of economic progress. He argued that human capital, defined as education, skill, and health, enhances workers' productivity and generates spillover effects that benefit the wider economy. In his formulation, individuals allocate time between production and human capital accumulation, and continuous learning results in self-sustaining growth. The Lucas model is represented as:

$$Y(t) = AK(t)^{\beta}\ [\mu(t)h(t)L(t)]^{1-\beta}\ h_{\alpha}(t)^{\gamma} \qquad (8)$$

where $Y(t)$ is total output, $K(t)$ represents physical capital, $L(t)$ denotes labour, $h(t)$h(t) indicates individual human capital, $\mu(t)$is the fraction of time devoted to production, and $h_{\alpha}(t)^{\gamma}$ captures the external effects of aggregate human capital. When $\gamma > 0$, these spillovers yield increasing returns to scale, meaning that continuous investment in education and learning can generate sustained long-run growth (Stokey, 2019).

Within this framework, health and life expectancy form an integral part of human capital. Improved health enhances worker productivity, reduces absenteeism, and extends the working lifespan, thereby increasing the effective labour supply and promoting innovation (Bloom et al., 2004; Gyimah-Brempong & Wilson, 2021). In the context of the BRICS economies, the endogenous growth model provides a theoretical justification for examining how investments in health, education, and technological development contribute to both economic performance and life expectancy. These countries have pursued varying strategies of human capital enhancement, ranging from health sector reforms to digital innovation, that align closely with the endogenous growth mechanism of self-reinforcing development (Hmimou et al., 2024).

Criticisms

Despite its strong explanatory power, the endogenous growth theory faces notable criticisms. First, its assumption of constant or increasing returns to knowledge and human capital may be overly optimistic, particularly in developing economies where institutional weaknesses, limited absorptive capacity, and inequality can constrain the translation of innovation into productivity (Jones, 2019). Second, EGT tends to underemphasize the role of governance, institutional quality, and resource distribution, all of which critically affect how knowledge and human capital influence growth outcomes (Temple, 1999). Third, empirical testing of EGT remains complex, because variables such as innovation, technological diffusion, and human capital spillovers are difficult to measure consistently across countries (Romer, 1994; Aghion & Howitt, 1998).

Furthermore, the model's policy dependence is a key limitation – it predicts sustained growth only under continuous public investment in R&D, education, and infrastructure (Barro & Sala-i-Martin, 2004). In low- and middle-income economies, such as some BRICS members, fiscal

constraints and institutional inefficiencies can limit these investments, undermining the theory's assumptions.

Nevertheless, this theory remains a basis of modern macroeconomic theory. It emphasizes that long-term growth relies not just on capital accumulation but also on productivity and the quality of human capital, which includes health and life expectancy**.** Hence, for the BRICS countries, the theory provides a conceptual foundation for analyzing how health improvements, educational expansion, and innovation-driven policies jointly enhance both economic growth and population well-being.

3.3 Empirical Review on Life Expectancy

In this segment the empirical literatures relating the dependent variables to the various independent variables specified in the models of this current study are critically examined.

3.3.1 Life expectancy and economic growth

The relationship between life expectancy and economic growth has long been a central theme in development economics, owing to its implications for human capital formation, productivity, and long-term welfare outcomes. Improvements in population health as measured by life expectancy are generally viewed as both a cause and a consequence of economic progress. Theoretically, longer life expectancy enhances labour productivity, increases incentives for human capital accumulation, and extends investment horizons, thereby stimulating sustained economic performance (WHO, 2000; Bloom et al., 2004). Nevertheless, empirical evidence remains mixed, with the magnitude and direction of this relationship varying substantially across countries, stages of development, and methodological frameworks.

Deaton (2020) examined the intricate linkages between life expectancy, health systems, and economic growth in a cross-country regression and panel data analysis. Incorporating controls such as education, income inequality, and healthcare quality, the study established that life expectancy positively influences growth, but this relationship is mediated by institutional and structural factors. Countries with stronger healthcare systems and more equitable income distributions benefit more from rising life expectancy. This underscores that improvements in health alone may not guarantee economic gains without complementary investments in social and institutional infrastructure.

In a similar vein, Yang and Lin (2021) employed dynamic panel models (GMM) covering 100 countries from 1980 to 2019, and found that gains in life expectancy significantly stimulate economic growth, mainly in middle-income countries. The study however revealed that this positive effect depends on concurrent improvements in education and health expenditure. The authors further noted that countries undergoing demographic transition – where populations remain largely within productive age cohorts – tend to experience the strongest growth dividends from rising life expectancy.

Further extending this line of inquiry, Nicolau et al. (2021) applied a panel vector autoregression (PVAR) model across emerging and advanced economies between 1990 and 2020 to investigate bidirectional causality. Their results confirmed a two-way relationship: improvements in life expectancy enhance economic growth through greater productivity and human capital, while economic expansion further improves life expectancy via better living standards and increased public health investment. Interestingly, they found that this relationship is stronger in emerging economies, implying that the marginal gains from life expectancy improvements decline at higher income levels. Similarly, Goh and Lee (2022), using a structural equation modelling (SEM) approach across 50 countries (1990–2020), reinforced the existence of this bidirectional linkage, and identified governance quality and institutional efficiency as important mediating variables that strengthen the health–growth nexus.

Complementing these findings, Manea and Pătruțiu (2022) examined EU countries between 1995 and 2020, and found that life expectancy has a positive significant influence on economic growth, particularly in nations with substantial public health and social protection investments. They argued that healthier workers contribute to sustained productivity growth by remaining economically active for longer periods. Meanwhile, Zhang et al. (2023) introduced a non-linear dimension by employing threshold regression models across 120 countries (1980–2023). Their study showed that the positive impact of life expectancy on growth are strongest in low- and middle-income economies, but taper off in advanced ones, where technological innovation and education, rather than health improvements alone, become the dominant growth drivers.

Turning to developing and emerging economies, Ozturk and Acar (2023) conducted Granger causality tests using time-series data from 60 emerging and developing countries (1990–2022). Their results revealed that in developing economies, causality runs from life expectancy to

economic growth, indicating that health improvements drive growth, but in advanced economies, the reverse relationship predominates. This asymmetry highlights the stage-dependent nature of the life expectancy–growth nexus and suggests that policy priorities may need to differ according to a country's level of development.

In the African context, several studies have provided additional empirical insights. Ngangue and Manfred (2015) examined 141 developing countries between 2000 and 2013 using a dynamic panel model, and found that improvements in life expectancy significantly enhanced gross national income (GNI) per capita, although the effects varied across income levels. Similarly, Modibbo and Idris (2020) investigated 33 African countries (1990–2017) using fixed and random effects estimators, and found that life expectancy contributes positively to growth, particularly in West Africa. However, both studies relied on relatively narrow health indicators and static econometric approaches that limit causal inference. Semmanda (2020), analysing sub-Saharan Africa between 2006 and 2017, also reported that population growth and life expectancy were significant growth drivers, though the study's short time span and lack of dynamic modelling limited its robustness.

At a sub-regional level, Biyase and Maleka (2019) used a fixed-effects two-stage least squares (FE-2SLS) model to examine ten Southern African Development Community (SADC) countries (1985–2017). Their results confirmed that life expectancy has a positively significant impact on economic growth. The use of instrumental variables addressed endogeneity concerns, but the study's narrow focus on a single sub-region and reliance on life expectancy as the sole health measure limited its generalizability. Similarly, Eweade (2021) investigated the link between life expectancy, public health expenditure and mortality rate in Nigeria for the period 1985–2020, using cointegration and error correction models, and found a strong positive long-run relationship. While these single-country analyses provide depth, they remain context-specific and cannot easily be extrapolated to broader regions or economic groupings.

More recently, Momoh et al. (2024) reversed the causality by examining the impact of economic welfare on life expectancy across 44 sub-Saharan African countries between 2000 and 2021. They employed the Generalised Method of Moments (GMM) as well as Augmented Mean Group estimations, and found that reductions in carbon emissions and increases in secondary school enrolment substantially improved life expectancy, while GDP had a positive but statistically insignificant effect. Although this study effectively integrates environmental

and educational variables into the welfare–health nexus, it does not fully capture how life expectancy itself feeds back into economic performance, leaving the bidirectional mechanism partially unexplored.

Collectively, these studies provide valuable but fragmented evidence. The general consensus points to a positive long-run relationship between life expectancy and economic growth, though the strength, direction, and transmission channels vary across development stages, institutional quality, and regional contexts. Empirical inconsistencies largely stem from methodological heterogeneity, omission of key structural variables, and differences in model specification.

There are still significant gaps in the literature on the relationship between life expectancy and economic growth, despite a great deal of empirical research. The majority of studies use life expectancy as a limited indicator of population health, ignoring the complex relationships between trade openness, healthcare spending, education, and environmental quality (such as carbon emissions), all of which have an impact on economic performance and health outcomes. Furthermore, despite the fact that emerging economies like the BRICS have different institutional settings, industrial policies, and health financing systems, comparative analyses across these nations are still rare, even though regional studies in Africa and other developing regions highlight significant structural heterogeneity. In terms of methodology, a large portion of the literature currently in publications uses static panel estimators (fixed or random effects), which are insufficient for handling endogeneity or capturing long-term equilibrium relationships. In this situation, more complex methods are rarely used, such as panel cointegration techniques like Dynamic Ordinary Least Squares and Fully Modified Ordinary Least Squares. Lastly, while the effect of economic growth on life expectancy is occasionally examined, few studies model the feedback effects from life expectancy to economic growth within a single long-run analytical framework, indicating that the research does not adequately account for bidirectional causality.

3.3.2 Life expectancy and Education (School enrolment, Secondary (SES))

The link between education and life expectancy has been widely explored, with evidence consistently revealing education as a significant determinant of health and longevity. It influences life expectancy through multiple channels, including improved health awareness, higher income potential, and greater access to healthcare services. Raghupathi and Raghupathi

(2020) examined nexus for 26 OECD countries for 1995–2015, and demonstrated that higher educational attainment, especially tertiary education, improves longer lifespans, lower infant mortality, and higher vaccination and enrolment rates. They argue that education not only enhances personal health literacy but also promotes social equity and economic opportunity. However, their analysis was largely descriptive and limited to developed economies. Complementing this, Hazan (2011) found a robust positive connection between life expectancy and years of schooling across countries between 1960 and 2000. This suggests that improvements in health and longevity incentivize individuals to invest more in education, particularly in low-income countries, where the returns for longevity are most pronounced.

Empirical evidence also highlights the reverse relationship; that is, how improvements in life expectancy influence education. Hansen (2012) found that a one percent increase in life expectancy at birth results in a 3.5% rise in years of schooling, independent of general living standards or child mortality. Similarly, Cervellati and Sunde (2015), using historical panel data from 1800 to 2000, demonstrated that increases in life expectancy not only enhance human capital accumulation but also generate long-term economic growth, underscoring the enduring role of health in fostering educational advancement. More recently, Vu (2022) employed system GMM estimators on panel data for 1970–2019, and established a causal link between life expectancy and human capital accumulation across countries, showing that increased longevity stimulates higher investments in education rather than vice versa.

Evidence from developing regions, particularly Africa, also reinforces the education–health nexus. Byaro and Mpeta (2021) examined 33 sub-Saharan African (SSA) countries (2000–2016) and found that parents' secondary education significantly improves child health outcomes, suggesting intergenerational benefits of education. Similarly, Kouladoum (2023), using Driscoll–Kraay and GMM estimations for 48 SSA countries (2000–2020), found that inclusive education (at primary, secondary, and tertiary levels) enhances both male and female life expectancy, though the study was limited to educational indicators and excluded broader socio-economic factors. Oseni (2022) also found that school enrolment, rather than health aid, significantly improves life expectancy in SSA countries, highlighting education as a more sustainable determinant of population health than external aid interventions. However, most African studies remain constrained by the use of single education indicators (typically enrolment), and limited control for endogeneity or environmental factors.

In the BRICS context, Sart (2023) conducted a panel data analysis for 2000–2020 and reported a significant positive association between life expectancy and quality of education. Improvements in life expectancy were found to reinforce educational outcomes, while higher education levels, particularly secondary and tertiary attainment, contribute to better health behaviours and access to healthcare. This underscores the bidirectional and synergistic relationship between education and health within emerging economies. Likewise, Immurana (2021) found that school enrolment and foreign direct investment jointly improve life expectancy across African countries, though methodological limitations such as potential endogeneity weaken causal inference. Regionally focused studies, such as Samer et al. (2017) for MENA countries, further support the view that educational attainment among both males and females significantly enhances life expectancy, with evidence that expanding access to education can narrow health gaps within and across countries.

At the global level, Novak, Čepar and Trunk (2016) confirmed that a country's education level is a strong determinant of life expectancy, based on regression analysis of 187 countries. Their findings advocate for lifelong learning and educational inclusivity as means to improve population health. Yet their cross-sectional design precluded long-term causal interpretations. Collectively, these studies affirm that education and life expectancy are interlinked in both directions: education enhances health and longevity, while longer lifespans motivate greater educational investment. Nevertheless, most analyses are region-specific, employ limited indicators, and often fail to integrate broader structural and environmental variables such as income inequality, healthcare access, and carbon emissions, which jointly influence this relationship. Furthermore, few studies employ dynamic or cointegration techniques such as FMOLS or DOLS to capture the long-run relationship between education and life expectancy, particularly within emerging economies such as the BRICS.

3.3.3 Life expectancy and Trade

The link between life expectancy and trade openness has attracted increasing scholarly attention, with mixed evidence across regions and methodological frameworks. Trade openness influences population health through multiple pathways such as economic growth, income distribution, environmental externalities, and access to health-related goods and technologies. However, empirical studies have shown divergent results depending on country context, data structure, and econometric approach.

In Nigeria, Aigheyisi and Oligbi (2019) examined the effects of trade openness; specifically import openness and foreign direct investment (FDI) inflows on life expectancy, using annual data from 1981 to 2017. Applying the Autoregressive Distributed Lag (ARDL) model for cointegration and error correction analysis, they found that import openness negatively affects life expectancy, while FDI inflows exert a positive but statistically insignificant influence. The study further revealed that higher per capita income and increased government expenditure on health improve life expectancy, whereas inflation reduces it. Similarly, Anozie and Nkoro (2023), using ARDL estimation for 1981–2020, found that imports and exchange rate depreciation lower life expectancy, while FDI inflows have a positive impact. However, exports were not found to significantly influence longevity. Both studies recommended policies to promote productive investment, strengthen trade regulation, and control importation of sub-standard goods that pose health risks.

More recent Nigerian evidence from Olakunle et al. (2024) and Olayiwola (2023) yields mixed results. Olakunle et al. (2024), using ARDL estimation (1986–2023), found that trade openness negatively affects life expectancy, whereas Olayiwola (2023) reported that openness and net exports improve health outcomes. While these studies contribute to understanding the trade–health nexus in Nigeria, they share methodological constraints: reliance on linear aggregate models, limited treatment of endogeneity, and the absence of non-linear or structural analyses that could uncover asymmetric effects of trade on health outcomes.

Extending the analysis to sub-Saharan Africa (SSA), Novignon et al. (2016) investigated the effect of trade openness on population health and financing across 42 SSA countries, from 1995 to 2013. Employing fixed effects, random effects, and the Generalized Method of Moments (GMM) estimators, they found a significant impact of trade openness on life expectancy and it reduced infant and under-five mortality. Similarly, Byaro et al. (2021), using a two-step system GMM estimator for 33 SSA countries (2000–2016), reported that trade openness, per capita income, and health financing contribute to longer life expectancy and reduced child mortality. These findings suggest that, when supported by adequate health investment, trade liberalization can enhance health outcomes in the region. However, both studies highlight the need for more micro-level disaggregation and consideration of structural differences in trade composition.

Contrasting results emerge in other regional studies. Ochinanwata et al. (2020), using second-generation panel econometric techniques for five English-speaking West African countries (1985–2018), found no significant impact of external trade on life expectancy, implying that trade alone may not yield health gains without complementary human capital and institutional development. In a broader macroeconomic context, Bul and Moracha (2020) examined economic growth and health outcomes in SSA (1991–2015) using pooled OLS and two-way fixed effects models. Their results indicated that economic growth reduces infant and adult mortality and improves life expectancy, but the study fell short of establishing causality and accounting for dynamic feedback effects between trade, growth, and health.

Outside Africa, Shah et al. (2021) analyzed the link between trade openness and life expectancy in China (1960–2018), using a regime-switching regression model. They found that while trade liberalization boosts income and raises life expectancy, it simultaneously increases CO_2 emissions that harm health. This indicates the mutually exclusive nature of economic expansion and environmental degradation. The study emphasized the importance of green trade policies and environmental regulation to sustain health improvements under globalization.

Overall, research shows that depending on a nation's economic structure, regulatory environment, and environmental management, trade openness can either increase or decrease life expectancy. In developing economies, particularly Nigeria and SSA, the relationship remains fragile and highly context-dependent. Methodologically, existing studies are dominated by static or linear models such as ARDL and fixed effects, with limited attention to endogeneity, asymmetry, or cross-country spillover effects. Few studies employ dynamic cointegration techniques, such as FMOLS or DOLS, capable of capturing long-run equilibrium relationships between trade and health indicators. Future research could thus expand this literature by incorporating broader trade components (imports, exports, FDI), environmental and institutional variables, and advanced econometric approaches, to uncover the nuanced, multidirectional effects of trade openness on life expectancy in emerging economies.

3.3.4 Life expectancy and Carbon emission (CO_2)

The relationship between carbon emissions and life expectancy has been widely examined across various regions, revealing predominantly adverse health outcomes from rising CO_2 levels. Empirical evidence generally indicates that increased environmental pollution reduces

longevity, though the magnitude and direction of this effect vary, depending on regional economic structures, policy frameworks, and methodological approaches.

In sub-Saharan Africa, Akpan and Udo (2021) found that CO_2 emissions significantly decreased life expectancy between 1990 and 2018, while both health expenditure and GDP per capita exerted positive influences, suggesting that economic prosperity can partly offset environmental degradation. Similarly, Usman and Abdullahi (2022), using panel cointegration and Fully Modified Ordinary Least Squares (FMOLS) methods for 1990–2020, confirmed the negative impact of CO_2 emissions on life expectancy across African countries, though improvements in clean water access and income levels mitigated these effects. Cavusoglu and Gimba (2021) further supported these findings using Pedroni cointegration and pooled mean group estimation, demonstrating a significant long-run negative relationship between CO_2 emissions and life expectancy in sub-Saharan Africa.

Studies in Asia have reported comparable results. Chen et al. (2020), employing a Vector Error Correction Model (VECM) for BRICS economies from 1980–2017, identified a long-term inverse relationship between CO_2 emissions and life expectancy, with urbanization and energy consumption exerting country-specific mixed effects. Likewise, Karim and Alam (2021) used an Autoregressive Distributed Lag (ARDL) model for Southeast Asian nations (1985–2019) and observed that CO_2 emissions significantly reduced life expectancy in the long run, whereas energy consumption and healthcare spending improved it. Das and Debanth (2023) deepened this perspective by uncovering a quadratic long-run relationship between CO_2 emissions and life expectancy in India, concluding that the country has surpassed its optimal emission threshold, beyond which health outcomes deteriorate.

At the country level, several single-nation analyses have reinforced the detrimental role of carbon emissions. Liang and Zhang (2017) showed that CO_2 emissions significantly reduced life expectancy across Chinese provinces between 1995 and 2015, with spatial spillover effects worsening outcomes in adjacent regions. In Nigeria, Osabohien et al. (2020) applied an ARDL framework for 1980–2017, and found that carbon emissions were negatively associated with life expectancy, though the study's focus on energy consumption limited its broader policy implications. Similarly, Redzwan and Ramli (2024) examined Malaysia (1997–2021) using ARDL bounds testing and confirmed a significant short-run relationship between CO_2 emissions and reduced life expectancy.

Beyond these regional findings, several cross-regional studies highlight the complex, and sometimes non-linear, nature of the CO_2–health nexus. Ahmad et al. (2019), using Generalized Method of Moments (GMM) estimation for MENA countries (1995–2015), established that CO_2 emissions reduced life expectancy, while healthcare expenditure and economic growth improved it, indicating that fiscal health investment can moderate environmental harms. Shahbaz et al. (2020), examining G7 nations (1971–2016) with Dynamic Ordinary Least Squares (DOLS), similarly found that CO_2 emissions had a negative impact on life expectancy, but renewable energy use and health spending alleviated these effects. In contrast, Matthew et al. (2020), analysing West Africa via a two-stage least squares approach (2000–2018), reported a surprising positive association between CO_2 emissions and life expectancy, possibly reflecting the short-term income and infrastructure benefits of industrialization, though this finding likely masks long-term environmental costs.

Expanding on the comparative dimension, Osei-Kusi et al. (2024) analysed data from 82 countries across sub-Saharan Africa, the Middle East and North Africa, and Europe and Central Asia, over a 30-year period. Their results indicated a positive correlation between carbon production, energy use, and life expectancy, suggesting that, in developing regions, early-stage industrialization may yield short-term health benefits before pollution effects intensify. However, such linear specifications overlook potential non-linear or threshold dynamics that could reveal turning points, where emissions shift from being growth-enhancing to health-damaging.

Other studies underscore the causal direction of this relationship. Rafique and Khan (2018) found unidirectional causality running from CO_2 emissions to life expectancy in South Asia, confirming that increased emissions directly worsen longevity. Hossain and Ahmed (2019), studying South American countries (1980–2015), similarly reported that CO_2 emissions adversely affected life expectancy in the long run, while reductions in energy intensity and income inequality improved it. Nguyen et al. (2018), using Structural Equation Modelling (SEM) for Vietnam, confirmed that CO_2 emissions negatively affected life expectancy by aggravating respiratory diseases, calling for stricter environmental controls and improved healthcare access.

Overall, the literature presents a coherent pattern of evidence that links rising CO_2 emissions to declining life expectancy, with differences in results often arising from regional context,

estimation techniques, and the inclusion of mediating factors such as income, energy use, or health expenditure. Nevertheless, persistent methodological and empirical gaps remain. Many studies rely on linear models such as ARDL, FMOLS, and GMM, which, though useful, may inadequately address endogeneity, reverse causality, and cross-country heterogeneity (Cavusoglu & Gimba, 2021; Osabohien et al., 2020; Redzwan & Ramli, 2024). Furthermore, research coverage is geographically uneven: while sub-Saharan Africa, China, India, and Malaysia are well-represented, Latin America, smaller developing economies, and Small Island Developing States (SIDS) remain underexplored. These gaps underscore the need for comparative, multi-country analyses employing advanced econometric methods, such as Dynamic Panel Threshold Models or second-generation cointegration techniques, to better capture the non-linear, bidirectional, and long-run equilibrium relationships between carbon emissions and life expectancy.

3.3.5 Life expectancy and health expenditure per capita (HEPC)

The relationship between health expenditure per capita (HEPC) and life expectancy (LEXP) has been widely examined in health economics, with most studies generally confirming a positive association between increased health spending and improved population longevity. The theoretical foundation for this relationship lies in human capital theory, which argues that investment in health improves labour productivity, reduces mortality, and enhances overall economic performance. However, empirical findings suggest that the magnitude of this relationship varies significantly across countries depending on income level, institutional quality, and efficiency of health systems.

A foundational contribution is provided by Bloom, Canning, and Sevilla (2004), who demonstrated that improvements in population health significantly increase economic performance through higher labour productivity and reduced morbidity. Their results highlight that health expenditure contributes to longer life expectancy by improving access to medical services and strengthening human capital formation. Similarly, Bokhari, Gai, and Gottret (2007) found that public health expenditure has a significant positive effect on life expectancy, although the efficiency of spending plays a critical role in determining outcomes.

In developing countries, Novignon, Olakojo, and Nonvignon (2012) examined Sub-Saharan Africa and found that health expenditure is positively associated with life expectancy, though

the effect is relatively weak due to inefficiencies in health systems and governance challenges. Their findings suggest that increasing health spending alone is insufficient unless accompanied by improvements in institutional quality and healthcare delivery systems.

More recent panel evidence by Sharma (2018) confirms a long-run positive relationship between health expenditure and life expectancy across countries, using advanced econometric techniques that account for heterogeneity and cross-sectional dependence. The study emphasizes that both public and private health spending contribute to improved longevity, although public expenditure has a stronger effect in low-income countries.

Further evidence by Farag et al. (2013) shows that income remains a major determinant of health expenditure, which indirectly affects life expectancy. Their findings suggest that wealthier countries tend to allocate more resources to health care, resulting in better health outcomes and higher life expectancy levels.

Overall, the empirical literature consistently indicates that higher health expenditure per capita is associated with improved life expectancy. However, recent studies emphasize that this relationship is not purely mechanical; rather, it depends on how efficiently health resources are allocated and the strength of institutional frameworks. Countries with similar levels of health expenditure may experience different health outcomes due to differences in governance quality, access to care, and health system efficiency. Consequently, the health expenditure–life expectancy nexus is best understood as a conditional relationship influenced by structural and institutional factors rather than expenditure alone.

3.3.6 Physician Density and Life Expectancy

As countries confront widening health inequalities and resource constraints, investigating the link between physician availability and population health outcomes has attracted sustained scholarly attention. A growing body of empirical evidence demonstrates that higher physician density, measured as physicians per 1,000 or 100,000 population, is generally associated with improved life expectancy and reduced mortality. However, the strength, direction, and causality of this relationship remain contested, particularly across differing levels of economic development and health system capacity.

As one of the earliest cross-country study that related health outcomes and health workforce, Anand and Bärnighausen (2004) demonstrated that, after adjusting for income and education, increases in physician and nurse density considerably decreased maternal and infant mortality. However, causal interpretation was constrained by the study's cross-sectional methodology and emphasis on mortality as opposed to life expectancy. Researchers have since then improved this understanding with more advanced econometric techniques and detailed data. Basu et al. (2019), in a longitudinal investigation, observed that life expectancy improves by about 51.5 days with every ten additional primary care physicians per 100,000 residents, but a follow up projection by Basu et al. (2021) proposed that eradication of primary care shortages would translate into extra national benefits. Although these outcomes revealed the significance of primary care, it is unclear if it is applicable outside high-income environments.

Recent global and regional analyses have reaffirmed the positive association between physician density and life expectancy. You (2022) reported that physician availability contributes significantly to life expectancy gains worldwide, particularly in developing economies where baseline densities are low, suggesting diminishing marginal returns at higher levels of supply. Similarly, Liu (2022) demonstrated a positive relationship between physician density and healthy life expectancy (HALE), indicating benefits not only in longevity but also in morbidity reduction. Partyka et al. (2022) extended the analysis to European contexts, finding that both physician and nurse densities correlated positively with longevity, highlighting the multidimensional character of health workforce effects. OECD (2023) reports further illustrate that countries with higher doctor-to-population ratios tend to exhibit longer life expectancy, although these descriptive patterns cannot infer causality.

Despite this convergence of evidence, significant empirical gaps persist. First, most studies remain cross-sectional or context-specific, lacking a robust long-run analytical framework that captures both short-term and equilibrium relationships between physician density and life expectancy. Second, while U.S. and OECD-based studies employ sophisticated identification strategies, low- and middle-income settings, including the BRICS countries, remain underrepresented, even though they exhibit substantial variation in physician supply and health outcomes. Third, few analyses account for the endogeneity between physician density and economic development: wealthier nations may attract more physicians, while healthier populations may enhance productivity and income, introducing reverse causality. Finally, the potential non-linearities and threshold effects of physician density on health outcomes are

rarely tested empirically. In light of this, the current study contributes by employing panel cointegration techniques, specifically Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS), to investigate the long-run relationship between physician density and life expectancy across the BRICS economies. By applying robust econometric procedures that address endogeneity and cross-country heterogeneity, the study offers empirical clarity on whether increases in physician supply yield sustainable health gains in emerging economies. In doing so, it advances the literature from descriptive correlations toward causal inference and long-run policy relevance within a development context.

3.4 Empirical Review on Economic Growth

This segment encapsulate literature review on economic growth and the independent variables.

3.4.1 Education and Economic Growth

The relationship between education and economic growth has attracted substantial empirical attention in the growth literature. One of the pioneering studies is that of Barro (1991), who examined 98 countries between 1960 and 1985 using cross-country regression analysis. The study found that higher levels of school enrolment, particularly at the primary and secondary levels, significantly promoted economic growth. However, the study was criticized for potential endogeneity problems and the inability of cross-sectional regressions to adequately capture country-specific effects.

Similarly, Mankiw, Romer, and Weil (1992) extended the Solow growth model by incorporating human capital as a factor of production. Using data from 98 countries, the study revealed that investment in human capital, proxied by school enrolment rates, significantly explained differences in economic growth across countries. Although the study strengthened the theoretical link between education and growth, critics argue that school enrolment rates may not accurately measure the quality of education and human capital accumulation.

Benhabib and Spiegel (1994) investigated the contribution of human capital to economic growth using panel data from several countries. Their findings suggested that education influences growth primarily through facilitating technological innovation and technology adoption rather than directly increasing output. While the study provided important insights

into the transmission mechanism of education, its measurement of human capital based on years of schooling was considered restrictive.

Temple (1999) reassessed the education-growth nexus using improved econometric techniques and found that the positive relationship between education and economic growth remained significant after controlling for outliers. The study demonstrated that education enhances productivity and contributes to long-run growth. Nevertheless, the results were sensitive to model specification and sample selection, raising concerns regarding their generalizability.

Krueger and Lindahl (2001) examined the robustness of the relationship between education and growth using international panel data. Their findings indicated that education has a significant positive effect on economic growth, especially in developing countries. However, the authors highlighted substantial measurement errors in educational attainment data, suggesting that previous studies may have underestimated the impact of education on growth.

Hanushek and Kimko (2000) argued that educational quality is more important than educational quantity in promoting economic growth. Using international mathematics and science test scores as proxies for educational quality, they found that cognitive skills had a strong positive impact on economic growth. The study's major strength lies in its focus on learning outcomes rather than enrolment rates, although international test score data were unavailable for many developing countries.

Building on this argument, Hanushek and Woessmann (2008) analyzed data from over 50 countries and found that cognitive skills significantly influenced long-run economic growth. The study concluded that improvements in educational quality yielded greater economic returns than merely increasing years of schooling. Despite its methodological rigor, the study faced criticism regarding the comparability of international achievement tests across countries.

Further extending this line of inquiry, Hanushek and Woessmann (2021) examined the relationship between educational outcomes and economic growth using international measures of cognitive skills and cross-country growth data. The study found that a nation's stock of knowledge capital, measured through students' achievement in mathematics and science assessments, is a stronger predictor of long-run economic growth than years of schooling. The authors demonstrated that countries with higher cognitive skill levels tend to experience faster rates of economic growth and higher levels of income per capita. They concluded that policies

aimed at improving educational quality and learning outcomes are likely to yield greater economic benefits than policies focused solely on increasing school enrolment or years of schooling. However, the study acknowledged that improvements in educational quality may take considerable time to translate into measurable economic gains and that cognitive test scores may not fully capture all dimensions of human capital.

Aghion et al. (2009) investigated the role of higher education in economic growth using panel data from OECD countries. Their results revealed that tertiary education contributes significantly to innovation and technological progress, which in turn stimulate economic growth. However, the study's focus on advanced economies limits the applicability of its findings to developing countries where educational structures differ substantially.

Using panel data techniques, Pegkas (2014) examined the impact of education on economic growth in Greece and found that secondary and tertiary education positively affected economic performance in both the short and long run. The study employed cointegration analysis, thereby addressing some of the shortcomings of earlier cross-sectional studies. Nonetheless, its country-specific focus restricts the generalization of findings to other economies.

More recently, Pradhan et al. (2018) explored the causal relationship between education and economic growth in a panel of emerging economies. Employing panel vector error correction models, the study found evidence of bidirectional causality between education and economic growth, implying that education promotes growth while economic growth simultaneously enhances educational development. Although the study offers robust evidence on causality, differences in educational systems across countries may affect the consistency of the results.

Overall, empirical evidence overwhelmingly supports the existence of a positive relationship between education and economic growth. However, the literature reveals important differences regarding the channels through which education affects growth. Earlier studies emphasized educational attainment and enrolment rates, whereas more recent research highlights the importance of educational quality, cognitive skills, innovation, and technological diffusion. Furthermore, methodological challenges such as endogeneity, measurement errors, and cross-country.

3.4.2 Gross Fixed Capital Formation and Economic Growth.

One of the earliest and most influential empirical studies is that of De Long and Summers (1991), who examined the impact of equipment investment on economic growth across developed and developing countries. Using cross-country regression analysis, they found a strong positive relationship between investment in machinery and equipment and economic growth, concluding that capital accumulation enhances productivity and promotes long-run economic performance. Similarly, Levine and Renelt (1992) employed extreme-bounds analysis on data from over 100 countries and identified investment as one of the few variables consistently associated with economic growth. Their findings provided robust evidence that capital formation constitutes a fundamental determinant of economic performance, although the study was limited by its cross-sectional methodology and inability to adequately address endogeneity issues.

Using country-specific time-series analysis, Asteriou and Agiomirgianakis (2001) investigated the effects of physical and human capital on economic growth in Greece. Employing cointegration techniques, the study found that gross fixed capital formation exerted a positive and statistically significant impact on economic growth in both the short and long run. The findings reinforced the argument that sustained investment in productive assets contributes significantly to economic expansion. Likewise, Bakare (2011) examined the relationship between capital formation and economic growth in Nigeria using an error correction model and found that gross fixed capital formation positively influenced economic growth by increasing productive capacity and supporting industrial development. However, the study noted that the effectiveness of capital formation depends on the efficient utilization of investment resources.

More recent empirical evidence continues to support the importance of gross fixed capital formation in promoting economic growth. Boamah, Adongo, Essieku, and Lewis (2018) examined the relationship among financial depth, gross fixed capital formation, and economic growth in 18 Asian economies using panel estimation techniques. Their findings revealed that gross fixed capital formation had a positive and statistically significant effect on economic growth, suggesting that increased investment in fixed assets enhances output and productivity. The study further emphasized that investment-driven growth is more sustainable when supported by a well-developed financial system.

In contrast, Onwiodiokit and Otolorin (2021) re-examined the relationship between capital formation and economic growth in Nigeria using Dynamic Ordinary Least Squares (DOLS). Contrary to conventional expectations, the study found that gross fixed capital formation exerted a negative and significant effect on economic growth. The authors attributed this result to inefficiencies in public investment, poor infrastructure maintenance, corruption, and weak institutional frameworks that reduce the productivity of capital investments. This finding suggests that the growth effects of capital formation depend not only on the quantity of investment but also on its efficiency and allocation.

Further evidence was provided by Islam and Biswas (2023), who investigated the effects of foreign grants and gross fixed capital formation on economic growth in Bangladesh using Johansen cointegration and Vector Error Correction Model (VECM) techniques. The study established a long-run relationship between capital formation and economic growth and found that gross fixed capital formation positively and significantly affected economic performance. The authors argued that investment in fixed assets improves productive efficiency and strengthens the economy's growth potential.

Similarly, Abdulkarim (2023) conducted a systematic review of investment indicators and economic growth in Nigeria and found that gross fixed capital formation remains one of the most consistent predictors of economic growth. However, the review emphasized that the growth-enhancing effects of capital formation are conditional upon complementary factors such as infrastructure quality, institutional effectiveness, macroeconomic stability, and policy consistency. The study also noted that empirical evidence from Nigeria remains mixed, thereby indicating the need for further investigation using more robust econometric approaches.

More recently, Nsonwu (2024) examined the determinants of gross fixed capital formation in Nigeria using linear and nonlinear Autoregressive Distributed Lag (ARDL) models. Although the study focused on factors influencing capital formation rather than directly estimating its impact on economic growth, the findings highlighted the importance of macroeconomic stability in sustaining investment levels. The study argued that improvements in capital formation are essential for enhancing productive capacity and achieving sustainable economic growth.

Overall, the empirical literature largely supports the existence of a positive relationship between gross fixed capital formation and economic growth. Both cross-country and country-

specific studies generally conclude that increased investment in fixed assets enhances productivity, expands productive capacity, and promotes long-run economic growth. However, recent evidence, particularly from developing economies such as Nigeria, suggests that the effectiveness of capital formation depends on the quality of investment, institutional efficiency, infrastructure development, and macroeconomic stability. The mixed findings observed in the literature indicate that while capital accumulation remains an important driver of economic growth, its growth-enhancing effects are contingent upon the broader economic and institutional environment in which investments are undertaken.

3.4.3 Carbon Dioxide (CO_2) Emissions and Economic Growth

The relationship between carbon dioxide (CO_2) emissions and economic growth has been widely examined in environmental economics, with a central focus on whether economic expansion leads to environmental degradation or whether higher income levels eventually improve environmental quality. The theoretical debate is commonly framed within the Environmental Kuznets Curve (EKC) hypothesis, which suggests an inverted U-shaped relationship between income and environmental pollution (Grossman & Krueger, 1995). However, empirical findings remain mixed across countries, time periods, and methodological approaches.

Grossman and Krueger (1995) provided one of the earliest and most influential empirical examinations of the EKC hypothesis. Using cross-country data, they found evidence of an inverted U-shaped relationship between income and environmental degradation, implying that CO_2 emissions initially rise with economic growth but begin to decline after a certain income threshold is reached. This study laid the foundation for subsequent empirical investigations, although later researchers have questioned the robustness of the EKC across different pollutants and econometric specifications.

Dinda and Coondoo (2006) further examined the income–emissions relationship using panel data techniques. Their findings showed that economic growth is associated with higher CO_2 emissions in the early stages of development. However, the evidence supporting a clear EKC pattern was weak, particularly for developing countries. The study concluded that income growth alone is insufficient to improve environmental quality without complementary environmental policies and technological advancement.

Apergis and Payne (2009) analyzed the dynamic relationship among CO_2 emissions, energy consumption, and economic growth in Central American countries using panel cointegration and causality methods. Their results revealed a long-run equilibrium relationship among the variables and indicated bidirectional causality between economic growth and CO_2 emissions. This suggests that while economic growth increases emissions through higher energy demand, environmental conditions may also influence growth through energy constraints and policy responses.

Similarly, Shahbaz, Lean, and Shabbir (2012) investigated the CO_2 emissions–growth nexus in Pakistan using the Autoregressive Distributed Lag (ARDL) approach. The study found that economic growth significantly increases CO_2 emissions in both the short and long run. Their results also supported the EKC hypothesis, indicating that emissions rise at early stages of development but may decline as income increases. However, the findings were country-specific and may not be generalizable to economies with different structural characteristics.

Dogan and Seker (2016) examined the influence of renewable energy consumption, non-renewable energy, trade openness, and economic growth on CO_2 emissions in European Union countries. Their findings showed that economic growth contributes to higher CO_2 emissions, while renewable energy consumption helps reduce environmental degradation. The study highlighted that the growth–emissions relationship is strongly influenced by the energy mix and the level of technological advancement, although its focus on developed economies limits applicability to developing countries.

Salahuddin and Gow (2014) investigated the relationship among economic growth, energy consumption, CO_2 emissions, and financial development in Gulf Cooperation Council (GCC) countries using panel cointegration and causality analysis. Their results showed that economic growth significantly increases CO_2 emissions, confirming that rapid economic expansion places pressure on environmental quality. The study also established a long-run relationship among the variables, suggesting that environmental sustainability challenges persist in oil-dependent economies with energy-intensive growth structures.

More recent empirical evidence continues to confirm that economic growth is closely linked with environmental degradation, particularly in developing and energy-dependent economies. However, the literature increasingly emphasizes that the magnitude of CO_2 emissions is not determined by economic growth alone but is significantly influenced by energy structure,

technological innovation, and environmental regulations. While some studies support the EKC hypothesis, many others find no evidence of a turning point, especially in developing countries where industrialization and fossil fuel dependence remain dominant.

Overall, the empirical literature suggests that economic growth tends to increase CO_2 emissions, particularly in the early and middle stages of development. However, the relationship is not uniform across countries, as it is shaped by energy consumption patterns, policy frameworks, and technological progress. The mixed findings in the literature highlight the need for country-specific studies that account for structural differences in economic and energy systems when examining the growth–environment nexus.

3.4.4 Economic Growth and Per Capita Health Expenditure

The relationship between economic growth and per capita health expenditure (PCHE) has been widely investigated in health economics. The literature is grounded in the proposition that higher income levels increase demand for health services, while improved health spending may also contribute to productivity and economic growth. However, most empirical studies tend to focus on whether income drives health expenditure or whether health expenditure drives income, with results often varying across countries and methodologies.

Early empirical evidence by Newhouse (1977) established that per capita income is a major determinant of per capita health expenditure across countries. The study demonstrated that income elasticity of health expenditure is greater than one, implying that health care behaves as a luxury good. This finding has been influential in shaping subsequent research, although it has been criticized for not fully accounting for institutional differences and technological change in health care systems.

Similarly, Gerdtham and Jönsson (2000) examined OECD countries and found that GDP per capita is strongly associated with per capita health expenditure. Their results suggest that as economies grow, individuals and governments allocate a larger share of resources to health care. The study also highlighted that demographic factors and institutional arrangements significantly influence health spending patterns, indicating that income alone does not fully explain variations in per capita health expenditure.

Using panel data techniques, Hitiris and Posnett (1992) found a positive and significant relationship between GDP per capita and per capita health expenditure across OECD countries. Their results support the view that economic growth leads to higher health spending. However, the study is limited by its static framework, which does not fully capture dynamic feedback effects between the variables.

In contrast, Hansen and King (1996) used cointegration techniques to re-examine the relationship between health expenditure and income in OECD countries. Their findings showed weak and unstable long-run relationships between per capita GDP and health expenditure, suggesting that the relationship may not be uniform across countries or over time. This challenged earlier findings and introduced the possibility of structural breaks and non-stationarity affecting results.

More recent panel econometric studies have strengthened the evidence for a long-run relationship. Lopreite and Mauro (2017), using European data, found a stable long-run relationship between GDP per capita and per capita health expenditure. Their results support the hypothesis that economic growth leads to increased health spending, but also indicate feedback effects in some countries, suggesting a bidirectional relationship in certain contexts.

In a broader global context, Farag et al. (2012) examined health expenditure determinants across countries and found that income remains the strongest predictor of per capita health spending. However, the study emphasized that the elasticity of health expenditure with respect to income varies significantly between low-, middle-, and high-income countries, reflecting differences in health systems, demographics, and policy priorities.

More recently, Wang et al. (2019) investigated OECD countries using panel causality and cointegration techniques and found evidence of bidirectional causality between GDP per capita and per capita health expenditure. This implies that not only does economic growth increase health spending, but rising health expenditure may also contribute to growth through improved human capital and labour productivity.

Overall, the empirical literature suggests that there is a strong and generally positive relationship between economic growth and per capita health expenditure, with income often acting as the primary driver. However, more recent studies increasingly highlight bidirectional causality, indicating that health expenditure may also contribute to economic growth through

productivity improvements. The magnitude and direction of the relationship vary depending on country income levels, institutional efficiency, demographic structure, and the methodological approach employed.

3.5 Conclusion

The theoretical and empirical literature supporting the investigation were both reviewed in this chapter. The study looked at theories such as the Preston curve hypothesis, the Human Capital theory, Health-Led Growth hypothesis, and the Endogenous Growth model. However, the functional models for this study will be constructed based on the Preston curve hypothesis and the Endogenous Growth Theory, which give an all-encompassing framework as it incorporates insights from both health-led growth hypothesis and human capital theory in conjunction with empirical literature reviewed in this chapter. Therefore, the literature evaluation supports the inclusion of the variables required in the model of this study to accomplish the goal of the study. We observed that there is yet significant gaps in the literature on the relationship between life expectancy and economic growth, despite a great deal of empirical research. The majority of studies use life expectancy as a limited indicator of population health, ignoring the complex relationships between trade openness, healthcare spending, education, and environmental quality (such as carbon emissions), all of which have an impact on economic performance and health outcomes. Furthermore, despite the fact that emerging economies such as the BRICS have different institutional settings, industrial policies, and health financing systems, comparative analyses across these nations are still rare, even though regional studies in Africa and other developing regions highlight significant structural heterogeneity. In terms of methodology, a large portion of the literature currently in publication uses static panel estimators (fixed or random effects), which are insufficient for handling endogeneity or capturing long-term equilibrium relationships. In this situation, more complex methods are rarely used, such as panel cointegration techniques as well as Dynamic Ordinary Least Squares and Fully Modified Ordinary Least Squares. Lastly, while the effect of economic growth on life expectancy is occasionally examined, few studies model the feedback effects from life expectancy to economic growth within a single long-run analytical framework, indicating that the research does not adequately account for bidirectional causality. Consequently, this study contributes to closing these gaps by investigating the long-run causal and equilibrium relationship between life expectancy and economic growth in BRICS countries, while incorporating additional structural factors such as education, trade openness, carbon emissions,

and health expenditure, by employing FMOLS and DOLS estimators. This approach provides a multidimensional and methodologically-rigorous understanding of the health–growth nexus in emerging economies.

CHAPTER FOUR

RESEARCH METHODOLOGY

4.1 Introduction

The goal in this chapter is to provide concise, intelligible descriptions of the study's methods. It involves the various model specifications which are based on the theoretical and empirical literature reviewed in the previous chapter. The chapter also discusses the modelling approach used to accomplish the goal of the study, in addition to the data description and a priori assumptions. The study adopts an ex post facto research design within a longitudinal panel data framework. The design is considered appropriate because it utilizes historical secondary data obtained from reliable database (World Bank Development Indicator) and does not involve manipulation of the study variables. The panel data approach combines cross-sectional observations from the BRICS countries (Brazil, Russia, India, China, and South Africa) with annual time-series observations spanning the period 2000–2023. This design provides a robust basis for examining the long-run relationship and causal interactions between economic growth and life expectancy while controlling for country-specific heterogeneity and temporal effects. The employs annual data. This are highly valuable in empirical research due to their availability, comparability, and suitability for long-run econometric analysis. However, they are limited by aggregation bias, measurement errors, lack of short-term variation, and potential endogeneity issues. These limitations highlight the importance of using robust econometric methods and careful interpretation of results in empirical studies. The study analysis began with descriptive statistics, graphical analysis, panel unit root tests, panel cointegration analysis, Panel Fully Modified Ordinary Least Square (FMOLS), Panel Dynamic Ordinary Least Square (DOLS), and panel causality tests to achieve the study objectives.

This chapter presents the methodology adopted for the study. It describes the procedures and techniques employed in achieving the study's objectives and testing the formulated hypotheses. Specifically, the chapter discusses the research design, research approach, sources and nature of the data, model specification, variable measurement, and estimation techniques. The methodological framework is informed by the theoretical and empirical literature reviewed in the preceding chapter.

The study adopts an ex post facto research design within a quantitative research framework. This design is considered appropriate because it relies on historical secondary data and does not involve manipulation of the study variables. The analysis is based on panel data comprising annual observations for the BRICS (Brazil, Russia, India, China, and South Africa) countries covering the period 2000 to 2023. The use of panel data provides the advantage of combining both cross-sectional and time-series dimensions, thereby enhancing the robustness of the analysis and allowing for the control of country-specific heterogeneity.

To achieve the study objectives, the analysis proceeds through a sequence of econometric procedures. These include descriptive statistics, graphical analysis, panel unit root tests, panel cointegration analysis, Panel Fully Modified Ordinary Least Squares (FMOLS), Panel Dynamic Ordinary Least Squares (DOLS), and panel causality tests. The chapter concludes with a discussion of the diagnostic procedures employed to ensure the reliability and validity of the empirical results.

4.2 Model Formulation

This study will estimate the life expectancy model as well as the economic growth model. the models are estimated so observed interrelationship existing between the two variables and the causality test would determine the direction of causation. The empirical models of this current study are thus specified in section 4.2.1 and 4.2.2 respectively

4.2.1 Life Expectancy Model (MODEL 1)

The empirical model of Jetter et al. (2019) and the Preston curve hypothesis (1975) served as the theoretical foundation for this investigation. Jetter et al. (2019) developed a panel empirical technique that recognised the basic assumption of the Preston curve using a multiple regression approach. They regressed life expectancy in years on linear, quadratic, and cubic terms of GDP

per capita. The Preston curve is an empirical connection that shows the impact of real per capita income on life expectancy. The Preston curve expressed mathematically is as follows:

$LEXP = \alpha + \beta \log (GDPPC)$ 1.0

Where LEXP represents Life Expectancy while GDPPC represent Gross Domestic Product Per Capita.

While the functional model of Jetter et al. (2019), which estimates the amount of variance in life expectancy that can be accounted for by income levels alone is shown as follows:

$$LE_{i,t} = \beta_0 + \beta_1 \left(\frac{GDP}{cap}\right)_{it} + \beta_2 \left(\frac{GDP}{cap}\right)^2_{it} + \beta_3 \left(\frac{GDP}{cap}\right)^3_{it} + \delta_i + X_{it}\beta_4 + \vartheta_i + \omega_{it} + \epsilon_{it} \quad \ldots 1.1$$

The above model is specified with life expectancy $LE_{i,t}$ as the dependent variable while linear, quadratic, and cubic terms of GDP per capita are the independent variables, (δi) represents the country-fixed effect, (X_{it}) measures the population size and conflict incidence. The time-fixed effects is captured by (ϑ_i), country-specific time trends are represented by (ω_{it}), and ϵ_{it} is the error term.

It is worth noting that both the Preston curve (1975) and Jetter et al. (2019) expressed life expectancy as the function of economic growth (Income). This study however follows a multivariate model therefore to modify our adopted model, this current study adopts variables found to impact life expectancy, from the empirical work of Mahumud et al.,(2013) and Agheli and Emamgholipour (2015) among others, such as number of physicians per 1000 population (PHY) instead of number of doctors per 10,000 population, School enrolment, Secondary (SES) as a proxy for education, health expenditures per capita (HEPC), CO_2 Emission (CO_2), and a measure of globalization (TRADE) is added to this model.

The modified functional model of this current study is thus specified as:

$LEXP_{it} = f (GDPPC_{it}, SES_{it} TRADE_{it}, PHY_{it}, CO2it, HEPC_{it})$ 1.2

Our study employs the panel data method, wherein the same cross-sectional unit is examined over time (Gujarati, 2004). The normal panel data form is specified as:

$$y_{it} = \alpha_i + \beta X_{it} + \epsilon_{it} \quad 1.3$$

Where y is the dependent variable (i.e. life expectancy at birth)

i represents the cross-sectional units (country)

X_{it} represent the independent variables (explanatory variables)

μ_{it} represent the error term

Using logarithmic transformation of the variables is empirically justified, as it helps to stabilize variance, correct for skewness, and produce more robust parameter estimates in panel econometric models. Prior empirical studies such as Pedroni (2001) and Baltagi (2013) demonstrate that log-transformed series improve model fit by linearizing multiplicative relationships and reducing the influence of extreme values. Additionally, the use of logged variables allows the coefficients to be interpreted as elasticities, which is widely adopted in growth and development literature to capture proportional changes rather than absolute effects.

Therefore, the logarithmic form of the above model is specified as in equation 1.4 so as to explain the results as elasticity.

$$LLEXP_{i,t} = \beta_0 + \beta_1 LGDPPC_{i,t} + \beta_2 LSES_{i,t} + \beta_3 \mathrm{LTRADE}_{i,t} + \beta_{41} \mathrm{LPHY}_{i,t} + \beta_5 \mathrm{LCO2}_{i,t} + \beta_6 \mathrm{LHEPC}_{i,t} + \epsilon_{i,t} \quad 1.4$$

Where

LLEXP is the dependent variable (life Expectancy at birth)

i = individual units and t represents time

β_0 = the equation intercept

β_1 = the coefficient estimates of (**GDPPC)**

β_2 = the coefficient estimates of **(SES)**

β_3 = the coefficient estimates of **(TRADE)**

β_4 = the coefficient estimates of **(PHY),**

β_5 = the coefficient estimates of (**CO_2)**

β_6 = the coefficient estimates of **(HEPC)** and ϵ represent the error term

4.2.2 Economic Growth Model (Model 2)

This model is built based on the endogenous growth theory as an all-encompassing framework, as it incorporates insights from both the health-led growth hypothesis and human capital theory. Endogenous growth models emphasis the role of internal factors such as knowledge spill over, human capital accumulation, and health improvements, in sustaining long-run economic growth. Within this framework, health and education are viewed as complementary forms of human capital that enhance labour productivity and innovation capacity (Romer, 1986; Lucas, 1988; Bloom & Canning, 2000). Accordingly, the model specifies economic growth as a multivariate function of life expectancy, education, health expenditure, gross fixed capital formation and carbon emissions (CO_2), consistent with the human-capital-augmented endogenous growth paradigm. On basis of the endogenous growth theory and the empirical works of Ogunleye and Owolabi (2017), and Lawanson and Umar (2021).

The modified functional model for the study is thus specified and restated as below:

$LGDPPC_{it} = f(LEXP_{it}, SES_{it,} CGFCF_{it}, CO_{2it}, HEPC_{it})$ 1.5

Using logarithmic transformation of the variables is empirically justified, as it helps to stabilize variance, correct for skewness, and produce more robust parameter estimates in panel econometric models. Prior empirical studies such as Pedroni (2001) and Baltagi (2013) demonstrate that log-transformed series improve model fit by linearizing multiplicative relationships and reducing the influence of extreme values. Additionally, the use of logged variables allows the coefficients to be interpreted as elasticities, which is widely adopted in growth and development literature to capture proportional changes rather than absolute effects. We therefore specify the logarithmic form of the above model as:

$$GDPPC_{i,t} = \beta_0 + \beta_1 LLEXP_{i,t} + \beta_2 LSES_{i,t} + \beta_3 \mathrm{LGFCF}_{i,t} + \beta_4 \mathrm{LCO2}_{i,t} + \beta_5 \mathrm{LHEPC}_{i,t} + \epsilon_{i,t} \quad 1.6$$

Here i = represent individual units while t = time

β_0 = the equation intercept

β_1 = the coefficient estimates of (**LEXP)**

β_2 = the coefficient estimates of **(SES)**

β_3 = the coefficient estimates of **(CGFCF),**

β_4 = the coefficient estimates of (**CO_2)**

β_5= the coefficient estimates of **(HEPC)**

ϵ = represent the error term

4.3 Data Source/A priori Expectation/Data description.

This study utilizes secondary data obtained from the World Bank's World Development Indicators (WDI) database. The data consist of annual panel observations for the BRICS countries. The period 2000–2023. The WDI database was selected due to its reliability, comprehensive coverage, and provision of standardized and internationally comparable macroeconomic and development indicators.

The use of annual panel data combines cross-sectional and time-series dimensions, making it suitable for examining long-run relationships and causal interactions among the study variables. Panel data improve estimation efficiency, increase the number of observations, and allow researchers to control for unobserved country-specific heterogeneity, thereby enhancing the robustness of empirical findings (Baltagi, 2008). However, annual secondary data may be affected by aggregation bias, measurement errors, missing observations, and limited capacity to capture short-term fluctuations. Despite these limitations, their consistency, comparability, and extensive coverage make them appropriate for achieving the objectives of this study, while robust econometric techniques are employed to ensure the reliability and validity of the empirical results.

The a priori expectation indicates the expected sign of the variables included in the two models of this study. The signs implies the relationship existing between the dependent and independent variables of the models

Table 4.1: Data Source/A priori Expectation/Data description.

VARIABLES	DESCRIPTION	UNIT OF MEASUREMENT	SOURCE	A PRIORI EXPECTATION
LLEXP	Life expectancy at birth	Total (years)	WBD Indicators	+ (Positive) Model 2
LGDPPC	GDP Per Capita	Annual data measured in current international dollars	WBD Indicators	+ (Positive) Model 1
LSES.	School enrolment, secondary (Education)		WBD Indicators	+ (Positive) MODEL 1&2
LTRADE	Trade (% of GDP)	Annual data measured as a share of gross domestic product	WBD Indicators	+ (Positive) MODEL 1&2
LPHY	Physician per 1000 people	Per 1,000 live births	WBD Indicators	+ (Positive) Model 1
LCO2	CO_2 Emission	Carbon dioxide emission	WBD Indicators	-(Negative) MODEL 1&2

LHEPC	Current Health expenditure per capita	Measured in current US dollars	WBD Indicators	+(Positive) MODEL 1&2
GFCF	Gross fixed capital formation	Current US dollars	WBD Indicator	+(Positive) Model 1B

Source: Author's design based on literature. Authors' Design

Data sourced from World Bank development indicator

4.4 Estimation Technique

The Panel cointegration technique, Fully Modified Ordinary Least Squares and Dynamic Ordinary Least Square are employed in this study. The panel cointegration approach is appropriate for this study, in order to overcome erroneous result usually associated with non-stationary macroeconomics variables. It will reveal if these variables have long-run relationship (Pedroni, 2004). Kao (1999) noted that this technique has the ability to improve the reliability and power of inference by exploiting the time series and cross-section dimensions of the data. Westerlund (2007) further observed that both cross-sectional dependence and heterogeneity are accounted for in this test. Studies such as Adewuyi and Awodumi (2020) and Atil et al. (2021) revealed the robustness of these technique.

Upon confirmation cointegration, the FMOLS and DOLS are the next suitable techniques employed in this study to generate unbiased long-run coefficients. FMOLS particularly accounts for both serial correlation and endogeneity issues, which is usually the case with cointegrated regression, thus it provides reliable and efficient parameter estimates (Pedroni, 2000). Shahbaz et al. (2019) demonstrated empirically that this estimator is effective in generating a robust long-run relationship. On the other hand, DOLS adds leads and lags that help to remove feedback effects between residuals and regressors, thus complementing FMOLS (Stock & Watson, 1993). Mark and Sul (2003) observed that this estimator is best for small samples and heterogeneous panels.

The process involved in this techniques begins by obtaining the descriptive statistics, a visual evaluation of the variables, then the unit root test (Levin et al. and Im Persaran unit root tests).

Panel cointegration test is performed to ascertain the long-run relationship of the variables, after which the panel FMOLS and DOLS are utilised to obtain the long term coefficients of the variables. These will be immediately followed by the panel causality test. The modelling strategy is summarized in the flow chart:

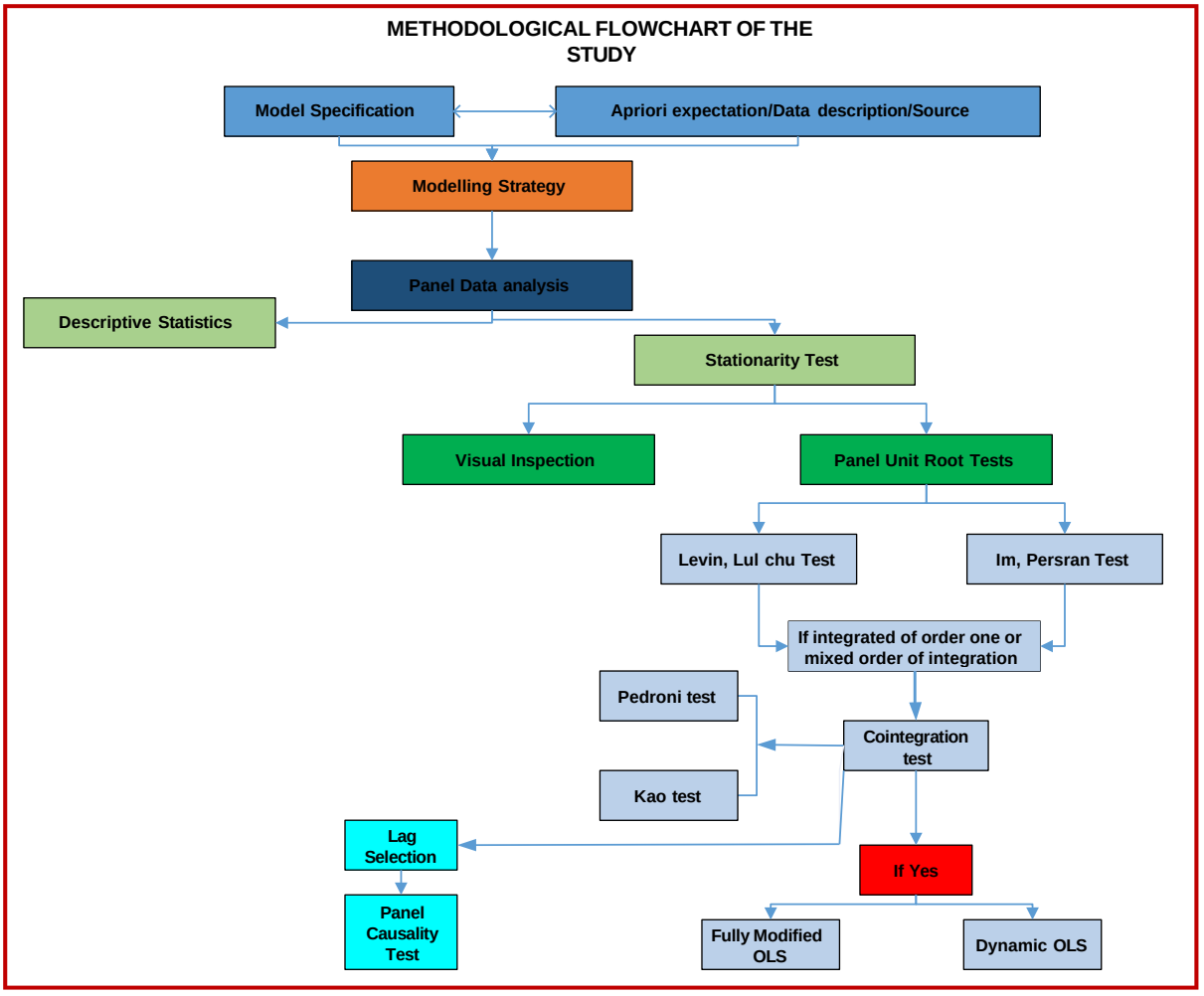


Figure 4.1: Flow chart of Estimation Techniques

Source: Oche and Mah (2020).

The pooled OLS, fixed effect, and random effect models will be used to estimate the regression model if the unit root test findings indicate that the variables are integrated of order zero (I(0)), or that they are stationary at their level. The Hausman test will be used to evaluate the fixed effect and random effect models in order to determine the best model. The fixed effect model is the proper model in this situation if the null hypothesis – which states that there is no

association between the regressors and the fixed effects – is rejected. Nonetheless, the F-test will be used to compare the fixed effect model with the pooled OLS.

4.4.1 Descriptive Statistics

According to Mahadeva and Robinson (2004), acquiring the variables' descriptive statistics is a smart place to start when performing econometric analysis. The mean, median, standard deviation, kurtosis, and data skewness are examples of descriptive statistics. The quantitative form of the data is summarised using descriptive statistics. Thus, this part examines the time series features of the variables before examining the link between the independent factors and the dependent variable (life expectancy at birth).

4.4.2. Visual Investigation of the Variables

This visual inspection involves graphical presentation of the variables that enables easy assessment of the series for stationarity (Rachev et al., 2010). It shows how the series moves around the covariance and the mean. This is a preliminary test of stationarity, hence there is the need for a proper stationarity test that will show at what level the variable is stationary.

4.4.3 Panel Unit Root Test

Gujarati and Porter (2009) state that a regression model estimated using non-stationary data may yield falsely high t-, F-, and R^2 statistics, which could result in erroneous conclusions and findings. Before estimating any regression model, it is crucial to confirm that the variables' time-series characteristics are stationary, in order to prevent such econometric mistakes. Because spurious regression occurs when non-stationary variables in their levels are regressed against one another, producing statistically significant but economically nonsensical associations, conducting unit root tests becomes an essential first step. According to Baltagi (2009), panel data differs from pure time-series data because it incorporates both cross-sectional and temporal variability, even though panel estimators can be consistent when the cross-sectional dimension (N) is small and the time dimension (T) goes to infinity. As a result, checking panel datasets for stationarity serves as a foundation for further cointegration analysis in addition to protecting against erroneous correlations. There are two types of panel unit root testing: homogeneous and heterogeneous. Unlike heterogeneous panels, which could assume a

separate unit root process, homogeneous panels share the same unit root process for the cross-section.

To ascertain whether or not the variables are stationary, this study employed two first generation panel unit root tests, the IPS (Im et al., 2003) and Levin et al. (2002). LLC assumes a homogeneous slope coefficient for each unit in the panel, but IPS, sometimes called the heterogeneity panel unit root test, permits the slope coefficients to be heterogeneous even when both tests permit heterogeneity in the intercept across panel members.

4.4.3.1 Levin-Lin-Chu (LLC) unit root test

This test assumes that all units within a panel share a common slope coefficient. It represents one of the earliest forms of unit root tests for panel data. Given that traditional individual unit root tests have limited power against the alternative hypothesis, Levin et al. (2002) proposed a panel unit root test, which is more effective when the ρi is negative and identical across units. The procedure begins by estimating the Augmented Dickey-Fuller (ADF) regression for each cross-sectional unit, expressed as:

$$\Delta y_{it} = \rho_i y_{i,t-1} + \sum_{i=1}^{\rho i} \varphi_{i,l} \Delta y_{i,t-L} + \alpha_i d_{it} + \varepsilon_{it}$$

The above ADF equation is applied individually to each cross-section unit

While αi denotes the vector of the model's coefficients, d_{it} represents the vector of the deterministic variable. A value of $\rho_i < 0$ suggests that the process is stationary around the deterministic component, whereas $\rho_i = 0$ implies the presence of a unit root in the y process for individual i. Accordingly, the hypotheses are stated as follows: the null hypothesis (H_0: $\rho_i = 0$) indicates the existence of a unit root, and the alternative hypothesis (H_1: $\rho_i < 0$) suggests stationarity.

Decision Rule: If the p-value of the statistics is less than 5% at the 5% significance level, we reject the null hypothesis and accept the alternative hypothesis; if it is more than 5%, we cannot reject the null hypothesis, indicating that a unit root is present in the series.

4.4.3.2 The Im, Pesaran, and Shin unit root test (IPS test)

To determine if a unit root of our series exists, the study equally use the IPS (Im et al., 2003) test. Compared to LLC test, this examination is simpler. For heterogeneous panels, it is the

most-used unit root test. As a result, differences in the intercept and slope coefficients among the units of the panel are permitted. Serial correlation and cross-section dependency in the mistakes are permitted by the test. Hoang and McNown (2006) state that the panel specifics results are obtained by combining the results of the separate unit root tests. It is based on the averages of the ADF tests calculated for each cross-section unit. All of the data is effectively subjected to the enhanced Dickey–Fuller (1979) test, despite the fact that each data cross-section is meant to be independent. Therefore, the null hypothesis is investigated by combining the wide sample distribution of the t-statistics. The LLC unit root test's extremely low power needs are managed by the IPS. Studies by Im et al. (2003), Maddala and Wu (1999), O'Connell (1998), and Jonsson (2005) have demonstrated that the Levin, Lin, and Chu (LLC) unit root test generally possesses lower power compared to the Im, Pesaran, and Shin (IPS) test. As previously discussed, the IPS test considers the average of individual Augmented Dickey-Fuller (ADF) statistics, particularly in cases where ε_{it} exhibits serial correlation across cross-sectional units.

Since both IPS and LLC have the same starting point, the equation is replicated below:

$$\Delta y_{it} = \rho_i y_{i,t-1} + \sum_{i=1}^{\rho i} \varphi_{i,l} \Delta y_{i,t-L} + \alpha_i d_{it} + \varepsilon_{it}$$

Null Hypothesis: H_0: $\rho i = 0$: individual series has unit root for all cross-sections

The alternative hypothesis, on the other hand, allows for the presence of unit roots in some cross-sections.

$$H_1 : \begin{cases} \rho_i < 0 \; for \; i = 1,2, \dots N_1 \\ \rho_i = 0 \; for \; i = N_1 + 1, \dots, N \end{cases}$$

A fraction of the cross-sectional series that are stationary (i.e., do not contain a unit root) must be greater than zero but not exceed one. That is, $\lim_{N\to\infty} (N_1 / N) = \delta, but \; 0 < \delta \leq 1$.

This implies that as the number of cross-sectional units (N) approaches infinity, the proportion (δ) of stationary series remains positive and less than or equal to one.

This condition is crucial, as it ensures the consistency of the panel unit root test. The IPS *t*-statistic represents the average of the individual ADF *t*-statistics and is expressed as: $\bar{t} = \frac{1}{N} \sum_{i=0}^{N} t\rho_i$. $t\rho_i$ denotes the ADF statistics used to test the null hypothesis $H_0 : \rho_i = 0$ for each individual cross-section series in the above equation.

In general, when ρ_i is not zero for the cross-section, IPS indicates that $\bar{t}$ will have an asymptotic N (0,1) distribution.

Decision Rule:

The null hypothesis is accepted at the 5% significant level if the statistics' p-value is more than the 5% level, but if it is less than the 5% level, the alternative hypothesis is accepted, and the series is regarded as stationary for a certain cross-section. It is worth noting that rejecting the null hypothesis does not imply rejection of unit root for all cross-section units. Rather, it is rejected for some cross-section units. Furthermore, the test does not reveal the identities of those cross-sections with unit roots.

4.4.4 Panel Cointegration Test

Although there are many tests for panel cointegration, the Pedroni test is the most popular. It can be performed with or without a constant and/or time trend (and for homogeneous or heterogeneous panels). Other tests for panel cointegration include Kao (residual based), Johansen Fisher-based (combines p-values for the Johansen's test for different cross-section units; akin to the Maddala-Wu test for panel unit roots) and Westerlund. However, for the purpose of this current study, the Pedroni and Kao tests will be used.

4.4.4.1 Pedroni Test of Cointegration

In this study, the existence of a long-run equilibrium relationship among the variables is verified using the Pedroni's panel cointegration approach (Pedroni, 1999; 2004) which extends the residual-based panel cointegration test initially proposed by Pedroni (1995). This method allows for the inclusion of multiple regressors, and evaluates the null hypothesis of no cointegration among the variables through seven residual-based test statistics.

The first four statistics – panel-v, panel-ρ, semi-parametric panel-t, and parametric panel-t – are based on within-dimension estimations that sum the numerator and denominator separately across cross-sectional units. The remaining three tests – semi-parametric group-t, parametric group-t, and group-ρ – are based on between-dimension estimations, computed by dividing the denominator by the numerator and then summing across cross-sections. Overall, the Pedroni (1999; 2004) panel cointegration test relies on the residuals obtained from the estimated

cointegrating regression, to determine whether a long-run relationship exists among the variables.

$y_{i,t} = \delta 0i + \delta 1i,t + x'i,t\beta i + ei,t,$

$i = 1\ldots, N; t = 1\ldots, T$, where N is the number of panel members and T is the total number of observations across time. The trend parameter ($\delta 0i$) and the individual specific intercept ($\delta 1it$) may fluctuate over cross-sections. The K-dimensional vector of exogenous variables, $xit = xi,t-1 + vit$, and yit, are assumed to be integrated of order one. Additionally, it is assumed that the error process $wit = (eit, v'it)'$ has an independent distribution. For a cross-section, the cointegrating vector $\beta i = (\beta 1i\ldots \beta Ki)'$ may likewise change. It is interesting to note that, according to the ADF analysis, one of the four within-dimension statistics is parametric, whereas the other three are non-parametric adjustments. Three tests make up the second category: two are non-parametric adjustments and one is a parametric test based on the ADF-test. Pedroni (2000, 2004) provided several tests to examine the null hypothesis of no cointegration in a model that includes a measure of heterogeneity. A list of them is provided below:

1. Panel υ-Statistic: $T^2 N^{3/2} Z_{\hat{v}N,T} \equiv T^2 N^{3/2} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} e_{i,t-1}^2\right)^{-1}$

2. Panel ρ-Statistic:

$$T\sqrt{N}Z_{\hat{\rho}N,T-1} \equiv T\sqrt{N}\left(\sum_{i=1}^{N} \sum_{t=1}^{N} \hat{L}_{11i}^{-2} e_{i,t-1}^2\right)^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \left(\hat{e}_{i,t-1}\Delta\hat{e}_{i,t} - \hat{\lambda}_i\right)$$

3. Panel t- Statistic (non-parametric):

$$Z_{t_{N,T}} \equiv \left(\tilde{\sigma}_{N,T}^2 \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} e_{i,t-1}^2\right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \left(\hat{e}_{i,t-1}\Delta\hat{e}_{i,t} - \hat{\lambda}_i\right)$$

4. Panel t- Statistic (parametric):

$$Z^*_{t_{N,T}} \equiv \left(S_{N,T}^{*2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} e_{i,t-1}^{*2}\right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} e_{i,t-1}^{*} \Delta e_{i,t}^{*}$$

5. Group ρ-Statistic:

$$TN^{-1/2}\tilde{Z}_{\hat{\rho}N,T-1} \equiv TN^{-1/2} \sum_{i=1}^{N} \left(\sum_{t=1}^{T} \hat{e}_{i,t-1}^2\right)^{-1} \sum_{t=1}^{T} \left(\hat{e}_{i,t-1}\Delta_{\hat{e}_{i,t}-\hat{\lambda}_i}\right)$$

6. Group t-Statistic (non-parametric):

$$N^{-1/2}\tilde{Z}_{t_{N,T}} \equiv N^{-1/2} \sum_{i=1}^{N} \left(\hat{\sigma}_i^2 \sum_{t=1}^{T} \hat{e}_{i,t-1}^2\right)^{-1/2} \sum_{t=1}^{T} \left(\hat{e}_{i,t-1}\Delta_{\hat{e}_{i,t}-\hat{\lambda}_i}\right)$$

7. Group t-Statistic (parametric):

$$N^{-\frac{1}{2}}\tilde{Z}^{*}_{t\,N,T} \equiv N^{-\frac{1}{2}}\sum_{i=1}^{N}\left(\sum_{t=1}^{T} s^{*2}_{i,} e^{*2}_{i,t-1}\right)^{-1}\sum_{t=1}^{T} e^{*}_{i,t-1}\,\Delta e^{*}_{i,t}$$

Wherein,

$$\hat{\lambda}_i = \frac{1}{T}\sum_{s=1}^{g_i}\left(1-\frac{s}{K_i+1}\right)\sum_{t=s+1}^{T}\hat{\mu}_{i,}\hat{\mu}_{i,t-s}\,,\quad s^{2}_{i} \equiv \frac{1}{T}\sum_{t-1}^{T}\mu^{2}_{i,t}\,,\quad \sigma^{2}_{i} = s^{2}_{i} + 2\hat{\lambda}_{i},\quad \sigma^{2}_{N,T}$$
$$\equiv \frac{1}{N}\sum_{i=1}^{N} L^{-2}_{11i}\,\sigma^{2}_{i}$$

$$s^{*2}_{i} \equiv \frac{1}{t}\sum_{t=1}^{T}\hat{\mu}^{*2}_{i,t}, s^{*2}_{N,T} \equiv \frac{1}{N}\sum_{i=1}^{N} s^{*2}_{i}\,,\quad L^{2}_{11i} = \frac{1}{T}\sum_{t=1}^{T}\hat{\eta}^{2}_{i,t} + \frac{2}{T}\sum_{s=1}^{g_i}\left(1-\frac{s}{k_i+1}\right)\sum_{t=s+1}^{T}\hat{\eta}_{i,t}\hat{\eta}_{i,t-s}$$

But the residuals $\hat{\mu}_{i,t}, \hat{\mu}^{*}_{i,t}$ and $\hat{\eta}_{i,t}$ are obtained from the regressions stated as follow:

$$\hat{e}_{i,t} = \hat{\gamma}_i \hat{e}_{i,t-1} + \hat{\mu}_{i,t},\ \hat{e}_{i,t} = \hat{\gamma}_i \hat{e}_{i,t-1} + \sum_{g=1}^{g_i}\hat{\gamma}_{i,g}\Delta\hat{e}_{i,t-g} + \hat{u}^{*}_{i,t}\,,\ \Delta y_{i,t} = \sum_{m=1}^{M}\hat{b}_{mi}\Delta x_{mi,t} + \hat{\eta}_{i,t}$$

Decision Rule

The null hypothesis of no cointegration is retained when the p-value exceeds the 5% significance level. Conversely, the alternative hypothesis indicating the presence of cointegration is accepted when the p-value falls below the chosen significance threshold. Additionally, if most of the tests favour the alternative, we may conclude that cointegration occurs, in contrast to the null hypothesis that it does not. Given the large number of regressors in this study, the Pedroni test of cointegration is crucial, because it clarifies the null hypothesis, that there is no cointegration in both homogeneous and heterogeneous panels of multivariate relationships. This will lessen the likelihood of false estimation.

4.4.4.2 Kao test of cointegration

The Kao cointegration test is employed in this study to confirm the existence of a long-run relationship among the variables. It is a residual-based test that extends the Engle and Granger (1987) cointegration methodology, originally developed for time series data, to panel data

analysis. Similar to the Pedroni (2000, 2004) test, it examines whether the residuals from non-

stationary series are stationary. Specifically, two series are considered cointegrated when the residuals of two I(1) variables are integrated of order zero, I(0).

While the Kao and Pedroni tests share a comparable residual-based framework, they differ in that the Kao test assumes homogeneity in the slope coefficients and individual-specific intercepts across the cross-sections**.** The Kao test is derived from a spurious least squares dummy variable (LSDV) panel regression model with a single regressor, expressed as:

$y_{it} = \alpha_i + x_{it}\beta + e_{it}$, i = 1, . . ., N; t = 1, . . ., T,

In this equation, the slope coefficient, β, is assumed to be homogenous across the cross-section while the intercept, α_i, is heterogeneous. The error term e_{it}, along with y_{it} and x_i, is integrated of order one [I(1)].$_t$. The Kao test employs both the Dickey-Fuller and ADF procedures to assess cointegration, using the following test equations:

$$DF_\rho = \frac{\sqrt{NT}(\rho\hat{}-1)+3\sqrt{N}}{\sqrt{10.2}}$$

$$DF_t = \sqrt{1.25.\, t_\rho + \sqrt{1.875N}}$$

$$DF_\rho^* = \frac{\sqrt{NT}(\rho\hat{}-1)+\frac{3\sqrt{N\sigma\hat{}_v^2}}{\sigma\hat{}_{ov}^2}}{\sqrt{3+\frac{36\sigma\hat{}_v^4}{5\sigma\hat{}_{ov}^4}}}$$

$$DF_t^* = \frac{t_\rho+\frac{\sqrt{6N\sigma\hat{}_v^2}}{2\sigma\hat{}_{ov}}}{\sqrt{\frac{\sigma\hat{}_{ov}^2}{\sigma\hat{}_v^2}+\frac{3\sigma\hat{}_v^2}{10\sigma\hat{}_{ov}^2}}}$$

From the above equations, $\sigma\hat{}_v^2 = \hat{\Sigma}_{yy} - \hat{\Sigma}_{yx}\hat{\Sigma}_{xx}^{-1}$, $\sigma\hat{}_{ov}^2 = \hat{\Omega}_{yy} - \hat{\Omega}_{yx}\hat{\Omega}_{xx}^{-1}$ where $\hat{\Sigma}$ represents the estimator of long-run covariance of $\xi_{it} = (\Delta y_{it}, \Delta x_{it}')'$, and $\hat{\Omega}$ denotes the estimator of contemporaneous covariance of $\xi_{it} = (\Delta y_{it}, \Delta_i x_t')'$. DF_ρ and DF_t are derived under the assumption of strong exogeneity between the independent variables and the error term, whereas DF_ρ^* and DF_t^* are based on a cointegrating relationship, with an endogenous relationship amongst independent variables and the error term.

The ADF test is estimated from the regression below:

$$e\hat{}_{it} = pe\hat{}_{i,t-1} + \sum_{j=1}^{p} \delta_j \Delta e\hat{}_{i,t-j} + v_{it}$$

To test the null hypothesis of no cointegration, the ADF test statistics is estimated as:

$$ADF = \frac{t_{ADF} + \frac{\sqrt{6N}\hat{\sigma}_V}{2\hat{\sigma}_{OV}}}{\sqrt{\hat{\sigma}^2} \sqrt{\frac{\hat{\sigma}_{OV}}{2\hat{\sigma}_V^2} + \frac{\hat{\sigma}_V^2}{10\hat{\sigma}_{OV}^2}}}$$

t_{ADF} is the t-statistic of ρ in the above equation. The asymptotic distributions of DF_ρ, DF_t, DF_ρ^*, DF_t^* and ADF converges to a standard normal distribution N (0,1) by sequential limit theory.

Decision Rule:

The decision criterion is based on a 5% significance level. Thus, if the p-value of the Kao ADF statistic exceeds 0.05, the null hypothesis of no cointegration cannot be rejected. Conversely, if the p-value is below the 5% threshold, the null hypothesis is rejected in favour of the alternative, indicating the presence of a long-run relationship among the variables.

4.4.5 Panel Fully Modified OLS (FMOLS) And Dynamic OLS (DOLS)

An important preliminary step in estimating the long-run parameters is to determine whether the variables are cointegrated. Once cointegration is established, the long-run relationships will be estimated using Panel Dynamic Ordinary Least Squares (DOLS) and Panel Fully Modified Ordinary Least Squares (FMOLS) methods. These estimators can manage the endogeneity, serial correlation, and heteroscedasticity of the residuals in traditional pooled ordinary least square (OLS) which are commonly observed in long-run equilibrium (Kao and Chiang, 2000). Asymptotically unbiased and regularly distributed coefficient estimates are produced by the estimators (Pedroni, 2002; Kao and Chiang, 2000). These estimators are discussed in the next section.

4.4.5.1 Panel Dynamic Ordinary Least Square (DOLS)

Unlike FMOLS, this estimator is parametric. According to Arize *et al*. (2000) endogeneity is accounted for in panel dynamics OLS with addition of leads and lags. However, this approach reduces the degrees of freedom, which is one of the limitations of the DOLS method. The DOLS estimator is expressed as: $y_{it} = \alpha_i + \beta_i x_{it} + \Sigma_{k=q}^{q} c_{ik} \Delta X_{it+k} + \mu_{it}$;

t=1,...T i= 1...N

where α_{it} and C_{ik} , the disturbance terms denoted by μi_t, ought to be integrated of order zero, or [I(0)], are the coefficients of leads and lags of the first difference of independent variables, respectively, and country-specific effects.

According to Pedroni (2004), the DOLS parameter estimate is specified as below:

$$\beta^*_{i,DOLS} = \lfloor N^{-1} \sum_{i=1}^{N} (\sum_{t=1}^{T} Z_{it} Z`_{it}) (\sum_{t=1}^{T} Z_{it} y^*_{it}) \rfloor$$

Zit = (xit - $\bar{x}_{it}, \Delta x_{it-k}, \ldots \Delta x_{it+k}$ is the 2(k+1)*1. This equation measures the vector of the independent variables.

Decision Rule:

If the p-value of a coefficient is less than the 5% significance level, it indicates that the variable has a significant effect on the dependent variable. Conversely, if the p-value exceeds the 5% level, the variable is considered insignificant in explaining changes in the dependent variable.

4.4.5.2 Fully Modified Ordinary Least Square (FMOLS)

The fully modified OLS is a non-parametric estimator that takes endogeneity and bias issues into consideration. Due the non-parametric nature of the FMOLS, any correlation between the disturbance term and the first differences of the regressors is taken into consideration. To properly account for the serial correlation problem, it admits the existence of a constant term. The Panel Fully Modified OLS can be traced back to Pedroni's (2000) and Phillips and Hasen's (1999) studies. It is analogous to Phillips and Hasen's (1990) FMOLS in time series. This is explained given the following equation:

$$\beta^*_{i\,FM} = [\sum_{i=1}^{N} \sum_{i=1}^{T} (x_{it}\text{-}x\check{}\text{i})2] \text{-}1 \, [\sum_{i=1}^{N} (\sum_{i=1}^{T} (x_{it}\text{-}x\check{}\text{i}) \, y^*_{it} - T\Delta\text{^*i}\,\epsilon u)]$$

Where $\Delta\text{^*}\, i\epsilon u = \Omega_{i\epsilon}^{-\frac{1}{2}} \hat{\Delta}\, i\epsilon u + \hat{\Omega}\text{i}u.\epsilon\text{-}1/2$

y it is transformed as $y^*_{it} = (x_{it} - y\check{}_i) - \frac{\check{}_{2L_{1u}}}{\check{}_{L_{21l}}} \Delta x_{it}$ to correct for endogeneity problems in the series.

Any tendency of serial correlation is accounted for with the following:

$$\Delta\text{^+}_{i\epsilon u} = (\Delta\text{^}_{i\epsilon u}, \Delta\text{^}_{i\epsilon})\begin{pmatrix} 1 \\ -\hat{\Omega}_{i\epsilon}^{-1}\hat{\Omega}_{i\epsilon u} \end{pmatrix} = \Delta\text{^}_{i\epsilon u} - \Delta\text{^}_{i\epsilon}\hat{\Omega}^{-1}_{i\epsilon}\hat{\Omega}_{i\epsilon u}.$$

According to Kao and Chiang (2002), the long-run covariance matrix is explained as:

$$\Sigma_{j=0}^{\infty} E(w_{ij}\, w_{i0}/)$$

$$= \Sigma + \Gamma + \Gamma\sqrt{}$$

$$= \begin{bmatrix} \Omega_{u} & \Omega_{u\epsilon} \\ \Omega_{\epsilon u} & \Omega_{\epsilon} \end{bmatrix}$$

Decision Rule:

If the p-value of the coefficient is below the 5% significance level, then we conclude that the variable is statistically significant in impacting the dependent variable. The reverse will be the case if the p-value is greater than the 5% level of significance.

4.4.6 Panel Granger Causality

To assess the life expectancy-led growth and growth-driven life expectancy hypotheses, this study will go on to investigate the causal relationships between life expectancy and economic growth in the BRICS nations. For this, the Granger causality tests in heterogeneous panels proposed by Dumitrescu and Hurlin (2012) will be used. This is because the test takes into consideration the cross-section's heterogeneity. It is important to note that disregarding the heterogeneity of cross-sections might result in inaccurate or misleading findings, assuming that every unit has a causal link, while in reality, only a portion of the cross-section has a causal link. It could also reject the existence of a causal link for all the cross-sections, while it is present in at least one of the cross-sections, as observed by Hurlin and Venet (2005).

The homogeneous non-causality (HNC) hypothesis, which holds that there is no causal link between two variables for all the cross-sections of the panel, is tested first in this technique.

However, under the alternative hypothesis, Dumitrescu and Hurlin (2012) assume that there is causation between the variables for (N-N1) of the panel's cross-sections but not for some of the cross-sections, N1, of the panel. The suggested test structure is similar to the heterogeneous panel unit root test presented by Im, Pesaran, and Shin (2003). Therefore, they propose the following model to investigate causality between stationary x and y variables:

$$y_{i,t} = \alpha_i + \sum_{k=1}^{k} \lambda_i^{(\kappa)} y_{i,t-k} + \sum_{k=1}^{k} \varphi_i^{(k)} x_{i,t-k} + \upsilon_{i,t}$$

From the model, K is the order of lag and for all the cross sections; it is the same for balanced panel; i=1, 2…, N; $\lambda_i^{(\kappa)}$ and $\varphi_i^{(k)}$ represent the autoregressive parameter and slope of the regression coefficient. They vary for the cross-sections but are constant over time in a fixed individual effects and fixed coefficients model.

Also, the null hypothesis of the homogeneous non-causality is specified as:

$H0 = \varphi_i = 0, \ \forall_i = 1,2, \dots, N$

Here, $\varphi_i = (\varphi_i^{(1)}, \varphi_i^{(2)}, \dots, \varphi_i^{(k)}$

In the null hypothesis, all the cross-sections have no causality.

Nonetheless, in the alternative hypothesis, in a subset of the cross-section with dimension N1, the x variable does not Granger-cause the y variable, while in another subset of dimension (N-N_1) of the cross-section of the panel, the x variable Granger-causes the y variable, as one of the regression slope coefficients related with $x_{,i,t-k}$ is statistically different from zero.

H1: $\varphi_i = 0, \ \forall_i \ = 1, \dots, N_1$

$\varphi_i \neq 0, \forall_i \ = N_1 + 1, N_1 + 2, \dots, N$

When$N_1 \ = \ N$, it means that for all the units of the panel, there is no causality. That is, homogeneous non-causality is the case here. We get Homogeneous causality when

$N_1 = 0$. This implies that causality exists for all the units of the panel.

Nonetheless, we have a heterogeneous causal relationship when$N_1 > \ 0$, implying the existence of a different causal order for the units of the panel.

According to Dumitrescu and Hurlin (2012), the mean value of the individual Wald statistics, of the null hypothesis of no causation for each unit of the panel i = 1, …,N, is suggested, to investigate the homogeneous non-causation hypothesis.

The Average Wald statistic suggested is specified as:

$W_{N,T}^{HNC} = \frac{1}{N} \sum_{i=1}^{N} W_{i,T}$

Individual Wald statistics related to the null hypothesis $H0 = \varphi_i = 0$, for each unit i, is represented as $W_{i,T}$.

It worth noting that as observed by the authors, the average Wald statistic does not follow the standard Chi-square distribution in a small T sample. Hence, they suggest both the approximated standardized statistic ($Z_N^{\sim HNC}$), and asymptotic standardized statistic (Z_N^{HNC}) that follow normal distribution as an addition to the Wald statistic.

Z_N^{HNC} which is the asymptotic standardized statistic for small T sample, which is specified as:

$$Z_N^{HNC} = \frac{\sqrt{N}\,[W_{N,T}^{HNC} - N^{-1}\sum_{i=1}^{N} E(W_{i,T})]}{\sqrt{N^{-1}\sum_{i=1}^{N} Var(W_{i,T})}} \rightarrow N(0,1)$$

$N^{-1}\sum_{i=1}^{N} E(W_{i,T}),\ E(W_{i,T}) = \mathrm{K} * \frac{(T-2K-1)}{(T-2K-3)}$

$N^{-1}\sum_{i=1}^{N} Var(W_{i,T}),\ Var(W_{i,T}) = 2\mathrm{K} * \frac{(T-2K-1)^2 * (T-K-3)}{(T-2K-3)^2 * (T-2K-5)}$

And the approximated standardized statistic ($Z_{\tilde{N}}^{HNC}$) is specified as:

$$Z_N^{\sim HNC} = \frac{\sqrt{N}\,[W^{NH,TNC} - E(W_{i,T})]}{\sqrt{Var(W_{i,T}}} \rightarrow N(0,1)$$

Decision Rule

The rule for decision is that we reject the homogeneous non-causality hypothesis when the value of Z_N^{HNC} or $Z_N^{\sim HNC}$ is more than the normal critical value for a given significance level. However, if the homogeneous non-causality hypothesis is accepted or rejected, it indicates that the x variable does not cause the y variable in every cross-section. This would imply that the non-causation is uniform, thus the test stops there. The existence of causation in at least one unit of the cross-section is implied when the homogeneous non-causality hypothesis is disproved. Therefore, the test continues by determining which cross-sections exhibit causation and which do not. Granger-causality testing for each panel cross-section can be used to do this.

In other words, if the statistic's p-value is below the 5% significant threshold, we reject the null hypothesis that the independent (x) variable did not impact the dependent (y) variable in a homogenous manner. Stated differently, the independent variable directly affects the dependent variable. The null hypothesis is accepted when the p-value is higher than 5%.

4.4.7 Diagnostic Test

Arize et al. (2000) acknowledged that fully-modified OLS and Dynamic OLS account for both bias and endogeneity in the OLS. Correlation between the disturbance term and the first difference of the regressors are accounted for by these estimators. Thus they consider the existence of a constant term so that the serial correlation problem is corrected for. With this observation, since this study employed the Fully Modified OLS and Dynamic OLS to generate

long-run coefficient statistics of the independent variables, the diagnostic test to be carried out is the normality test.

4.4.7.1 Normality Test

From the classical regression framework, it is assumed that the residuals follow a normal distribution. Under the null hypothesis, the residuals are normally distributed, meaning that both skewness and excess kurtosis are equal to zero. The normality test is therefore used to evaluate this null hypothesis.

H_0: Residuals are normally distributed

H_1: Residuals are not normally distributed

Decision rule:

If the probability value of the Jarque-Bera statistics is significant at 5% level, then we accept the null hypothesis and conclude that the model is normally distributed. That is, if the p-value of the Jarque-Bera statistic is greater than 5% we accept the null hypothesis. This implies the residuals are normally distributed. However, if the p-value is less than 5%, the null hypothesis is rejected, and we conclude that the residuals are not normally distributed.

4.5 Conclusion

The empirical techniques of this study were succinctly described in this chapter. As discussed in the previous chapter, it reflected the selected model specification, which was based on the theoretical and empirical findings that backed up the investigation. This chapter discussed the a priori expectations, data description, and modelling strategies utilised to accomplish the goal of the study. Upon the justification for the Panel Cointegration modelling technique as a suitable approach for this investigation, the logical process will begin with descriptive statistics, a visual inspection of the variables (graphical representation), and unit-root tests (the Im Persaran and Levin et al. unit root tests). Panel cointegration tests will be conducted immediately to ascertain the long-term connection among the variables. FMOLS and DOLS will then be used to evaluate the long-term influence of the independent variables on the dependent variables in the different models specified for this study. This is immediately followed by the panel Granger-causality test. Lastly, a diagnostic check will be performed.

CHAPTER FIVE

RESULTS PRESENTATION AND DISCUSSION OF FINDINGS

5.1 Introduction

This chapter presents and discusses the results of the various tests conducted in the study. All the statistical analyses and outputs were generated using the EViews 12 software package. The presentation of results begins with the descriptive statistics, a visual inspection of the variables, and the panel unit root test result. After this, the panel cointegration results, FMOLS and DOLS estimations, diagnostic tests and Granger-causality tests for the life expectancy model and the economic growth model are presented in sections 5.4 and 5.5 respectively.

5.2 Descriptive Statistics

Before the econometric analysis begins, this part contains the descriptive data for every variable in the current study. These factors apply to the BRICS countries from 2000 to 2023. Table 5.1 displays the values of the descriptive statistics, which include the skewness, kurtosis, median, mean, standard deviation, and Jarque-Bera statistics. To observe if our data is normally distributed, the focus of interest here will be the value of kurtosis and skewness.

Table 5.1: Descriptive Statistics

	LLEXP	LGDPPC	LSES	LTRADE	LPHY	LCO2PC	LCHEPC
Mean	4.230593	11.01095	4.46258	3.755015	0.433597	1.508826	5.556379
Median	4.250956	10.87613	4.539216	3.833992	0.339131	1.915651	6.023928
Maximum	4.368979	13.97821	4.755136	4.220888	1.995408	2.591685	7.143618
Minimum	3.988614	8.827309	3.803814	3.095848	-0.6436	-0.06429	2.890372
Std. Dev.	0.092082	1.191192	0.219194	0.291072	0.776119	0.846482	1.165745
Skewness	-0.88375	0.520938	-1.22115	-0.67675	0.637	-0.31092	-0.72227
Kurtosis	3.266321	2.882785	3.749891	2.409703	2.314902	1.561329	2.190889
Jarque-Bera	15.97495	5.496218	32.63583	10.90198	10.46217	12.2823	13.70669
Probability	0.00034	0.064049	0	0.004292	0.005348	0.002152	0.001056
Sum	507.6711	1321.314	535.5096	450.6018	52.03164	181.0591	666.7654
Sum Sq. Dev.	1.009007	168.8537	5.717498	10.08202	71.68097	85.26736	161.7164
Observations	120	120	120	120	120	120	120

Authors' Design

Data sourced from World Bank development indicator

Table 5.1 shows that the value of the kurtosis ranges from 1.561329 to 3.266321. These values reveal the peakedness or the flatness of the distribution. The skewness value of the variables LLEXP, LSES, LTRADE, LCO2PC and LCHEPC skewed negatively; that is, their values are less than zero (0) indicating that the distribution is left-tailed. In contrast, the variables LGDPPC and LPHY exhibit positive skewness, meaning their values are greater than zero. This means that the distribution tails to the right. The implication of the skewness value is that the series are not normally distributed, because they are not symmetrical. The series are not normally distributed at the 5% significant level, because their p-values are less than the 5% significance level, according to the probability of the Jarque-Bera statistics. Therefore, there is a need to examine the variables for stationarity.

5.3 Stationarity Investigation

The stationarity investigation begins with visual inspection and this will be followed by panel unit root tests. This is shown as follows:

5.3.1 Visual Inspection For Stationarity

This section presents the graphical trends of the variables in their level form and first difference for the BRICS countries over the period 2000–2020. The plots provide a preliminary understanding of the behaviour and long-run evolution of the key economic, environmental, and human development indicators prior to the formal econometric analysis.

5.3.1.1 Graphical Representation of Variables at Level for the various countries

The visual inspection of the variables at level is presented in Figure 5.1

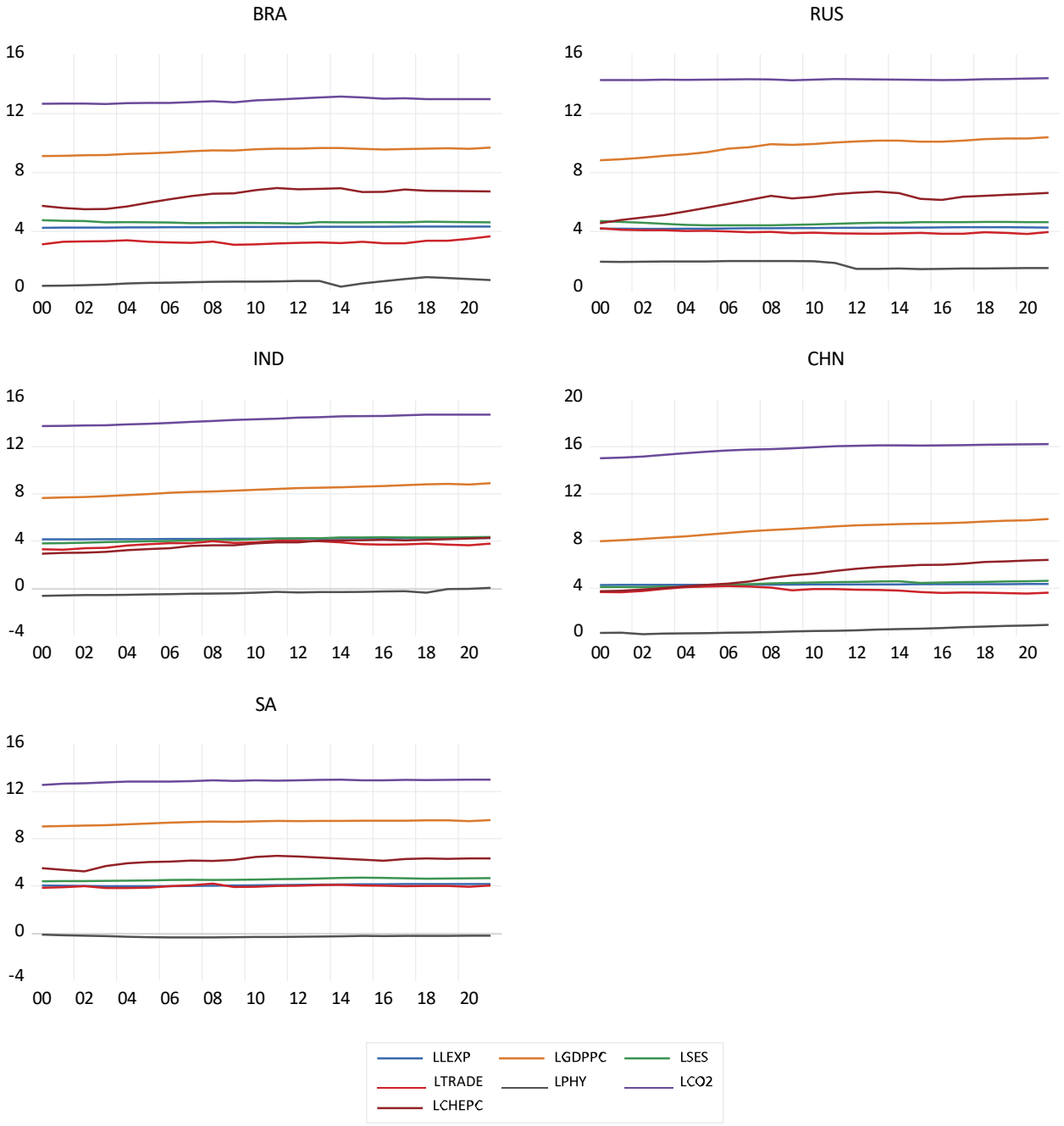


Figure 5.1: Graphical Representation of Variables at Level for the various countries

Authors' Design

Data sourced from World Bank development indicator

BRA, RUS, IND, CHN and SA stand for Brazil, Russia, India, China, and South Africa respectively. From the visual inspection, all the variables generally exhibit upward trending

patterns, indicating sustained growth and improvements across the BRICS region. Overall, the observed increasing patterns imply that the variables are likely non-stationary in their level form**,** with persistent trends over time. A further inspection is done for variables at first difference.

5.3.1.2 Graphical Representation of Variables at first Difference for the various countries

The visual representation of variables at first difference is presented in Figure 5.2 to reveal the trend.

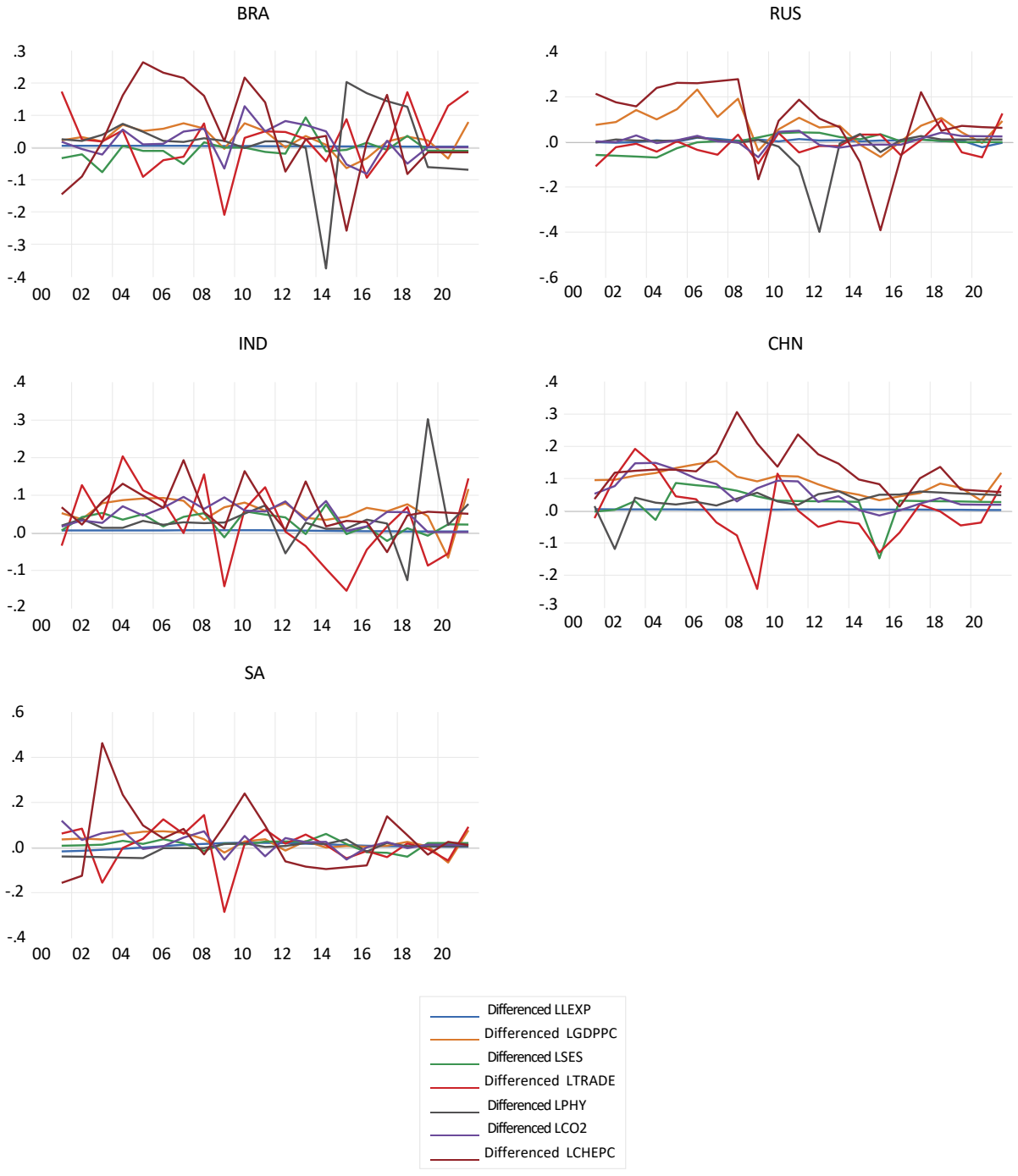


Figure 5.2: Graphical Representation of Variables at first Difference for the various countries

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Data sourced from World Bank development indicator

The graphs of the first-differenced variables for the BRICS countries reveal that the data fluctuate closely around the zero axis, which indicates that underlying long-term trends have been successfully removed through the differencing process. However, since this is just a preliminary test of stationarity, the next section will handle panel unit root test.

5.3.2 Panel unit root test

Before estimating the panel econometric models, it is essential to examine the stationarity properties of the variables used in this study. Non-stationary data may produce misleading regression outcomes and spurious relationships that could invalidate the empirical results. Therefore, panel unit root tests were conducted to determine the order of integration of each variable across the BRICS countries over the period 2000–2023. The findings of the Levin, Lin & Chu (LLC) test and the IM, Pesaran, and Shin (IPS) panel unit root test are presented in Table 5.2.

Table 5.2: Panel Unit Root Test Result

Methods	LCHEPC				
	Level		Difference		Conclusion
	Statistics	P-value	Statistics	P-value	
Levin, Lin & Chu (LLC)	-1.138	0.1276	-3.7206	0.0001	I (1)
IM, Pesaran and Shin W-Stat (IPS)	-0.1595	0.4367	-1.8516	0.032	
	LCO2PC				
	Level		Difference		Conclusion
	Statistics	P-value	Statistics	P-value	
Levin, Lin & Chu (LLC)	0.2624	0.6035	-5.8176	0.0000	I (1)

IM, Pesaran and Shin W-Stat (IPS)	2.11896	0.983	-563058	0.0000	
	LGDPPCC				
	Level		Difference		Conclusion
	Statistics	P-value	Statistics	P-value	
Levin, Lin & Chu (LLC)	-0.6297	0.2645	-6.6065	0.0000	I (1)
IM, Pesaran and Shin W-Stat (IPS)	1.61267	0.9466	-4.6857	0.0000	
	LLEXP				
	Level		Difference		Conclusion
	Statistics	P-value	Statistics	P-value	
Levin, Lin & Chu (LLC)	1.36805	0.9144	-1.7472	0.0403	I (1)
IM, Pesaran and Shin W-Stat (IPS)	0.50043	0.6916	-1.4552	0.0328	
	LPHY				
	Level		Difference		Conclusion
	Statistics	P-value	Statistics	P-value	
Levin, Lin & Chu (LLC)	1.58594	0.9436	-6.8643	0.0000	I (1)
IM, Pesaran and Shin W-Stat (IPS)	2.16122	0.9847	-5.9978	0.0000	

	LSES				
	Level		Difference		Conclusion
	Statistics	P-value	Statistics	P-value	
Levin, Lin & Chu (LLC)		0.976		0.0002	I (1)
	1.97732				
			-3.4977		
IM, Pesaran and Shin W-Stat (IPS)					
	-13414	0.4466	-4.7436	0.0000	
	LTRADE				
	Level		Difference		Conclusion
	Statistics	P-value	Statistics	P-value	
Levin, Lin & Chu (LLC)		0.136		0.0000	I (1)
	-1.0983		-6.8837		
IM, Pesaran and Shin W-Stat (IPS)				0.0000	
	-0.6811	0.2479	-5.8488		
	LCGFCF				
	Level		Difference		
	Statistics	P-value	Statistics	P-value	
Levin, Lin & Chu (LLC)	1.05231	0.8537		0.0000	
			-6.0951		
IM, Pesaran and Shin W-Stat (IPS)	3.08175				
		0.999	-4.0599	0.0000	

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Data sourced from World Bank development indicator

The Panel unit root tests (Levin, Lin & Chu (LLC) and IM, Pesaran and Shin W-Stat (IPS)) indicate that our variables are stationary at first difference, having observed that all of their probabilities values were less than 5% at the 5% significant level (Table 5.2). Thus, we conclude that all our variables are integrated of order one, or I(1). Having confirmed the order integration of the variables, we can now proceed with the cointegration test to examine if our variables have long-run relationships.

5.4 Estimation of Life Expectancy Model (Model 1)

Econometric estimation of the relationship between Life expectancy (dependent variable) and the explanatory variables (Economic growth, Education, Trade, Number of physicians per 1000, carbon emissions and health expenditure per capita) for the BRICS countries are presented in this segment.

5.4.1 Panel Cointegration Test of Life Expectancy Model (Model 1)

Upon confirming the order of integration of our variables to be order one I(1), we proceeded with the cointegration test to ascertain whether the variables have a long-term relationship. The Pedroni and Kao tests of cointegration were used in this work to achieve this. It should be noted that the Engle-Granger approach, which is the foundation of both tests, searches for stationarity in the residuals that results from regressing I(1) variables. In Sections 5.4.1.1 and 5.4.1.2, the outcomes of these tests are presented.

5.4.1.1 Kao test of cointegration of Life Expectancy Model (Model 1)

The table 5.3 captures the Kao cointegration test output for model 1 of this study. The table 5.3 indicates the p-value of 0.0073, and the Kao ADF-statistic is -2.440543. We therefore, conclude that, at the 5% significance level, there is a long-run relationship among the variables in model 1. This implies cointegration; thus we accept the alternative hypothesis and reject the null hypothesis, that cointegration does not occur. Given that our variables are cointegrated, this implies that they have a long-run relationship.

Table 5.3: Kao Cointegration Test Result for Life Expectancy Model (Model 1)

Method	t-Statistic	Prob.
ADF	-2.440543	0.0073
Residual variance	0.000141	
HAC variance	0.000162	

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5.4.1.2 Pedroni Test of Cointegration of Life Expectancy Model (Model 1)

The Pedroni cointegration test reports eleven statistics in total. In the within-dimension category, the statistics include the Panel v-Statistic, Panel rho-Statistic, Panel PP-Statistic, Panel ADF-Statistic, along with their corresponding weighted versions. The between-dimension category consists of the Group rho-Statistic, Group PP-Statistic, and Group ADF-Statistic.

Table 5.4: Pedroni Cointegration Test Result for Life Expectancy Model (Model 1)

Alternative hypothesis: common AR coefs. (within-dimension)				
			Weighted	
	Statistic	Prob.	Statistic	Prob.
Panel v-Statistic	-1.90122	0.9714	-2.94347	0.9984
Panel rho-Statistic	1.131999	0.8712	1.431413	0.9238
Panel PP-Statistic	-2.36407	0.009	-5.96922	0.0000
Panel ADF-Statistic	-2.42911	0.0076	-3.72732	0.0001
Alternative hypothesis: individual AR coefs. (between-dimension)				
	Statistic	Prob.		
Group rho-Statistic	2.097165	0.982		
Group PP-Statistic	-3.12998	0.0009		
Group ADF-Statistic	-2.26571	0.0117		

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Under the Within-Dimension results, both the Panel PP-Statistic and the Panel ADF-Statistic as well as their weighted statistics are statistically significant at the 5% level. In contrast, the Panel v-Statistic and Panel rho-Statistic are not significant at the 5% level. For the Between-Dimension results, the Group PP-Statistic and Group ADF-Statistic are significant at the 5% level, whereas the Group rho-Statistic is not. Overall, six out of the eleven test statistics are statistically significant at the 5% significance level, indicating evidence of cointegration among the variables. Therefore, we conclude that the variables share a long-run relationship.

Remarkably, both the Pedroni and Kao cointegration tests confirm the presence of a long-run relationship among the variables in this study. Since the Kao ADF-statistic is significant at the 5% level, and six out of the eleven Pedroni test statistics are also significant at the same level, we reject the null hypothesis of no cointegration, and accept the alternative hypothesis. Consequently, the Panel Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS) methods are employed in the subsequent section to estimate the long-run coefficients of the variables.

5.4.2 Panel Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS**) of Life Expectancy Model (Model 1)**

In the preceding section, cointegration among the variables was established; therefore, the FMOLS and DOLS estimators are applied to obtain the long term coefficients. These estimators enable us to assess the influence of the independent variables on the dependent variable, and to quantify the extent of their impact over time.

5.4.2.1 Fully Modified OLS (FMOLS) of Life Expectancy Model (Model 1)

The result of FMOLS estimator for the life expectancy model is presented and discussed in this section.

Table 5.5: Fully Modified (FMOLS) of Life Expectancy Model (Model 1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LGDPPC	0.044691	0.014873	3.004762	0.0033
LSES	0.149920	0.048407	3.097102	0.0025
LTRADE	0.002674	0.025213	0.106040	0.9158
LPHY	0.007990	0.020807	0.384006	0.7018
LCO2PC	-0.141848	0.034967	-4.056615	0.0001
LCHEPC	0.008739	0.018492	0.472603	0.6375
R-squared	0.931078			
Adjusted R-squared	0.924451			

Authors' Design

Data sourced from World Bank development indicator

Table 5.5 presents the results of the Fully Modified Ordinary Least Squares (FMOLS) estimation examining the determinants of life expectancy (LEXP) in the BRICS countries. The model exhibits a high explanatory power, with an R-squared value of 0.93 and an adjusted R-squared of 0.92, indicating that about 93% of the variations in life expectancy are explained by the independent variables included in the model. The coefficients of all the variables are consistent with a priori expectations.

The coefficient of GDP per capita (LGDPPC) is 0.044691. This indicates that economic growth is positive and statistically significant at the 5% level (p = 0.0033). This implies that a 1% increase in GDP per capita results in approximately a 0.0447% increase in life expectancy among the BRICS countries. This positive and significant relationship aligns with the Preston Curve Hypothesis, which posits that improvements in income levels enhance population health and longevity (Preston, 2007). The result supports empirical findings by Ebenstein et al. (2015), Alam et al. (2016), and Abubakari et al. (2019), who documented similar evidence of income-driven health improvements. However, as noted by Clark (2011), the marginal gains in life expectancy from higher income tend to diminish with economic maturity, a pattern observable in some BRICS economies such as China and Russia. Therefore, while economic growth significantly contributes to longevity, it is not the sole driver of improved life expectancy in these emerging economies.

Secondary school enrolment (LSES), used as a proxy for educational attainment, has a coefficient of 0.149920 and is statistically significant at the 5% level (p = 0.0025). This result suggests that a 1% increase in secondary school enrolment enhances life expectancy by approximately 0.15% across the BRICS. Education improves health outcomes through increased health awareness, better lifestyle choices, and higher income potential. This finding corroborates those of Raghupathi and Raghupathi (2020), Trung (2022), and Gamze (2023), who emphasized the strong role of education in improving population health and longevity. Thus, human capital development through education remains a critical mechanism linking social development to life expectancy in emerging economies.

The coefficient of carbon dioxide emissions per capita (LCO2PC) is -0.141848 and statistically significant at the 1% level (p = 0.0001), implying that a 1% increase in CO_2 emissions reduces life expectancy by approximately 0.14%. This inverse relationship highlights the detrimental impact of environmental degradation on public health. Increased air pollution contributes to respiratory and cardiovascular diseases, thereby reducing life expectancy. The result aligns with findings by Ali and Amad (2014), Ahmad et al. (2019), Chen et al. (2020), and Akpan and Udo (2021), who consistently observed that higher carbon emissions adversely affect health outcomes. This outcome reinforces the need for BRICS nations to pursue sustainable industrialization and environmental policies that safeguard public health while sustaining economic growth.

Trade openness (LTRADE) shows a positive coefficient of 0.002674, although it is statistically insignificant (p = 0.9158). This suggests that while increased trade may have a mild positive influence on life expectancy through the diffusion of health technologies, improved access to pharmaceuticals, and higher income from global integration, the effect is not strong enough to be conclusive in the BRICS context. This outcome is consistent with the findings of Wei and Wu (2002), Owen and Wu (2007), and Herzer (2017), who found that trade contributes positively to health outcomes, albeit sometimes insignificantly in developing regions. However, it contrasts with Byaro et al. (2021), who found a significant positive relationship in African economies. The insignificance here may reflect structural differences in trade composition or unequal distribution of trade benefits among BRICS members.

Number of physicians per 1,000 people (LPHY) has the coefficient of 0.007990, but the variable is statistically insignificant (p = 0.7018). This indicates that while an increase in physician density tends to improve life expectancy, the relationship is weak and not statistically reliable within the BRICS context. The result may suggest disparities in healthcare access, efficiency, or quality of medical infrastructure across member countries. In some cases, higher physician density does not automatically translate into better health outcomes if accompanied by inequality in healthcare delivery or poor public health systems.

Health expenditure per capita (LCHEPC) has a positive but insignificant coefficient of 0.008739 (p = 0.6375). This implies that although higher health spending is associated with longer life expectancy, the effect is statistically weak. This could be due to inefficiencies in health spending, unequal access to healthcare services, or lags in the effects of health investment. Similar findings were reported by Li and Li (2021) and Zhou and Wang (2017) in the context of China, where the effectiveness of health expenditure depends on institutional quality and regional disparities.

Overall, the FMOLS results indicate that economic growth (LGDPPC) and education (LSES) are key determinants of life expectancy in the BRICS countries, both being positive and statistically significant. Conversely, carbon emissions (LCO2PC) exert a strong and significant negative effect, highlighting the trade-off between industrialization and health outcomes. Meanwhile, trade openness (LTRADE), physician density (LPHY), and health expenditure (LCHEPC) have positive but statistically insignificant effects, suggesting that structural,

policy, and institutional factors may mediate their impact on longevity in these emerging economies.

5.4.2.2 Dynamic OLS (DOLS) of Life Expectancy Model (Model 1)

A follow-up result is obtained from the DOLS estimation to confirm the outcome from FMOLS. This outcome is shown in Table 5.6

Table 5.6: Dynamic (DOLS) Result for Life Expectancy Model (Model 1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LGDPPC	0.014555	0.053695	0.271076	0.7997
LSES	0.084386	0.105766	0.797856	0.4696
LTRADE	0.028123	0.040887	0.687826	0.5294
LPHY	0.027337	0.035335	0.773655	0.4823
LCO2PC	-0.019470	0.122185	-0.159350	0.8811
LHEPC	0.010099	0.074457	0.135642	0.8987
R-squared	0.999041			
Adjusted R-squared	0.975073			

Authors' Design

Data sourced from World Bank development indicator

From Table 5.6 it is equally observed that the coefficient of all our variables are consistent with the a priori expectation. The coefficients of LGDPPC, LSES, LTRADE, LPHY, and LHEPC are all positive, while LCO2PC is negative, just as these are in FMOLS. By implication, the positive coefficients show that a 1% increase in these variables would result in the rise of the life expectancy for the BRICS countries. Thus, LLEXP would increase by 0.014555%, 0.084386%, 0.028123%, 0.027337% and 0.010099% if there is a 1% increase in LGDPPC, LSES, LTRADE, LPHY, and LHEPC respectively. Although these variables have an impact on LEXP, they are statistically insignificant at the 5% level, given that their probability values are larger than the 5% significance level. On the other hand, it is observed that the variable LCO2PC is negatively related to LLEXP, implying that an increase in LCO2PC will cause LLEXP to fall. The coefficient is -0.019470, meaning that LLEXP will fall by approximately

0.02% with a 1% rise in LCO2. The probability value, like the other independent variables, indicates that it is not statistically significant at the 5% level.
The corrected R-squared is 0.999041, which indicates that the changes in the independent variables used in our model's estimation account for almost 0.99% of the variation in life expectancy among the BRICS nations. Our estimated model is good, given the value of Adjusted R-squared as 0.975073.

In summary, the DOLS results reveal that all explanatory variables, except carbon dioxide emissions, are positively related to life expectancy in the BRICS countries, while CO_2 emissions maintain a negative association. However, none of the relationships are statistically significant at the 5% level, suggesting that the long-run dynamics captured by DOLS are weaker or less immediate than those observed under FMOLS. The high R-squared value (0.999) and adjusted R-squared (0.975) indicate a strong overall model fit, confirming that the variables collectively explain most of the variation in life expectancy. Nonetheless, the insignificance of individual coefficients implies that long-term improvements in longevity within the BRICS require multifaceted and sustained interventions that combine economic growth, education, environmental management, and health sector efficiency.

It is worthy of note that given the advantages of FMOLS over DOLS, this current study will base its conclusion on the outcome of the FMOLS Estimation being most appropriate. These advantages, according to Pedroni (2001), are that FMOLS has the capacity to address endogeneity and serial correlation in the regressors which arises from cointegration. Also, Bashier and Siam (2014) state that FMOLS produces reliable estimates for small sample size and is equally good in checking the robustness of the results. Mehmood and Shahid (2014) noted also that FMOLS is appropriate for variables that are stationary after first difference and are cointegrated. Furthermore, Arize et al. (2000) stated that the leads and lags included in DOLS reduces the degrees of freedom. Hence, given these advantages of FMOLS, and the shortcoming of DOLS identified, the conclusion and policy recommendations are based on the outcome of the FMOLS analysis, because of its robustness.

5.4.3 Diagnostic Test for Life Expectancy model (Model 1)

The appropriate diagnostic test performed is the normality test. This was performed on the model estimating the relationship between life expectancy (dependent variable) and the

explanatory variables (Economic growth, Education, Trade, number of physicians per 1000, carbon emissions and health expenditure per capita) for the BRICS.

5.4.3.1 Normality Test for Life Expectancy model (Model 1)

This test examines if the data are normally distributed. The null hypothesis is specified as:

H_0: Residual are normally distributed

H_1: Residual are not normally distributed

The result of the normality test is presented in figure 5.3

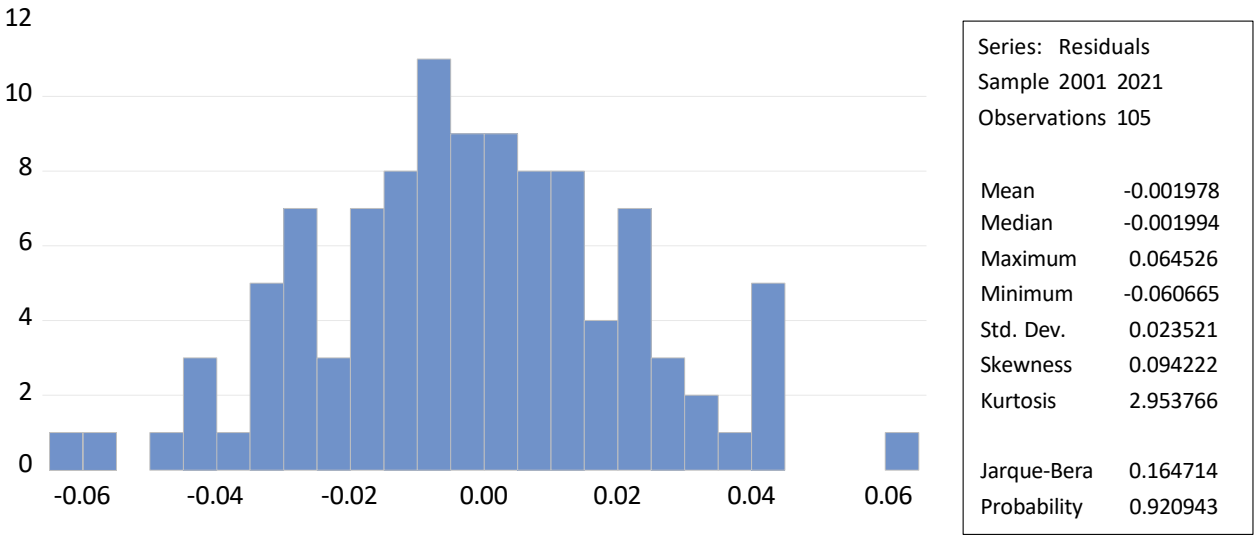


Figure 5.3: Normality Test Result for Life Expectancy Model

Authors' Design

Data sourced from World Bank development indicator

The null hypothesis is that the residuals are normally distributed. Given that the p-value of the Jarque-Bera statistic is larger than the 5% significance level, we conclude that the data is normally distributed. This implies that we fail to reject the null hypothesis; we accept the null hypothesis. Having observed that the model is good and data normally distributed, we processed with other tests such as panel Granger-causality test.

5.4.4 Panel Causality Test of Life Expectancy Model (Model 1)

This approach starts by testing the homogeneous non-causality (HNC) hypothesis, which maintains that there is no causal link between two variables throughout the whole panel cross-section. According to Dumitrescu and Hurlin (2012), the alternative hypothesis, however, assumes that the variables are causally associated for (N-N1) of the panel's cross-section but not for some of the cross-sections, N1. The following table displays the Granger-causality result:

Table 5.7: Panel Granger-Causality Result of Life Expectancy Model (Model 1)

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
LGDPPC does not homogeneously cause LLEXP	14.0268	10.1451	0.0000
LLEXP does not homogeneously cause LGDPPC	5.28835	2.60671	0.0091

LSES does not homogeneously cause LLEXP	3.38399	0.96388	0.3351
LLEXP does not homogeneously cause LSES	2.96386	0.60145	0.5475
LTRADE does not homogeneously cause LLEXP	3.01741	0.64764	0.5172
LLEXP does not homogeneously cause LTRADE	4.90987	2.28021	0.0226
LPHY does not homogeneously cause LLEXP	1.88520	-0.32908	0.7421
LLEXP does not homogeneously cause LPHY	14.2998	10.3806	0.0000
LCO2PC does not homogeneously cause LLEXP	9.09114	5.88727	4.E-09
LLEXP does not homogeneously cause LCO2PC	2.77341	0.43715	0.6620
LCHEPC does not homogeneously cause LLEXP	4.10998	1.59017	0.1118
LLEXP does not homogeneously cause LHEPC	2.20843	-0.05024	0.9599

Authors' Design

Data sourced from World Bank development indicator

The null hypothesis of this test asserts that the independent variable does not homogenously cause the dependent variable, life expectancy, or LLEXP. The outcome of the test is as displayed in Table 5.7. At a significant level of 5%, there is a causal relationship between LGDPPC and LLEXP based on the probability values. At the 5% level, LGDPPC homogenously caused LLEXP and LLEXP equally causes LGDPPC, since the p-values are less than 0.05. We conclude that there is bidirectional causality between LGDPPC and LLEXP .This outcome is consistent with Gürler et al. (2018) and Neofytidou et al. (2019), who both reported bidirectional causation between life expectancy and GDP per capita.

Like Rahman and Yusuf (2020), we observed that at the 5% significance level, there is no causal relation between education (LSES) and life expectancy (LLEXP). Nonetheless, a unidirectional causal relationship exists between LTRADE and LLEXP; this result corroborates Shah and Ibrahim (2021), who revealed that life expectancy Granger-causes trade,

but unlike Basu et al. (2022) and Cervantes et al. (2019), we found causation running from life expectancy to physicians per 1000.This implies a unidirectional causality from LLEXP to LTRADE and LPHY at the 5% significance level.

Though Rahman et al. (2022), and Mahalik (2022) found that CO_2 emissions Granger-causes life expectancy, our study found no causal relationship between these variables. Also, like Joseph and Agada (2024), we found health expenditure has no significant homogeneous causal relationship with life expectancy for the BRICS countries.

Since the goal of this test is to ascertain the direction of causation between GDP per capita and life expectancy, we thus conclude that for the BRICS countries under study, causation runs in both directions. Given this bidirectional causation between GDP per capita and life expectancy, we reject the null hypothesis, that GDP per capita does not homogenously cause life expectancy and accept the alternative hypothesis that GDP per capita homogenously causes life expectancy. Upon the conclusion on the estimation of the Life Expectancy Model, we shall proceed with the estimation of the Economic model.

5.5 The Estimation of Economic Growth Model (Model 2)

The empirical results of the relationship between Economic growth, (dependent variable) and the explanatory variables (Life expectancy, Education, Gross Fixed Capita Formation, carbon emissions and health expenditure per capita) for the BRICS countries are presented in this section.

5.5.1 Panel cointegration test of Economic Growth Model (Model 2)

It has been confirmed that the variables of this model are integrated of order one I(1), thus we shall proceed with the cointegration test to ascertain whether the variables have a long-term relationship. The Pedroni and Kao tests of cointegration are used in this work to achieve this. It should be noted that the Engle-Granger approach, which is the foundation of both tests, searches for stationarity in the residuals that results from regressing I(1) variables. In Sections **5.5.1.1** and 5.5.1.2, the outcomes of these tests are presented.

5.5.1.1 Kao test of cointegration for Economic Growth Model (Model 2)

Table 5.8 captures the Kao cointegration test output for the economic growth model of this study. The Table indicates the p-value of 0.0199 and the Kao ADF-statistic is -2.056832. We therefore conclude that, at the 5% significance level, there is a long-run relationship among the variables in model 2 This implies cointegration, thus we accept the alternative hypothesis and reject the null hypothesis, that cointegration does not occur since the variables are cointegrated; this implies that they have a long-run relationship.

Table 5.8: Kao Cointegration Test Result for Economic Growth Model

Method	t-Statistic	Prob.
ADF	-2.056832	0.0199
Residual variance	0.005800	
HAC variance	0.011053	

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Data sourced from World Bank development indicator

5.5.1.2 Pedroni Test of Cointegration for Economic Growth Model (Model 2)

The Pedroni cointegration test reports eleven statistics in total. In the within-dimension category, the statistics include the Panel v-Statistic, Panel rho-Statistic, Panel PP-Statistic, Panel ADF-Statistic, along with their corresponding weighted versions. The between-dimension category consists of the Group rho-Statistic, Group PP-Statistic, and Group ADF-Statistic.

Table 5.9: Pedroni Cointegration Test Result for Economic Growth Model

Alternative hypothesis: common AR coefs. (within-dimension)				
			Weighted	

	Statistic	Prob.	Statistic	Prob.
Panel v-Statistic	36.11963	0.0000	-16.46080	0.0000
Panel rho-Statistic	1.255276	0.8953	2.469373	0.9932
Panel PP-Statistic	-1.639319	0.0506	-0.509119	0.6947
Panel ADF-Statistic	-3.177835	0.0007	-4.064633	0.0000
Alternative hypothesis: individual AR coefs. (between-dimension)				
	Statistic	Prob.		
Group rho-Statistic	2.655775	0.9960		
Group PP-Statistic	-0.367709	0.3565		
Group ADF-Statistic	-3.906090	0.0000		

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Data sourced from World Bank development indicator

Under the within-dimension category, both the Panel v-Statistic and Panel ADF-Statistic are statistically significant at the 5% level, and their corresponding weighted statistics are also significant. The Panel PP-Statistic is significant at the 5% level, but its weighted version is not. Meanwhile, the Panel rho-Statistic and its weighted statistic are not statistically significant. For the between-dimension results, the Group rho-Statistic and Group PP-Statistic are not significant at the 5% level, whereas the Group ADF-Statistic shows statistical significance. Overall, six of the eleven test statistics are significant at the 5% threshold. This provides sufficient evidence to reject the null hypothesis of no cointegration, and conclude that the variables share a long-run equilibrium relationship.

Both the Pedroni and Kao tests of cointegration confirm the existence of a long-term cointegrating relationship of the variables in this model. Since the Kao ADF-statistic is significant at the 5% level, and six of the eleven Pedroni statistics are also significant at the same threshold, we reject the null hypothesis of no cointegration and accept the alternative hypothesis. Consequently, we proceed in the next section to estimate the long-run coefficients of the variables using the FMOLS and DOLS methods.

5.5.2 Panel Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS**) of Economic Growth Model (Model 2)**

We shall generate the long-run coefficients of our variables by deploying the Panel Fully Modified Ordinary Least Square (FMOLS) and Panel Dynamic Ordinary Least Square (DOLS) estimators. These allow us to determine how those independent variables affect the dependent variable, and how much of an impact they have had over time.

5.5.2.1 Fully Modified OLS (FMOLS) of Economic Growth Model (Model 2)

The outcome of FMOLS estimation for the Economic growth model is presented and discussed in this section.

Table 5.10: FMOLS Result of Economic Growth Model (Model 2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LLEXP	4.534975	1.209370	3.749865	0.0003
LCGFCF	0.054151	0.231423	0.233994	0.8154
LSES	0.584426	0.494965	1.180742	0.2404
LCO2PC	-0.302695	0.384430	-0.787387	0.4328
LCHEPC	0,779138	0.225470	3.455617	0.0008
R-squared	0.965472			
Adjusted R-squared	0.962512			

Authors' Design

Data sourced from World Bank development indicator

Table 5.10 shows the outcome of the Fully Modified Ordinary Least Squares (FMOLS) estimation, examining the determinants of economic growth proxied by gross domestic product per capita, denoted as (GDPPC), for the BRICS countries. With an R-squared of approximately 0.97 and an adjusted R-squared of 0.96, the model exhibits a high explanatory power, indicating that about 97% of the changes in the GDP per capita are caused by the independent variables included in the model. The coefficients of all the variables are consistent with a priori expectations.

The FMOLS results show a strong and significant positive long-run relationship between life expectancy and economic growth in the BRICS economies, which aligns closely with several empirical studies that support the Health-Led Growth Hypothesis. Specifically, the findings are consistent with Yang and Lin (2021), Nicolau et al. (2021), Goh and Lee (2022), Manea and Pătruțiu (2022), Ozturk and Acar (2023), Ngangue and Manfred (2015), Modibbo and Idris (2020), and Biyase and Maleka (2019), all of whom found that improvements in life expectancy significantly enhance economic growth, particularly in developing and emerging economies. These studies collectively affirm that better health and longer life expectancy contribute to productivity gains and sustained output growth. However, the present study diverges from Deaton (2020) and Momoh et al. (2024), who reported that the health–growth relationship is conditional on institutional quality and inequality, or found GDP's effect on life expectancy to be insignificant. Unlike these findings, the BRICS results indicate that health improvements directly and significantly stimulate economic performance, suggesting that in emerging economies, health remains a primary long-run driver of growth independent of institutional mediation.

The FMOLS result indicates that gross fixed capital formation (LCGFCF) exerts a positive but statistically insignificant effect on economic growth in the BRICS economies, implying that while investment supports output expansion, its long-run impact is weak. This partially aligns with the endogenous growth theory (Romer, 1986; Lucas, 1988; Bloom and Canning, 2000), which emphasizes capital accumulation as a growth driver but highlights the need for complementary factors such as health, education, and institutional quality (Yang and Lin, 2021). The finding contrasts with studies such as Mankiw, Romer, and Weil (1992) and Levine and Renelt (1992), which identified gross capital formation as a key determinant of global growth, and with Soludo and Adeniyi (2019) and Abdoulaye and Karim (2020), who reported strong investment-led growth effects in developing regions. Instead, it aligns with Biyase and Maleka (2019) and Udoh and Ogbuagu (2021), who found that inefficiencies and weak technological absorption limit the growth returns of investment. Overall, the result suggests that in BRICS, the quality and productivity of investment matter more than its volume, reinforcing the human-capital-augmented endogenous growth framework adopted in this study.

Education (LSES) has a positive but statistically insignificant coefficient of 0.5844 (p = 0.2404). The finding suggests that while education contributes positively to economic growth in the BRICS countries, its impact is not strong enough to be statistically conclusive in the long

run. This implies that although educational improvements may enhance human capital formation and productivity, as posited in the human capital and endogenous growth theories, the short-to-medium-term effects may be overshadowed by other more dominant growth drivers, such as health expenditure (significant at $p < 0.01$) and life expectancy (significant at $p < 0.001$). This result partly aligns with Raghupathi and Raghupathi (2020) and Hazan (2011)**,** who argue that education improves health and longevity, which in turn support productivity and growth. However, it diverges from Cervellati and Sunde (2015) and Vu (2022)**,** who found that education and longevity jointly and significantly drive long-term economic performance. The insignificant coefficient for education in the BRICS context may reflect challenges such as unequal access to quality education, skills mismatches, or delayed returns to educational investment, as highlighted in Kouladoum (2023) and Byaro and Mpeta (2021) for developing regions. Therefore, while the direction of the relationship supports the theoretical expectation, that education promotes economic growth, the weak statistical evidence indicates that the growth-enhancing potential of education in BRICS remains underutilized and may depend on complementary factors such as health, technology, and institutional quality.

Our results showed that carbon emissions (LCO2PC**)** have a negative but statistically insignificant coefficient (–0.3027, $p = 0.4328$), implying that although rising CO_2 emissions exert a mild adverse effect on economic growth in the BRICS economies, the impact is not strong enough to be conclusive in the long run. This outcome partially aligns with numerous empirical studies, such as Chen et al. (2020) for BRICS, Akpan and Udo (2021)**,** Usman and Abdullahi (2022**)**, and Cavusoglu and Gimba (2021**)** for Africa, and Liang and Zhang (2017) for China, which consistently report that higher emissions reduce life expectancy and, by extension, weaken productivity and sustainable growth. Similarly, Ahmad et al. (2019) and Shahbaz et al. (2020) found that carbon emissions negatively affect long-run health and economic performance, though the damage can be mitigated by higher health expenditure and cleaner energy use. However, our findings diverge from Matthew et al. (2020) and Osei-Kusi et al. (2024)**,** who observed a temporary positive association between emissions and growth in developing regions, attributing this to the short-term industrial benefits of early-stage economic expansion. Overall, the BRICS evidence suggests that while industrialization may initially boost output, unchecked carbon emissions undermine long-term economic sustainability, and confirms that environmental degradation imposes a latent drag on growth, despite its weak immediate statistical significance.

The result equally revealed that health expenditure per capita (LCHEPC) has a positive and statistically significant impact on economic growth (coefficient = 0.7791, p = 0.0008), indicating that increased investment in healthcare enhances long-run economic performance in the BRICS economies. This finding is consistent with a wide body of literature that emphasizes the growth-promoting role of health spending through improved productivity, reduced mortality, and enhanced human capital accumulation. For instance, Li and Li (2021) and Zhou and Wang (2017) found that higher public health expenditure significantly improved life expectancy in China, reflecting stronger human capital formation that translates into higher output over time. Similarly, Wang and Zhang (2015) and Tariq and Javed (2016) reported that in India and South Asia, increased health investment not only raised life expectancy but also indirectly boosted economic growth through better education and sanitation outcomes. The result also aligns with Choi et al. (2020**)** and Papageorgiou and Kousis (2018)**,** who showed that health expenditure, alongside income and education, positively affects longevity and, by extension, economic development, particularly when supported by effective governance. However, the current finding diverges from studies such as Redzwan and Ramli (2024**),** and Salami and Tijjani (2021)**,** which found weaker or regionally mixed long-run effects, attributing them to institutional inefficiencies and unequal resource distribution. Thus, while the BRICS evidence supports the mainstream view that sustained health investment fosters economic growth, it also highlights that the magnitude of this impact depends on governance quality, equity in health access, and the capacity of health systems to convert fiscal inputs into measurable productivity gains.

5.5.2.2 Dynamic OLS (DOLS) of Economic Growth Model (Model 2)

A follow-up result is obtained from the DOLS estimation so as to confirm the outcome from FMOLS. This outcome is shown in Table 5.11

Table 5.11: Dynamic OLS Results for Economic Growth Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LLEXP	5.791476	2.420278	2.392897	0.0266
LCGFCF	-0.380525	0.438056	-0.868666	0.3953
LSES	0.851041	0.875568	0.971987	0.3427
LCO2PC	0.255995	0.646250	0.396124	0.6962

LHEPC	1.01624	0.514593	1.974855	0.0623
R-squared	0.998208			
Adjusted R-squared	0.990681			

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Data sourced from World Bank development indicator

The DOLS results complement the FMOLS findings, by reinforcing the overall direction of relationships among key growth determinants in the BRICS economies, while revealing some variation in their statistical strength and short-run dynamics. Consistent with the FMOLS results, life expectancy (LLEXP) and health expenditure (LHEPC) maintain positive associations with economic growth, highlighting the critical role of human capital and health investment in driving long-term development. Nonetheless, the DOLS results indicates that the significance of health expenditure weakens slightly ($p = 0.0623$), suggesting that its short-run effect is marginal compared to its strong long-run impact in the FMOLS model. Similarly, education (LSES) retains a positive but insignificant influence on growth, aligning with the FMOLS conclusion that education's growth effect in BRICS is underutilized due to uneven quality and lagged returns. Gross fixed capital formation (LCGFCF), however, shifts from a positive to a negative but still insignificant coefficient, indicating that while capital investment theoretically supports growth in the long run (as seen in FMOLS), its short-run contribution is limited, possibly due to inefficiencies in capital utilization or delayed investment returns, as highlighted by Biyase and Maleka (2019) and Udoh and Ogbuagu (2021). Carbon emissions (LCO2PC) also change from a negative to a weakly positive but insignificant relationship, suggesting that industrial activity may yield short-term gains while posing long-run sustainability risks, consistent with Ahmad et al. (2019) and Chen et al. (2020). Overall, the DOLS results confirm the robustness of the FMOLS findings in demonstrating that in the BRICS economies, health and longevity remain the dominant drivers of economic growth, while the roles of capital formation, education, and environmental factors are conditional and more evident over the long term than in the short run.

It is important to emphasize here that, due to the benefits of FMOLS over DOLS, the results of the FMOLS estimation will form the basis for the conclusion of this study as more suitable. Pedroni (2001) lists these benefits as FMOLS's ability to handle endogeneity and serial

correlation in the regressors that result from cointegration. Additionally, FMOLS generates accurate estimates for small sample sizes, and is similarly effective in assessing the robustness of the results, according to Bashier and Siam (2014). Mehmood and Shahid (2014) equally point out that FMOLS is suitable for cointegrated variables that are stationary after first difference, which is the case with our variables. Moreover, Arize et al. (2000) states that the leads and lags included in DOLS reduces the degrees of freedom. Hence, given these advantages of FMOLS and the shortcomings of DOLS identified, conclusion and policy recommendations are based on the outcome of the FMOLS analysis, because of its robustness.

5.5.3 Diagnostic Test for Economic Growth Model

The appropriate diagnostic test performed is the normality test. This was performed on the model estimating the relationship between Economic growth (dependent variable) and the explanatory variables (Life expectancy, Education, Gross fixed capital formation, carbon emissions emission and health expenditure per capita) for the BRICS.

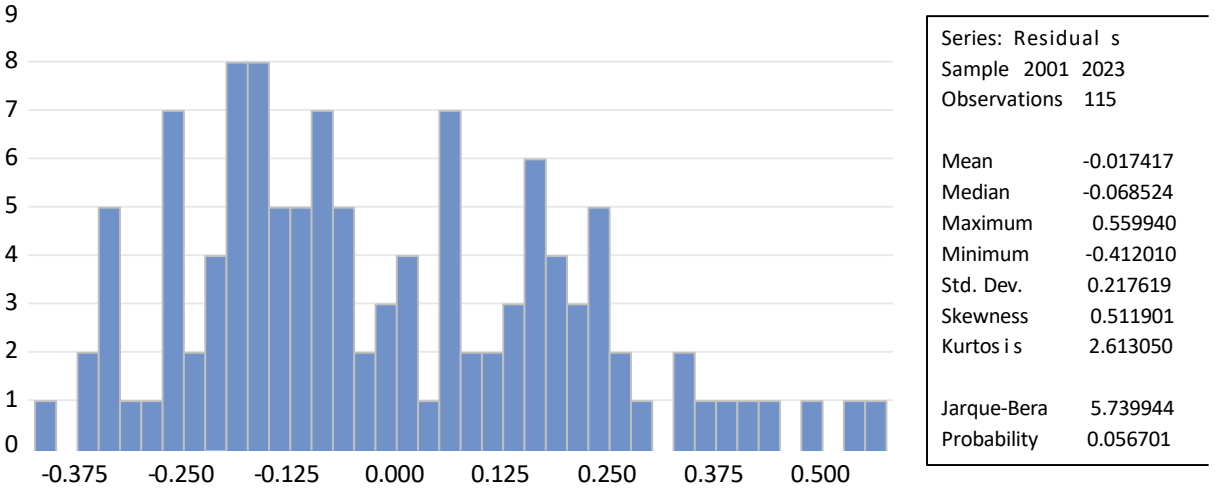
5.5.3.1 Normality Test for Economic Growth Model (Model 2)

This test examines if the data are normally distributed. The null hypothesis is specified as:

H_0: Residual are normally distributed

H_1: Residual are not normally distributed

The result of the normality test is presented in figure 5.4



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Data sourced from World Bank development indicator

Figure 5.4: Normality Test Result for Economic Growth Model

The residuals are approximately normally distributed, with mild right skewness and slightly flattened tails. The Jarque–Bera probability (0.0567) confirms that normality is acceptable at the 5% significance level. Therefore, the model's residuals satisfy the normality assumption, supporting the validity of subsequent statistical inferences. With this outcome, we shall proceed with the Panel Granger causality test.

5.5.4 Panel Causality Test for Economic Growth Model (Model 2)

This approach starts by testing the homogeneous non-causality (HNC) hypothesis, which maintains that there is no causal link between two variables throughout the whole panel cross-section. According to Dumitrescu and Hurlin (2012), the alternative hypothesis, however, assumes that the variables are causally associated for (N-N1) of the panel's cross-section but not for some of the cross-sections, N1. The following table displays the Granger causality result:

Table 5.12: Panel Granger Causality Result for Economic Growth Model

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
LLEXP does not homogeneously cause LGDPPC	5.28835	2.60671	0.0091
LGDPPC does not homogeneously cause LLEXP	14.0268	10. 1451	0.0000
LCGFCF does not homogeneously cause LGDPPC	0.82856	-1.24061	0.2147
LGDPPC does not homogeneously cause LCGFCF	0.57416	-1.46008	0.1443

LSES does not homogeneously cause LGDPPC	1.31959	-0.81702	0.4139
LGDPPC does not homogeneously cause LSES	5.49071	2.78128	0.0054
LCO2PC does not homogeneously cause LGDPPC	4.60987	2.02141	0.0432
LGDPPC does not homogeneously cause LCO2PC	4.19420	1.66282	0.0963
LCHEPC does not homogeneously cause LGDPPC	2.08676	-0.15520	0.8767.
LGDPPC does not homogeneously cause LCHEPC	4.80232	2.18743	0.0287

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Data sourced from World Bank development indicator

The panel Granger causality results presented in Table 5.12 shows the direction of causal relationships between economic growth (LGDPPC) and its key determinants across the BRICS countries.

Firstly, a bidirectional causality exists between life expectancy (LLEXP) and economic growth (LGDPPC), as both causality tests are statistically significant ($p = 0.0091$ and $p = 0.0000$). This indicates that not only does improved health and longevity stimulate higher economic growth (supporting the Health-Led Growth Hypothesis), but economic growth in turn enhances life expectancy through higher income, improved healthcare access, and better living standards. This mutual relationship is consistent with empirical findings by Gürler et al. (2022) and Ngangue and Manfred (2015), who also reported two-way causality between income and life expectancy in developing economies.

We observe no causal relationship between gross fixed capital formation (LCGFCF) and economic growth, as both directions are statistically insignificant ($p = 0.2147$ and $p = 0.1443$). This suggests that investment does not Granger-cause growth in the short run, nor does growth drive investment significantly across the BRICS. This might likely be as a result of inefficiencies in capital utilization, or long gestation periods of investment projects. Similar weak causality findings were reported by Biyase and Maleka (2019) and Udoh and Ogbuagu (2021) for developing economies, where institutional and technological factors constrain investment effectiveness.

Additionally, a unidirectional causality runs from economic growth to education (LSES) (p = 0.0054), but not vice versa (p = 0.4139). This implies that rising income levels promote educational expansion, possibly through increased public funding and household investment in education, whereas education improvements do not immediately translate into higher growth within the sample period. This supports the argument by Kouladoum (2023),that the growth benefits of education often manifest over the long term through enhanced human capital accumulation.

Also, we found a unidirectional causality from CO_2 emissions (LCO2PC) to economic growth (p = 0.0432), while the reverse causality is weakly insignificant (p = 0.0963). This means that higher carbon emissions, which reflect industrialization and energy consumption, tends to precede economic growth, consistent with early-stage industrial growth patterns observed by Matthew et al. (2020) and Osei-Kusi et al. (2024). However, this also signals potential sustainability concerns, as long-run excessive emissions can harm growth through environmental degradation.

Finally, unidirectional causality is observed from economic growth to health expenditure (LCHEPC) (p = 0.0287), while the reverse causation is not significant (p = 0.8767). This implies that as economies grow, governments and households allocate more resources to healthcare, but short-run increases in health expenditure do not immediately cause growth. This pattern mirrors findings by Li and Li (2021) and Papageorgiou and Kousis (2018), who argue that the growth effects of health spending emerge gradually through cumulative improvements in human capital and productivity.

In summary, the causality results reveal that the BRICS economies exhibit strong bidirectional links between health and growth, growth-driven effects on education and health expenditure, and pollution-led short-run growth dynamics, while investment remains non-causal. These outcomes reinforce the integrated framework of endogenous growth and health-led growth theories, stressing the critical role of human capital and environmental management in sustaining long-term economic development.

5.6 Conclusion

The outcomes of every test that was conducted are shown in this chapter. The statistical software package EViews 12 was used to produce the various test results. The study employed

the panel cointegration approach, which confirmed long-run relationship among the variables in the two models estimated in this study. We proceeded with FMOLS and DOLS estimators to generate the long-run coefficients of our variables, diagnostic tests and finally the causality tests.

For life expectancy model (Model 1) of this study, the FMOLS estimation provides a clear picture of the long-run determinants of life expectancy in the BRICS countries. The results show that GDP per capita and education have statistically significant positive effects on life expectancy, suggesting that higher income levels and improved educational attainment are key drivers of better population health over time. Conversely, CO_2 emissions exhibit a significant negative relationship with life expectancy, indicating that environmental degradation poses a serious threat to health outcomes. Other variables, including trade openness, the number of physicians per 1,000 people, and health expenditure, have positive but statistically insignificant coefficients, implying that their long-run effects on life expectancy are relatively weak or indirect. The FMOLS model yields a high coefficient of determination ($R^2 = 0.93$), demonstrating that the included variables collectively explain a substantial proportion of the variation in life expectancy across BRICS nations. Overall, the FMOLS results highlight that sustained economic growth, improved education, and effective environmental management are essential for enhancing long-term health outcomes within the BRICS economies. The Granger causality results indicate a bidirectional relationship between GDP per capita and life expectancy, confirming that economic growth and population health mutually reinforce each other in the BRICS countries. A unidirectional causality from carbon emissions to life expectancy suggests that environmental degradation significantly affects health outcomes. Additionally, life expectancy Granger-causes both trade openness and the number of physicians per 1,000 people, implying that improved health promotes greater economic engagement and investment in healthcare capacity. However, no causal links were found between life expectancy and either social sector expenditure or health expenditure. Overall, the results highlight the interdependence between economic performance, environmental quality, and health outcomes in the BRICS economies.

In the Model 2 of this study, the FMOLS estimation reveals that life expectancy (LLEXP) and current health expenditure per capita (LCHEPC) exert strong and statistically significant positive effects on economic growth in the BRICS countries. This finding implies that improvements in population health and sustained investment in healthcare systems enhance

productivity and long-term economic performance. Conversely, gross fixed capital formation (LCGFCF), education (LSES), and carbon emissions (LCO2) display statistically insignificant coefficients, indicating weaker or indirect impacts on growth in the long run. The high R^2 value (0.97) confirms that the included variables collectively explain most of the variation in GDP per capita across the BRICS economies. Overall, the FMOLS results highlight that healthier populations and effective health investments are key drivers of sustainable economic growth, while traditional growth inputs such as capital accumulation and education are not. The Granger causality analysis reveals a bidirectional relationship between life expectancy (LLEXP) and GDP per capita (LGDPPC), indicating that improvements in population health and economic growth mutually reinforce each other in the BRICS countries. Economic growth also Granger-causes education (LSES) and health expenditure per capita (LCHEPC), suggesting that rising income levels promote investment in human capital and healthcare systems, while the reverse effects are not significant. Carbon emissions (LCO_2PC) exhibit a unidirectional causality toward GDP per capita, highlighting the influence of environmental quality on economic performance. In contrast, gross fixed capital formation (LCGFCF) shows no significant causal relationship with GDP per capita in either direction, implying a weaker or delayed impact on economic growth. Overall, the results emphasize the critical role of population health in driving economic performance, while environmental factors and human capital investments are largely shaped by income growth within the BRICS economies.

CHAPTER SIX

SUMMARY, CONCLUSION AND POLICY RECOMMENDATION

6.1 Introduction

This chapter encapsulates the summary and conclusion of the study. It also captures the policy recommendations for the two estimated models of this study, and the limitations of the study as well as areas for further study.

6.2 Summary

The primary objective of this study was to empirically investigate the relationship between economic growth and life expectancy in the BRICS countries over the period 2000 to 2023. Base on the tenets of the Preston curve theory and endogenous growth model, the study

examined the applicability of this relationship for the BRICS nations and proceeded to examine the direction of causation between life expectancy and economic growth. The study was divided into five main chapters in order to accomplish the above described objective. The sixth and last chapter contains the summary, conclusion, and policy proposals.

The basis of the study was established in Chapter one. The introduction, problem statement, objective, hypotheses, and contribution of the study were all presented in this chapter. Chapter two began with a brief overview of life expectancy, whereby the definition of life expectancy, factors influencing life expectancy as well as life expectancy in the BRICS countries were examined. It was observed that significant progress has been made in raising life expectancy in the BRICS countries. Each country, however, has encountered distinct obstacles and has implemented diverse government efforts to tackle them. Although the precise circumstances and techniques may vary, the ultimate objective remains to continue improving the health and life span of their population. Also captured in this chapter is the definition of and economic growth of the BRICS countries. The influence of technology on life expectancy and economic growth of the BRICS was briefly examined in the chapter.

We captured the literature, both theoretical and empirical, supporting the investigation in chapter three. Theories such as the Preston curve hypothesis, Human Capital theory, Health-Led Growth hypothesis, and Endogenous Growth model lend explanation to the relationship between economic growth and life expectancy (health). However, the functional model for this study was constructed based on the Preston curve hypothesis and the empirical literature reviewed in this chapter. Therefore, the literature evaluation supports the inclusion of the variables required in the models of this study to accomplish the goal of the study. Having observed from the reviewed literature and studies that there are not many studies on life expectancy and economic growth in the BRICS nations, this current study intends to provide recommendations that are pertinent to the development of BRICS policies.

Chapter Four outlined the empirical methodology adopted in this study. It presented the model specification based on the theoretical and empirical literature, as well as the a priori expectations, data description, and analytical techniques used to achieve the research objectives. The Panel Cointegration approach was deemed suitable for the study; therefore, the analysis began with descriptive statistics, graphical exploration, and unit root tests (Im-Pesaran-Shin and Levin et al.). Panel cointegration tests were then applied to establish the

existence of a long-term relationship among the variables. This was followed by the estimation of long term coefficients using FMOLS and DOLS. Lastly, the panel Granger causality test was conducted to observe the direction of causality among the variables. The empirical model of Jetter et al. (2016) and the Preston curve hypothesis (1975) served as the theoretical foundation for the functional model of Life Expectancy (model 1) while the Economic growth model (model 2) of this study is built basis of the endogenous growth theory and the empirical work of Yang and Lin (2021).

6.3. Conclusion of the Study

In conclusion, from the unit root tests it was observed that the variables were integrated of order one [I(1)] hence the Pedroni and Kao tests of cointegration was utilized to confirm the long run relationship of the variables. Upon confirming that the variables are conitegrated, the coefficients of variables were generated with use of both the FMOLS and DOLS models to determine the precise effect of our independent variables on the dependent variable in the various model. The logical implication of findings of the study are made on the outcome of the FMOLS estimates.

For life expectancy model (Model 1) of this study, the FMOLS estimation provides a clear picture of the long-run determinants of life expectancy in the BRICS countries. The results show that GDP per capita and education have statistically significant positive effects on life expectancy, suggesting that higher income levels and improved educational attainment are key drivers of better population health over time. Conversely, CO_2 emissions exhibit a significant negative relationship with life expectancy, indicating that environmental degradation poses a serious threat to health outcomes. Other variables, including trade openness, the number of physicians per 1,000 people, and health expenditure, have positive but statistically insignificant coefficients, implying that their long-run effects on life expectancy are relatively weak or indirect. The FMOLS model yields a high coefficient of determination ($R^2 = 0.93$), demonstrating that the included variables collectively explain a substantial proportion of the variation in life expectancy across BRICS nations. Overall, the FMOLS results highlight that sustained economic growth, improved education, and effective environmental management are essential for enhancing long-term health outcomes within the BRICS economies. The Granger causality results indicate a bidirectional relationship between GDP per capita and life expectancy, confirming that economic growth and population health mutually reinforce each

other in the BRICS countries. A unidirectional causality from carbon emissions to life expectancy suggests that environmental degradation significantly affects health outcomes. Additionally, life expectancy Granger-causes both trade openness and the number of physicians per 1,000 people, implying that improved health promotes greater economic engagement and investment in healthcare capacity. However, no causal links were found between life expectancy and either social sector expenditure or health expenditure. Overall, the results highlight the interdependence between economic performance, environmental quality, and health outcomes in the BRICS economies.

In the Economic Growth Model of this study, the estimated result reveals that life expectancy (LLEXP) and current health expenditure per capita (LCHEPC) exert strong and statistically significant positive effects on economic growth in the BRICS countries. This finding implies that improvements in population health and sustained investment in healthcare systems enhance productivity and long-term economic performance. Conversely, gross fixed capital formation (LCGFCF), education (LSES), and carbon emissions (LCO2) display statistically insignificant coefficients, indicating weaker or indirect impacts on growth in the long run. The high R^2 value (0.97) confirms that the included variables collectively explain most of the variation in GDP per capita across the BRICS economies. Overall, the results highlight that healthier populations and effective health investments are key drivers of sustainable economic growth, while traditional growth inputs such as capital accumulation and education are not. The Granger causality analysis reveals a bidirectional relationship between life expectancy (LLEXP) and GDP per capita (LGDPPC), indicating that improvements in population health and economic growth mutually reinforce each other in the BRICS countries. Economic growth also Granger-causes education (LSES) and health expenditure per capita (LCHEPC), suggesting that rising income levels promote investment in human capital and healthcare systems, while the reverse effects are not significant. Carbon emissions (LCO_2PC) exhibit a unidirectional causality toward GDP per capita, highlighting the influence of environmental quality on economic performance. In contrast, gross fixed capital formation (LCGFCF) shows no significant causal relationship with GDP per capita in either direction, implying a weaker or delayed impact on economic growth. Overall, the results emphasize the critical role of population health in driving economic performance, while environmental factors and human capital investments are largely shaped by income growth within the BRICS economies.

6.4 Policy Recommendations

Based on the findings of this study, several key policy recommendations emerge for the BRICS countries aimed at improving life expectancy and overall health outcomes, while simultaneously supporting sustainable economic growth. The evidence highlights the need for integrated policy approaches that strengthen population health, promote effective health sector investments, and address environmental challenges, all of which play essential roles in enhancing long-term economic performance within the BRICS economies.

6.4.1 Policy Recommendation for Life Expectancy Model

For the life expectancy model of this study, the empirical findings indicate several policy directions are necessary to enhance life expectancy and overall health outcomes in the BRICS countries. Firstly, the significant and mutually reinforcing relationship between GDP per capita and life expectancy underscores the need for policies that promote sustainable economic growth. Governments should invest in productive sectors, strengthen social protection systems, and ensure that economic gains are channelled into improving living standards and health-related infrastructure. Integrating health considerations into economic planning is essential, as healthier populations contribute more effectively to labour productivity and long-term economic performance.

Furthermore, the strong positive effect of education on life expectancy highlights the importance of expanding access to quality education across all levels. Public investment should prioritize ensuring universal basic and secondary education, reducing dropout rates, and integrating health literacy into school curricula. Improved educational attainment not only equips individuals with the knowledge needed to adopt healthy behaviours but also enhances their long-term socio-economic prospects, which in turn supports better health outcomes.

Given the significant negative effect of CO_2 emissions on life expectancy, and the unidirectional causality from emissions to health outcomes, environmental protection must be prioritized. Policymakers should adopt stringent emission-reduction strategies, promote renewable energy sources, and enforce industrial pollution controls. Strengthening environmental regulations and monitoring systems will reduce pollution-related health risks and help build climate-resilient health systems capable of responding to environmental threats.

6.4.2 Policy Recommendations for Economic Growth Model

The results show that life expectancy exerts a significant long-run positive effect on economic growth, and also Granger-causes GDP per capita, underscoring the critical role of population health in driving economic performance. Consequently, policymakers should prioritize strategies aimed at improving health outcomes through expanded access to quality healthcare, stronger preventive health programmes, and targeted interventions addressing the major causes of morbidity and mortality. Investments in clean water, sanitation, nutrition, and improved living conditions should also be expanded, as these measures contribute directly to increased life expectancy and, by extension, sustained economic productivity. Integrating health improvement initiatives into national development planning is therefore essential, given the direct causal pathway running from population health to economic output.

Furthermore, the study finds that current health expenditure per capita has a strong and statistically significant long-run impact on economic growth. This result indicates that sustained investment in healthcare is a productive expenditure that enhances labour efficiency and supports long-term economic performance. BRICS governments should therefore increase the level and quality of health-sector financing, ensuring that resources are allocated efficiently toward strengthening health infrastructure, expanding healthcare coverage, modernizing medical equipment, and building a well-trained health workforce. Emphasizing cost-effective and preventive healthcare interventions will enhance the economic returns on health spending and contribute to a more resilient and productive population.

In addition, the Granger causality results reveal that carbon emissions exert a unidirectional causal influence on economic growth, suggesting that environmental conditions have a measurable effect on economic performance, even though carbon emissions are not significant in the long-run estimation. This finding highlights the need for stronger environmental management policies within the BRICS economies. Policymakers should adopt stricter emission control regulations, promote the use of renewable energy, and encourage cleaner industrial technologies to reduce the economic burden associated with pollution-induced health problems and reduced labour productivity. Enhancing environmental quality through sustainable practices will help safeguard long-term economic growth by minimizing the adverse effects of environmental degradation on human health and economic activity. Overall, these results emphasize the importance of population health, effective health-sector investment,

and sound environmental management in promoting sustainable economic growth across the BRICS countries.

6.5 Limitations of the Study

Although the study provides valuable insights into the health–growth nexus among BRICS countries, certain limitations remain. The analysis is confined to BRICS economies, which may limit the generalizability of findings to other developing regions with different institutional contexts. It also relies on secondary data, which may contain measurement or reporting inconsistencies. Moreover, the focus on macro-level indicators excludes micro-level and institutional factors, such as governance quality or health system efficiency, that could influence outcomes. The econometric methods used (FMOLS, DOLS, and panel causality tests) assume linearity and cross-country homogeneity, potentially overlooking country-specific or non-linear dynamics. DOLS estimator produced statistically insignificant output, thus revealing its weakness identified in the study. Finally, the study period does not fully capture post-pandemic developments, which could alter the relationship between health outcomes and economic performance.

6.6 Areas for Future Research

While this study offers important insights into the long- and short-run linkages between life expectancy and economic growth in the BRICS countries, several areas merit further exploration. Future research could incorporate additional variables such as income inequality, institutional quality, innovation, and demographic dynamics to capture broader socio-economic influences on health and growth. Country-specific analyses within the BRICS bloc and comparisons with other emerging regions would also enhance the robustness and generalizability of findings. Employing advanced econometric techniques, such as panel VAR or non-linear cointegration models, could provide deeper understanding of the dynamic and potentially asymmetric relationships between health and economic performance. Moreover, examining the post-pandemic period would offer valuable insights into how health shocks and policy responses reshape the health–growth nexus in developing economies.

REFERENCES

Aakvik, A., de Castro, M.C. and Souza, P.H., 2024. *Public health and life expectancy trends in Brazil: Post-pandemic recovery and equity challenges*. Journal of Global Health, 14(3), pp.221–236.

Aakvik, A., Jones, A.M. and Salvanes, K.G. 2024 *Determinants of Life Expectancy: Health, Environment and Policy Interactions*. Cambridge: Cambridge University Press.

Abbas, Q., 2008. Human capital and economic growth: Pakistan, 1960-2003. *The Lahore journal of economics*.

Abdulkarim, Y. 2023. A systematic review of investment indicators and economic growth in Nigeria. *Humanities and Social Sciences Communications, 10*, 500.

Abubakari, M., Kolo, I. and Balami, D. 2019. *Economic growth and life expectancy in sub-Saharan Africa: Evidence from panel data analysis.* African Journal of Economic Review, 7(2), pp. 1–17.

Acemoglu, D. and Johnson, S. 2007 'Disease and development: The effect of life expectancy on economic growth', *Journal of Political Economy*, 115(6), pp. 925–985.

Adewuyi, A.O. and Awodumi, O.B. 2020. *Renewable and non-renewable energy-growth-emissions linkages: Review of emerging trends with policy implications*. Renewable and Sustainable Energy Reviews, 120, 109620. https://doi.org/10.1016/j.rser.2019.109620

Afshin, A., Sur, P.J., Fay, K.A. et al. 2019 'Health effects of dietary risks in 195 countries, 1990–2017: A systematic analysis for the Global Burden of Disease Study 2017', *The Lancet*, 393(10184), pp. 1958–1972.

Agarwal, A. 2023. *BRICS economies and global economic transformation*. Journal of Emerging Economies, 15(2), 45–62.

Agarwal, S. 2023 *Economic Growth and Development in BRICS: Challenges and Prospects*. New Delhi: Routledge India.

Agheli, L. and Emamgholipour, S., 2015. Determinants of life expectancy at birth in Iran: a modified Grossman health production function. *Eur Online J Nat Soc Sci*, *4*(2), pp.427-37.

Aghion, P. and Howitt, P. 1998 *Endogenous Growth Theory*. Cambridge, MA: MIT Press.

Aghion, P., Boustan, L., Hoxby, C., & Vandenbussche, J. 2009. The causal impact of education on economic growth: Evidence from U.S. states. Brookings Papers on Economic Activity, 40(1), 1–73.

Ahmad, N., Khan, S. and Raza, N., 2019. *Environmental degradation, healthcare expenditure and life expectancy in MENA countries: Evidence from GMM approach.* Environmental Economics and Policy Studies, 21(4), pp.637–655.

Ahmad, N., Zhao, Z.Y., Irfan, M. and Mukeshimana, M.C. 2019. *Empirical analysis on the impact of CO_2 emissions on health indicators in developing countries.* Environmental Science and Pollution Research, 26(14), pp. 13947–13960. https://doi.org/10.1007/s11356-019-04918-6

Aigheyisi, O.S. and Oligbi, B.O., 2019. *Trade openness, FDI and life expectancy in Nigeria: An ARDL approach.* West African Journal of Monetary and Economic Integration, 19(1), pp.1–26.

Akinbode, S.O. & Oseni, I.O., 2022. *Health expenditure, governance and population health outcomes in sub-Saharan Africa: A dynamic panel analysis.* African Journal of Economic Policy, 29(2), pp.45–63.

Akinyemi, J.O., Nwosu, C.O. & Odimegwu, C.O., 2020. *Public health expenditure, governance and health outcomes in South Africa.* BMC Public Health, 20(1), pp.1–13.

Akpan, G.E. and Udo, U.E. 2021. *Environmental degradation and life expectancy in developing countries: A panel data analysis.* Environmental Economics, 12(1), pp. 56–66. https://doi.org/10.21511/ee.12(1).2021.05

Akpan, U.F. and Udo, E.E., 2021. *CO_2 emissions, economic growth and life expectancy in Sub-Saharan Africa.* African Journal of Economic Review, 9(2), pp.16–34.

Alam, M.S., Raza, S.A. and Shahbaz, M. 2016. *Economic growth, energy consumption, and environmental degradation in Pakistan: Is the environmental Kuznets curve a reality?* Renewable and Sustainable Energy Reviews, 54, pp. 1119–1132. https://doi.org/10.1016/j.rser.2015.10.025

Ali, H.S. and Amad, A.A. 2014. *CO_2 emissions and health outcomes: Evidence from developing countries.* Journal of Economics and Sustainable Development, 5(10), pp. 16–24.

Aliyu, S. & Eze, B., 2019. *Public health expenditure, governance and life expectancy: Evidence from cross-country analysis.* International Journal of Health Economics and Policy, 4(2), pp.45–57.

Almeida, G., Lima, R. and Pereira, F., 2023. *Healthcare financing and access in Brazil: The fiscal constraints of SUS*. Health Economics Review, 13(2), pp.112–129.

Amin, G., Rahman, M.M. and Chowdhury, M. 2018 'Economic growth and life expectancy: Evidence from developing countries', *Journal of Economic Development Studies*, 6(3), pp. 45–58.

Anand, S. & Bärnighausen, T., 2004. *Human resources and health outcomes: Cross-country econometric study*. The Lancet, 364(9445), pp.1603–1609.

Anand, S., & Ravallion, M. 1993. Human development in poor countries: On the role of private incomes and public services. *Journal of Economic Perspectives, 7*(1), 133–150. https://doi.org/10.1257/jep.7.1.133

Anderson, G.F., Frogner, B.K. and Reinhardt, U.E. 2019 'Health spending and outcomes: Trends in OECD countries', *Health Affairs,* 38(7), pp. 1157–1165.

Anozie, U.O. and Nkoro, E., 2023. *Trade openness and life expectancy in Nigeria: Evidence from ARDL model.* Economic Horizons, 25(3), pp.47–64.

Apergis, N., & Payne, J. E. 2009. CO_2 emissions, energy usage, and output in Central America. *Energy Policy, 37*(8), 3282–3286.

Araújo, E., Santos, D. and Oliveira, J., 2023. *Health workforce development and policy responses to COVID-19 in Brazil*. Public Health Policy Journal, 45(1), pp.33–50.

Arize, A.C., Malindretos, J. and Slottje, D.J. 2000. *Cointegration, structural breaks, and the demand for money: Evidence from lesser-developed countries.* International Advances in Economic Research, 6(1), pp. 33–47. https://doi.org/10.1007/BF02295020

Armijo, L.E. and Roberts, C., 2014. *The emerging powers and global governance: The BRICS and beyond*. London: Palgrave Macmillan.

Arora, S. 2017 'Health, human productivity, and long-term economic growth', *Journal of Economic Growth,* 22(4), pp. 321–352.

Asteriou, D., & Agiomirgianakis, G. M. 2001. Human capital and economic growth: Time series evidence from Greece. *Journal of Policy Modeling, 23*(5), 481–489.

Atil, A., Gupta, R. and Majumdar, A. 2021. *The effects of energy consumption and economic growth on CO_2 emissions in BRICS countries: Evidence from panel FMOLS and DOLS approaches*. Environmental Science and Pollution Research, 28(17), pp. 22094–22106. https://doi.org/10.1007/s11356-020-12025-2

Bai, Y., Sun, H. and Liu, J. 2022 'Double burden of diseases in BRICS countries: Challenges for health systems', *International Journal of Environmental Research and Public Health*, 19(4), pp. 2156–2172.

Bakare, A. S. 2011. A theoretical analysis of capital formation and growth in Nigeria. *Far East Journal of Psychology and Business, 3*(1), 11–24.

Baldwin, R. & Thompson, L., 2020. *Fiscal policy, inequality and health outcomes: Evidence from Brazil's Unified Health System.* Health Policy and Planning, 35(8), pp.963–978.

Baltagi, B.H. 2009. *Econometric Analysis of Panel Data*. 4th ed. Chichester: John Wiley & Sons. ISBN: 978-0-470-51906-1

Baltagi, B.H., 2013. *Econometric Analysis of Panel Data*. 5th ed. Hoboken: Wiley

Banerjee, A., Mukherjee, S. and Singh, R., 2022. *Excess mortality and life expectancy loss during COVID-19 in India*. The Lancet Regional Health – Southeast Asia, 3(4), 100059.

Barreto, M.L., Paim, J.S. and Almeida-Filho, N., 2023). *SUS and the future of Brazilian public health: Lessons from the pandemic*. Cadernos de Saúde Pública, 39(1), pp.1–15.

Barro, R. J. 1991. Economic growth in a cross section of countries. Quarterly Journal of Economics, 106(2), 407–443.

Barro, R.J. 1996 'Health and economic growth', *World Health Organization Working Paper Series on Health and Development*, Geneva: WHO.

Barro, R.J. and Sala-i-Martin, X. 2004 *Economic Growth*, 2nd edn. Cambridge, MA: MIT Press.

Bashier, A. and Siam, R. 2014. *Determinants of economic growth in Arab countries: Panel data approach using FMOLS and DOLS techniques.* International Journal of Economics and Finance, 6(10), pp. 191–203. https://doi.org/10.5539/ijef.v6n10p191

Basu, S., Berkowitz, S.A. & Phillips, R.L., 2019. *Association between primary care physician supply and population mortality in the United States, 2005–2015.* JAMA Internal Medicine, 179(4), pp.506–514.

Basu, S., Phillips, R.L. & Bitton, A., 2021. *Projected impact of eliminating primary care shortages on population health in the United States.* Health Affairs, 40(1), pp.62–70.

Becker, G.S. 1964 *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education*. Chicago: University of Chicago Press.

Benhabib, J., & Spiegel, M. M. 1994. The role of human capital in economic development: Evidence from aggregate cross-country data. Journal of Monetary Economics, 34(2), 143–173.

Bhargava, A., Jamison, D.T., Lau, L.J. and Murray, C.J.L. 2014 'Modeling the effects of health on economic growth', *Journal of Health Economics*, 20(3), pp. 423–440.

Bhorat, H., Cassim, A. and Hirsch, A., 2021. *South Africa's growth constraints and labour market challenges*. South African Journal of Economics, 89(3), pp.301–321.

Biyase, M. and Maleka, M. 2019 'Life expectancy and economic growth in SADC countries: Evidence from panel data analysis', *International Journal of Economics and Finance Studies*, 11(1), pp. 1–15.

Bloom, D. E., & Canning, D. 2000. The health and wealth of nations. *Science*, 287(5456), 1207–1209.

Bloom, D. E., Canning, D., & Sevilla, J. 2004. *The effect of health on economic growth: A production function approach*. World Development, 32(1), 1–13.

Bloom, D. E., Canning, D., & Sevilla, J. 2004. The effect of health on economic growth: A production function approach. *World Development, 32*(1), 1–13. https://doi.org/10.1016/j.worlddev.2003.07.002

Bloom, D.E. and Canning, D. 2000. *The health and wealth of nations*. Science, 287(5456), pp. 1207–1209. https://doi.org/10.1126/science.287.5456.1207

Bloom, D.E. and Canning, D. 2008. 'Population health and economic growth', *Commission on Growth and Development Working Paper*, No. 24, Washington, DC: World Bank.

Bloom, D.E. and Canning, D., 2000. The health and wealth of nations. *Science*, 287(5456), pp.1207–1209.

Bloom, D.E., Canning, D. and Sevilla, J. 2004. *The Effect of Health on Economic Growth: A Production Function Approach*. World Development, 32(1), pp. 1–13.

Bloom, D.E., Kuhn, M. and Prettner, K. 2018. 'Health and economic growth', *Oxford Research Encyclopedia of Economics and Finance*, Oxford: Oxford University Press.

Boamah, J., Adongo, F. A., Essieku, R., & Lewis, J. A. 2018. Financial depth, gross fixed capital formation and economic growth: Empirical analysis of 18 Asian economies.

Bokhari, F. A. S., Gai, Y., & Gottret, P. 2007. Government health expenditures and health outcomes. *Health Economics, 16*(3), 257–273. https://doi.org/10.1002/hec.1157

Bongaarts, J. 2016. Slow down population growth. *Nature*, 530(7591), 409–412.

Bongaarts, J. 2019 'Trends in life expectancy and mortality: The role of demographic and social factors', *Population and Development Review*, 45(2), pp. 337–355.

Braveman, P., Egerter, S. and Williams, D.R. 2019. 'The social determinants of health: Coming of age', *Annual Review of Public Health*, 40, pp. 381–398.

BRICS Brasil 2025b *BRICS Health Ministers' Meeting 2025 – Communiqué*. Brasília: BRICS Secretariat.

BRICS *BRICS Joint Statistical Publication 2018*. Moscow: National Statistical Offices of BRICS Countries.

BRICS Data, 2025. *BRICS Economic Outlook 2025*. Available at: https://www.bricsdata.org [Accessed 15 October 2025].

Briller, A. 2007 'Health, income, and inequality in sub-Saharan Africa: Revisiting the Preston Curve', *African Development Review*, 19(3), pp. 234–249.

Bul, J. and Moracha, G., 2020. *Economic growth, trade and health outcomes in Sub-Saharan Africa.* African Economic Review, 12(2), pp.123–144.

Byaro, M. and Mpeta, D., 2021. *Education, parental background and child health outcomes in Sub-Saharan Africa: Evidence from panel data.* Journal of African Development Studies, 13(2), pp.55–72.

Byaro, M. et al., 2021. *Trade openness, health financing and life expectancy in Sub-Saharan Africa.* African Development Review, 33(4), pp.559–573.

Byaro, M., Mlay, S.V. and Mrema, M. 2021. *Trade openness, economic growth and life expectancy in Africa: A panel data analysis.* African Journal of Economic and Management Studies, 12(3), pp. 429–444. https://doi.org/10.1108/AJEMS-02-2020-0062

Carlbäck, H., Jensen, P. and Wittenberg, M. 2024. 'Reassessing the human capital model: Behavioural and institutional constraints in emerging economies', *World Development Perspectives*, 29, pp. 100–114.

Case, A. and Deaton, A. 2020. *Deaths of Despair and the Future of Capitalism*. Princeton: Princeton University Press.

Castro, M.C., Gurzenda, S. and Barros, A.J.D., 2021. *COVID-19 and life expectancy in Brazil: Disparities and decline*. Nature Medicine, 27(10), pp.1629–1635.

Castro, M.C., Massuda, A. and Almeida, G., 2022. *Health inequalities and universal health coverage in Brazil*. The Lancet, 399(10330), pp.1876–1889.

Cavusoglu, B. & Gimba, A.M., 2021. *Health expenditure, environmental quality and life expectancy in Sub-Saharan Africa: Evidence from panel cointegration analysis.* Environmental Science and Pollution Research, 28(9), pp.11410–11425.

Cavusoglu, B. and Gimba, A.M., 2021. *Carbon emissions and health outcomes in Sub-Saharan Africa: Evidence from panel cointegration analysis.* Environmental Economics, 12(1), pp.21–38.

Cervellati, M. and Sunde, U., 2015. *The effect of life expectancy on education and population dynamics.* Economic Journal, 125(584), pp.1161–1195.

Chakraborty, S. 2021 ‘Health, human capital and growth: A theoretical survey’, *Journal of Economic Surveys*, 35(3), pp. 744–773.

Chandola, T. 2020 ‘Inequality and the social determinants of health: A global perspective’, *Social Science & Medicine*, 267, pp. 113375–113385.

Chatterjee, P. and Naka, R. 2022 ‘Economic performance and structural transformation of BRICS economies’, *Journal of Economic Studies*, 49(3), pp. 521–540.

Chatterjee, S., & Naka, A. 2022. Technological advancement and economic transformation in BRICS economies. *International Economics Review*, 18(3), 77–95.

Chen, S., Wu, Q. and Li, H. 2020. *CO_2 emissions, health expenditure and economic growth: Empirical evidence from China.* Environmental Science and Pollution Research, 27(2), pp. 1640–1652. https://doi.org/10.1007/s11356-019-06908-2

Chen, W., Li, R. and Zhang, Y., 2020. *Carbon emissions, urbanization and life expectancy in BRICS economies: A VECM approach.* Energy Reports, 6, pp.520–531.

Chida, Y. and Steptoe, A. 2008 ‘Positive psychological well-being and mortality: A quantitative review of prospective observational studies’, *Psychosomatic Medicine*, 70(7), pp. 741–756.

Choi, I., Kim, D. & Lee, J., 2020. *Health expenditure, education, and economic growth: Evidence from OECD countries using dynamic panel GMM.* Health Economics Review, 10(1), pp.1–14.

Christensen, K., Doblhammer, G., Rau, R. and Vaupel, J.W. 2019.‘Ageing populations: The challenges ahead’, *The Lancet*, 374(9696), pp. 1196–1208.

Clark, R. 2011 ‘Economic development and mortality decline: A re-examination of the Preston relationship’, *Population and Development Review*, 37(4), pp. 675–698.

Clark, R. 2011. *World health inequality: Convergence, divergence, and development.* Social Science & Medicine, 72(3), pp. 617–624. https://doi.org/10.1016/j.socscimed.2010.12.008

Cohen, D. and Soto, M. 2007 ‘Growth and human capital: Good data, good results’, *Journal of Economic Growth,* 12(1), pp. 51–76.

Colantonio, A., Poulin, C., Karg, R.S., Lollar, D., Vanderloo, S. and Georgiades, K. 2010 ‘Health status, stress, and life satisfaction among adults’, *Social Indicators Research*, 99(1), pp. 1–12.

Connolly, R., 2018. *Russia’s response to sanctions: How Western economic statecraft is reshaping political economy in Russia*. Cambridge: Cambridge University Press.

Coovadia, H., Jewkes, R. and Barron, P., 2023. *Health policy and life expectancy trends in South Africa: Progress and inequality*. South African Medical Journal, 113(7), pp.532–545.

Cutler, D.M. and Lleras-Muney, A. 2019 ‘Education and health: Evaluating theories and evidence’, in Glied, S. and Smith, P.C. (eds.) *The Oxford Handbook of Health Economics*. Oxford: Oxford University Press, pp. 203–221.

Cutler, D.M., Deaton, A. and Lleras-Muney, A. 2020 ‘The determinants of mortality’, *Journal of Economic Perspectives*, 34(4), pp. 97–120.

Das, D. and Debnath, R., 2023. *Environmental pollution and life expectancy in India: Non-linear evidence from threshold regression.* Ecological Economics, 210, 107844.

De Long, J. B., & Summers, L. H. 1991. Equipment investment and economic growth. *Quarterly Journal of Economics, 106*(2), 445–502.

de Paula, L.F. and Pires, M.C., 2017. *Crises and recovery in Brazil: Structural limits of growth*. Review of Keynesian Economics, 5(2), pp.179–198.

Deaton, A. 2020. *The Great Escape: Health, Wealth, and the Origins of Inequality*. Princeton: Princeton University Press.

Deaton, A., 2004. Health in an age of globalization. *Brookings Trade Forum*, 2004, pp.83–130.

Department of Health South Africa, 2023. *National Health Insurance (NHI) Progress Report 2023*. Pretoria: Government of South Africa.

Desai, R., 2023. *Healthcare inequality and poverty in India: The post-COVID-19 context*. Economic and Political Weekly, 58(12), pp.21–28.

Desai, R., 2024. *The rise of NCDs and life expectancy implications in India*. Indian Journal of Public Health, 68(1), pp.44–56.

Diani, M., Ferreira, J. and Wu, L. 2024 'Income inequality, health disparities, and the limits of human capital accumulation in emerging markets', *International Economic Review*, 65(2), pp. 345–369.

Dickey, D.A. and Fuller, W.A. 1979. *Distribution of the estimators for autoregressive time series with a unit root*. Journal of the American Statistical Association, 74(366), pp. 427–431. https://doi.org/10.1080/01621459.1979.10482531

Dinda, S., & Coondoo, D. 2006. Income and emission: A panel data-based cointegration analysis. *Ecological Economics, 57*(2), 167–181.

Dogan, E., & Seker, F. 2016. The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in European Union countries. *Renewable and Sustainable Energy Reviews, 60*, 1074–1085.

Dollar, D. and Kraay, A., 2004. Trade, growth, and poverty. *The Economic Journal*, 114(493), pp.F22–F49.

Dollar, D., 2001. Is globalization good for your health?. *Bulletin of the World Health Organization*, 79(9), pp.827–833.

Dorrington, R., Moultrie, T. and Laubscher, R. 2018 *Life Expectancy and Mortality Trends in South Africa: 1997–2017*. Cape Town: University of Cape Town Centre for Actuarial Research.

Dumitrescu, E. and Hurlin, C. 2012. *Testing for Granger non-causality in heterogeneous panels.* Economic Modelling, 29(4), pp. 1450–1460. https://doi.org/10.1016/j.econmod.2012.02.014

Ebenstein, A., Fan, M., Greenstone, M., He, G., Yin, P. and Zhou, M. 2015. *Growth, pollution, and life expectancy: China from 1991–2012.* American Economic Review: Papers & Proceedings, 105(5), pp. 226–231. https://doi.org/10.1257/aer.p20151094

Edwards, S. 2016 'Economic growth and health outcomes: Revisiting the Preston Curve using panel data', *Applied Economics Letters*, 23(9), pp. 659–663.

Engle, R.F. and Granger, C.W.J. 1987. *Co-integration and error correction: Representation, estimation, and testing.* Econometrica, 55(2), pp. 251–276. https://doi.org/10.2307/1913236

Epping, J., Mackenbach, J.P. and Brønnum-Hansen, H. 2024 'Healthy life expectancy: A longitudinal study across European populations', *European Journal of Public Health*, 34(2), pp. 241–249.

Estruch, R., Ros, E., Salas-Salvadó, J. et al. 2019 'Primary prevention of cardiovascular disease with a Mediterranean diet supplemented with extra-virgin olive oil or nuts', *New England Journal of Medicine*, 378(25), pp. e34–e45.

Eweade, F.B. 2021 'Public health expenditure, mortality and life expectancy in Nigeria', *International Journal of Social Economics*, 48(5), pp. 734–751.

Farag, M., NandaKumar, A.K., Wallack, S., Hodgkin, D., Gaumer, G. and Erbil, C., 2012. The income elasticity of health care spending in developing and developed countries. *International journal of health care finance and economics*, *12*(2), pp.145-162.

Food and Agriculture Organization (FAO) 2022. *The State of Food Security and Nutrition in the World 2022*. Rome: FAO.

Frankel, M. 1962) 'The production function in allocation and growth: A synthesis', *American Economic Review*, 52(5), pp. 995–1022.

Gadelha, C.A.G., Costa, L.S. and Nunes, J., 2023. *Health industrial complex and Brazil's post-pandemic development model*. Revista de Saúde Pública, 57(2), pp.89–102.

Gakidou, E., Afshin, A., Abajobir, A.A. et al. 2019 ‘Global, regional, and national comparative risk assessment of 84 behavioural, environmental, and occupational, and metabolic risks, 1990–2017’, *The Lancet*, 392(10159), pp. 1923–1994.

Gamze, A. 2023. *Education, health and development: A panel study on emerging economies.* International Journal of Development Studies, 12(2), pp. 95–108.

Ganna, A. and Ingelsson, E. 2015 ‘5-year mortality predictors in 498,103 UK Biobank participants: A prospective population-based study’, *The Lancet*, 386(9993), pp. 533–540.

Gates, B. and Chambers, R. 2020 *Global Health 2030: Innovations and Challenges*. Seattle: Bill & Melinda Gates Foundation.

Gerdtham, U.G. and Jönsson, B., 2000. International comparisons of health expenditure: theory, data and econometric analysis. In *Handbook of health economics* (Vol. 1, pp. 11-53). Elsevier.

Ghebreyesus, T.A. 2020 ‘Public health policies and global preparedness: Lessons from COVID-19’, *The Lancet*, 395(10229), pp. 1111–1113.

Global Health Research and Policy. 2023. BRICS health cooperation and sustainable healthcare systems. *Global Health Research and Policy*, 8(14), 1–12.

Goh, S.K. and Lee, K. 2022 ‘Governance, life expectancy and economic growth: Evidence from structural equation modelling’, *Economic Modelling*, 107, Article 105731.

Goldin, C. 2024 *Career and Family: Women’s Century-Long Journey toward Equity*. Princeton: Princeton University Press.

Goldman Sachs, 2023. *The BRICS and the world economy: 20 years after the acronym*. New York: Goldman Sachs Research.

Gopal, R. and Mehta, P., 2023. *Non-communicable diseases and life expectancy in India: Current patterns and policy implications*. Indian Journal of Community Medicine, 48(4), pp.510–519.

Graham, C. 2019 *Happiness for All? Unequal Hopes and Lives in Pursuit of the American Dream*. Princeton: Princeton University Press.

Griffen, L. 2024 'Inequality, education, and health: Revisiting human capital theory in the 21st century', *Review of Development Studies*, 30(1), pp. 55–74.

Grossman, G. M., & Krueger, A. B. 1995. Economic growth and the environment. *Quarterly Journal of Economics, 110*(2), 353–377.

Grossman, G.M. and Helpman, E., 1993. *Innovation and growth in the global economy*. MIT Press.

Guimarães, R., Silva, P. and Oliveira, J., 2023. *Public health system stress and productivity loss in Brazil*. Journal of Development Studies, 59(5), pp.897–913.

Gujarati, D.N. 2004. *Basic Econometrics*. 4th ed. New York: McGraw-Hill.

Gujarati, D.N. and Porter, D.C. 2009. *Basic Econometrics*. 5th ed. New York: McGraw-Hill/Irwin. ISBN: 978-0-07-337577-9

Gyimah-Brempong, K. and Wilson, M. 2021 'Health, human capital and economic growth revisited', *Applied Economics*, 53(23), pp. 2665–2681.

Haines, A. and Ebi, K.L. 2019 'The imperative for climate action to protect health', *New England Journal of Medicine*, 380(3), pp. 263–273.

Halicioglu, F. 2010 'Modeling life expectancy in Turkey', *Economic Modelling*, 27(1), pp. 207–215.

Hallal, P.C., 2021. *COVID-19 in Brazil: The unfolding of a tragedy*. The Lancet, 397(10273), pp.93–94.

Hansen, C.W., 2012. *Life expectancy and human capital: Evidence from the international data.* Journal of Economic Growth, 17(1), pp.1–38.

Hansen, P. and King, A., 1996. The determinants of health care expenditure: a cointegration approach. *Journal of health economics*, *15*(1), pp.127-137.

Hanushek, E. A., & Kimko, D. D. 2000. Schooling, labor-force quality, and the growth of nations. American Economic Review, 90(5), 1184–1208.

Hanushek, E. A., & Woessmann, L. 2008. The role of cognitive skills in economic development. Journal of Economic Literature, 46(3), 607–668.

Hanushek, E. A., & Woessmann, L. 2021. *Education and economic growth*. In the Oxford Research Encyclopedia of Economics and Finance. Oxford University Press. https://doi.org/10.1093/acrefore/9780190625979.013.651

Harttgen, K., Misselhorn, M. and Klasen, S. 2013 'Economic growth and health inequality: Evidence from BRICS', *World Development*, 52, pp. 1–12.

Hazan, M., 2011. *Life expectancy and schooling: New insights from cross-country data.* Journal of Economic Growth, 16(2), pp.99–133.

Herzer, D. 2017. *Cross-country heterogeneity and the trade–income relationship.* World Development, 96, pp. 324–340. https://doi.org/10.1016/j.worlddev.2017.03.007

Hippe, R. and Fouquet, R. 2023. 'The human capital transition and economic growth: A long-run analysis', *Journal of Economic History*, 83(1), pp. 1–33.

Hitiris, T. and Posnett, J., 1992. The determinants and effects of health expenditure in developed countries. *Journal of health economics*, *11*(2), pp.173-181.

Hmimou, I., Alami, M. and El Houssine, K. 2024 'Health-led growth hypothesis in emerging economies: Empirical evidence from BRICS', *International Journal of Health Economics and Management*, 24(2), pp. 115–137.

Hmimou, R., Allali, A. and Cheikhi, A. 2024 'Human capital, innovation, and growth dynamics in emerging economies: Evidence from BRICS', *Economic Change and Restructuring*, 57(2), pp. 221–242.

Hoang, N.T. and McNown, R. 2006. *Panel data unit roots tests using various estimation methods*. University of Colorado at Boulder, Department of Economics Working Paper No. 06-06.

Hossain, M. and Ahmed, R., 2019. *Carbon emissions, inequality and life expectancy in South America.* Journal of Cleaner Production, 234, pp.315–325.

Hu, F.B., Satija, A. and Manson, J.E. 2018 'Curbing the obesity epidemic: Lessons from the United States', *Journal of the American Medical Association*, 320(13), pp. 1337–1339.

Hurlin, C. and Dumitrescu, E. 2012. *Testing for Granger non-causality in heterogeneous panels.* Economic Modelling, 29(4), pp. 1450–1460. https://doi.org/10.1016/j.econmod.2012.02.014

Hurlin, C. and Venet, B. 2005. *Granger causality tests in panel data models with fixed coefficients.* Mimeo, University of Orleans, France.

Husain, M. 2011 'Income, health, and the Preston Curve: A reassessment with longitudinal evidence', *Social Science & Medicine*, 72(1), pp. 169–177.

IBGE (Instituto Brasileiro de Geografia e Estatística), 2024. *Brazilian Life Expectancy Report 2024*. Rio de Janeiro: IBGE.

Ibragimovich, A.S. 2024 'Informal learning and productivity: Extending the human capital framework in developing countries', *Asian Economic Journal*, 38(2), pp. 147–165.

IIPS (International Institute for Population Sciences), 2023. *India Population and Health Statistics 2023*. Mumbai: IIPS.

Im, K.S., Pesaran, M.H. and Shin, Y. 2003. *Testing for unit roots in heterogeneous panels.* Journal of Econometrics, 115(1), pp. 53–74. https://doi.org/10.1016/S0304-4076(03)00092-7

IMF (International Monetary Fund), 2023. *World Economic Outlook: Global recovery and challenges ahead*. Washington, DC: IMF.

IMF (International Monetary Fund), 2025. *BRICS Economic Update 2025*. Washington, DC: IMF.

Immurana, M., 2021. *School enrolment, foreign direct investment and health outcomes in Africa: A panel analysis.* African Development Review, 33(3), pp.440–455.

International Journal for Equity in Health 2021 ‘BRICS response to COVID-19 and global health governance’, *International Journal for Equity in Health*, 20(1), pp. 210–222.

International Journal for Equity in Health. 2021. Health equity challenges and COVID-19 responses in BRICS nations. *International Journal for Equity in Health*, 20(1), 1–10.

Islam, K. M. S., & Biswas, G. K. 2023. Do foreign grants and capital formation indeed impact economic growth? An empirical evidence from Bangladesh. *European Journal of Development Studies, 3*(3), 35–42.

Ivanov, A. and Petrova, N., 2022. *Demographic shifts and pandemic effects on mortality in Russia*. Population Studies Review, 48(2), pp.210–225.

Ivanov, A., Petrova, N. and Sidorov, V., 2024. *Preventive health and mortality trends in Russia: Post-COVID-19 recovery*. Russian Journal of Public Health, 19(1), pp.1–15.

Ivins, C. 2013 *Health Challenges in the BRICS Nations: Burden of Disease and Policy Implications*. Geneva: World Health Organization.

Jafrin, N., Rahman, M., & Islam, M. 2021. Public health challenges in BRICS countries: Emerging trends and policy responses. *BMC Public Health*, 21(1), 1–11.

Jafrin, S., Ahmed, K. and Kumar, S. 2021 ‘Non-communicable diseases and health inequalities in India and BRICS countries’, *BMC Public Health*, 21(1120), pp. 1–15.

Jasso, G., Massey, D.S., Rosenzweig, M.R. and Smith, J.P. 2021 ‘Social inequalities in the pandemic era: Life expectancy and vulnerability’, *Demography*, 58(5), pp. 1655–1673.

Jen, M., Sundaram, V. and McLeod, C. 2010 ‘Measuring health outcomes: Beyond mortality and morbidity’, *Public Health Reports*, 125 (Suppl 4), pp. 78–84.

Jetter, M., Laudage, S., & Stadelmann, D. (2019). *The Intimate Link Between Income Levels and Life Expectancy: Global Evidence from 213 Years*. Social Science Quarterly, 100(4), 1387–1403. https://doi.org/10.1111/ssqu.12638

Jha, P. and Peto, R. 2014 ‘Global effects of smoking, of quitting, and of taxing tobacco’, *New England Journal of Medicine*, 370(1), pp. 60–68.

Jones, C.I. 2019 *Introduction to Economic Growth*, 4th edn. New York: W.W. Norton & Company.

Jonsson, T. 2005. *Cross-sectional dependence in panel unit root tests: A Monte Carlo study*. Economics Letters, 86(3), pp. 305–312. https://doi.org/10.1016/j.econlet.2004.08.020

Jorgenson, D.W. and Fraumeni, B.M. 2023 'Human capital theory and economic growth: Revisiting the foundations', *Cambridge Journal of Economics*, 47(4), pp. 913–935.

Joseph P., & Agada M. 2024. *Public Health Expenditure and Life Expectancy in Nigeria*. Journal of Economics and Allied Research, 9(2), 33–44.

Jung, K., Lee, H. and Park, J. 2024 'Healthy life expectancy and socio-economic disparities: Evidence from OECD countries', *Health Policy*, 136(3), pp. 287–297.

Kao, C. 1999. *Spurious regression and residual-based tests for cointegration in panel data.* Journal of Econometrics, 90(1), pp. 1–44. https://doi.org/10.1016/S0304-4076(98)00023-2

Kao, C. and Chiang, M.H. 2000. *On the estimation and inference of a cointegrated regression in panel data.* Advances in Econometrics, 15, pp. 179–222. https://doi.org/10.1016/S0731-9053(00)15007-8

Kao, C. and Chiang, M.H. 2002. *Nonstationary panel time series using NPT tests.* In: B.H. Baltagi (ed.), *Nonstationary Panels, Panel Cointegration and Dynamic Panels.* Advances in Econometrics, Volume 15, pp. 179–222. Amsterdam: Elsevier Science.

Kao, C., & Chiang, M. H. 2000. On the estimation and inference of a cointegrated regression in panel data. In B. Baltagi (Ed.), *Nonstationary panels, panel cointegration, and dynamic panels* (pp. 179–222). Emerald Group Publishing.

Karim, M.Z. and Alam, K., 2021. *Environmental pollution, energy use and life expectancy in Southeast Asia.* Environmental Science and Policy, 123, pp.97–107.

Khera, A.V., Emdin, C.A. and Kathiresan, S. 2016 'Genetic risk, adherence to a healthy lifestyle, and coronary disease', *New England Journal of Medicine*, 375(24), pp. 2349–2358.

Kitterlin-Lynch, M., Zhao, T. and Nguyen, D. 2024 ‘Health expenditure, education, and productivity: Empirical testing of human capital models’, *Journal of Economic Policy Research*, 17(3), pp. 289–308.

Koehler, H. 2017 *Poverty, Inequality and Health Outcomes in Developing Nations*. Geneva: United Nations Research Institute for Social Development (UNRISD).

Kouladoum, J.C., 2023. *Inclusive education and life expectancy in Sub-Saharan Africa: Evidence from panel estimations.* International Journal of Social Economics, 50(4), pp.501–519.

Krueger, A. B., & Lindahl, M. 2001. Education for growth: Why and for whom? Journal of Economic Literature, 39(4), 1101–1136.

Kumar, N. and Joseph, K.J., 2005. Export of software and business process outsourcing from developing countries: Lessons from the Indian experience. *Asia-Pacific Trade and Investment Review*, 1(1), pp.91–110.

Kuznets, S. 1955 ‘Economic growth and income inequality’, *American Economic Review*, 45(1), pp. 1–28.

Kuznetsov, V., 2022. *Healthcare inequality and economic disparities in Russia*. Moscow Economic Review, 31(4), pp.44–61.

Kuznetsov, V., 2023. *Non-communicable diseases and the future of Russian health policy*. Health Policy Perspectives, 11(3), pp.77–91.

Lawanson, O.I. and Umar, D.I., 2021. The life expectancy–economic growth nexus in Nigeria: the role of poverty reduction. *SN business & economics*, *1*(10), p.127.

Lelieveld, J., Klingmüller, K., Pozzer, A. et al. 2020 ‘Cardiovascular disease burden from ambient air pollution in Europe reassessed using novel hazard ratio functions’, *European Heart Journal*, 41(39), pp. 3821–3830.

Levin, A., Lin, C.F. and Chu, C.S.J. 2002. *Unit root tests in panel data: Asymptotic and finite-sample properties*. Journal of Econometrics, 108(1), pp. 1–24. https://doi.org/10.1016/S0304-4076(01)00098-7

Levine, R., & Renelt, D. 1992. A sensitivity analysis of cross-country growth regressions. *American Economic Review, 82*(4), 942–963.

Li, M. and Li, Z. 2021. *Public health expenditure and life expectancy in China: Evidence from provincial panel data.* Frontiers in Public Health, 9, 728326. https://doi.org/10.3389/fpubh.2021.728326

Li, Y. & Li, J., 2021. *Government health expenditure and life expectancy in China: Evidence from provincial panel data (1990–2019).* International Journal of Health Policy and Management, 10(5), pp.230–244.

Li, Y., Schoufour, J., Wang, D.D. et al. 2020 'Healthy lifestyle and life expectancy free of cancer, cardiovascular disease, and type 2 diabetes: Prospective cohort study', *BMJ*, 368, l6669.

Liang, X. and Zhang, D., 2017. *CO_2 emissions and life expectancy in China: A spatial econometric analysis.* Environmental Science and Pollution Research, 24(25), pp.20372–20382.

Lima, A., Santos, R. and Carvalho, T., 2022. *Telemedicine and digital health transformation in Brazil*. Telehealth Journal, 38(6), pp.412–427.

Liu, H., 2022. *Physician density and healthy life expectancy: Global evidence from 2000–2020.* Social Science & Medicine, 304, 115088.

Liu, Y., Bai, J. and Sun, H. 2022 'Socioeconomic inequality and disease burden in BRICS countries', *BMC Health Services Research*, 22(1), pp. 1–12.

Liu, Z., Wang, Z., Xu, M., Ma, J., Sun, Y. and Huang, Y., 2023. The priority areas and possible pathways for health cooperation in BRICS countries. *Global Health Research and Policy*, 8(1), p.36.

Lopreite, M. and Mauro, M., 2017. The effects of population ageing on health care expenditure: A Bayesian VAR analysis using data from Italy. *Health policy*, *121*(6), pp.663-674.

Lucas, R.E. 1988 'On the mechanics of economic development', *Journal of Monetary Economics*, 22(1), pp. 3–42.

Lucas, R.E. 1988. *On the mechanics of economic development*. Journal of Monetary Economics, 22(1), pp. 3–42. https://doi.org/10.1016/0304-3932(88)90168-7

Lustig, N., Higgins, S. and Scott, L., 2022. *Bolsa Família and inclusive health development in Brazil*. Social Policy & Administration, 56(5), pp.802–819.

Lutz, W. and Kebede, E. 2018 'Education and health: Reducing disparities through human capital investment', *Population and Development Review*, 44(3), pp. 517–548.

Ma, Y. and Liu, Z., 2023. *Public health resilience and COVID-19 containment in China*. Asian Journal of Health Policy, 18(2), pp.34–51.

Macinko, J. and Harris, M.J., 2015. Brazil's family health strategy—delivering community-based primary care in a universal health system. *New England Journal of Medicine*, *372*(23), pp.2177-2181.

Maddala, G.S. and Wu, S. (1999). *A comparative study of unit root tests with panel data and a new simple test*. Oxford Bulletin of Economics and Statistics, 61(S1), pp. 631–652. https://doi.org/10.1111/1468-0084.0610s1631

Mahadeva, L. and Robinson, P. (2004). *Unit Root Testing to Help Model Building*. London: Centre for Central Banking Studies, Bank of England. ISBN: 978-1-85730-145-6

Mahumud, R.A., Rawal, L.B., Hossain, G., Hossain, R. and Islam, N., 2013. Impact of life expectancy on economics growth and health care expenditures: a case of Bangladesh. *Universal Journal of Public Health*, *1*(4), pp.180-186.

Manea, M.D. and Pătruțiu, A. (2022) 'Life expectancy and economic growth in the European Union: A panel data approach', *Economic Computation and Economic Cybernetics Studies and Research*, 56(3), pp. 21–36.

Mankiw, N. G., Romer, D., & Weil, D. N. 1992. A contribution to the empirics of economic growth. Quarterly Journal of Economics, 107(2), 407–437.

Marinho, F., et al., 2022. *Excess mortality and decline in life expectancy in Brazil during COVID-19*. Revista Brasileira de Epidemiologia, 25(2), e220005.

Mark, N.C. and Sul, D. (2003). *Cointegration vector estimation by panel DOLS and long-run money demand*. Oxford Bulletin of Economics and Statistics, 65(5), pp. 655–680. https://doi.org/10.1111/j.1468-0084.2003.00066.x

Marmot, M. (2015). *The Health Gap: The Challenge of an Unequal World*. London: Bloomsbury.

Marmot, M. (2020) *Build Back Fairer: The COVID-19 Marmot Review*. London: Institute of Health Equity.

Massuda, A., et al., 2022. *Structural challenges in Brazil's healthcare delivery system*. Global Health Action, 15(1), pp.202–216.

Matthew, O., Osabohien, R. and Ogunlusi, T., 2020. *Industrialization, CO_2 emissions and health outcomes in West Africa.* Cogent Economics & Finance, 8(1), 1787682.

Mayosi, B.M. and Benatar, S.R., 2023. *Health and health care in South Africa — 20 years after Mandela*. New England Journal of Medicine, 388(1), pp.89–97.

Mehmood, B. and Shahid, M. (2014). *Dynamic linkages between foreign direct investment, trade openness, and economic growth: Evidence from selected Asian countries.* Pakistan Economic and Social Review, 52(2), pp. 123–144.

MHFW (Ministry of Health and Family Welfare, India), 2023. *National Health Profile 2023*. New Delhi: Government of India.

Mincer, J. (1958) 'Investment in human capital and personal income distribution', *Journal of Political Economy*, 66(4), pp. 281–302.

Ministério da Saúde (Brazil), 2023. *Plano Nacional de Recuperação Pós-Pandemia*. Brasília: Ministério da Saúde.

Modibbo, A. and Idris, M. (2020) ‘Life expectancy and economic growth in Africa: Evidence from panel data’, *African Journal of Economic Review*, 8(1), pp. 77–95.

Momoh, A., Okafor, J. and Adewale, T. (2024) ‘Economic welfare, education, and life expectancy in Sub-Saharan Africa: New evidence from dynamic panel estimations’, *African Development Review*, 36(1), pp. 58–76.

Monteiro, C.A., Levy, R.B. and Claro, R.M., 2022. *Health promotion and disease prevention strategies in Brazil*. Revista de Saúde Pública, 56(4), pp.445–462.

Mozaffarian, D., Rosenberg, I. and Uauy, R. (2020) ‘History of modern nutrition science—implications for current research, dietary guidelines, and food policy’, *BMJ*, 369, m997.

Mújica, O. J., Moreno, C. M., & others. 2014. From words to action: Measuring health inequalities to “leave no one behind.” *Pan American Journal of Public Health*, 38(1), 9–15.

Mújica, O.J., Vázquez, E. and Victora, C.G. (2014) ‘Health inequalities and life expectancy in Latin America: BRICS perspective’, *Revista Panamericana de Salud Pública*, 35(3), pp. 213–221.

Murray, C.J.L., Piot, P. and Lopez, A.D. (2022) ‘COVID-19, health systems, and future pandemics: Building resilient systems’, *The Lancet*, 399(10334), pp. 1302–1313.

NBSC (National Bureau of Statistics of China), 2022. *China Statistical Yearbook 2022*. Beijing: NBSC.

NBSC (National Bureau of Statistics of China), 2023. *Demographic and Aging Report 2023*. Beijing: NBSC.

Newhouse, J.P., 1977. Medical-care expenditure: a cross-national survey. *The journal of human resources*, *12*(1), pp.115-125.

Ngangue, N. and Manfred, E. (2015) ‘Health and economic growth in developing countries: A dynamic panel analysis’, *Journal of Economics and Development Studies*, 3(2), pp. 1–12.

Nguyen, T.H., Pham, C. and Le, D., 2018. *Environmental pollution and public health in Vietnam: A structural equation modeling approach.* International Journal of Environmental Research and Public Health, 15(12), 2677.

NHC (National Health Commission of China), 2024. *Health Development Report 2024*. Beijing: NHC.

Nicolau, J., Păun, C. and Silva, M. 2021 'The dynamic interplay between life expectancy and economic growth: A panel VAR approach', *Economic Systems*, 45(4), Article 100899.

Novak, A., Čepar, Ž. and Trunk, A., 2016. The role of expected years of schooling among life expectancy determinants. *International Journal of Innovation and Learning*, *20*(1), pp.85-99.

Novignon, J., Olakojo, S. A., & Nonvignon, J. 2012. The effects of public and private health care expenditure on health status in sub-Saharan Africa: New evidence from panel data analysis. *Health Economics Review, 2*(22), 1–8. https://doi.org/10.1186/2191-1991-2-22

Nsonwu, M. 2024. Macroeconomic variables and gross fixed capital formation in Nigeria: An asymmetric analysis.

Nunes, J., Almeida, G. and Santos, R., 2023. *Non-communicable diseases and workforce productivity in Brazil*. Journal of Public Health Policy, 44(2), pp.176–192.

O'Connell, P.G.J. 1998. *The overvaluation of purchasing power parity*. Journal of International Economics, 44(1), pp. 1–19. https://doi.org/10.1016/S0022-1996(97)00017-2

O'Neill, J., 2022. *Revisiting the BRICS: The next 20 years of growth*. London: Chatham House.

Obrizan, M. and Wehby, G.L. 2017 'Health expenditures and life expectancy around the world: A new evidence', *Health Economics Review*, 7(31), pp. 1–15.

Oche, M.O. & Ma, G. (2020) 'A panel analysis of health expenditure and economic growth in ECOWAS countries', *African Journal of Business and Economic Research*, 15(1), pp. 55–82.

Ochinanwata, C., Uche, M. and Okafor, C., 2020. *Trade openness and life expectancy in West Africa: A second-generation panel approach.* African Journal of Economic Policy, 27(2), pp.77–94.

OECD, 2022. *Health at a Glance 2022: OECD Indicators*. Paris: OECD Publishing.

OECD, 2023. *Economic Outlook 2023: Rebalancing after the pandemic*. Paris: OECD Publishing.

OECD, 2023. *Health at a Glance 2023: OECD Indicators.* Paris: OECD Publishing.

OECD. (2021). *Health at a glance 2021: OECD indicators*. OECD Publishing.

Ogunleye, O. and Owolabi, O.A., 2017. Human capital development and economic growth in Nigeria. *International Journal of Research and Development-Organization (IJRDO)-Journal of Business Management*.

Ogunleye, T. & Akinwale, A., 2021. *Health expenditure and life expectancy in Africa: A panel data approach.* African Development Review, 33(3), pp.451–464.

Olakunle, J., Akinwale, A. and Yusuf, M., 2024. *Trade liberalization and health outcomes in Nigeria: Evidence from ARDL model.* Journal of Applied Economics and Policy, 8(2), pp.89–107.

Olayiwola, K., 2023. *Trade openness and population health in Nigeria: Empirical insights from ARDL analysis.* Nigerian Journal of Economic Studies, 21(1), pp.33–54.

Oliveira, R., et al., 2022. *Health inequalities and chronic disease management in Brazil*. Public Health Research, 9(3), pp.287–301.

Onwiodiokit, E. A., & Otolorin, G. E. 2021. Capital formation and economic growth in Nigeria: An empirical re-examination. *Bullion, 45*(2), 58–72

Organisation for Economic Co-operation and Development (OECD) 1960s *Education and Economic Growth: Report of the OECD Seminar*. Paris: OECD Publishing.

Organisation for Economic Co-operation and Development (OECD) 2020 *Health at a Glance 2020: OECD Indicators*. Paris: OECD Publishing.

Osabohien, R., Afolabi, A. and Matthew, O., 2020. *Energy consumption, CO_2 emissions and health outcomes in Nigeria: An ARDL approach.* International Journal of Energy Economics and Policy, 10(6), pp.427–435.

Osei-Kusi, A., Boateng, F. and Adom, P., 2024. *Carbon production, energy use and life expectancy: Cross-regional evidence from 82 countries.* Environmental Economics and Policy Studies, 26(2), pp.179–201.

Oseni, I.O., 2022. *Education, aid and life expectancy in Sub-Saharan Africa: A panel data approach.* African Journal of Economic Policy, 29(2), pp.65–84.

Owen, A.L. and Wu, S. 2007. *Is trade good for your health?* Review of International Economics, 15(4), pp. 660–682. https://doi.org/10.1111/j.1467-9396.2007.00679.x

Oxfam 2013 *Working for the Few: Political Capture and Economic Inequality*. Oxford: Oxfam International.

Ozawa, S., Clark, S., Portnoy, A. et al. 2016 'Return on investment from childhood immunization: Updated cost–benefit analysis of vaccination programs in 94 low- and middle-income countries, 2011–2020', *Health Affairs*, 35(2), pp. 199–207.

Ozturk, I. and Acar, A. 2023 'Does life expectancy cause economic growth? New global evidence from Granger causality tests', *Health Economics Review*, 13(2), pp. 1–15.

Paes-Sousa, R. and Santos, L.M.P., 2023. *Social policies and health equity: Evaluating Bolsa Família impacts*. Social Science & Medicine, 326, 115924.

Paim, J., 2022. *The role of SUS in COVID-19 response and Brazil's health equity*. The Lancet Regional Health – Americas, 5, 100120.

Palloni, A. 2020 'Health transitions and global patterns of mortality: Re-examining the evidence', *Population Studies*, 74(3), pp. 295–315.

Panagariya, A., 2020. *India Unlimited: Reclaiming the lost growth momentum*. Oxford: Oxford University Press.

Papageorgiou, C. & Kousis, N., 2018. *Institutional quality, public health expenditure and life expectancy: Evidence from the European Union.* Economic Modelling, 72, pp.206–217.

Partyka, A., Zając, T. & Krawczyk, M., 2022. *Physician density, nursing workforce and longevity in Europe: An econometric analysis.* International Journal of Health Economics and Management, 22(2), pp.185–202.

Paul, J. 2008 'Institutions, health, and the Preston Curve: Beyond GDP', *Health Economics Review*, 2(3), pp. 245–259.

Pedroni, P. 1995. *Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis.* Indiana University Working Paper in Economics No. 95-013.

Pedroni, P. 1999. *Critical values for cointegration tests in heterogeneous panels with multiple regressors.* Oxford Bulletin of Economics and Statistics, 61(S1), pp. 653–670. https://doi.org/10.1111/1468-0084.61.s1.14

Pedroni, P. 2000. *Fully modified OLS for heterogeneous cointegrated panels.* Advances in Econometrics, 15, pp. 93–130. https://doi.org/10.1016/S0731-9053(00)15004-2

Pedroni, P. 2001 *Fully Modified OLS for Heterogeneous Cointegrated Panels*. In: B.H. Baltagi, T.B. Fomby and R.C. Hill (eds.) *Nonstationary Panels, Panel Cointegration, and Dynamic Panels*. Advances in Econometrics, Vol. 15. Bingley: Emerald Group Publishing Limited, pp. 93–130.

Pedroni, P. 2001. *Purchasing power parity tests in cointegrated panels.* Review of Economics and Statistics, 83(4), pp. 727–731. https://doi.org/10.1162/003465301753237803

Pedroni, P. 2002. *Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis.* Econometric Theory, 20(3), pp. 597–625. https://doi.org/10.1017/S0266466604203073

Pedroni, P. 2004. *Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis.* Econometric Theory, 20(3), pp. 597–625.

Pegkas, P. 2014. The link between educational levels and economic growth: A neoclassical approach for the case of Greece. International Journal of Applied Economics, 11(2), 38–54.

Pereira, C., et al., 2023. *Public health financing trends in Brazil: Post-pandemic recovery and challenges*. Health Systems & Reform, 9(1), pp.1–14.

Petrov, I., 2023. *Lifestyle, diet, and NCD burden in Russia*. Russian Journal of Preventive Medicine, 25(2), pp.123–139.

Phillips, P.C.B. and Hansen, B.E. 1990. *Statistical inference in instrumental variables regression with I(1) processes.* Review of Economic Studies, 57(1), pp. 99–125. https://doi.org/10.2307/2297545

Phillips, P.C.B. and Hansen, B.E. 1999. *Fully modified estimation and testing for cointegration regressions.* Econometrica, 67(5), pp. 829–856.

Poças, A. and Soukiazis, E. 2010 'Life expectancy and health expenditure: A panel data analysis', *Empirical Economics Letters*, 9(10), pp. 983–992.

Popov, A. and Smirnova, E., 2023. *Public health delivery challenges and inequalities in Russia*. Eurasian Economic Review, 13(3), pp.456–473.

Pradhan, R. P., Arvin, M. B., Nair, M., & Bennett, S. E. 2018. The dynamics among education, financial development and economic growth in European Union countries. Journal of Economic Studies, 45(2), 310–330.

Preston, S.H. (1975). *The changing relation between mortality and level of economic development.* Population Studies, 29(2), pp. 231–248. https://doi.org/10.1080/00324728.1975.10410201

Preston, S.H. 2007. *The changing relation between mortality and level of economic development.* International Journal of Epidemiology, 36(3), pp. 484–490. https://doi.org/10.1093/ije/dym075

Pritchett, L. and Summers, L.H. 1996 'Wealthier is healthier', *Journal of Human Resources*, 31(4), pp. 841–868.

Prüss-Ustün, A., Wolf, J., Bartram, J. et al. 2019 *Burden of Disease from Inadequate Water, Sanitation and Hygiene: Updated Global Estimates and Regional Comparisons*. Geneva: World Health Organization.

Rachev, S.T., Mittnik, S., Fabozzi, F.J., Focardi, S.M. and Jasic, T. 2010. *Financial Econometrics: From Basics to Advanced Modeling Techniques*. Hoboken, NJ: John Wiley & Sons. ISBN: 978-0-470-47413-1

Rafique, M. and Khan, R.E.A., 2018. *CO_2 emissions and life expectancy in South Asia: A causality analysis.* Environmental Science and Pollution Research, 25(20), pp.19647–19655.

Raghupathi, V. and Raghupathi, W. 2020. *The influence of education on health: An empirical assessment of OECD countries for the period 1995–2015.* Archives of Public Health, 78(1), 20. https://doi.org/10.1186/s13690-020-00402-5

Raghupathi, V. and Raghupathi, W., 2020. *The influence of education on health: An empirical assessment of OECD countries for 1995–2015.* International Journal of Environmental Research and Public Health, 17(21), 7768.

Rao, K. D., Shahrawat, R., & Bhatnagar, A. 2014. Composition and distribution of the health workforce in India. *Human Resources for Health*, 12(1), 1–10.

Rao, K.D., Petrosyan, V., Araujo, E. and McIntyre, D. 2014 'Health system reform and universal health coverage in BRICS countries', *Health Policy and Planning*, 29(7), pp. 849–857.

Rao, V. & Zhang, P., 2018. *Health expenditure, economic growth and life expectancy in Asia: A panel cointegration approach.* Asian Development Policy Review, 6(1), pp.23–38.

Ravallion, M. 2020 *Poverty, Inequality, and Development: Micro and Macro Perspectives*. Oxford: Oxford University Press.

Rebelo, S. 1991 'Long-run policy analysis and long-run growth', *Journal of Political Economy*, 99(3), pp. 500–521.

Reddy, S., Thomas, D. and Krishnan, P., 2023. *Public health response and life expectancy trends in India during and after COVID-19*. Indian Journal of Medical Research, 157(5), pp.455–467.

Redzwan, M. and Ramli, N., 2024. *CO_2 emissions and health outcomes in Malaysia: Evidence from ARDL bounds testing.* Journal of Environmental Management, 352, 120880.

Redzwan, R. & Ramli, N., 2024. *Health expenditure, environmental quality and life expectancy in Malaysia: Evidence from ARDL bounds testing.* Environmental Economics and Policy Studies, 26(3), pp.489–506.

Reis, C., et al., 2023. *Preventive health initiatives and NCD reduction strategies in Brazil*. International Journal of Public Health, 68(1), pp.12–29.

Ridley, D. 2024 'Health inequality and human capital investment in emerging markets', *Journal of Comparative Policy Analysis*, 26(2), pp. 199–217.

Romaniuk, K.C., Brinkerhoff, D. and Oliveira, A. 2020 'Health and development in BRICS: Divergent trajectories and shared challenges', *Global Public Health*, 15(9), pp. 1345–1361.

Romaniuk, P., Poznańska, A., Brukało, K., & Holecki, T. 2020. Health systems and health outcomes in BRICS countries. *International Journal of Environmental Research and Public Health*, 17(3), 1–15.

Romer, P.M. 1986. *Increasing returns and long-run growth*. Journal of Political Economy, 94(5), pp. 1002–1037.https://doi.org/10.1086/261420

Romer, P.M. 1990 'Endogenous technological change', *Journal of Political Economy*, 98(5), pp. S71–S102.

Romer, P.M. 1994 'The origins of endogenous growth', *Journal of Economic Perspectives*, 8(1), pp. 3–22.

Rosstat (Federal State Statistics Service), 2024. *Demographic Yearbook of Russia 2024*. Moscow: Rosstat.

Sá, L., et al., 2022. *Poverty, inequality, and healthcare outcomes in Brazil*. Development Policy Review, 40(6), e12523.

Sachs, J.D. 2005 *The End of Poverty: Economic Possibilities for Our Time*. New York: Penguin Press.

Salahuddin, M., & Gow, J. 2014. Economic growth, energy consumption and CO_2 emissions in Gulf Cooperation Council countries. *Energy, 73*, 44–58.

Salami, K. & Tijjani, B., 2021. *Regional variations in health expenditure and life expectancy in Africa: A panel data analysis.* African Health Sciences, 21(4), pp.1720–1734.

Samer, S., Al-Khouri, A. and Al-Saleh, A., 2017. *Education and health outcomes in the MENA region: A gender-based approach.* Middle East Development Journal, 9(2), pp.145–167.

Sart, G., 2023. *Education quality and life expectancy in BRICS countries: Panel data evidence.* Journal of Emerging Economies and Policy, 8(1), pp.33–49.

Sarti, F.M., et al., 2023. *Health promotion and behavioral change in Brazil: Policy lessons*. Global Public Health, 18(2), pp.255–273.

Schmidt, M.I., Duncan, B.B. and Azevedo, M., 2021. *Chronic diseases and health transitions in Brazil*. The Lancet, 397(10275), pp.1180–1195.

Schultz, T.W. 1960 'Capital formation by education', *Journal of Political Economy*, 68(6), pp. 571–583.

Semmanda, S. 2020 'Population growth, life expectancy and economic development in Sub-Saharan Africa', *African Journal of Economic and Sustainable Development*, 9(4), pp. 387–402.

Sen, A., 2023. *Healthcare inequality in India: Access, affordability, and outcomes*. Indian Economic Review, 58(1), pp.77–95.

Shah, A., Li, X. and Xu, Z., 2021. *Trade openness, CO_2 emissions, and life expectancy in China: Evidence from regime-switching regression.* Environmental Science and Pollution Research, 28(24), pp.31527–31543.

Shahbaz, M., Balsalobre-Lorente, D. and Sinha, A., 2020. *Environmental degradation, health outcomes and renewable energy in G7 countries: A DOLS analysis.* Renewable Energy, 150, pp.661–670.

Shahbaz, M., Gozgor, G., Adom, P.K. and Hammoudeh, S. 2019. *The technical decomposition of carbon emissions and the concerns about FDI and trade openness effects in the United States*. International Economics, 159, pp. 56–73 https://doi.org/10.1016/j.inteco.2019.04.001

Shahbaz, M., Lean, H. H., & Shabbir, M. S. 2012. Environmental Kuznets Curve hypothesis in Pakistan: Cointegration and Granger causality. *Renewable and Sustainable Energy Reviews, 16*(5), 2947–2953.

Sharma, R. 2018. Health and economic growth: Evidence from dynamic panel data of 143 countries. *International Journal of Health Economics and Management, 18*(3), 1–22. https://doi.org/10.1007/s10754-017-9226-2

Sidorov, V., Ivanov, A. and Petrova, N., 2023. *Public health infrastructure and pandemic response in Russia*. Eurasian Health Journal, 17(2), pp.112–128.

Silva, A., Mendes, J. and Barreto, M.L., 2023. *Vaccination, mortality, and life expectancy recovery in post-COVID Brazil*. Epidemiology and Infection, 151, e73.

Soares, R., Santos, L. and Paim, J., 2022. *Economic inequality and healthcare access in Brazil*. Social Indicators Research, 164(1), pp.233–251.

Spence, M. and Lewis, M. 2009 'Health and growth', *Commission on Growth and Development Working Paper No. 24*. Washington, DC: World Bank.

Stats SA (Statistics South Africa), 2022. *Mid-year population estimates 2022*. Pretoria: Statistics South Africa.

Stock, J.H. and Watson, M.W. 1993. *A simple estimator of cointegrating vectors in higher order integrated systems*. Econometrica, 61(4), pp. 783–820. https://doi.org/10.2307/2951763

Stokey, N.L. 2019 *The Economics of Growth*, 2nd edn. Princeton: Princeton University Press.

Sulaimon, O. & Olamide, A., 2022. *Public health spending, inequality, and health outcomes in South Africa.* Journal of African Development Studies, 34(1), pp.88–104.

Sun, H., Bai, Y. and Liu, J. 2022 'Epidemiological transition and NCD burden in BRICS countries: Policy implications', *Frontiers in Public Health*, 10, pp. 1–10.

Tamara, M. 2019. *The Future of BRICS: Economic Growth and Global Governance*. London: Palgrave Macmillan.

Tang, S., Zhou, Y. and Wang, Y., 2023. *Healthcare inequality and rural–urban life expectancy gaps in China*. Health & Place, 79, 102960.

Tariq, M. & Javed, Z., 2016. *Health expenditure, education, and life expectancy: Evidence from South Asia.* International Journal of Economics and Empirical Research, 4(9), pp.463–472.

Temple, J. 1999 'The new growth evidence', *Journal of Economic Literature*, 37(1), pp. 112–156.

Temple, J. 1999. A positive effect of human capital on growth. Economics Letters, 65(1), 131–134.

Trostle, J., Sommerfeld, J. and Simon, J. 2017 'Strengthening global health research: Lessons from infectious disease', *Social Science & Medicine*, 187, pp. 239–247.

Trung, N.Q. 2022. *Education, income and health outcomes in developing countries: Evidence from panel data analysis.* Journal of Asian Development Studies, 11(2), pp. 55–72.

UNAIDS 2020 *Global HIV & AIDS Statistics – 2020 Fact Sheet*. Geneva: Joint United Nations Programme on HIV/AIDS.

UNCTAD, 2022. *Trade and Development Report 2022*. Geneva: United Nations.

UNCTAD, 2023. *World Investment Report 2023: The shift in global value chains*. Geneva: United Nations.

UNDESA. 2022. *World population prospects 2022*. United Nations Department of Economic and Social Affairs.

UNDP, 2022. *Human Development Report 2022: Uncertain times, unsettled lives*. New York: United Nations Development Programme.

UNDP, 2024. *Human Development Report 2024: Health and resilience in post-pandemic recovery*. New York: UNDP.

UNESCO 2022 *Global Education Monitoring Report 2022: Inclusion and Education*. Paris: UNESCO Publishing.

United Nations 2022 *World Social Report 2022: Building Resilience in a Changing World*. New York: United Nations.

United Nations Conference on Trade and Development (UNCTAD) 2023 *World Investment Report 2023: Investing in Sustainable Value Chains*. Geneva: UNCTAD.

United Nations Development Programme (UNDP) 1990 *Human Development Report 1990*. New York: Oxford University Press.

Usman, O. and Abdullahi, I., 2022. *Carbon emissions and life expectancy in Africa: Evidence from FMOLS estimation.* Environmental Science and Pollution Research, 29(12), pp.17945–17959.

Venter, F., et al., 2023. *Rural healthcare resilience and COVID-19 in South Africa*. South African Journal of Public Health, 67(4), pp.422–439.

Victora, C.G., Barreto, M.L. and Almeida, G., 2023. *The resilience of Brazil's health system in the pandemic era*. BMJ Global Health, 8(1), e011223.

Volkov, A., 2023. *Health inequalities and digital transformation in Russian healthcare*. Russian Economic Journal, 96(3), pp.77–92.

Vollmer, M.A.C., Ritchie, H. and Roser, M. 2021 'Impact of the COVID-19 pandemic on life expectancy across countries', *Nature Human Behaviour*, 5(12), pp. 1708–1717.

Vu, T.B., 2022. *Life expectancy and human capital accumulation: A global panel data analysis.* World Development Perspectives, 26, 100407.

Wang, J., Liu, Z. and Ma, Y., 2022. *COVID-19 mortality and life expectancy changes in China*. BMJ Global Health, 7(11), e009876.

Wang, X. & Zhang, Y., 2015. *Health expenditure and life expectancy in India: Evidence from cointegration and causality analysis (1991–2014).* Asian Economic Journal, 29(3), pp.243–260.

Wang, Y., Ma, Y. and Liu, Z., 2024. *Aging, public health, and life expectancy in China: Future challenges*. Population and Development Review, 50(1), pp.45–68.

Wang, Z., Asghar, M.M., Zaidi, S.A.H. and Wang, B., 2019. Dynamic linkages among CO2 emissions, health expenditures, and economic growth: empirical evidence from Pakistan. *Environmental Science and Pollution Research*, *26*(15), pp.15285-15299.

Watts, N., Amann, M., Arnell, N. et al. 2021 'The 2020 report of The Lancet Countdown on health and climate change', *The Lancet*, 397(10269), pp. 129–170.

Wei, S.J. and Wu, Y. 2002. *Globalization and inequality: Evidence from within China.* Review of Economics and Statistics, 84(1), pp. 99–107. https://doi.org/10.1162/003465302317331930

Weil, D.N., 2014. Health and economic growth. In *Handbook of economic growth* (Vol. 2, pp. 623-682). Elsevier.

Well, D.N., 2007. Accounting for the effect of health on economic growth. *The quarterly journal of economics*, *122*(3), pp.1265-1306.

Westerlund, J., 2007. Testing for error correction in panel data. *Oxford Bulletin of Economics and statistics*, *69*(6), pp.709-748.

Willcox, B.J., Donlon, T.A., He, Q. et al. 2018 'FOXO3A genotype is strongly associated with human longevity', *Proceedings of the National Academy of Sciences*, 105(37), pp. 13987–13992.

World Bank 2021 *World Development Indicators 2021*. Washington, D.C.: World Bank.

World Bank. International Economics Department. Development Data Group and World Bank. International Economics Dept. Development Data Group, 1978. *World development indicators*. World Bank.

World Health Organization, 2000. *The world health report 2000: health systems: improving performance*. World Health Organization.

World Health Organization, 2015. World health statistics 2015. Geneva: WHO. Retrieved fromhttp. *who. int/gho/publications/world_health_statistics/EN_WHS2015_Part2. pdf*.

World Health Organization, 2021. *Primary health care measurement framework and indicators: monitoring health systems through a primary health care lens*. World Health Organization.

World Health Organization, 2022. *Working for health 2022-2030 action plan*. World Health Organization.

World Health Organization, 2023. *Tracking universal health coverage: 2023 global monitoring report*. World Health Organization.

World Health Organization, 2023. *Tracking universal health coverage: 2023 global monitoring report*. World Health Organization.

World Health Organization, 2024. *Compendium of WHO and other UN guidance in health and environment, 2024 update*. World Health Organization.

You, S., 2022. *Global evidence on physician density and life expectancy: A dynamic panel approach.* Health Policy, 126(5), pp.367–379.

Zhang, J. 2017. The evolution of China's one-child policy and its effects on population and family outcomes. *Journal of Economic Perspectives*, 31(1), 141–160.

Zhang, Q., Li, S. and Chen, T. 2023 'Life expectancy and economic growth: A nonlinear threshold analysis', *Empirical Economics*, 65(4), pp. 1761–1784.

Zhou, J. and Wang, X. 2017. *Health expenditure, economic growth and life expectancy: Evidence from China.* International Journal of Environmental Research and Public Health, 14(11), 1323. https://doi.org/10.3390/ijerph14111323

Zhou, Y. & Wang, L., 2017. *Health expenditure and longevity in China: An ARDL bounds testing approach.* China Economic Review, 44, pp.106–118.

Zhou, Y., Tang, S. and Wang, Y., 2023. *Rural–urban disparities and pandemic effects on life expectancy in China*. China Population and Development Studies, 7(2), pp.156–170.

APPENDIX

1. Table 5.7: Kao Cointegration Test Result for Economic Growth Model

Kao Residual Cointegration Test
Series: LGDPPC LLEXP LCGFCF LSES LCO2PC LCHEPC
Date: 10/15/25 Time: 08:54
Sample: 2000 2023
Included observations: 120
Null Hypothesis: No cointegration
Trend assumption: No deterministic trend
Automatic lag length selection based on SIC with a max lag of 5
Newey-West automatic bandwidth selection and Bartlett kernel

	t-Statistic	Prob.
ADF	-2.056832	0.0199
Residual variance	0.005800	
HAC variance	0.011053	

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RESID)
Method: Least Squares
Date: 10/15/25 Time: 08:54
Sample (adjusted): 2002 2023
Included observations: 110 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID(-1)	-0.143067	0.045044	-3.176179	0.0019
D(RESID(-1))	0.372106	0.088098	4.223769	0.0001

R-squared	0.159216	Mean dependent var	0.010452
Adjusted R-squared	0.151431	S.D. dependent var	0.102574
S.E. of regression	0.094488	Akaike info criterion	-1.862664
Sum squared resid	0.964231	Schwarz criterion	-1.813564
Log likelihood	104.4465	Hannan-Quinn criter.	-1.842749
Durbin-Watson stat	2.040476		

2. Table 5.8: Pedroni Cointegration Test Result for Economic Growth Model

Pedroni Residual Cointegration Test
Series: LGDPPC LLEXP LCGFCF LSES LCO2PC LCHEPC
Date: 10/15/25 Time: 08:53
Sample: 2000 2023
Included observations: 120
Cross-sections included: 5
Null Hypothesis: No cointegration
Trend assumption: Deterministic intercept and trend
Automatic lag length selection based on SIC with a max lag of 3
Newey-West automatic bandwidth selection and Bartlett kernel

Alternative hypothesis: common AR coefs. (within-dimension)

	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	36.11963	0.0000	16.46080	0.0000
Panel rho-Statistic	1.255276	0.8953	2.469373	0.9932
Panel PP-Statistic	-1.639319	0.0506	0.509119	0.6947
Panel ADF-Statistic	-3.177835	0.0007	-4.064633	0.0000

Alternative hypothesis: individual AR coefs. (between-dimension)

	Statistic	Prob.
Group rho-Statistic	2.655775	0.9960
Group PP-Statistic	-0.367709	0.3565
Group ADF-Statistic	-3.906090	0.0000

Cross section specific results

Phillips-Peron results (non-parametric)

Cross ID	AR(1)	Variance	HAC	Bandwidth	Obs
1	0.234	0.000395	0.000414	1.00	23
2	0.019	0.002232	0.002036	2.00	23
3	0.033	0.000287	0.000105	11.00	23
4	0.445	0.000408	0.000250	4.00	23
5	0.345	0.000412	0.000412	0.00	23

Augmented Dickey-Fuller results (parametric)

Cross ID	AR(1)	Variance	Lag	Max lag	Obs
1	-0.848	0.000261	3	3	20
2	0.019	0.002232	0	3	23
3	-0.450	0.000230	1	3	22
4	0.087	0.000250	1	3	22
5	0.068	0.000302	1	3	22

3. Table 5.9.: FMOLS Result of Economic Growth Model (Model 2)

Dependent Variable: LGDPPC
Method: Panel Fully Modified Least Squares (FMOLS)
Date: 10/15/25 Time: 08:48
Sample (adjusted): 2001 2023
Periods included: 23
Cross-sections included: 5
Total panel (balanced) observations: 115
Panel method: Pooled estimation
Cointegrating equation deterministics: C
Coefficient covariance computed using default method
Long-run covariance estimates (Bartlett kernel, Newey-West fixed bandwidth)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LLEXP	4.534975	1.209370	3.749865	0.0003
LCGFCF	0.054151	0.231423	0.233994	0.8154
LSES	0.584426	0.494965	1.180742	0.2404
LCO2PC	-0.302695	0.384430	-0.787387	0.4328
LCHEPC	0.779138	0.225470	3.455617	0.0008

R-squared	0.965472	Mean dependent var	11.06744
Adjusted R-squared	0.962512	S.D. dependent var	1.174923
S.E. of regression	0.227486	Sum squared resid	5.433718
Long-run variance	0.102522		

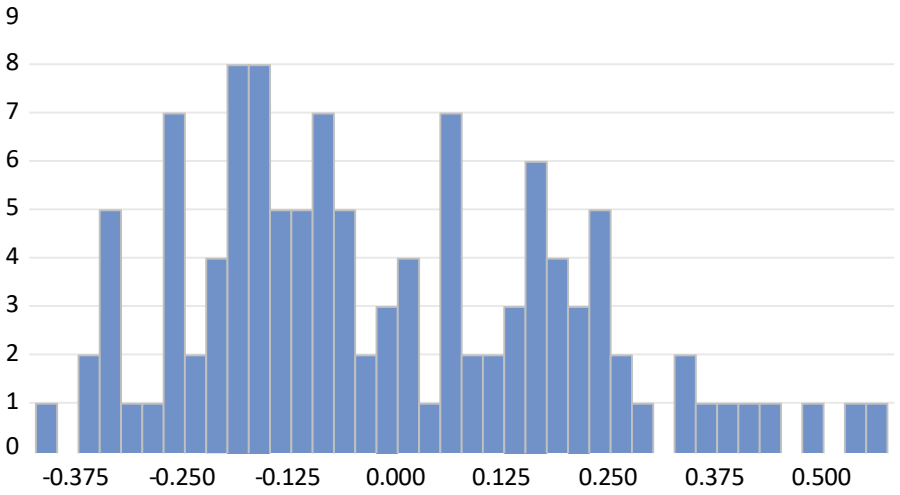
4. Table 5.10: Dynamic OLS Results for Economic Growth Model

Dependent Variable: LGDPPC
Method: Panel Dynamic Least Squares (DOLS)
Date: 10/15/25 Time: 08:51
Sample (adjusted): 2002 2022
Periods included: 21
Cross-sections included: 5
Total panel (balanced) observations: 105
Panel method: Pooled estimation
Cointegrating equation deterministics: C
Fixed leads and lags specification (lead=1, lag=1)
Coefficient covariance computed using default method
Long-run variance (Bartlett kernel, Newey-West fixed bandwidth) used for coefficient covariances

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LLEXP	5.791476	2.420278	2.392897	0.0266
LCGFCF	-0.380525	0.438056	-0.868666	0.3953
LSES	0.851041	0.875568	0.971987	0.3427
LCO2PC	0.255995	0.646250	0.396124	0.6962
LCHEPC	1.016247	0.514593	1.974855	0.0623

R-squared	0.998208	Mean dependent var	11.08165
Adjusted R-squared	0.990681	S.D. dependent var	1.144578
S.E. of regression	0.110489	Sum squared resid	0.244157
Long-run variance	0.002294		

5. Figure 5.4: Normality Test Result for Economic Growth Model



Series: Residuals	
Sample	2001 2023
Observations	115
Mean	-0.017417
Median	-0.068524
Maximum	0.559940
Minimum	-0.412010
Std. Dev.	0.217619
Skewness	0.511901
Kurtosis	2.613050
Jarque-Bera	5.739944
Probability	0.056701

6. Table 5.11: Panel Granger Causality Result for Economic Growth Model

Pairwise Dumitrescu Hurlin Panel Causality Tests
Date: 10/15/25 Time: 08:57
Sample: 2000 2023
Lags: 2

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
LLEXP does not homogeneously cause LGDPPC	5.28835	2.60671	0.0091
LGDPPC does not homogeneously cause LLEXP	14.0268	10.1451	0.0000
LCGFCF does not homogeneously cause LG...	0.82856	-1.24061	0.2147
LGDPPC does not homogeneously cause LC...	0.57416	-1.46008	0.1443
LSES does not homogeneously cause LGDPPC	1.31959	-0.81702	0.4139
LGDPPC does not homogeneously cause LSES	5.49071	2.78128	0.0054
LCO2PC does not homogeneously cause LG...	4.60987	2.02141	0.0432
LGDPPC does not homogeneously cause LC...	4.19420	1.66282	0.0963
LCHEPC does not homogeneously cause LG...	2.08676	-0.15520	0.8767
LGDPPC does not homogeneously cause LC...	4.80232	2.18743	0.0287
LCGFCF does not homogeneously cause LLEXP	4.58523	2.00016	0.0455
LLEXP does not homogeneously cause LCGFCF	2.54391	0.23917	0.8110
LSES does not homogeneously cause LLEXP	3.38399	0.96388	0.3351
LLEXP does not homogeneously cause LSES	2.96386	0.60145	0.5475
LCO2PC does not homogeneously cause LLEXP	9.09114	5.88727	4.E-09
LLEXP does not homogeneously cause LCO2PC	2.77341	0.43715	0.6620
LCHEPC does not homogeneously cause LLEXP	4.10998	1.59017	0.1118
LLEXP does not homogeneously cause LCHEPC	2.20843	-0.05024	0.9599
LSES does not homogeneously cause LCGFCF	3.94534	1.44814	0.1476
LCGFCF does not homogeneously cause LSES	4.36715	1.81203	0.0700
LCO2PC does not homogeneously cause LC...	3.88113	1.39275	0.1637
LCGFCF does not homogeneously cause LCO...	5.06583	2.41476	0.0157
LCHEPC does not homogeneously cause LC...	1.46131	-0.69476	0.4872
LCGFCF does not homogeneously cause LC...	2.31629	0.04281	0.9659
LCO2PC does not homogeneously cause LSES	2.61100	0.29704	0.7664
LSES does not homogeneously cause LCO2PC	4.73951	2.13324	0.0329
LCHEPC does not homogeneously cause LSES	6.19847	3.39185	0.0007
LSES does not homogeneously cause LCHEPC	4.35861	1.80466	0.0711
LCHEPC does not homogeneously cause LC...	6.80792	3.91760	9.E-05
LCO2PC does not homogeneously cause LC...	2.88048	0.52952	0.5964