



**The Effect of Population Growth on Economic Growth in South Africa for the Period of
1950 to 2022**

by

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Abstract

This study examines the relationship between population dynamics and economic growth in South Africa, assessing both the short-run and long-run effects. The study uses annual South African data covering 1960-2022 for the formal econometric analysis, with broader historical discussion covering 1950-2022, used to contextualise demographic and economic trends. The analysis applies cointegration, Dynamic Ordinary Least Squares (DOLS), Autoregressive Distributed Lag (ARDL) modelling, error-correction models, Granger causality tests, structural-break analysis and nonlinear ARDL (NARDL) asymmetry testing.

The results produce five principal findings. First, population size is positively associated with aggregate real GDP in the long run, conditional on capital formation and human-capital development as cointegration is found in all long-run DOLS and ARDL bounds tests. Second, population dynamics provide predictive information for economic performance, and the direction of causality is robust from population size to real GDP. Causality is interpreted as predictive causality and not strict structural causality. Third, the short-run population-growth effect is weaker, with delayed effects in the short-run compared to the long-run relationship, while error-correction terms confirm adjustment towards long-run equilibrium. Fourth, structural and regime changes affect GDP level movements and short-run dynamics but do not overturn the long-run population-output relationship. Fifth, NARDL Wald tests show that positive and negative deviations of population from its long-run trend have asymmetric effects on economic performance in both the short-run and long-run, with negative deviations having a greater economic cost than gains of positive deviations on the South African economy.

The study concludes that population growth is neither automatically growth-enhancing nor inherently growth-reducing. Its economic effect depends on capital formation, education, labour-market absorption, demographic structure and institutional conditions. The findings support policies that treat demographic planning, investment, human-capital formation and employment creation as connected components of South Africa's long-run growth strategy rather than treating demographic factors as separate social-sector issues.

Keywords: Population dynamics; Population growth; Economic growth; South Africa; ARDL; NARDL; Cointegration; Granger causality; Demographic transition; Asymmetric effects; Structural break Dummies.

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Declaration

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Ethical Clearance

Ethical approval for this study was granted by the University of South Africa, College of Economic and Management Sciences Ethics Review Committee (CEMS ERC Economics), under reference number: 3462, for the period 5 April 2024 to 4 April 2027. Ethical clearance issued on 05/04/2024.

The research was conducted entirely using secondary macro-economic data and did not involve any human or animal participants. The study uses only publicly available secondary data from the World Bank, Statistics South Africa, and the United Nations and does not involve human participants, personal data, or confidential information. No primary data collection was undertaken, and no personally identifiable information was accessed or utilised at any stage of the research process.

In the absence of direct participants, the study adhered strictly to the ethical principles and standards prescribed by the University of South Africa, as well as applicable national legislation, including the Protection of Personal Information (Act No. 4 of 2013). All data were handled responsibly, ensuring confidentiality, integrity, and secure storage in accordance with institutional requirements.

The research was conducted in line with the approved methodologies of the economics and econometric discipline, and the researcher maintained full compliance with ethical standards of academic integrity, transparency, and responsible reporting throughout the study.

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Dedication

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This work is dedicated to all of you.

List of Acronyms

Full term	Acronym
Augmented Dickey-Fuller (unit root test)	ADF
Akaike Information Criterion	AIC
Autoregressive Distributed Lag	ARDL
Birth rate	BIR
Cumulative Sum Control Chart	CUSUM
Cumulative Sum of Squared Recursive Residuals	CUSUMSQ
Death Rate	DEA
Dependency Ratio	DEP
Department of Economic and Social Affairs	DESA
Dummy Variable	DUM
Dynamic Ordinary Least Squares	DOLS
Error Correction Model	ECM
Educational Attainment	EDU
F-statistic of Pesaran-Shin-Smith bounds test	FPSS
Gross Domestic Product	GDP
GDP Growth Rate	GDPgrw
Hodrick-Prescott	HP
Integrated of Order Zero (stationary)	I(0)
Integrated of Order One (first difference stationary)	I(1)
International Monetary Fund	IMF
International Organization for Migration	IOM
Investment	INV
Innovational Outlier (Structural Break Test)	IO
Kwiatkowski-Phillips-Schmidt-Shin test	KPSS
Life Expectancy	LIF
Logarithm of Gross Domestic Product	logGDP
Logarithm of Gross Domestic Product per capita	logGDPpc
Logarithm of Capital Formation	logCAP
Logarithm of Population	logPOP
Non-Linear Autoregressive Distributed Lag	NARDL
Organisation for Economic Co-operation and Development	OECD
Population (Total Population)	POP
Population Growth Rate	POPgrw
Phillips-Perron	PP
Residual	RESID
Regression Equation Specification Error Test	RESET
Schwarz Information Criterion	SIC
Sustainable Development Goal	SDG
South Africa	ZAR / SA
T-statistic of Banerjee-Dolado-Mestre cointegration test	TBDM
United Nations	UN
Variance Inflation Factor	VIF
Vector Autoregression	VAR
Vector Error Correction Model	VECM
Heteroskedasticity- and Autocorrelation-Consistent	HAC
World Development Indicators	WDI
Zivot-Andrews (Breakpoint Unit Roots test)	ZA

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Title:

The effect of population growth on economic growth in South Africa for the period of
1950 to 2022.

CHAPTER ONE: INTRODUCTION AND BACKGROUND

1. Introduction

The relationship between population growth and economic growth remains one of the most disputed topics in economics. Classical views such as Malthus (1798) warn that rapid population growth may strain resources and suppress living standards, while modern theories argue that a larger population can expand the labour force, increase innovation and stimulate long-term growth (Acemoglu & Restrepo, 2022). South Africa reflects many of these global tensions, which require careful empirical investigation. The country's population increased steadily across the period of 1950-2022, but GDP growth fluctuated sharply, as shown in Table 1. The population increase is driven by natural increase through fertility, decreasing mortality and rising immigration, along with structural challenges of unemployment, inequality, poverty and periodic xenophobic conflict, which have been linked in the South African literature to economic insecurity, migration social exclusion of foreign nationals caused by misconceptions of population dynamics (Gordon, 2020; Hassim et al., 2008).

Table 1: South African Population and Economic Growth 1950 to 2022

Years	Population (millions)	Real GDP (billions of ZAR)	Population growth rate (annual %)	GDP growth rate (annual %)	Labour Force (millions)	Employment rate (annual %)
1950	13.04	R185.00	2.01%	3.50%	4.59	80.0%
1960	16.44	R407.00	2.68%	4.50%	5.72	82.0%
1970	22.28	R740.00	2.99%	4.50%	8.11	84.0%
1980	29.52	R1,295.00	3.38%	1.50%	8.69	80.0%
1990	40.75	R2,035.00	2.69%	-1.50%	11.44	77.0%
2000	47.16	R2,775.00	0.83%	2.50%	16.08	75.0%
2010	52.34	R6,937.50	1.21%	2.50%	18.35	75.0%
2020	60.56	R6,258.37	1.60%	0.30%	21.34	65.6%
2022	62.38	R7,497.50	1.34%	0.50%	23.38	65.5%

Source: Population data is from United Nations DESA¹ World Population Prospects 2024. Real GDP data is from Statistics South Africa's historical national accounts database.

In Table 1, historical evidence shows that the 1950s-1970s were characterised by rapid growth and high employment, suggesting a positive relationship between population and economic performance. However, the 1980s-1990s saw slowing growth, rising unemployment and political turbulence, weakening this link drastically. The observed movements in Table 1 call for formal econometric testing of both long-run relationships and short-run dynamics between population and output.² Since 2000, GDP growth has been modest and unstable, while employment rates have declined. These patterns imply that the population-growth relationship is not constant over time and may depend on structural conditions, institutions and labour-market dynamics. Given

¹ DESA stands for Department of Economic and Social Affairs, United Nation Population Prospects Division, 2024.

² Although this study discusses economic development-related implications, the formal econometric analysis focuses on economic growth and economic performance measured by aggregate real GDP, its growth rate and referred as output or economic progress.

these outcomes, three dominant perspectives define the population-growth debate namely (i) Population-driven growth, (ii) Population-induced constraints and (iii) Conditional effects.

The population-driven growth hypothesis suggests that a larger population may boost labour supply, market size and innovation capacity when supported by investment, skills and productive employment (Bloom & Williamson, 1998; Headey & Hodge, 2009). The population-induced constraints perspective argues that rapid demographic expansion may increase pressure on resources, infrastructure and employment when capital formation and labour absorption are weak (Brander & Dowrick, 1994; Kelley & Schmidt, 2005). By contrast, the conditional-effects perspective argues that economic outcomes depend on each country's demographic structure, technology, governance and institutional capacity (Bloom et al., 2001; World Bank, 2024). South Africa's experience appears to reflect aspects of all three perspectives, yet most studies focus on developed countries or shorter samples, leaving a gap in understanding for developing nations such as South Africa.

Since 1994, South Africa's population has grown rapidly and migration patterns have shifted, raising new challenges for policy and economic development. The population grew from about 13 million in 1950 to over 62 million by 2022 (Statistics South Africa, 2023). But the economic benefits of this demographic expansion have been uneven, shaped by apartheid-era restrictions, post-1994 reforms, fluctuating investment, global shocks and deep structural inequalities (Nattrass & Seekings, 1994). South African evidence emphasises labour-market and structural channels linking demography and economic performance. Existing literature review at the time of the present study did not identify South African time-series studies that directly estimate the effect of population growth on aggregate economic growth using ARDL or NARDL frameworks over a sample covering both the apartheid and democratic periods. Bhorat and Oosthuizen (2008), using descriptive and econometric analysis of post-apartheid Labour Force Survey and October Household Survey microdata for 1995-2004, show that rapid labour-force expansion without sufficient job creation increases structural unemployment.

Fedderke and Simkins (2012), employing time-series and growth-accounting methods on South African macro-economic data for 1917-2006, find that investment and productivity growth, rather than population size alone, explain long-run output performance. Burger and von Fintel (2014), using econometric age-period-cohort techniques on nationally representative household survey microdata covering 1995-2007, demonstrate that education and human-capital accumulation condition the growth effects of demographic change. Similarly, Bhorat et al. (2014), using applied labour-econometric techniques on labour force survey and sectoral

employment data for the post-1994 period (1994-2012), highlight that labour-market absorption capacity determines whether demographic expansion translates into employment gains. More recent demographic studies by Statistics South Africa (2024), the United Nations (2024), and Mason et al. (2017) show that South Africa's demographic transition has reduced fertility and changed the age structure but has not automatically generated a full demographic dividend because unemployment, inequality and weak labour absorption remain persistent.

Studies also indicate that the relationship is not strictly one-directional. Mostly, the South African evidence points to a context-dependent relationship in which population growth may either support or constrain economic performance depending on labour-market absorption, human capital development and institutional conditions. Despite these dynamics, the empirical link between population changes and economic performance in South Africa remains poorly understood, particularly after the profound political and socio-economic reforms that followed the end of apartheid in 1994. Existing studies tend to focus either on developed economies or South Africa's pre-1994 period (Fedderke & Simkins, 2012), leaving a gap in understanding how demographic shifts have interacted with economic outcomes in both the apartheid and democratic eras. Thus, this study evaluates whether population growth has supported or suppressed economic progress and how this relationship has evolved over 63 years.

This study addresses the lack of long-run analysis on how demographic changes relate to economic performance in South Africa. The broader descriptive discussion covers 1950-2022, while the econometric analysis focuses on 1960-2022 because consistent annual macro-economic series are more reliable from 1960 onward. By examining both the long-run and short-run effects of population growth and demographic structure on economic growth and incorporating structural breaks, demographic transitions and institutional change, the study provides evidence relevant to unemployment, inequality, urbanisation and resource pressures in modern South Africa (Acemoglu & Robinson, 2012).

1.1. Problem Statement

South Africa presents a specific demographic-output puzzle. Its population expanded over the long run, yet aggregate real GDP, investment and employment did not rise at an equal or stable rate across the apartheid, democratic-transition and recent periods. A larger population can enlarge labour supply, domestic demand and market size, but high unemployment, weak capital formation, skills mismatch and spatial inequality can prevent those scale effects from becoming productive output (Bhorat & Oosthuizen, 2008; Bhorat et al., 2014; Fedderke & Simkins, 2012). The empirical problem is therefore not merely whether population changed, but the sign,

magnitude, timing and stability of its relationship with real GDP after accounting for capital and demographic structure based on the augmented Cobb-Douglas production function operators.

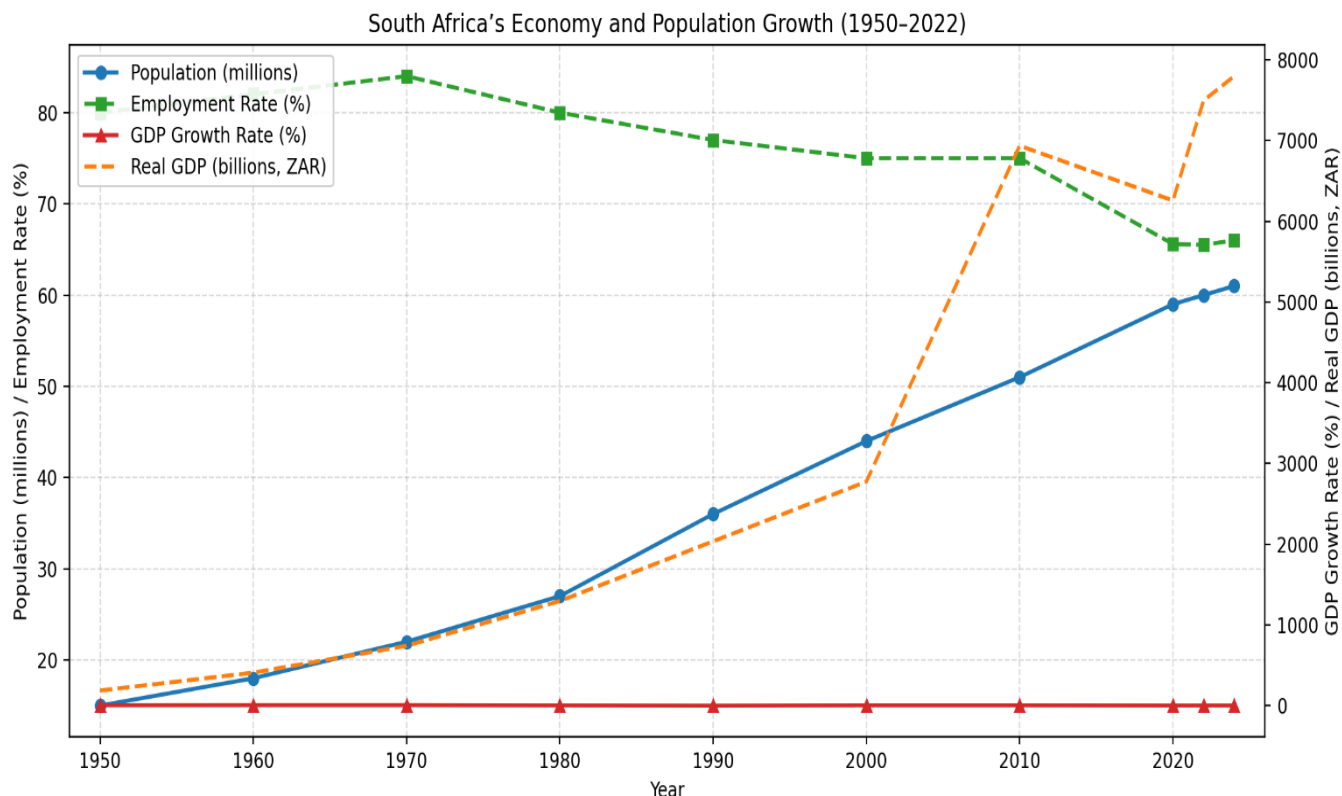
Economic theory does not resolve this puzzle. Malthusian and Solow–Swan mechanisms predict resource pressure and capital dilution when population expands faster than productive capacity, whereas endogenous-growth, demographic-transition and two-sector theories predict gains when additional people are healthy, educated and absorbed into productive employment. International evidence accordingly reports positive, negative and conditional effects (Kelley & Schmidt, 2005; Headey & Hodge, 2009; Adeleye et al., 2022). The reviewed South African literature explains investment and productivity (Fedderke & Simkins, 2012), unemployment and labour absorption (Bhorat & Oosthuizen, 2008; Bhorat et al., 2014), and education–labour-market interactions (Burger & von Fintel, 2014), but does not jointly estimate long-run association, direct short-run responses and equilibrium adjustment, predictive causality, structural sensitivity and sign asymmetry in one country-specific framework.

Five distinct unknowns therefore remain: the long-run population-output association; whether population contains predictive information for output; the direct short-run response and speed of error correction; sensitivity to structural or regime shocks; and whether positive and negative population deviations have equal effects. The dissertation addresses these unknowns through DOLS and Engle–Granger/ARDL cointegration, Granger causality tests, ECM/ARDL short-run models, structural-break and consolidated-dummy checks, and NARDL Wald tests, respectively. Each method supplies a different evidential component, while the design identifies long-run and short-run associations and predictive causality and effects of major economic and health effects on economic outcomes across apartheid and democratic periods. Without this integrated evidence, policy cannot distinguish a demographic asset from a dependency burden created by weak capital, human-capital and labour-absorption capacity.

1.2. Contextual background on demographic-economic trends and policy responses

The descriptive record illustrates why the unresolved relationship matters. Population expansion can support output when accompanied by investment, job creation and skills development (Bloom et al., 2003), but it can intensify unemployment and service pressure when productive absorption is weak. In South Africa, unemployment rose beyond 30% after 2010 despite continued demographic expansion, signalling persistent labour-market constraints (National Treasury, 2023). Figures 1 and 2 place these outcomes between economic growth, employment and demographic trends in their historical context.

Figure 1: South Africa's Economy and Population Growth (1950–2022)



Source: Author's illustration based on World Bank (2022) and Statistics South Africa (2023) data. <https://data.worldbank.org>.

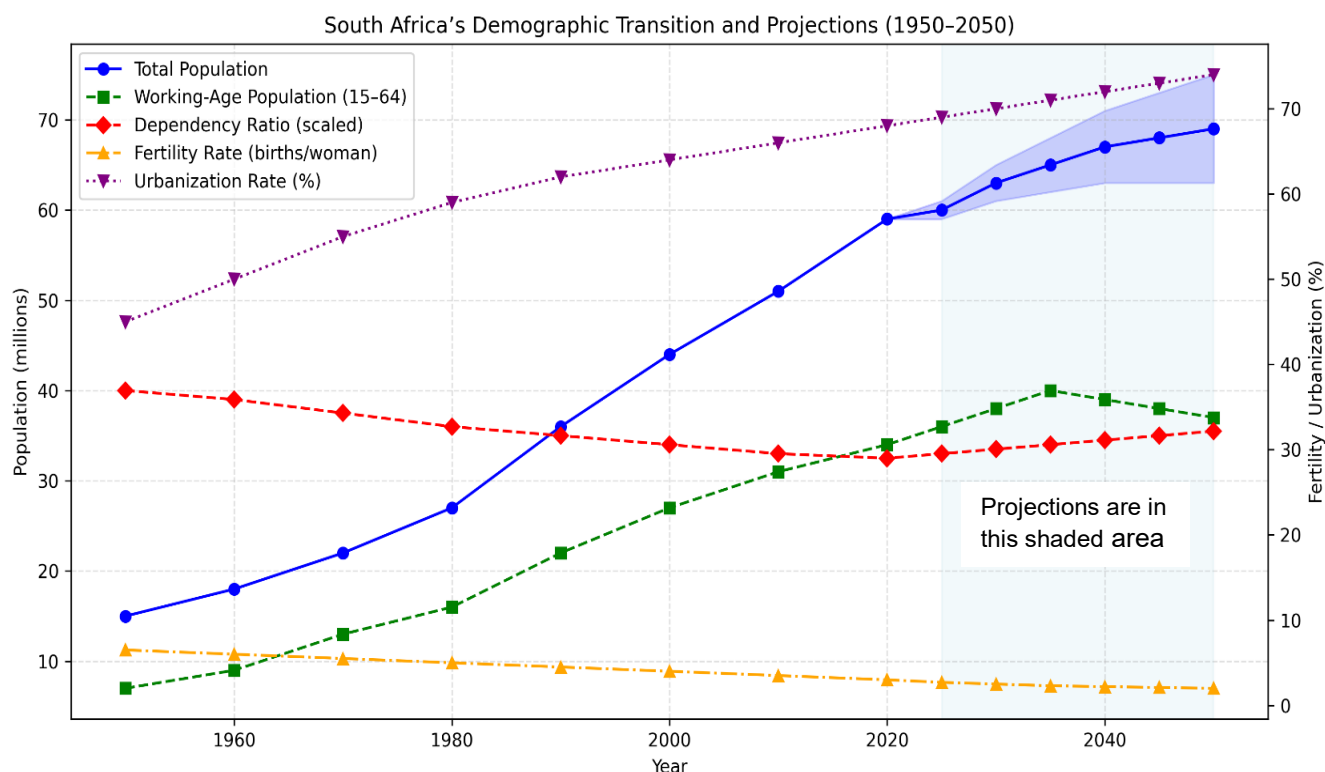
Notes: Real GDP in levels is plotted in billions of Rands at constant prices.

Figure 1 illustrates that while real GDP increased substantially over the long run, employment levels did not keep pace with population growth, especially after 2010. This mismatch between demographic expansion and productive employment calls for formal econometric testing of the population-growth relationship in South Africa. Since 1994, South Africa has undergone extensive demographic and economic transformations, including rapid urbanisation, increased migration inflows, declining fertility and shifts in labour-market structure. However, high unemployment, persistent inequality, low productivity and imbalances continue to place pressure on economic performance. Despite these developments, empirical studies that evaluates how population influences economic progress across both the apartheid and democratic periods is scarce. South Africa's demographic transition from 1950 to projected levels in 2050 is depicted in Figure 2. The total population increased from 15 million in 1950 to 62 million in 2022 and is expected to reach about 70 million by 2050, reflecting continued but slowing population growth (United Nations, 2024).

Figure 2 indicates that the working-age population (15-64 years) is projected to peak at approximately 40.4 million in 2035 before gradually declining to 38.6 million by 2050, indicating the onset of demographic ageing. Fertility declined sharply from 6.0 births per woman in 1950 to around 2.4 in 2020 and it is expected to approach the replacement level of 2.1 by 2050.

Urbanisation has also accelerated, increasing from 42% of the population in 1950 to 65% in 2020, with projections suggesting a rise to 70% by 2050. These trends indicate that South Africa is in the mid-stage of demographic transition, characterised by falling fertility, a maturing labour force and rising urbanisation (Mason et al., 2017). Understanding these shifts is crucial for analysing how population dynamics influence economic growth, central to the motivation and purpose of this dissertation. These demographic and economic realities stress the importance of investigating whether population growth has been a driver or constraint on economic progress.

Figure 2: South Africa's Demographic Transition (1950–2050)



Source: Author's illustration of United Nations World Population Prospects, blue shading bands in population line graph are possible variations in population levels (2024). <https://population.un.org/wpp/graphs?loc>

South Africa's population-growth relationship must be interpreted within the policy regimes that shaped labour absorption, capital formation and human-capital accumulation. During apartheid, influx control, racially segmented education, spatial planning and labour-market exclusion weakened the productive use of demographic expansion. Population growth occurred along with structural restrictions that limited mobility, skills formation and employment creation, which explain why demographic scale could not be translated fully into broad-based economic progress.

After 1994, policy shifted towards democratic inclusion, expanded social services, infrastructure delivery, industrial restructuring and macro-economic stabilisation. The Reconstruction and Development Programme, Growth, Employment and Redistribution strategy, later industrial-

policy initiatives, and the National Development Plan and the public-health response to HIV/AIDS all attempted, in different ways, to align a growing and urbanising population with employment, investment and service delivery needs. However, persistent unemployment, energy constraints, inequality and uneven education quality have continued to weaken the conversion of demographic potential into a sustained demographic dividend (National Planning Commission, 2012; National Treasury, 2024; World Bank, 2023).

This historical policy context supports the need for a long-run time-series approach. It suggests that the effect of population on economic growth is unlikely to be purely linear or automatic; instead, it is expected to depend on investment, education, health, labour-market absorption and institutional capacity. The econometric strategy used in this dissertation tests not only the average population-growth relationship, but also structural breaks and asymmetric demographic effects.

The absence of a comprehensive long-term analysis creates a critical knowledge gap. Without understanding whether population growth stimulates or constrains economic development, and whether this relationship has changed over time, policymakers lack the empirical basis needed to design strategies for sustainable and inclusive growth. Therefore, this study examines the effect of population growth on economic growth, including whether significant long-run and short-run effects exist. In addition, it addresses the gap concerning whether positive and negative deviations of population from its long-run trend exert symmetric or asymmetric long-run and short-run effects on economic growth. Unlike standard applications of Shin et al. (2014), which decompose changes in an explanatory variable, this dissertation focuses on deviations of actual population from its long-run trend and their effects on economic performance (Lianos et al., 2023).

1.3. Significance of this study

This study is significant because it supplies South Africa-specific evidence on a disputed demographic–growth relationship across major institutional and health shocks. The evidence is relevant to Sustainable Development Goal 8³ and to national planning because it distinguishes aggregate output growth from broader development and shows when demographic scale is accompanied by capital, human capital and labour absorption. The policy relevance is evidenced: recommendations in Chapter Five are traced to the reported long-run, short-run, structural and asymmetric results rather than treated as independent causal estimates.

³ SDG stands for Sustainable Development Goal. SDG 8 is 'Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.' Which is a pillar of the United Nations planned achievement.

1.4. Contribution of the study

This study makes three central contributions. First, it provides long-horizon, country-specific evidence on South Africa's population-output relationship, covering formal annual estimation for 1960-2022 and historical context for 1950-2022. It distinguishes the long-run associations, predictive causality direction, direct short-run response, equilibrium adjustment, structural sensitivity and asymmetric demographic effects across apartheid-era constraints, democratic transition, HIV/AIDS, the global financial crisis and COVID-19. Second, it makes an integrated methodological contribution by combining DOLS, Engle-Granger cointegration, ARDL bounds testing, error-correction models, Granger causality tests, structural-break and consolidated-dummy checks, and NARDL Wald tests in a single South African time-series design. Third, the study contributes to policy debate by showing that population growth is not automatically beneficial or harmful and whether the population-output relationship has evolved between the apartheid and democratic eras. The policy discussion is a transparent translation of these three contributions, not a standalone method or a claim that the models identify the causal effect of a particular intervention. Its economic implications depend on employment absorption, capital formation, human-capital development, demographic planning, urbanisation management and inclusive growth.

1.5. Aim

The aim of this study is to estimate and explain the relationship between population dynamics and aggregate real output in South Africa. Historical discussion covers 1950-2022, while econometric analysis uses 1960-2022 data. It utilises five objectives because each targets a distinct estimate: (i) long-run equilibrium association; (ii) predictive causality; (iii) direct short-run response and error-correction speed; (iv) structural or regime sensitivity; and (v) sign asymmetry.

1.6. Objectives

To operationalise the aim, the objectives of the study are to:

- i. Determine the long-run relationship between total population size and aggregate real GDP in South Africa.
- ii. Examine whether population dynamics provide statistically significant predictive information for economic performance.
- iii. Analyse the short-run effects of population growth and the speed at which the system adjusts towards long-run equilibrium.
- iv. Evaluate whether structural and regime changes significantly affect the level or growth path of real GDP.

- v. Assess whether positive and negative deviations of population from its estimated long-run trend exert asymmetric effects on economic performance.

1.7. Research Questions

The following questions correspond to each of the five objectives. (1) asks about the long-run equilibrium relationship; (2) asks about predictive causality; (3) asks about direct short-run effects and equilibrium adjustment; (4) asks about structural sensitivity; and (5) asks about asymmetry:

- i. What is the long-run relationship between total population size and aggregate real GDP in South Africa?
- ii. Do past values of population dynamics improve the prediction of economic performance in South Africa?
- iii. What are the short-run effects of population growth, and how does the system adjust towards its long-run equilibrium after a shock?
- iv. Do structural and regime changes significantly affect the level or growth path of real GDP in South Africa?
- v. Do positive and negative deviations of population from its estimated long-run trend have asymmetric short-run and long-run effects on economic performance?

1.8. Hypothesis Testing

Each objective and research question generates one testable hypothesis. The numbering and substantive meaning below are retained consistently through Chapters Three to Five.

Hypothesis 1: Long-run population-output relationship

- H_{01} : Total population size has no statistically significant long-run association with aggregate real GDP.
- H_{11} : Total population size has a statistically significant long-run association with aggregate real GDP.

Hypothesis 2: Predictive causality

- H_{02} : Population dynamics do not provide statistically significant predictive information for economic performance.
- H_{12} : Population dynamics provide statistically significant predictive information for economic performance.

Hypothesis 3: Short-run effects and adjustment speed relationships

- H_{03} : Population growth has no statistically significant direct short-run effect, and the error-correction term is not negative and statistically significant.
- H_{13} : Population growth has a statistically significant direct short-run effect and/or the error-correction term is negative and statistically significant.

Hypothesis 4: Structural change

- H_{04} : Structural and regime changes do not significantly affect the level or growth path of real GDP in South Africa.
- H_{14} : Structural and regime changes significantly affect the level or growth path of real GDP in South Africa.

Hypothesis 5: Trend-gap asymmetry

- H_{05} : Positive and negative deviations of population from its estimated long-run trend have equal short-run and long-run effects on economic performance.
- H_{15} : Positive and negative deviations of population from its estimated long-run trend have unequal short-run and long-run effects on economic performance.

The asymmetric analysis of macro-economic adjustment is motivated by the possibility that economic performance may respond differently when actual population is above or below its estimated long-run demographic trend. Statistics South Africa provides mid-year population estimations over a relatively short period for policy use due to demographic changes. Hence, these estimates may overpredict or underpredict the actual population which has implications for service delivery and policy planning. In the absence of long series population estimates, this study employs deviations from the long-run population trend rather than raw growth rates to examine the asymmetric effects of positive and negative deviation of actual population from trend population. This will help policymakers and households to plan properly in responding to unexpected demographic accelerations or slowdowns. Following Lianos et al. (2023) population below trend may reduce labour supply, domestic goods demand and increases dependency burdens. The trend-gap is a statistical measure rather than an estimate of official population undercounting or overcounting. Below-trend deviations may be associated with weaker labour supply and domestic demand, while above-trend deviations may expand markets but also increase pressure on employment, infrastructure and public services. In South Africa, where labour absorption and fiscal capacity are constrained, these responses may not be equal, motivating the use of NARDL and asymmetric causality models. The trend-gap NARDL extension tests whether above-trend and below-trend deviations have different short-run and long-run associations with economic performance.

1.9. Conclusion

South Africa's demographic trends highlight both opportunities and risks. Although the country has a large and relatively youthful population, structural unemployment, inequality and institutional constraints limit its ability to translate demographic expansion into sustained and inclusive economic growth. Understanding how population dynamics influence the economy is therefore essential for effective development policy and this dissertation provides an empirical basis for that task. Chapter One has outlined the background, problem statement, significance, research gap, contribution, objectives, research questions and hypotheses of the study. Chapter Two reviews the theoretical and empirical literature, Chapter Three presents the methodology, Chapter Four reports and discusses the empirical findings and Chapter Five concludes with policy implications, limitations and recommendations. Table 2 displays the organisation of the study's flow into Chapter 1 to 5.

Table 2: Organisation of the Study – Population growth and Economic growth

Chapter	Focus and content
Chapter One: Introduction and Background	Introduces the study by outlining the background, problem statement, research objectives, research questions, hypotheses, and motivates the analysis of population growth and economic performance in South Africa.
Chapter Two: Literature Review	Reviews the theoretical and empirical literature on population dynamics and economic growth, highlighting competing perspectives and identifying gaps addressed by the study.
Chapter Three: Research Methodology	Presents the econometric methodology, data sources, model specifications, and estimation techniques used to analyse the population-growth relationship.
Chapter Four: Empirical Results and Discussion	Reports and interprets the empirical findings, including long-run and short-run effects, predictive causality, structural change with dummies, and asymmetric population-growth dynamics.
Chapter Five: Conclusion and Policy Implications	Summarizes the main findings, draws conclusions, discusses policy implications, outlines study limitations, recommendations, suggests future research and concludes the study.

Source: Author's compilation

CHAPTER TWO: THEORIES OF POPULATION GROWTH AND ECONOMIC GROWTH

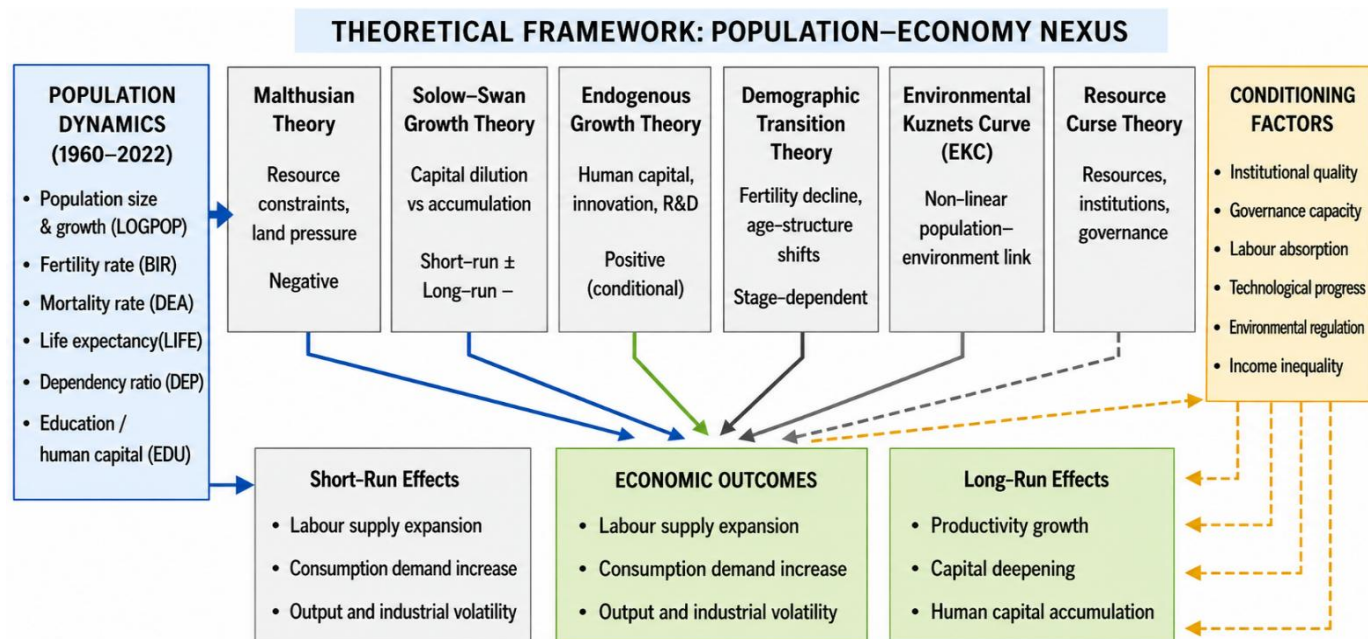
2. Introduction

This chapter builds the theoretical foundation for analysing how population dynamics influence economic performance, measured by GDP, in South Africa over the period 1950-2022. It reviews the principal theoretical models that explain how population growth and demographic change may affect output. Theory remains inconclusive about the effect of population growth on economic growth. Therefore, this chapter provides the conceptual basis for interpreting the empirical results presented later in the dissertation. There are eight theoretical perspectives that are core to this review. These are the Malthusian theory (resource pressure), Solow-Swan theory (capital dilution and steady state), growth accounting framework (capital, labour and total factor productivity decomposition), two-sector structural transformation theory (labour absorption and modern-sector expansion), endogenous growth theory (human capital and innovation), demographic transition theory (fertility-mortality change and age structure), Environmental Kuznets Curve (growth-environment trade-offs), and resource curse theory (institutional and structural effects of resource dependence). Together, they show that population does not affect growth uniformly; the sign and magnitude of the effect depend on capital accumulation, labour absorption, institutions, technology, environmental constraints and broader economic conditions.

The conceptual framework for the population-economy nexus links population dynamics and control variables to economic performance through key transmission channels, including labour supply, consumption demand, capital deepening or dilution, human-capital accumulation, dependency pressure, labour absorption and asymmetric demographic shocks. The framework is informed by Solow-Swan and growth accounting, endogenous growth, demographic-transition and two-sector structural-transformation perspectives. It also shows that the effect of population dynamics on real GDP is conditioned by institutional quality, governance capacity, labour absorption, education and skills, technological progress and structural shocks.

Figure 3 summarises the theoretical frameworks which includes demographic variables that encompass population growth (POP), fertility (BIR), mortality (DEA), life expectancy (LIFE), dependency ratio (DEP), and education/human capital (EDU). These are six theoretical pathways tested empirically. Amongst these theoretical frameworks and perspectives, two emphasise the constraint mechanisms (Malthusian and Solow-Swan theories), while other two highlight potential gains from demographic change (Demographic Transition and Endogenous Growth theories). The two theories (Environmental Kuznets hypothesis and Resource Curse theory) explain why growth responses become conditional on environmental limits and governance quality-issues that are central in South Africa's mining-energy structure, spatial inequality and policy capacity.

Figure 3: Theoretical Models



Source: Author's population-economic growth conceptual framework, informed by Malthus (1798), Solow (1956), Bloom et al. (2003), Romer (1990), Grossman & Grossman and Krueger (1995), and Sachs & Warner (2001).

2.1. Malthusian Theory

Thomas Malthus's (1798) theory centres on the idea that humans tend to reproduce faster than they can increase their food supply, arguing that populations grow exponentially (multiplying), while resources like land and food only grow arithmetically (adding). This means that the population can expand faster than land-based resources, thereby generating scarcity. This gap creates a "trap" where the population eventually becomes too large for the economy to support, leading to poverty, joblessness and lower quality of life. According to Malthus, unless people choose to have fewer children (lower fertility), the population will eventually be reduced by hunger, diseases or death (high mortality) if unmanaged.

The core prediction is negative long-run pressure where productive capacity fails to keep pace with demographic growth, especially in resource-constrained societies that have limited technological progress. For South Africa, the Malthusian channel is best interpreted as congestion and stress on service delivery, not literal food scarcity, fast population growth has intensified land pressure, service backlogs, ecological strain and unemployment because investment and job creation are weak. Its limitation is that it ignores the roles of technology and institutions, which are both central to South Africa's history (apartheid-era exclusion, the HIV/AIDS mortality shock, and post-1994 reforms). Thus, Malthusian theory is best seen as a risk condition, warning that population growth becomes growth-reducing when institutional capacity and investment fail to expand fast enough to accommodate a growing population (Nattrass & Seekings, 2019; Ashraf & Galor, 2011).

2.2. Solow-Swan Theory

The Solow-Swan (1956) model extends growth theory by arguing that long-run economic development is driven primarily by capital accumulation, technological progress and savings rates, rather than population growth alone (Barro & Sala-i-Martin, 2004). Population growth raises labour supply, but persistent growth in labour dilutes capital per worker because the number of workers employed exceeds resource availability, unless investment rises correspondingly to population growth (Kelley & Schmidt, 2005).

The model predicts that economies converge to a steady-state level of output per capita determined by investment, population growth and technology. Long-run improvements in living standards, therefore, require sustained productivity growth (technology), not population growth alone. This fits South Africa's experience, where episodes of weak investment, skills scarcity and uneven diffusion of productivity-enhancing technology have limited capital deepening (Fedderke & Simkins, 2012). In a Solow-Swan reading, population effects on growth are mediated by the investment rate and the ability to raise capital per worker through job creation; otherwise, demographic expansion can occur with stagnant per capita outcomes.

2.3. Endogenous growth model

Endogenous growth theory by Romer (1990) treats technological progress as produced by decisions of population, investment in human capital, innovation, research and development outcomes (R&D) (Lucas, 1988). Population is not inherently a burden; it can expand the idea base and skilled labour force, but only if education quality, institutions and labour markets convert population into productivity (Aghion & Howitt, 1998). The prediction is that a larger and better-educated population increases the pool of innovators, entrepreneurs and skilled labour, creating greater output, higher incomes and economic growth (Jones, 1995). However, high inequality, uneven school quality and skills mismatches limit the knowledge spillovers Romer describes (Hanushek & Woessmann, 2012).

South Africa illustrates this conditionality. Apartheid constrained human-capital formation through Bantu Education practice and restricted participation in high-productivity sectors because the economy relied on mining industries and agriculture, weakening the innovation channel (Spaull, 2013). Post-1994 expansion of education (NSFAS) and skills programmes (SETAs) improved access, yet high unemployment and inequality reduce the extent to which population growth translates into innovation-driven growth. The implication is clear: the population supports long-run growth when it is accompanied by human capital accumulation, inclusive labour absorption and stable policy. Therefore, population growth is not inherently harmful; its effect depends on a

country's ability to convert demographic change into human capital and innovation. Hence, the population's benefits depend heavily on institutional capacity, the quality of education and the degree of inclusive participation in the economy.

2.4. The Demographic Transition theory

The Demographic Transition Theory by Thompson (1929) and Notestein (1945) explains the shift from high birth and death rates to lower ones as a country develops. This process changes a country's age structure, moving the focus from total population size to "demographic quality." While early stages of this transition can strain an economy with a high number of child dependents, later stages increase the share of working-age adults. This shift creates the potential for a "demographic dividend", a period of rapid economic growth fuelled by a large, productive workforce, but dividends require job creation, skills upgrading and institutional capacity. Theory predicts that an early transition can raise dependency burdens; and later transition can expand the working-age share. Thus, transition theory links demographic patterns, fertility, mortality, age structure and population growth to economic performance.

In South Africa, this transition has been uneven and disrupted by significant historical shocks, recent policy uncertainty, social inequalities and misallocation of funds, complicating predictions about population dynamics. The HIV/AIDS epidemic caused a major mortality crisis affecting life expectancy, while the legacy of apartheid created deep inequalities in living essentials, like education, health and income (Dorrington et al., 2006). Today, uneven access to healthcare and public services has slowed the transition for different population groups, yet the income inequality persists, leading to inequality in educational outcomes. Although South Africa has a large working-age population, persistently high youth unemployment and labour market rigidities prevent the country from fully realizing its demographic dividend. Lastly, while the transition theory highlights the potential for wealth, based on high working-age population share, South Africa's success depends on whether its institutions can create the jobs and skills needed to absorb its growing workforce.

2.5. The Environmental Kuznets Curve theory

The Environmental Kuznets Curve (EKC) suggests an inverted U-shaped relationship between economic growth and environmental damage. It proposes that during early industrialization, a country's pollution and resource depletion increase together with its income. However, once a certain level of wealth is reached, the trend reverses; as the economy matures, it shifts toward cleaner technology and stricter regulations, leading to improvements in environmental quality. The Kuznets theory lacks a direct focus on demographic change. While population growth drives

resource demand and urban congestion, the theory focuses primarily on income, ignoring population dynamics. The "turning point" where pollution begins to drop is not guaranteed; it depends heavily on good governance and technology. Furthermore, some wealthy nations do not reduce pollution, they simply "export" it by moving their manufacturing to poorer countries, a concept known as the "pollution haven" hypothesis.

South Africa reflects different stages of the Kuznets's prediction at the same time. Historically, the country's growth was fuelled by mining and energy-intensive industries, moving it sharply up the curve toward high pollution and land degradation because of apartheid-era spatial planning and weak regulations. Currently, South Africa's progress toward the "turning point" is mixed, its mining exports are the backbone to government's revenue, production still relies on coal, and a struggling energy infrastructure (Eskom) make it difficult to change to a cleaner economy, limiting the full realisation of Kuznets's predicted long-term environmental improvements. However, Kuznets's theory does not explicitly model population growth, yet population pressures influence production patterns, land conversions, mining industry, resource use, urban congestions, biodiversity loss and environmental stress, making the theory indirectly relevant to population-economic growth analysis, highlighting feedback to health, productivity and long-run sustainability.

2.6. The Resource Curse theory

The Resource Curse theory (Auty, 1993; Collier, 2007) suggests a paradox that countries with an abundance of natural resources often experience slower economic growth and weaker development than those with fewer resources. This occurs because heavy reliance on a single sector, like mining gold or oil, can lead to corruption, discourage economic diversification and leave the country vulnerable to fluctuating global commodity prices. However, other countries (Dubai, Norway and Botswana) have avoided the curse through strong institutions, suggesting that natural-resource abundance can become a blessing when supported by good governance. The theory emphasises the importance of having quality governance and institutions that structure the economy in a manner that enables expansion into other industries like manufacturing, tourism and services, so a growing population can be absorbed in the labour market. Nonetheless, from the perspective of resource-curse theory, population growth is not inherently harmful; its impact on growth depends on governance and institutional quality.

In South Africa, the mining sector has reinforced inequality and extraction-based growth rather than creating a broad-based economy. The core issue is how funds from resources are used. In a healthy system, these funds are reinvested into education, healthcare and infrastructure. However, because mining and energy are often capital-intensive (using machines rather than

many people), they fail to absorb the growing workforce. This creates a disconnect between the country's mineral wealth and its high unemployment rates. For South Africa, the Resource Curse theory serves as a warning: natural resource wealth is only a blessing if institutions are strong enough to convert resource wealth into human capital. Without this, people end up competing for a shrinking share of resource wealth, leading to increased social and political instability. Population growth simply amplifies the stress on the economy that is already struggling to move beyond its extractive roots.

2.7. Growth Accounting Framework

Growth accounting provides an additional macro-economic foundation for the study because it decomposes output growth into the contributions of capital accumulation, labour input and total factor productivity. In its standard form, output growth can be expressed as:

$$gY = \alpha gK + (1 - \alpha) gL + gA$$

where gY is output growth, gK is capital growth, gL is labour growth and gA represents total factor productivity growth. Therefore, the framework links population growth to the labour-input channel, while capital accumulation and productivity determine whether a growing population raises output or dilutes capital per worker. This formulation is consistent with the standard macro-economic growth-accounting approach discussed in Dornbusch et al. (2013). In this study, aggregate real GDP represents economic performance, gross fixed capital formation captures capital accumulation, and total population captures the labour-supply and market-size channel. Education and life expectancy proxy human-capital and productivity-related effects, while dependency ratio, birth rate and death rate capture demographic-composition effects. The study does not estimate a separate growth-accounting decomposition because its objective is not to allocate exact percentage contributions of capital, labour and productivity to GDP growth. Instead, growth accounting provides the theoretical bridge between macro-economic growth theory and the DOLS, Engle–Granger, ARDL, Granger predictive-causality and NARDL models applied in the empirical analysis.

2.8. Two-Sector Structural Transformation Theory

Two-sector structural transformation theory provides an important framework for understanding the relationship between population growth, labour absorption and economic performance. The Lewis (1954) model explains development as a process in which labour moves from a traditional low-productivity sector, usually agriculture or informal subsistence activity, into a modern higher-productivity sector such as manufacturing, mining, formal services and industry. Economic growth occurs when surplus labour is productively absorbed into expanding modern sectors, raising

output, productivity and wages over time. However, it's more applicable to a micro-study assessing a sectoral or regional growth effects and not for macro-analysis.

The two-sector model is relevant to population-growth analysis because population expansion does not automatically raise economic growth. A growing population supports economic performance only when the modern sector can absorb additional labour productively. If the formal sector fails to expand sufficiently, population growth may instead increase unemployment, informal employment, underemployment and pressure on public services. Harris and Todaro (1970) extend this logic by showing that migration to urban areas may continue even when urban unemployment is high, because workers respond to expected income differences between rural and urban sectors.

South Africa reflects many of these two-sector dynamics. Under apartheid, labour mobility, education and settlement were restricted for racial groups, limiting the ability of the economy to absorb most of the population into high-productive formal employment. After 1994, political inclusion expanded, but structural unemployment, skills mismatch, inequality and weak industrial absorption continued to prevent demographic expansion from becoming a full demographic dividend. Population remains unevenly spread because infrastructure development and job opportunities differ between provinces in South Africa, which explains why urban areas have more residence, informal settlements and traffic congestions than rural areas. Therefore, the two-sector framework complements the Solow-Swan, endogenous growth and demographic-transition theories by emphasising that the effect of population growth depends on structural transformation and labour absorption.

The eight theories imply three disciplined propositions for South Africa.

1. Population effects are conditional:

Population growth can raise aggregate demand and labour supply, but per capita gains depend on investment, productivity and labour absorption.

2. Composition of population dominates its scale:

Fertility, mortality, life expectancy, dependency ratios and education shape productivity more directly than population size alone; hence, these factors form the main variables used in the analysis to support population dynamic effects.

3. Institutions and structure determine the sign of population effects:

Governance quality, resource dependence and environmental regulation determine whether demographic change becomes a dividend (through the human-capital and productivity channels) or a burden (through capital dilution, congestion and ecological stress).

This multi-theoretical approach justifies the study's empirical focus on both long-run equilibrium relationships and short-run dynamics, and it provides clear lens for interpreting why demographic variables may have unstable or model-dependent effects in South Africa.

Table 3: Summarised population-growth theory and prediction effects

Theory	Mechanism-assumption	Short term effects	Long-term effects
Malthusian theory (Thomas Malthus, 1798)	Population grows faster than land and basic resources, creating scarcity, unless well managed.	Rising labour supply and consumption pressure; congestion in food, land, and services.	Persistent population pressure reduces living standards, increases poverty, unemployment, and environmental stress if productivity does not rise.
Solow-Swan theory (Robert Solow & Trevor Swan, 1956)	Growth depends on capital accumulation and exogenous technology; population growth dilutes capital per worker.	Larger labour force raises aggregate output and demand.	Higher population growth lowers capital per worker and slows per-capita income growth unless offset by investment and technological progress.
Endogenous Growth theory (Pual Romer, 1980)	Human capital, innovation, and R&D generate sustained growth from within the economy.	Population expansion can increase market size, skills base, and innovation potential.	Conditional positive effect: long-run growth rises when population growth is transformed into education, skills, and technological innovation.
Population Transition theory (Warren Thompson, 1929 & Frank Notestein, 1945)	Development shifts fertility and mortality, altering age structure over time.	Early stages: falling mortality with high fertility raises dependency and service pressure.	Later stages: declining fertility lowers dependency ratios and creates a potential demographic dividend if employment and skills absorption are strong.
Kuznets Environmental theory (Simon Kuznets 1955; Grossman & Krueger 1995)	Environmental degradation rises during the early stages of growth, then falls after a turning point due to regulation and cleaner technologies.	Growth and urbanisation increase pollution and resource use; population pressure intensifies environmental stress.	Environmental constraints affect productivity and health; long-term improvements depend on regulation, the energy transition, and institutions.
Resource Curse theory (Richard Auty, 1993)	Resource dependence weakens institutions, crowds out diversification, and increases economic instability.	Resource booms raise output, employment, and fiscal revenues.	Weak institutions lead to inequality, instability, and slow diversification; strong institutions can convert resource income into sustainable growth.
Growth Accounting Framework (Robert Solw, 1957)	Population growth is decomposed into capital growth, labour/population growth and total factor productivity.	Population growth expands on labour input and market size, but output gains depend on capital and productivity response.	Population contributes to output when accompanied by capital accumulation and productive growth, otherwise per capita gains remain limited.
Two-Sector Structural Transformation (W. Aurthur Lewis, 1954)	Labour moves from low-productivity in traditional sectors to high-modern productivity sectors, Growth depends on modern-sectors capacity to absorb surplus labour.	Population growth increases labour supply and urbanisation pressures, if job creation is weak, unemployment and informality may rise, and create further inequality	Positive inclusive growth occurs when labour is absorbed into productive formal sectors, however, weak institutions and poor structural transformations turn population growth into unemployment and under-employment.

Source: Author's Population Growth Theory Summary

As shown in Table 3, population growth can affect economic outcomes conditionally, operating through resources, capital, labour absorption, human capital, environment and institutions. The effect may not be immediate and can be mediated through productivity, investment, education, structural transformation, which are influenced by government decisions and policy capacity.

Table 4: Anecdotal evidence in South Africa's Population-Economic theoretical comparison outcomes

Theory	Focus	Population-Growth relationship
Malthusian	Resource limits, congestion, Service backlogs.	Population growth is associated with downward pressure on economic growth when resources, infrastructure, and public services are insufficient to absorb a growing population.

Theory	Focus	Population-Growth relationship
Solow-Swan	Capital deepening, exogenous technology.	Population growth may support aggregate output in the short run through labour expansion, but over the long run it can reduce income per capita unless technological progress and capital accumulation offset dilution effects.
Endogenous Growth	Human capital, innovation	Population growth contributes positively to economic growth when it is accompanied by investments in education, skills development, and innovation that raise productivity.
Demographic Transition	Fertility, mortality, age structure, life span.	The effect of population dynamics on growth depends on the stage of demographic transition, with potential growth benefits emerging when the working-age population expands relative to dependents.
Environmental Kuznets Curve	Growth-environment interaction.	Population growth influences economic growth indirectly through its impact on environmental pressure, resource use, and regulatory responses, which can either constrain or support long-term growth.
Resource Curse	Institutions, structure, diversification.	The population-growth relationship is shaped by institutional quality, where weak governance can prevent population growth from translating into broad-based economic development.
Growth Accounting Framework	Capital, labour input, population and total factor productivity decomposition.	Population growth affects through the labour-input channel, but growth benefits depend on capital accumulation and productive employment.
Two-Sector Structural Transformation	Labour absorption, rural-urban movement and modern sector expansion.	Population growth supports economic growth when labour moves into productive employment, but it constrains growth when modern sectors fail to absorb the expanding labour force.

Source: Author's Compilation of Population-economic growth theories

The anecdotal relationship in Table 4 is not conclusive regarding South Africa's population-growth relationship, indicating that it is theory- and context-dependent. The negative effects could arise under weak absorption, while positive effects may arise from improvement in skills acquisitions, job creation and institution capacity. This justifies a multi-theoretical empirical framework. However, the variables of population, life expectancy, education, dependency ratios, birth and death rates are used in empirical analysis for capturing various effects of each theory.

2.9. Theoretical relevance to the present study

The growth accounting framework and two-sector structural transformation theory are not estimated as separate empirical models in this study. Instead, they are used as theoretical foundations for interpreting the population-growth relationship in South Africa. Growth accounting explains how output growth is linked to labour input, capital accumulation and productivity. This supports the inclusion of total population, gross fixed capital formation, education and life expectancy in the empirical models. Total population captures the labour-supply and market-size channel, gross fixed capital formation captures capital accumulation, education and life expectancy proxy human-capital and productivity-related effects.

Two-sector structural transformation theory strengthens the interpretation of the South African context. It explains why population growth does not automatically translate into higher economic growth. The growth effect depends on whether additional labour is absorbed into productive formal sectors. In South Africa, apartheid-era labour restrictions, inequality, skills mismatch and persistent unemployment weakened labour absorption. Therefore, the population-growth

relationship is interpreted as conditional on structural transformation, human capital, capital formation and the economy's capacity to absorb labour productively.

These theories therefore guide the interpretation of the empirical results rather than adding separate models. The DOLS, Engle-Granger, ARDL, ECM, Granger predictive-causality and NARDL models test the long-run association, short-run adjustment, predictive relationship and asymmetric responses between population dynamics and economic performance. The theoretical literature explains the channels through which these relationships may operate.

Table 5: Theoretical channels and empirical relevance

Theoretical channel	Theory	Thesis variable/proxy	Empirical relevance
Labour-input channel	Malthusian and Growth accounting.	Total population shown as $\log POP_t$ in empirical analysis.	Captures labour-supply and market-size effects.
Capital accumulation	Growth accounting and Solow-Swan	Gross fixed capital formation shown as $\log CAP_t$ in empirical analysis.	Captures investment and capital-deepening effects.
Productivity and human capital	Growth accounting and endogenous growth.	Education (EDU_t) and life expectancy (LIF_t) reflect human capital and productivity longevity	Captures skills, health and productivity-related effects.
Demographic composition	Demographic transition theory and Demographic Dividend	Birth rate (BIR_t), death rate (DEA_t) and dependency ratio (DEP_t).	Captures fertility, mortality and age-structure effects of demographic quality.
Labour absorption	Endogenous growth, Solow-Swan and Structural Transformation.	Interpreted through education, dependency ratio, employment context and structural-break results.	Explains why population growth may not become a demographic dividend when labour absorption is weak.
Structural transformation	Two-sector structural transformation.	Structural dummies and South African historical context.	Captures apartheid, democratic transition and major economic crisis and health shocks.
Economic growth and performance	Keynesian macro-economic theory and Growth Accounting Framework	Economic growth is Real GDP shown as $\log GDP_t$ in empirical analysis.	Serves as the baseline dependent metric to capture aggregate economic output, productive capacity, and changes in output
Asymmetric demographic effects	Demographic transition and Non-linear ARDL logic.	Positive deviations POP_{t-1}^+ and negative POP_{t-1}^- population deviations from the total population trend.	Tests whether demographic accelerations and slowdowns affect GDP differently for both short-run and long-run relationships.

Source: Author's compilation

Table 5 establishes the structural roadmap of the study by bridging macro-economic and demographic theory with empirical estimation. It organizes the analysis into distinct transmission channels to show exactly how population dynamics and structural shifts influence economic outcomes.

2.10. Linking Theory, South African Reality and Empirical Evidence

The theoretical review shows that population growth does not have a uniform effect on economic performance. Malthusian and Solow-Swan perspectives predict that population growth may constrain growth when it raises dependency burdens, dilutes capital per worker or places pressure on limited resources. In contrast, endogenous growth, demographic-transition and two-

sector structural-transformation theories suggest that population growth can support economic performance when it expands the labour force, increases market size, raises human-capital accumulation and is absorbed into productive formal employment.

These theories therefore imply that the population-growth relationship is conditional rather than automatic. South Africa's historical experience reflects this conditionality. The country experienced sustained population growth, declining fertility, rising educational attainment and a growing working-age population, but these demographic changes occurred along with persistent unemployment, inequality, skills mismatch, uneven capital formation and major institutional shifts.

The empirical evidence is organised according to the main theoretical predictions. Studies that find a positive association between population and growth are linked to labour-supply, human-capital, market-size and demographic-dividend channels. Studies that find negative effects are linked to Malthusian, Solow-Swan and capital-dilution channels. Studies that find weak, neutral or mixed effects are linked to the conditional-effects view, which argues that population growth affects economic performance only through institutions, human capital, labour-market absorption and structural change. This integrated reading also justifies nonlinear modelling, because demographic accelerations and slowdowns may not have equal short-run or long-run effects.

2.11. Conclusion

The eight theoretical perspectives on population-growth dynamics indicate various channels of transmission and different predictions. Malthusian and sustainability theories highlight constraints; Solow-Swan and growth accounting emphasise capital, labour and productivity; two-sector structural transformation emphasises labour absorption; endogenous growth emphasises human capital and innovation; demographic-transition theory focuses on fertility, mortality and age structure; and institutional-resource perspectives show why context determines the sign and magnitude of population effects. These insights underpin the study's conceptual framework and hypotheses, highlighting the importance of evaluating both short-run and long-run dynamics. The empirical literature reviewed below is therefore interpreted against the theoretical and South African background rather than as a separate set of studies.

EMPIRICAL LITERATURE OF POPULATION AND ECONOMIC GROWTH

2.12. Introduction

Empirical studies examining the relationship between population dynamics and economic growth report mixed and context-specific results. The empirical literature is grouped into three strands: (a) population-driven growth (positive effects), (b) population-induced constraints (negative

effects), and (c) conditional or neutral effects. Within each strand, the focus is on methodological approaches, main variables, and key findings, with particular attention to studies that inform the empirical design of the present dissertation. The first strand finds positive or conditionally positive effects of population growth on economic performance, especially where demographic expansion is supported by human capital, labour absorption, capital formation and institutional capacity. The second strand finds negative effects, usually through capital dilution, high dependency burdens, pressure on public services, unemployment and resource constraints. The third strand reports mixed, neutral or conditional effects, suggesting that the population-growth relationship depends on country context, demographic structure, policy quality and structural transformation, indicating that population growth alone does not determine economic outcomes. This classification links the empirical literature directly to the theoretical frameworks discussed earlier.

These differences in empirical findings arise from variations in levels of development, demographic structure, institutional quality, time periods and empirical methods. Much of the existing literature relies on cross-country or regional panel data, which allows for broad comparisons but often fails to capture country-specific historical changes and institutional transitions. This limitation is relevant for South Africa, where the economy and demographic structure have evolved under very different political and institutional regimes before and after 1994. The empirical literature is therefore organised into three main strands, namely population-driven growth, population-induced constraints, and conditional or neutral effects.

2.12.1. Population-Driven Growth: Positive Empirical Evidence

The first strand of empirical findings encompasses a significant body of empirical literature that supports the view that population growth can contribute positively to economic growth when supported by favourable economic and institutional conditions. From this perspective, population expansion increases the size of the labour force and domestic markets, potentially raising output and productivity, particularly when employment creation, investment and human-capital development keep pace with demographic change.

Empirical evidence from developing economies illustrates these mechanisms. Tatiyus et al. (2015), using a VAR model for Nigeria (1980-2010), find that population and fertility growth positively affected GDP in the short run by expanding labour supply and consumer demand. Headey and Hodge (2009) similarly show that the population-growth effect depends on savings, human capital and labour-market absorption. Bloom and Williamson (1998) further demonstrate that a favourable age-structure change can raise growth when demographic transition is accompanied by investment and productivity improvements. Also, Simon (1981), Bloom, Canning

and Sevilla (2001, 2003), Lee and Mason (2010), Statistics South Africa (2024) and the OECD (2022, 2025) provide verifiable evidence for this conditional positive channel.

Empirical analysis that focuses on long-run estimations increasingly emphasises demographic structure rather than population size alone. Bloom and Williamson (1998), using evidence from emerging Asian economies, show that demographic transition and a rising working-age population contributed materially to rapid growth through labour-supply, savings and dependency-ratio channels. Bloom et al. (2000) similarly show that age-structure change helps explain economic performance in Asia. Cervellati and Sunde (2011, 2015) further emphasise that life expectancy, mortality decline, human-capital formation and demographic transition interact in shaping long-run development. Together, these studies highlight demographic structure rather than population size alone. Also, Bloom, Canning and Sevilla (2001, 2003) and Lee and Mason (2010) show that age structure, support ratios, fertility transition and human-capital investment shape whether demographic change becomes growth-supporting. These findings indicate that population growth is most beneficial when it is combined with education, health, capital accumulation and effective labour-market absorption.

Urbanisation and human capital are also identified as key transmission channels. Furuoka (2005) shows that population growth can support long-run growth in Malaysia when accompanied by educational investment, while Chen et al. (2022) and World Bank (2024) confirm that well-managed urbanisation can enhance productivity through accumulation effects. Furthermore, human capital, labour absorption and institutional capacity are therefore central transmission channels. South African evidence from Statistics South Africa (2024) and the OECD (2025) show that population expansion increases labour-supply potential, but persistent unemployment, skills mismatch and productivity constraints limit the realisation of a demographic dividend.

However, the benefits depend heavily on labour-market absorption and institutional capacity. Despite their contributions in finding positive effects of population, most studies in this strand do not account for structural breaks, institutional regime changes, or the unique historical context of South Africa, limiting their ability to explain long-term demographic-economic dynamics across apartheid and democratic periods. Table 6 reports selected studies that find a positive association between population and economic growth, showing authors, methodology, region, variables, main findings and accompanying theory.

Table 6: Selected studies that find a positive association between population and economic growth

Authors & Year	Methodology	Country/region	Variables Used	Main Findings	Matching Theory
Simon (1981)	Historical data analysis	Various countries (1800–1980)	Population growth, economic growth, technological innovation	Positive correlation: population growth drives technological and economic development.	Population-Driven Innovation Theory
Bloom, Canning, & Bloom et al. (2001)	Solow growth model	Multiple countries (1960–1995)	Population growth, economic growth, human capital	Positive correlation: population growth enhances labour supply and human capital.	Solow-Swan Growth Model
Furuoka (2005)	Cointegration & causality analysis	Malaysia (1960–2000)	Population growth, GDP, employment rate	Positive correlation through human capital; unidirectional causality from population growth to economic progress.	Endogenous Growth Theory
Ali, Ali & Amin (2013)	OLS regression (time-series)	Pakistan (1972–2010)	Population growth, GDP, employment and unemployment	Population growth has a positive long-run effect on economic development and labour market size.	Labour Market Theories / Endogenous Growth
Acemoglu & Acemoglu and Johnson (2007)	Cross-sectional & Instrumental Variable	Multiple countries (1940–2000)	Population, technological progress, GDP	Population growth stimulates technological progress, boosting economic growth.	Population-Driven Innovation Theory
Headey & Hodge (2009)	Dynamic panel	Various countries 1960–2005	Population growth, economic growth, human capital, innovation	Positive correlation; enhanced human capital and innovation.	Endogenous Growth Theory
Tartiyus, Dauda, & Amade (2015)	VAR approach	Nigeria (1980–2010)	Population growth, GDP, labour force participation	Positive correlation; growth stimulated by population expansion.	Demographic Transition Theory
Bloom & Bloom and Williamson (1998)	Cross-country growth decomposition and econometric analysis	Emerging Asia (1965–1990)	Working-age population, dependency ratio, labour force, GDP growth	Demographic transition contributed materially to East Asia's growth through labour-supply, savings and dependency-ratio channels.	Demographic Dividend Theory
Bloom, Canning, & Malaney (2000)	Demographic-economic model	Asia (1965–1990s)	Age structure, population growth, GDP growth	Age-structure change and declining dependency ratios helped explain growth performance.	Demographic Transition Theory
Cervellati & Sunde (2011)	Panel and long-run development analysis	Global sample	Life expectancy, demographic transition, GDP per capita	Demographic transition conditions how life expectancy affects long-run growth.	Demographic Transition Theory
Amornkitvikai, Harvie & Karcharnubarn (2022)	Dynamic panel (fixed effects)	Asian economies (1960–2020)	Working-age population, labour force participation, old-age population, youth population, migration, GDP	Working-age share, labour force participation, and employed population growth positively affect GDP; youth share and old-age population are negative	Demographic Transition Theory
Statistics South Africa (2024)	Descriptive & trend analysis	South Africa (2008–2023)	Population growth, labour force size, unemployment	Population growth expands labour supply; benefits limited by high youth unemployment	Labour Market Theories
OECD (2025)	Structural analysis	South Africa (1994–2022)	Human capital, productivity, skills mismatch	Skills mismatch limits demographic dividend realisation	Human Capital Theory

Source: Author's Compilation

South Africa-specific evidence in the positive strand is limited. Although Bhorat and Oosthuizen (2008) document that labour-force expansion contributed to employment in certain sectors post-1994, their analysis does not estimate the aggregate population and GDP relationship directly. No South African study identified in this review employs ARDL or NARDL methods to test whether population growth positively affects aggregate economic growth over a long-time horizon, which the present study covers.

2.12.2. Population-Induced Constraints: Negative Empirical Evidence

The second strand of the empirical literature finds that population growth can constrain economic development, particularly in economies characterised by limited capital accumulation, weak institutions and high dependency ratios. From this perspective, rapid population growth increases pressure on savings, investment, infrastructure and public services, reducing productivity and slowing economic growth.

Early contributions by Coale and Hoover (1958) and Sachs (2008) argue that high population growth rates in developing countries reduce per capita income by depressing savings and capital formation. Evidence provides support for these claims. For instance, Ali et al. (2015) report related evidence for Bangladesh, Brander and Dowrick (1994), Kelley and Schmidt (2005), and National Research Council (1986) show that fertility and population-growth effects can reduce savings, strain capital formation and raise dependency burdens when demographic expansion is not matched by human-capital and investment growth. Also, Mankiw, Romer and Weil (1992), Galor and Weil (2000) and Sachs (2008) show that population growth can constrain economic performance when it raises dependency burdens, reduces savings, dilutes capital per worker or strains education, health and infrastructure systems.

Recent literature extends this argument by highlighting environmental and productivity channels. Chen et al. (2022) show that population growth, urbanisation, energy use and economic growth are linked to carbon-emissions pressure in BRICS economies, indicating that demographic and growth pressures may generate environmental costs. Galor and Weil (2000) emphasise that rapid population growth slows human-capital accumulation, while Birdsall et al. (1995) demonstrate its role in exacerbating income inequality. Recent work adds environmental and fiscal channels. Population and production growth can intensify ecological pressure, while ageing or high dependency can increase demands on public finance (Bradshaw et al., 2021; Crist et al., 2022). These channels are relevant to sustainable growth but are not modelled as direct environmental outcomes in the present paper.

Recent African-focused studies (International Monetary Fund [IMF], 2023, 2026; World Bank, 2024) caution that population growth without equal job creation and investment exacerbates unemployment and fiscal pressure, particularly in middle-income countries with rigid labour markets such as South Africa. These findings resonate strongly with South Africa's experience of a rising population along with persistently high unemployment. While these findings on the negative impact of population growth on economic growth highlight important risks associated with unmanaged population growth, many studies rely on cross-country data, shorter time spans,

or aggregate population measures, and often fail to distinguish between short-run adjustment effects and long-run equilibrium relationships. It is important particularly in economies undergoing major institutional changes, such as South Africa, to account for structural changes in empirical analysis.

These findings resonate with South Africa's experience of a rising population along with unemployment and inequality. While this literature highlights an important risk associated with unmanaged population growth, many studies also do not examine whether accelerations and slowdowns relative to a demographic trend have unequal effects on economic performance.

Table 7: Selected studies that find population growth suppressing economic growth

Authors & Years	Methodology	Country/Region	Variables Used	Main Findings	Matching Theory
Brander & Dowrick (1994)	Cross-country econometric analysis	Multiple countries (1960–1985)	Fertility, population growth, GDP growth	Higher fertility and population growth can reduce per-capita growth where capital deepening and productivity gains are insufficient.	Neoclassical Growth Theory / Capital Dilution
Mankiw, Romer, & Weil (1992)	Augmented Solow model / cross-country regression	Multiple countries (1960–1985)	Population growth, physical capital, human capital, income per capita	Population growth affects steady-state income through capital dilution unless offset by investment and human capital.	Augmented Solow Growth Theory
Kelley & Schmidt (2005)	Cross-country econometric analysis	Multiple countries (1960–2000)	Population growth rate, economic growth rate, quality of education	Population growth negatively impacts economic growth by reducing the quality of education	Human Capital Theory (Quantity-quality Trade-off)
Chen, Zhang, & Li (2022)	Panel-data analysis	BRICS economies (1990–2018)	Population growth, urbanisation, energy use, economic growth, carbon emissions	Population and growth pressures are associated with environmental pressure, indicating possible productivity and sustainability costs.	Environmental Kuznets Curve (EKC) / Sustainability Channel
Coale & Hoover (1958)	Empirical Analysis	India, Mexico (1920–1950)	Population Growth, Economic development	Negative correlation, high population growth exacerbates poverty and slows economic progress	Malthusian-Neoclassical Transition Theory.
Bloom, Canning, & Malaney (2000)	Demographic-Economic Models	Developing countries (1965–1995)	Population growth, economic growth, healthcare, education	Rapid population growth in developing countries negatively impacts economic growth by overwhelming healthcare and education systems	Demographic Burden Theory.
Birdsall, Ross, & Sabot (1995)	Cross-country econometric analysis	Developing countries (1960–1990)	Population growth, income inequality, economic growth	Population growth exacerbates income inequality and slows economic growth in developing countries.	Structuralist Development Theory.
Galor & Weil (2000)	Unified Growth Theory	Cross-country analysis Long-run. historical (pre-industrial–modern)	Population growth, human capital, economic growth, technological progress	Population growth hinders economic growth by reducing the accumulation of human capital and slowing technological progress.	Unified Growth Theory.
Sachs (2008)	Economic Growth Models	Sub-Saharan Africa (1980–2005)	Population growth, poverty, economic growth	High population growth in Sub-Saharan Africa exacerbates poverty and limits economic development.	Poverty Trap Theory / Big Push Theory.

Authors & Years	Methodology	Country/Region	Variables Used	Main Findings	Matching Theory
Thirlwall (1972)	Keynesian Growth Model	United Kingdom (1950–1970)	Population Growth, Economic Growth	Population growth constrains economic growth due to limited resources.	Keynesian Demand-Constrained Growth Theory.
Lee & Mason (2010)	National Transfer Accounts (NTA) methodology	Various developed and developing countries (1970–2005)	Population growth, economic dependency, public spending.	High population growth increases economic dependency, straining public resources and slowing economic growth.	Life-Cycle Hypothesis & Dependency Ratio Theory.
Banerjee & Duflo (2011)	Randomized controlled trials (RCTs) and observational studies	Various developing countries (1990–2005)	Population growth, poverty, education, economic development	High population growth exacerbates poverty and limits access to education, which hinders long-term economic development.	Human Capital Theory & Poverty Trap Theory.

Source: Author's Compilation

As summarised in Table 7, studies reporting growth-suppressing effects emphasise unemployment, capital dilution, dependency and resource pressure. In South Africa, this negative channel operates mainly through weak labour absorption and investment. Fedderke and Simkins (2012) find that investment and productivity, rather than population size alone, explain long-run output; however, their analysis does not test the asymmetric effects and structural sensitivities which the present study covers.

2.12.3. Conditional and Neutral Empirical Findings

A third strand of the empirical literature finds that population growth has neutral or conditional effects on economic growth. These studies argue that population growth does not have a systematic impact on economic performance unless it interacts with institutional quality, demographic structure, productivity and labour-market absorption. Jones (2002, 2005) and Pritchett (2001) argue that population growth has no consistent long-run effect on economic growth once productivity and institutional factors are considered. Time-series studies for Malaysia and Pakistan (Mushtaq, 2006) similarly find no evidence of long-run cointegration between population growth and income per capita. Also, Crenshaw et al. (1997), Acemoglu and Johnson (2007), Kelley and Schmidt (2005), Pritchett (2001) and the OECD (2022) support this conditional interpretation.

Recent research findings greatly emphasise the role of institutions and structural conditions. Peng (2023) indicates that demographic change has limited direct influence when institutional and productivity conditions mediate the growth effect. Bloom et al. (2001) show that age structure explains economic growth better than population growth rates alone. South African policy and macro-economic evidence suggest that industrial policy, skills mismatches and productivity constraints play a more decisive role than demographic change when labour absorption remains weak (National Planning Commission, 2012; National Treasury, 2024; World Bank, 2023).

South African evidence consistently points to conditional rather than automatic demographic gains. Oosthuizen and Borat (2005) show that labour-force expansion without sufficient job creation raises structural unemployment. Fedderke and Simkins (2012) identify investment and productivity as central long-run growth drivers, while Burger and von Fintel (2014) and Borat et al. (2014) emphasise education, skills demand and employment absorption. Moultrie et al. (2012) show that fertility decline has not automatically generated a demographic dividend because unemployment and inequality remain persistent. However, this literature has not combined a long annual sample for apartheid and democracy with conditional ARDL estimates, explicit short-run error correction, structural-break robustness and NARDL tests of above-trend and below-trend population deviations, which the present study fills this gap.

Recent work by UNDP (2024) and World Bank (2024) reinforces this view, emphasising that demographic change becomes economically relevant only when combined with inclusive labour markets, effective governance and sustained investment. This strand, therefore, highlights the importance of distinguishing between population size, population growth, demographic composition and stresses the need for country-specific analysis that incorporates institutional context and long-run dynamics.

Table 8: Selected studies revealing neutral effects of population growth on economic growth

Authors	Methodology	Country/region	Variables Used	Main Findings	Matching Theory
Crenshaw et al. (1997)	Cross-Sectional Analysis	Developing Countries (1965–1990)	Population Growth, Economic Growth, Institutional Variables	Mixed results with some positive and some negative effects, no clear association.	Institutionalist Theory / Conditional Growth Theory.
Lee & Mason (2010)	National Transfer Accounts and demographic-accounting analysis	Various developed and developing countries (1970–2005)	Fertility, human capital, support ratios, economic growth	Population effects depend on age structure, fertility decline, human-capital investment and support ratios rather than population growth alone.	Demographic Dividend / Life-Cycle Theory
Menegaki (2011)	Econometric Analysis	European Countries (1995–2007)	Greenhouse gas emissions, employment, economic growth	Temporary connection between environmental variables and employment; no correlation with economic growth	Environmental Kuznets Curve (EKC), Weak Form.
Jones (2002)	Cross-Country Analysis	Multiple countries (1960–1995)	Population growth, economic growth, capital-labour ratio	No significant effect of population growth on economic growth in the long run.	Semi-Endogenous Growth Theory.
Bloom, Canning, & Sevilla (2001)	Demographic Transition Theory	Global regions (1960–1995)	Population age structure, economic growth	Population age structure has a more significant impact on economic development than population growth.	Demographic Transition Theory & Demographic Dividend Theory.
Pritchett (2001)	Time-Series and Cross-Country Analysis	Various Developing Countries (1960–1990)	Population growth, economic growth, capital-labour ratio	No significant long-term effect of population growth on economic growth; complex and context-dependent relationship	Country-Specific Growth Theory / Institutional Economics.
Mushtaq (2006)	Time-Series Analysis	Pakistan (1960–2003)	Population growth, per capita income	No long-term cointegration between per capita income and population growth.	Neoclassical Growth Theory (Steady-State Neutrality).

Authors	Methodology	Country/region	Variables Used	Main Findings	Matching Theory
Peng (2023)	Autoregressive Distributed Lag (ARDL)	China (1980–2020)	Population aging, GDP, resource constraints	Population aging had minimal direct impact on GDP due to institutional robustness mitigating demographic challenges.	Institutional Resilience Theory / New Institutional Economics.

Source: Author's Compilation

As summarised in Table 8, neutral or mixed findings imply that demographic scale is conditional on institutions, skills and labour absorption. South African evidence broadly supports this interpretation: demographic transition has not automatically generated a dividend, while industrial capacity, productivity, education quality and employment absorption remain decisive (Moultrie et al., 2012; National Planning Commission, 2012; National Treasury, 2024; World Bank, 2023). These findings motivate the dissertation's conditioning variables and integrated long-run, short-run and nonlinear tests.

2.12.4. Conclusion and Empirical Gap

The review of the empirical literature reveals five specific gaps that this dissertation addresses: Firstly, most studies use cross-country or panel data which are useful for comparison but mask out country-specific historical and institutional dynamics, so a single-country time series design is needed. Secondly, few studies model different time horizons within the same empirical framework, so a combined short-run and long-run estimate is necessary. Thirdly, only a limited number of studies incorporate structural breaks despite their importance in transitional economies, which the present study explicitly tests for structural breaks. Fourthly, there is a scarcity of South Africa-specific time-series studies covering both the apartheid and democratic periods; hence the present study does the South African coverage. Fifthly, very little empirical work and none identified for South Africa under review test for symmetry and asymmetrical effects of population to economic activity.

A unique contribution of the present study is investigating whether positive and negative deviations of population from its long-run trend have asymmetric effects on economic growth. This gap is significant because South Africa's demographic trajectory has been shaped by large, asymmetric shocks (HIV/AIDS, migration waves, political transitions) that standard symmetric models cannot capture. This dissertation addresses these gaps by using a long South African time series. The descriptive discussion covers 1950–2022, while the econometric analysis focuses on 1960–2022. The study combines time-varying correlation, Granger causality, cointegration analysis, ARDL modelling, nonlinear ARDL (NARDL), structural-break tests and asymmetric causality analysis. These methods allow a rigorous assessment of whether population dynamics function as drivers, constraints or conditional influences on economic growth

in South Africa. They also align the empirical analysis with the theoretical insights from this chapter and directly motivate the econometric strategy set out in Chapter Three.

CHAPTER THREE: RESEARCH METHODOLOGY

3. Introduction

This chapter outlines the methodological framework used to examine the relationship between population dynamics and economic growth in South Africa. The broader descriptive discussion covers 1950–2022, while the econometric analysis focuses on 1960–2022. The chapter explains the research design, theoretical foundations, variable selection, model specification and econometric procedures used to test the study’s five hypotheses.

3.1. Research Design and Approach

The study applies a quantitative time-series econometric approach, which is appropriate for analysing long historical annual data. The design allows the study to estimate long-run relationships, short-run adjustments, predictive causal direction and asymmetric demographic effects within a single-country framework. Specifically, the study employs:

- Unit root and structural break tests (KPSS, Zivot-Andrews),
- Engle–Granger cointegration and Dynamic OLS (DOLS) for long-run estimation,
- Autoregressive Distributed Lag (ARDL) models and error-correction models (ECM) for short-run and long-run dynamics,
- Nonlinear ARDL (NARDL) to test asymmetric demographic effects,
- Pairwise Granger causality tests to assess directional predictability.

This integrated approach allows the study to distinguish long-run structural effects from short-run cyclical dynamics, to evaluate regime stability and to test whether demographic accelerations and slowdowns affect growth asymmetrically. Therefore, the methodology provides a robust framework for addressing the study’s five hypotheses and ensures consistency between theoretical expectations, empirical modelling and policy interpretation. This integrated approach ensures that the findings are not driven by a single estimation technique and enhances the credibility and robustness of the results.

Table 9: Alignment of Aim, Research Questions, Objectives, Methods, and Evidence

Aim: Estimate South Africa’s population–real-output relationship (formal sample: 1960–2022)			
Research Question (RQ)	Objective	Econometric Method (Chapter 3)	Chapter 4 Evidence (Tables/Figures)
RQ1: What is the long-run relationship between total population size and aggregate real GDP in South Africa?	Objective 1: Determine the long-run population–real-GDP association.	DOLS; Johansen/VECM robustness; Engle–Granger cointegration; ARDL bounds and long-run coefficients.	Tables 19–20, 23, 26 and 29: Johansen/VECM, DOLS, Engle–Granger and ARDL long-run evidence.

Aim: Estimate South Africa's population–real-output relationship (formal sample: 1960–2022)			
Research Question (RQ)	Objective	Econometric Method (Chapter 3)	Chapter 4 Evidence (Tables/Figures)
RQ2: Do past values of population dynamics improve prediction of economic performance?	Objective 2: Test whether population dynamics provide predictive information for output.	Cross-correlograms; pairwise Granger predictive-causality tests; VECM block-exogeneity tests.	Figures 12–15 and Tables 14–16 and 21: horizon-specific predictive evidence.
RQ3: What are the direct short-run population effects, and how quickly is disequilibrium corrected after a shock?	Objective 3: Estimate direct short-run effects and the error-correction speed.	Engle–Granger ECM; ARDL ECM; NARDL error-correction term.	Tables 27–28, 30, 32 and 37–38: short-run coefficients and adjustment speeds.
RQ4: Do structural and regime changes significantly affect the level or growth path of real GDP?	Objective 4: Evaluate structural and regime sensitivity of GDP levels and growth.	Break unit-root tests; event and consolidated dummies; split-sample DOLS.	Tables 18, 25, 28 and 31–34: break, dummy and regime robustness.
RQ5: Do positive and negative population trend deviations have unequal short- and long-run effects?	Objective 5: Test trend-gap asymmetry at both horizons.	NARDL; long- and short-run Wald equality tests.	Tables 35–37: HP-filter endpoint check, NARDL coefficients and Wald asymmetry tests.

Source: Author's compilation based on the study goals

Table 9 aligns between the study's aim, research questions, objectives, econometric methods specified in this chapter and the corresponding empirical evidence reported in Chapter Four. The table provides a concise methodological roadmap, ensuring consistency between the research design and the empirical analysis.

3.1.1. Theoretical Framework

This study is grounded in two complementary economic growth theories: Endogenous Growth Theory (Romer, 1990) and the Augmented Solow Growth Model (Mankiw et al., 1992). Together, these frameworks provide a coherent theoretical basis for analysing how population dynamics influence economic growth in both the short run and the long run. The integration of these theories is suitable for South Africa, where demographic change interacts with capital accumulation, human capital formation, institutional quality and historical structural constraints. The basis of equation (1) is derived from the Cobb-Douglas production (1928).

3.1.2. Endogenous Growth Theory

Endogenous Growth Theory emphasises that long-run economic growth is driven by internal factors such as human capital accumulation, knowledge creation and technological progress, rather than by exogenous technological change. In this framework, population dynamics influence growth by expanding the labour force, enlarging markets and enhancing innovation capacity, provided that adequate investment and institutional support exist. Formally, the basic endogenous growth production function is expressed as equation (1).

$$Y_t = A_t K_t^{\alpha_1} L_t^{\alpha_2} \quad (1)$$

In equation (1), Y_t denotes real economic output (GDP), A_t represents technology and knowledge accumulation, K_t is physical capital, L_t is labour input linked to population size, α_1 &

α_2 are output elasticities. In this study, population level and population growth capture labour supply and market-size effects. Educational attainment proxies' human capital, while life expectancy captures population health and productive capacity. Investment represents physical capital accumulation, and the dependency ratio reflects demographic pressure on the working-age population. Endogenous growth theory implies that population growth can support economic growth only if it is accompanied by improvements in education, health and capital formation. Without these complementary factors, population growth may dilute capital per worker and constrain productivity.

3.1.3. Augmented Solow Growth Model

To complement the endogenous framework, the study also adopts the Augmented Solow Growth Model, which extends the traditional Solow model by explicitly incorporating human capital and demographic factors. The model recognises diminishing returns to capital and labour and highlights that population growth alone does not guarantee sustained economic growth. The augmented production function is expressed in equation (2).

$$Y_t = K_t^{\alpha_1} H_t^{\alpha_2} (A_t L_t)^{\alpha_3} \quad (2)$$

In equation (2), Y_t denotes real economic output, which is GDP, H_t represents human capital, which is educational attainment, L_t denotes labour input linked to population, and this may be separated into other aspects of demographics, A_t captures technology.

Within this framework, population growth affects economic growth through labour-force expansion and capital dilution effects. High dependency ratios reduce savings and investment per worker, while improvements in education and health raise productivity and long-run output. In the South African context, the model highlights how rapid population growth combined with high dependency burdens and insufficient investment can constrain growth, whereas improvements in human capital and capital accumulation enable the economy to harness a demographic dividend.

3.1.4. Linking Theory to the Empirical Model

The theoretical frameworks discussed in Chapter Two inform both the choice of variables and the interpretation of the empirical results. The Malthusian perspective motivates the inclusion of population measures by suggesting that rapid population expansion may place pressure on resources and reduce economic performance when productive capacity does not keep pace. The Solow-Swan framework justifies the inclusion of capital formation, since the growth effect of population depends on whether investment is sufficient to offset capital dilution. Endogenous Growth Theory supports the inclusion of education and life expectancy as human-capital

variables, while Demographic Transition Theory informs the use of dependency ratios, fertility and mortality indicators.

The nonlinear model further allows the study to assess whether positive and negative departures of population from its long-run trend affect economic growth symmetrically or asymmetrically. The Environmental Kuznets Curve and Resource Curse theories are not directly operationalised in this study, as the econometric models do not include environmental or governance indicators. They are included in the theoretical review because they provide important contextual channels through which population growth may indirectly affect economic performance in South Africa particularly through resource pressures, environmental degradation and institutional constraints on labour absorption. Their exclusion from the empirical models is acknowledged as a limitation because the focus on this study is mainly on population dynamics affecting economic activity.

The empirical models are informed by the theoretical channels discussed in Chapter Two. The study does not estimate a separate growth-accounting decomposition or a separate two-sector labour-allocation model because labour force data sample only begins in 1991. Instead, these theories guide the selection and interpretation of variables within the time-series framework. logPOP represents the population and labour-supply channel, LogCAP captures capital accumulation, while education and life expectancy proxy human-capital and productivity-related effects. Birth rate, death rate and dependency ratio capture demographic-composition effects. The structural-break and NARDL specifications further allow the study to examine whether South Africa's historical transitions and asymmetric demographic deviations affect the population-output relationship.

3.1.5. Integrated Framework and Variable Justification

By integrating Endogenous Growth Theory and the Augmented Solow Growth Model, the study adopts a comprehensive framework that captures both the potential benefits and the structural constraints of population change. Therefore, the empirical specification is designed to test whether population affects economic growth directly, whether this effect is conditioned by complementary factors such as capital and human capital, and whether the effect differ across short-run and long-run horizons. This theoretical integration directly informs variable selection and model specification:

- GDP represents economic activity and performance.
- Population level and population growth capture labour supply and market size effects.
- Investment (as fixed capital formation) reflects physical capital accumulation.
- Educational attainment proxies human capital development.

- Life expectancy captures population health and productive capacity.
- Birth and death rates represent demographic transition dynamics.
- Dependency ratio reflects demographic pressure on the productive population.

Together, these variables allow the empirical models to test whether population dynamics promote economic growth conditionally, through capital, human capital, and favourable demographic structure, or whether they impose constraints in the absence of such conditions. Theories also justify the inclusion of investment, education, life expectancy, birth and death rates and the dependency ratio as conditioning variables through which population affects growth. To examine the core long-run relationship between population size, capital accumulation, and economic growth, the baseline model is expressed in log-linearised form given by growth equation (3).

$$\log GDP_t = \alpha_0 + \alpha_1 \log POP_t + \alpha_2 \log CAP_t + \varepsilon_t \quad (3)$$

In equation (3) GDP_t denotes real gross domestic product, POP_t denote the total population, CAP_t denotes gross fixed capital formation, ε_t is the error term. The expected signs are $\alpha_1 > 0$, $\alpha_2 > 0$. Population substitutes labour in the production function to reflect both labour supply and consumption effects, while capital refers to investment, which both make the two core drivers of growth. This model tests H1, the long-run population–GDP association:

- H_{01} : Total population size has no statistically significant long-run association with aggregate real GDP.
- H_{11} : Total population size has a statistically significant long-run association with aggregate real GDP.

The study progressively adds more demographic variables to the model to isolate the impact of population, thereby offering robustness testing of the population's effects on GDP, a key variable in the study. The inclusion of each demographic model captures a specific theoretical aspect. The first augmentation adds life expectancy, and this is the Human-Capital-Augmented Population (Life expectancy) Model. Equation (4) assesses the effect of population on growth that is conditional on health, measured by life expectancy and human capital.

$$\log GDP_t = \alpha_0 + \alpha_1 \log POP_t + \alpha_2 \log CAP_t + \alpha_3 LIF + \varepsilon_t \quad (4)$$

In equation (4) LIF_t denotes the life expectancy at birth (proxy for population health) and potential future productivity and is expected as $\alpha_3 > 0$. Population contributes to growth primarily when accompanied by improvements in population health. The model captures the conditional long-run effect of life expectancy on GDP.

The study further augments the baseline model with the age-dependency ratio in equation (5) to capture the role of age structure and dependency burdens in mediating the population-growth relationship.

$$\log GDP_t = \alpha_0 + \alpha_1 \log POP_t + \alpha_2 \log CAP_t + \alpha_3 DEP_t + \varepsilon_t \quad (5)$$

In equation (5) DEP_t denotes the age dependency ratio, expected to be $\alpha_3 < 0$, because a higher dependency burden constrains growth by reducing savings and productive labour. This captures the structural demographic channel. The baseline model is then augmented with education and skills accumulation as shown in equation (6).

$$\log GDP_t = \alpha_0 + \alpha_1 \log POP_t + \alpha_2 \log CAP_t + \alpha_3 EDU_t + \varepsilon_t \quad (6)$$

In equation (6) EDU_t denotes the average years in education and is expected as $\alpha_3 > 0$. The population scale effects translate into growth only when supported by adequate human capital. This equation captures the education-conditional growth effect. To explicitly capture the demographic transition mechanisms, the baseline model is augmented with dynamics of fertility and mortality.

$$\log GDP_t = \alpha_0 + \alpha_1 \log POP_t + \alpha_2 \log CAP_t + \alpha_3 BIR_t + \alpha_4 DEA_t + \varepsilon_t \quad (7)$$

In equation (7) BIR_t denotes crude birth rate and DEA_t represent crude death rate. It is expected that $\alpha_3 < 0$ which implies high fertility may dilute capital. Whereas $\alpha_4 < 0$ implies that high mortality reduces productive capacity. The demographic transition variables can either constrain or enhance growth, depending on the stage of development. This model captures the demographic transition effects and is referred to as the Fertility and Mortality-Augmented Demographic Model.

By integrating Romer's Endogenous Growth Theory with the Augmented Solow Growth Model, this study adopts a comprehensive theoretical framework that captures both the potential benefits and the necessary conditions under which population growth may influence economic development. Romer's theory emphasises the role of innovation and human capital in leveraging population dynamics for economic growth. The Augmented Solow Model stresses the importance of capital accumulation, human capital, and demographic structure in translating population growth into sustained economic performance.

3.1.6. Endogeneity and Identification

A fundamental challenge in estimating the population-growth relationship is that population and GDP are likely jointly determined. Economic growth may influence population through its effects on fertility decisions, mortality, migration, and life expectancy, creating reverse predictive

causality. Furthermore, omitted variables, such as institutional quality, governance capacity, or global commodity cycles, may simultaneously affect both population dynamics and economic performance.

This study addresses endogeneity through several complementary strategies rather than relying on a single identification approach. First, Dynamic Ordinary Least Squares (DOLS) corrects for endogeneity bias in the long-run cointegrating regression by including leads and lags of the first-differenced regressors (Stock & Watson, 1993). Second, the ARDL bounds testing approach accommodates feedback effects by modelling both current and lagged values of all variables within a single-equation conditional error-correction framework (Pesaran et al., 2001). Third, Granger causality tests assess the direction of predictive relationships between population and GDP in both levels and first differences, providing evidence on predictive causality. Fourth, the sequential inclusion of demographic controls (life expectancy, dependency ratio, education, fertility, and mortality) across multiple model specifications helps to isolate the population channel from correlated demographic influences.

It is important to acknowledge, however, that these methods establish temporal precedence and conditional correlation rather than strict structural causation. The Granger causality framework tests whether past values of one variable improve prediction of another, not whether the relationship is causal in the interventionist sense. Similarly, cointegration and error-correction models identify stable long-run co-movement and adjustment dynamics but cannot rule out all forms of confounding. Therefore, the findings are interpreted as providing robust evidence of conditional association and predictive causality, consistent with, but not definitive proof of, a causal population-to-growth channel. Establishing strict causality would require either a natural experiment or an instrumental variable that credibly affects population but not GDP through other channels, which is beyond the scope of annual macro-economic time-series analysis.

A possible response to endogeneity would be an instrumental-variable strategy. In principle, an instrument for population should be strongly correlated with population dynamics but should affect GDP only through population. Several possible instruments were considered. Lagged demographic variables, such as lagged population, fertility or mortality, may be relevant because demographic series are persistent over time. However, in an annual macro-economic time-series setting they are unlikely to satisfy the exclusion restriction fully, since past population dynamics may affect current GDP through labour supply, consumption demand, fiscal planning, human-capital accumulation and migration channels. Historical instruments such as settler mortality rates are also difficult to apply in this single-country annual framework because they are largely time-

invariant and were designed mainly for cross-country institutional analysis. Policy-induced migration restrictions may be more relevant to South Africa because apartheid-era influx control and post-1994 migration policy changes affected population distribution and labour mobility. However, these policies also affected GDP directly through labour-market allocation, urbanisation, human-capital access and institutional restrictions, making them unsuitable as clean instruments for population alone.

For these reasons, the study does not estimate a separate two-stage instrumental-variable model. Instead, the empirical strategy reduces endogeneity concerns through DOLS leads and lags, ARDL dynamic specifications with lags, error-correction modelling, Granger causality tests, sequential demographic controls and structural-break robustness checks. The results are therefore interpreted as evidence of conditional long-run association, short-run adjustment and predictive causality, rather than as strict structural causal effects. This interpretation is appropriate given the limitations of annual macro-economic time-series data and the absence of a clearly valid instrument for population dynamics in South Africa.

3.2. Econometric Methodology

The study applies an integrated sequence of econometric procedures to test the five hypotheses. DOLS and cointegration evidence address H_1 ; Granger predictive-causality tests address H_2 ; ECM and ARDL short-run terms address H_3 ; structural-break and dummy robustness checks address H_4 ; and NARDL Wald restrictions address H_5 .

3.2.1. Dynamic Ordinary Least Squares (DOLS)

DOLS is preferred because it corrects for endogeneity and serial correlation by augmenting the cointegrating regression with leads and lags of first-differenced regressors (Stock & Watson, 1993). The lead and lag length is set at one in both directions (± 1) based on the Schwarz Information Criterion (SIC), which is preferred for small samples due to its parsimony (Schwarz, 1978). With 63 annual observations, a conservative lead/lag structure preserves degrees of freedom while adequately correcting for endogeneity. As a robustness check, alternative lead/lag specifications of (± 2) were estimated; the core results, the sign, magnitude and significance of the population and capital coefficients, remain qualitatively unchanged with additional variables.

3.2.2. Methodology 1: Engle-Granger Cointegration

This study applies the Engle-Granger cointegration method to determine whether a stable long-run association exists among the variables in baseline model (3). The methodology involves three steps. This involves estimating the model in levels, deriving the residuals, and testing the null

hypothesis that residuals have a unit root. If the null hypothesis is rejected, then a short-run error correction model will be estimated.

3.2.3. First step in the Engle-Granger Cointegration

The baseline long-run equation is given by equation (8) with variables expressed in logarithmic format. Equation (9) gives the baseline long-run model augmented with other variables O_t as indicated in the theoretical framework. The O_t captures the additional variables in the model as additional demographic variables, like life expectancy (LIF_t), the age-dependency ratio (DEP_t), (EDU_t) educational attainment, (BIR_t) crude birth rate and (DEA_t) crude death rate, while the dependent variable (GDP_t) is real GDP at constant local prices. The Engle-Granger procedure is used to test Hypothesis 1:

$$\log GDP_t = \alpha_0 + \alpha_1 \log CAP_t + \alpha_2 \log POP_t + \varepsilon_t \quad (8)$$

$$\log GDP_t = \alpha_0 + \alpha_1 \log CAP_t + \alpha_2 \log POP_t + \alpha_3 O_t + \omega_t \quad (9)$$

South Africa's evolution from a racially segregated society under apartheid to a democratic state in 1994 resulted into structural changes that have profoundly influenced both demographic dynamics and economic performance (Bhorat et al., 2015; IMF, 2006). The apartheid era, officially began in 1948, is analysed from 1960 to 1993 in this study due to data availability. This period was marked by institutionalised racial segregation and economic exclusion of non-white populations. The National Party (NP) implemented policies that favoured the White minority at the expense of the Black majority and other racial groups, resulting in vast inequalities in education, income, employment, and land ownership (Britannica, 2024; CESR, 2019; Terreblanche, 2002). These structural inequalities significantly shaped South Africa's economic outcomes, population growth patterns, and human capital development during this period, leaving a legacy of unemployment, skill mismatches and labour market rigidities and poverty (IMF, 2006; World Bank, 2023; Nattrass, 1994; Burger & Jafta, 2006).

The democratic era began in 1994 when the African National Congress (ANC) assumed national governance in South Africa. The democratic transition in South Africa was intended not only to establish political freedoms but also to address socioeconomic gaps created by Apartheid. Rather than treating the apartheid and democratic periods as separate models, a dummy variable regression model is applied which captures a break in the data series without requiring the estimation of separate equations. A dummy variable (DUM) is used to indicate the regime change, where DUM = 0 for the apartheid period (1960-1993) and DUM = 1 for the democratic period (1994-2022). Equation (10) shows the baseline model augmented with dummy variable.

$$\log GDP_t = \alpha_0 + \alpha_1 \log POP_t + \alpha_2 \log CAP_t + \alpha_3 O_t + \beta_4 DUM + \epsilon_t \quad (10)$$

t represents time, and ϵ_t is the stochastic error term.

Real GDP at constant local-currency prices is the dependent variable because it measures the volume of final output produced within the economy after removing price-level effects. National-accounts practice uses constant-price GDP to measure aggregate output and its growth through time (United Nations et al., 2009; World Bank, 2024), and real GDP is the standard outcome in empirical growth research (Barro, 1991; Mankiw et al., 1992). Growth accounting is not a competing dependent variable: it decomposes growth in this same real-output aggregate into capital, labour and productivity contributions. Accordingly, ‘economic growth’ in this dissertation means expansion or change in aggregate real output, not comprehensive economic development or welfare. GDP does not by itself measure distribution, unpaid production, environmental depletion or quality of life.

α_1 – impact of total population is projected to be positive, implying that an increase in population growth contributes positively to GDP growth by expanding labour supply and market size. Population is hypothesised to influence economic growth through channels such as labour supply expansion, increased market size, and human capital development, consistent with the Solow Growth Model (Solow, 1956) and Endogenous Growth Theory (Romer, 1990). This variable is theorised to influence macro-economic development by shaping the size of the labour force, aggregate demand, consumption patterns and demographic structure.

α_2 – impact of investment is projected to be positive, reflecting the role of capital accumulation in driving economic expansion. Investment is measured as gross fixed capital formation and reflects the accumulation of physical capital. It is a key control variable grounded in neoclassical and endogenous growth models, where capital formation is a crucial driver of long-run economic growth (Mankiw et al., 1992; Romer, 1990).

α_3 – The term O_t represents a vector of additional demographic variables, rather than a single indicator. These variables capture population quality and demographic structure effects beyond total population size. O_t includes life expectancy, dependency ratio, educational attainment, birth rate and death rate. Therefore, α_3 captures the marginal effect of the corresponding demographic variable on economic growth. The inclusion of O_t is theoretically grounded in Human Capital Theory, Demographic Transition Theory, and the Demographic Dividend framework, which emphasise that the growth impact of population depends not only on size but also on health, education, age structure, and fertility–mortality dynamics.

α_4 – A dummy variable DUM is equal to 0 for the Apartheid era covering 1960 to 1993 and 1 for the Democratic era covering 1994 to 2022. This variable captures the structural break associated with the transition to democracy, allowing for the estimation of differential effects of population and economic variables under different political regimes. The Zivot-Andrews breakpoint unit roots will be used to structural break points to find break years in the data, and these will be added in the estimation for robustness checks.

3.2.4. Second step of Engle-Granger cointegration analysis

The second step of the Engle-Granger cointegration test requires testing the null hypothesis of unit roots on residuals from estimated equations (8) and (9) and their variants in the theoretical framework section. The rejection of the null hypothesis implies that the residuals are stationary and the variables are cointegrated.

The hypotheses tested are:

- H_0 : No cointegration (residuals contain a unit root)
- H_1 : Cointegration exists (residuals are stationary). Residual stationarity is expressed in equation (10a):

$$\Delta \hat{\varepsilon}_t = p \hat{\varepsilon}_{t-1} + \sum_{i=0}^p \gamma_i \Delta \hat{\varepsilon}_{t-i} + \mu_t \quad (10a)$$

Rejection of the null hypothesis implies that the variables share a long-run equilibrium relationship, implying the existence of cointegration. This step validates the use of error-correction models to analyse short-run dynamics.

3.2.5. Third step of Engle-Granger cointegration analysis

The short-run equation can be expressed in equations (11a) and (11b) with the error correction term (ε_{t-1}), measuring how quickly GDP growth returns to its long-run equilibrium after a shock. It is included in error correction models (ECMs), which are statistical models used to depict the short-run dynamic forces of cointegrated variables. The ε_{t-1} and ω_{t-1} are the residuals from long-run equations (8) and (9), respectively.

$$\Delta \log GDP_t = \gamma + \varphi \varepsilon_{t-1} + \varphi_0 \Delta \log GDP_{t-1} + \varphi_1 \Delta \log CAP_t + \varphi_2 \Delta \log POP_t + \mu_t \quad (11a)$$

$$\Delta \log GDP_t = \gamma + \varphi \omega_{t-1} + \varphi_0 \Delta \log GDP_{t-1} + \varphi_1 \Delta \log CAP_t + \varphi_2 \Delta \log POP_t + \varphi_3 \Delta O_t + \vartheta_t \quad (11b)$$

Equations (11a) and (11b) present the short-run error-correction forms linking real GDP growth $\Delta \log GDP_t$ to population dynamics and capital accumulation. The intercept γ captures mean economic growth when other variables are held constant, while the lagged error-correction term

(ε_{t-1} or ω_{t-1}) measures deviations from long-run equilibrium, with its coefficient $\varphi < 0$ indicating the speed of adjustment. The lagged growth φ_0 term reflects short-run persistence, φ_1 captures the positive effect of capital accumulation, and φ_2 measures the short-run impact of population growth, expected to be negative due to capital dilution and labour-market adjustment pressures in South Africa. In equation (11b), φ_3 represents the effect of an additional demographic or structural control O_t , while the error terms μ_t and ϑ_t capture unobserved short-term fluctuations allowing a clear distinction between long-run adjustment and short-run growth dynamics (Ogunmuyiwa, 2013).

3.3. Methodology 2: ARDL Method

The Autoregressive Distributed Lag (ARDL) framework estimates long-run level relationships and direct short-run dynamics when regressors are a mixture of $I(0)$ and $I(1)$, provided none is $I(2)$ (Pesaran & Shin, 1999; Pesaran et al., 2001). Lag lengths are selected using the Akaike Information Criterion with a maximum of four annual lags. The bounds and normalised long-run coefficients contribute corroborating evidence for H1, while the differenced population coefficient and the negative, statistically significant error-correction term test the two components of H3. Thus, a weak direct short-run population coefficient can coexist logically with significant equilibrium adjustment.

- H_0 : The population increase has insignificant long-run and short-run effects on economic activity.
- H_1 : The population increase has positive and significant long-run and short-run effects on economic activity.

The Autoregressive Distributed Lag technique is employed to estimate both the short- and long-term relationships and test for cointegration between variables. The ARDL specifications that include the long-run and short-run is specified in equations (12a) and (12b), presuming cointegration exists.

$$\Delta \log GDP_t = \alpha + \gamma \log GDP_{t-1} + \alpha \log CAP_{t-1} + \beta_1 \log POP_{t-1} + \sum_{i=0}^q \beta_{2i} \Delta \log POP_{t-i} + \sum_{i=0}^q \beta_{3i} \Delta \log CAP_{t-i} + \sum_{i=1}^q \beta_{4i} \Delta \log GDP_{t-i} + \varepsilon_t \quad (12a)$$

$$\Delta \log GDP_t = \alpha + \gamma \log GDP_{t-1} + \alpha \log CAP_{t-1} + \beta_1 \log POP_{t-1} + \beta_4 O_{t-1} + \sum_{i=0}^q \beta_{2i} \Delta \log POP_{t-i} + \sum_{i=0}^q \beta_{3i} \Delta \log CAP_{t-i} + \sum_{i=1}^q \beta_{4i} \Delta \log GDP_{t-i} + \sum_{i=0}^q \beta_{5i} \Delta O_{t-i} + \varepsilon_t \quad (12b)$$

In equations (12a) and (12b), the coefficient γ on the lagged dependent variable represents the error-correction component of the ARDL model and is expected to be negative and statistically

significant, indicating adjustment toward long-run equilibrium. A value of γ bounded between 0 and -1 confirms a stable long-run relationship, implying long-term connection between variables.

The coefficients β_{2i} , β_{3i} , and β_{5i} capture the short-run effects of population growth, capital accumulation, and the additional control variable O , respectively, on economic growth. The long-run coefficients are derived by normalising the lagged level variables on the coefficient of $\log GDP_{t-1}$. Specifically, the long-run impact of capital accumulation on GDP is given by $-\alpha/\gamma$, while the long-run impact of population on GDP is given by $-\beta_1/\gamma$. In equation (12b), the long-run impact of the control variable O is given by $-\beta_4/\gamma$. The long-run level terms contribute evidence to H1, while the differenced population term and the error-correction coefficient contribute evidence to H3.

3.3.1. Restricted error correction ARDL model

The ARDL model also includes an error correction term to analyse the short-run dynamics. The error correction shows how the system rectifies deviations from the long-term equilibrium. The ARDL equations (13a) and (13b) capture the short-run dynamics.

$$\Delta \log GDP_t = \alpha + \lambda \varepsilon_{t-1} + \sum_{i=0}^q \beta_{6i} \Delta \log POP_{t-i} + \sum_{i=0}^q \beta_{7i} \Delta \log CAP_{t-i} + \sum_{i=1}^q \beta_{4i} \Delta \log GDP_{t-i} + \vartheta_t \quad (13a)$$

$$\Delta \log GDP_t = \alpha + \lambda \varepsilon_{t-1} + \sum_{i=0}^q \beta_{6i} \Delta \log POP_{t-i} + \sum_{i=0}^q \beta_{7i} \Delta \log CAP_{t-i} + \sum_{i=1}^q \beta_{4i} \Delta \log GDP_{t-i} + \sum_{i=0}^q \beta_{8i} \Delta O_{t-i} + \varepsilon_t \vartheta_t \quad (13b)$$

In equations (13a) and (13b) $\Delta \log GDP_t$ represents the change in GDP at time t , α is the constant term, β_6 represents the effect of population growth on GDP growth, $\Delta \log POP_t$ denotes annual population growth in t . β_8 denotes the impact of change in independent variables O at time t in equation (13b). ΔO_t denotes a change in other demographic or other variables O at time t in equation (13a).

The coefficient on the error correction term (ε_{t-1}) is expected to be negative, whereas the magnitude of λ will indicate how quickly deviations from the long-term equilibrium are corrected by the system. A higher λ implies faster adjustments to equilibrium. The analysis assesses how population growth and other relevant variables, collectively represented by O_t influence GDP in both the short run and long run. The positive coefficient on $\Delta \log POP_t$ implies that population increase will have a positive effect on economic progress. If the $\Delta \log POP_t$ variable has a negative coefficient, this implies that population increase drags economic progress.

3.3.2. Non-Linear Autoregressive Distributed Lag Model (NARDL)

The use of NARDL is motivated by the theoretical and empirical evidence reviewed in Chapter Two, which suggests that demographic accelerations and slowdowns may not affect economic performance symmetrically. This study adopts the Nonlinear Autoregressive Distributed Lag (NARDL) model to investigate the short- and long-run asymmetric effects of population increases and decreases relative to trend population on economic growth in South Africa. The NARDL model, developed by Shin et al. (2014),⁴ represents an important advancement over the traditional linear ARDL framework by allowing for the decomposition of population growth into their positive and negative partial sums. This decomposition enables the model to capture potential nonlinearities and asymmetries in the relationship between independent and dependent variables, an essential feature when analysing economic behaviours that may not respond uniformly to positive and negative shocks.

Testing Hypothesis 5: Trend-gap asymmetry

- H_0 : Population increase and decrease from trend population have symmetric long run and short run effects on economic growth.
- H_1 : Population increase and decrease from trend population have asymmetric long-run and short-run effects on economic growth.

For instance, a rise in population growth may lead to an increase in consumption, thereby raising economic growth, while a decrease in population growth could lead to a decrease in consumption, which in turn lowers economic growth. By estimating separate coefficients for positive and negative changes in population growth, the NARDL model examines the asymmetric effects of population changes on economic growth. To analyse asymmetries in the impact of population growth changes, the study will apply a partial sum decomposition method to the population based on deviations from the Hodrick–Prescott-filtered trend. The HP filter separates the long-run demographic trend, which reflects structural population growth, from a cyclical deviation component, capturing short-run fluctuations around the long-term trend. These deviations are scaled by total population and multiplied by 100. The deviations are consistent with underestimation and overestimation in population estimates which are needed for policy, planning and service delivery. A positive deviation may imply greater pressure on service delivery than anticipated from the trend.

⁴ Shin, Y., Yu, B., & Greenwood-Nimmo, M. (2014). Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In *Festschrift in Honor of Peter Schmidt* (pp. 281-314). Springer.

The population growth is decomposed into the partial sums of positive and negative deviation, respectively, where ΔPOP_t^+ and ΔPOP_t^- will denote the positive and negative partial sum processes of an increase and a decrease in population respectively. Thus, this technique splits the population growth into two separate components: The partial sums of positive changes (increases) POP_t^+ captures the cumulative effects of positive population deviations. The partial sums of negative changes (decreases) POP_t^- : capturing the cumulative effects of negative population deviations.

$$POP_t^+ = \sum_{j=1}^t \Delta POP_t^+ = \sum_{j=1}^t \max(\Delta POP_t, 0) ; \quad POP_t^- = \sum_{j=1}^t \min(\Delta POP_t, 0) \quad (14)$$

The decomposition of population deviations from HP trend into positive and negative partial sums within the Non-linear Autoregressive Distributed Lag (NARDL) framework allows for the estimation of separate coefficients for population increases and decreases. This methodological innovation is crucial for capturing potential asymmetric effects, that is, whether economic growth responds differently to population increases compared to decreases relative to the population trend. Equation (14) gives the NARDL specification for economic growth, which models both short-run fluctuations and long-run equilibrium dynamics and accounts for asymmetric responses. To investigate the long-run cointegration relationship among the variables, we will apply the TBDM and FPSS tests to determine whether a long-run relationship exists among these variables. The TBDM test will assess the null hypothesis of no cointegration, for both the ARDL and NARDL models. The FPSS null hypothesis for the ARDL model is specified as follows. $H_0: \gamma = 0$. For NARDL, the null hypothesis is:

$$H_0: \gamma = \alpha = \beta_2^+ = \beta_2^- = 0.$$

If the null hypothesis is rejected, it indicates that there are long-run cointegration relationships between these variables.

$$\Delta \log GDP_t = \alpha + \gamma \log GDP_{t-1} + \alpha \log CAP_{t-1} + \beta_2^+ POP_{t-1}^+ + \beta_2^- POP_{t-1}^- + \sum_{i=1}^q \tau_i \Delta \log GDP_{t-i} + \sum_{i=0}^q \beta_{3i} \Delta \log CAP_{t-i} + \sum_{i=0}^q \gamma_i^- \Delta POP_{t-i}^- + \sum_{i=0}^q \gamma_i^+ \Delta POP_{t-i}^+ + \varepsilon_t \quad (15a)$$

The short-run and long-run asymmetries in the NARDL model are examined using the Wald test. Specifically, to assess the long-run asymmetry between population changes and economic growth, we will test the null hypothesis $H_0: -\frac{\beta_2^+}{\gamma} = -\frac{\beta_2^-}{\gamma}$.

The existence of a short run asymmetry is examined by testing the null hypothesis: $H_0: \sum_{i=0}^q \gamma_i^+ = \sum_{i=0}^q \gamma_i^-$. If the null hypothesis is rejected, it suggests the presence of asymmetric

effects. Equation (13) specifies the NARDL model that includes other variables captured in the O_{t-1} and ΔO_{t-i} to test Hypothesis 5.

$$\begin{aligned} \Delta \log GDP_t = & \alpha + \gamma \log GDP_{t-1} + \alpha \log CAP_{t-1} + \beta_2^+ POP_{t-1}^+ + \beta_2^- POP_{t-1}^- + \beta_4 O_{t-1} + \\ & \sum_{i=1}^q \tau_i \Delta \log GDP_{t-i} + \sum_{i=0}^q \beta_{3i} \Delta \log CAP_{t-i} + \sum_{i=0}^q \gamma_i^- \Delta POP_{t-i}^- + \sum_{i=0}^q \gamma_i^+ \Delta POP_{t-i}^+ + \sum_{i=0}^q \delta_i \Delta O_{t-i} + \\ & \varepsilon_t \end{aligned} \quad (15b)$$

The augmented NARDL specification applies Wald tests to the positive and negative population-deviation terms at both horizons. These restrictions test H5 directly; household consumption is not a variable in this dissertation. Long-run symmetry requires equality of the positive and negative long-run coefficients, while short-run symmetry requires equality of their cumulative differenced effects.

From equation (15a) and (15b) we can form a restricted ARDL form:

$$\begin{aligned} \Delta \log GDP_t = & \alpha + \gamma \varepsilon_{t-1} + \sum_{i=1}^q \tau_i \Delta \log GDP_{t-i} + \sum_{i=0}^q \beta_{3i} \Delta \log CAP_{t-i} + \sum_{i=0}^q \gamma_i^- \Delta POP_{t-i}^- + \\ & \sum_{i=0}^q \gamma_i^+ \Delta POP_{t-i}^+ + \varepsilon_t \end{aligned} \quad (16)$$

3.3.3. Asymmetric Population Effects: NARDL Results

To examine whether population growth exerts asymmetric effects on economic growth, the study employs the Nonlinear Autoregressive Distributed Lag (NARDL) model of Shin et al. (2014). Population growth is decomposed into positive and negative partial sum processes, denoted by POP_t^+ and POP_t^- , which capture cumulative deviations of population growth above and below its long-run mean. This decomposition allows population increases and decreases to influence economic growth differently in both the short run and the long run.

These partial sum variables enter the NARDL specification in equations (14) and (15) through lagged level terms POP_{t-1}^+ and POP_{t-1}^- , which capture long-run asymmetric effects, and first-difference terms ΔPOP_t^+ and ΔPOP_t^- , which capture short-run asymmetric dynamics. Long-run asymmetry is tested using the Wald restriction $-\beta_2^+/\gamma = -\beta_2^-/\gamma$, while short-run asymmetry is assessed by testing whether the cumulative short-run effects satisfy $\sum \gamma_i^+ = \sum \gamma_i^-$. This framework enables a formal assessment of whether positive and negative population growth shocks exert symmetric or asymmetric effects on economic growth, directly testing Hypothesis 5.

(a) Long-run symmetry hypothesis (H5):

- H_{05} : Positive and negative deviations of population from its estimated long-run trend have equal long-run effects on real GDP.

$$H_0: \frac{\beta_2^+}{\gamma} = \frac{\beta_2^-}{\gamma},$$

- H_{15} : Positive and negative deviations of population from its estimated long-run trend have unequal long-run effects on real GDP.

(b) Short-run symmetry hypothesis (H5):

- H_{05} : The cumulative short-run effects of positive and negative population deviations are equal.

$$H_0: \sum_{i=0}^q \gamma_i^+ = \sum_{i=0}^q \gamma_i^- ,$$

$$H_1: \sum_{i=0}^q \gamma_i^+ \neq \sum_{i=0}^q \gamma_i^-$$

- H_{15} : The cumulative short-run effects of positive and negative population deviations are unequal.

3.4. Methodology 3: Granger Causality

Granger predictive causality tests whether lagged values of one series add statistically significant information for forecasting another; it does not establish structural causation (Granger, 1969). The paired equations test both predictive directions between population and output. This procedure tests H2, while the sign of an associated bivariate dynamic coefficient is interpreted separately from the F-test of predictive content.

- H_{02} : Population dynamics provide no statistically significant predictive information for economic performance.
- H_{12} : Population dynamics provide statistically significant predictive information for economic performance.

Equations (17a) and (17b) test whether lagged population growth adds predictive information for GDP growth.

$$\log GDP_t = \alpha_{L1} + \sum_{i=1}^n \beta_{Li} \log GDP_{t-i} + \sum_{i=0}^n \pi_{Li} \log POP_{t-i} + \sigma_{Lt} \quad (17a)$$

$$\log POP_t = \alpha_{L2} + \sum_{i=0}^n \delta_{Li} \log GDP_{t-i} + \sum_{i=1}^n \rho_{Li} \log POP_{t-i} + \epsilon_{Lt} \quad (17b)$$

Testing the null hypothesis $\sum_{i=0}^n \pi_{Li} = 0$ against the alternative hypothesis $\sum_{i=0}^n \pi_{Li} \neq 0$. Rejecting the null implies that lagged population values add statistically significant predictive information for output; failing to reject it implies insufficient evidence of such predictive content.

Equations (18a) and (18b) test the reverse predictive direction. Neither result is interpreted as structural causation.

$$\Delta \log GDP_t = \alpha_{s1} + \sum_{i=1}^n \beta_{si} \Delta \log GDP_{t-i} + \sum_{i=0}^n \pi_{si} \Delta \log POP_{t-i} + \sigma_{st} \quad (18a)$$

$$\Delta \log POP_t = \alpha_{s1} + \sum_{i=0}^n \delta_{si} \Delta \log GDP_{t-i} + \sum_{i=1}^n \rho_{si} \Delta \log POP_{t-i} + \epsilon_{st} \quad (18b)$$

Testing the null hypothesis $\sum_{i=0}^n \pi_{si} = 0$ against the alternative hypothesis $\sum_{i=0}^n \pi_{si} \neq 0$.

The reverse-direction decision is based on the corresponding joint lag test. Rejection indicates predictive content from output to population; non-rejection indicates insufficient evidence. The interpretation remains predictive rather than structurally causal.

Economic relationships often unfold over time, requiring multiple lags to reflect delayed effects accurately. To establish lags in Granger-causality testing, this study uses the Akaike Information Criterion (AIC), which balances model fit and complexity, together with the Schwarz Information Criterion (SIC), which penalises additional parameters more heavily and favours more parsimonious specifications. The two Granger-causality equations are then applied to test whether lagged values of one variable significantly improve predictions of the other.

The preceding test determines whether Granger predictive causality is statistically significant; however, it does not determine the sign of the relationship. A pairwise model is estimated to determine the sign of the predictive relationship. If significant Granger predictive causality and its sign are identified, this implies a temporal predictive relationship between these variables, which will be further analysed using robustness checks. By evaluating the significance of the coefficients in the equations, the Granger causality test can be utilised to inspect the predictive relationship between population growth and economic growth. The Granger Causality Test helps to understand whether population growth and economic growth are causally related, which is useful for assessing whether population growth helps predict economic development in South Africa (Khan & Kellard, 2016).

Bivariate Granger causality tests indicate predictive causality, known as temporal precedence. The tests reveal whether one variable helps predict another but cannot confirm that population growth directly causes economic growth or vice versa. Other factors or omitted variables could be driving the observed relationships, and the direction of causality might change over different time periods.

3.4.1. Unit Root Tests

Unit root tests are a foundational step in time-series econometrics, used to determine whether the variables under investigation are stationary. A stationary time series is one whose statistical

properties (mean, variance, and autocovariance), remain constant over time. In contrast, non-stationary series often have trends or unit roots, which can result in spurious regression results, where relationships between variables appear statistically significant, but are not meaningful (Granger & Newbold, 1974).

3.4.2. Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test

The study applies Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test by reducing the risk of misleading inference arising from low power in conventional unit root tests and appropriate in small samples. The KPSS test examines the null hypothesis of stationarity. The KPSS test is based on the following hypotheses:

- Null hypothesis (H_0): The series is stationary (no unit root)
- Alternative hypothesis (H_1): The series is non-stationary (contains a unit root).

The KPSS test assumes that a time series Y_t can be decomposed into a deterministic component, a stochastic random walk, and a stationary error term, expressed as:

$$Y_t = \mu_t + \gamma t + \varepsilon_t$$

In which, $\mu_t = \mu_{t-1} + u_t$ is a random walk component, γt represents an optional deterministic trend, ε_t is a stationary error term. Under the null hypothesis of stationarity, the variance of the random walk component u_t is zero.

$$KPSS = \frac{1}{T^2} \sum_{t=1}^T S_t^2 / \widehat{\sigma^2} \quad (19)$$

In which $S_t = \sum_{i=1}^t \hat{\varepsilon}_i$ is the partial sum of residuals from the regression of Y_t on deterministic components, $\hat{\sigma}^2$ is the Newey-West estimator of the long-run variance, and T is the sample size. Each variable is tested in levels and first differences. A rejection of the null hypothesis in levels but failure to reject it in first differences indicates that the series is integrated of order one, $I(1)$. Conversely, failure to reject the null hypothesis in levels suggests stationarity, that is, $I(0)$.

Each variable will be tested both in levels and in first differences to determine the order of integration. Variables found to be integrated of order one, that is $I(1)$, are used in cointegration or ARDL analysis. While the KPSS test improves upon conventional unit root testing by reversing the null hypothesis, it remains sensitive to structural breaks. A stationary series with a structural break may be incorrectly identified as non-stationary. The analysis additionally employs the Zivot and Andrews (1992) and Perron unit root test, which allow for an endogenously determined structural break in either the intercept or trend, without requiring prior knowledge of the break date.

3.4.3. Zivot-Andrews Test for Structural Breaks

Given South Africa's substantial economic, social and political transformations over the sample period, mostly the transition from apartheid to democracy in 1994, it is highly likely that structural breaks are present in the underlying time series. Ignoring such breaks can lead to biased unit root inference. To address this issue, the study employs the Zivot and Andrews (1992) and Perron unit root test, which allows for an endogenously determined single structural break in the intercept and/or trend of the series. Unlike conventional unit root tests, the Zivot-Andrew's test does not require prior knowledge of the break date. Instead, the break point is determined internally by the data through minimisation of the one-sided t-statistic for the unit root hypothesis.

$$Y_t = \alpha + \beta Y_{t-1} + \theta DU_t + \gamma DT_t + \delta t + \sum_{i=1}^k c_i \Delta Y_{t-i} + \varepsilon_t \quad (20)$$

Y_t is the time series under investigation, α is a constant term, Y_{t-1} is the lagged level of the series, DU_t is a dummy variable capturing a shift in the intercept at the break date, DT_t is a dummy variable capturing a change in the trend slope at the break date, t is a deterministic time trend, ΔY_{t-i} are lagged first differences included to control for serial correlation, ε_t is a white-noise error term. The dummy variables are defined as:

$$DU_t = \{1 \text{ if } t > TB \mid 0 \text{ others}\}, DT_t = (t - TB) \cdot \{1 \text{ if } t > TB, 0 \text{ otherwise}\}$$

TB denotes the endogenously determined break date. The test is applied to POP, GDP and demographic variables: life expectancy, dependency ratio, education, birth and death rates. The most likely break date is determined endogenously, meaning the model identifies the point of structural change without relying on pre-specified dates. Standard unit root tests (ADF, PP) may fail to reject the null hypothesis of a unit root if a structural break exists, even if the series is stationary around a broken trend. The Zivot-Andrew's test corrects for this by explicitly modelling such breaks, making it well-suited for South Africa's context, where major economic and institutional changes occurred in 1994. Zivot-Andrews Hypotheses:

- The null hypothesis: The series has a unit root with a possible structural break.
- The alternative hypothesis: The series is stationary with a one-time break in the intercept and/or trend.

The Zivot-Andrews test is relevant because South Africa experienced large political, institutional and macro-economic changes around 1994. It is interpreted alongside KPSS so that integration orders and subsequent cointegration models do not mistake a broken deterministic path for a stochastic trend. The break and dummy specifications provide the evidence for H4, which

concerns whether structural and regime changes affect GDP levels or growth while the long-run relationship remains stable.

- H_{04} : Structural and regime changes do not significantly affect the level or growth path of real GDP.
- H_{14} : Structural and regime changes significantly affect the level or growth path of real GDP.

3.4.4. Degrees of Freedom Concern with Structural Dummies

The inclusion of six structural-break dummies alongside multiple regressors and their lags places demands on degrees of freedom in a sample of 63 annual observations. To ease this concern, the dummies enter as simple intercept shifters rather than slope dummies. As a sensitivity check, the structural-break variables were also consolidated into two broader shock indicators: a domestic/regime-transition dummy combining 1980, 1985 and 1994, and an external/health-shock dummy combining 2002, 2008 and 2020. This consolidation reduces the number of shock indicators and tests whether the main population and capital coefficients remain stable when the model is less parameterised. The consolidated-dummy results are reported in Chapter Four and confirm that the core conclusions are robust.

3.4.5. Cross Correlation Function

To examine the dynamic lead-lag relationships between demographic variables and economic growth prior to formal causality testing, this study employs the cross-correlation function. It provides preliminary evidence on the timing and persistence of interactions between demographic indicators and GDP without imposing a structural causal framework. Let O_t denote a demographic variable (population size, educational attainment, dependency ratio, birth rate, and death rate) and Y_t denotes real GDP. The cross-correlation coefficient at lag k is defined as:

$$\rho_{OY}(k) = \frac{\text{Cov}(O_t, Y_{t-k})}{\sqrt{\text{Var}(O_t) \text{Var}(Y_t)}}, k = 0, \pm 1, \pm 2, \dots \quad (21)$$

where $\rho_{OY}(k)$ measures the correlation between O_t and Y_{t-k} . A positive value of k indicates that the demographic variable leads GDP by k periods, while a negative value indicates that GDP leads the demographic variable. In empirical implementation, the cross-correlation is estimated using the sample analogue:

$$\hat{\rho}_{OY}(k) = \frac{\sum_{t=k+1}^T (O_t - \bar{O})(Y_{t-k} - \bar{Y})}{\sqrt{\sum_{t=1}^T (O_t - \bar{O})^2 \sum_{t=1}^T (Y_t - \bar{Y})^2}} \quad (22)$$

Statistical significance is assessed using asymptotic confidence bands defined by:

$$\pm \frac{2}{\sqrt{T}}$$

Cross-correlations are computed for level variables, consistent with the long-run specifications in equations (3) to (7), and for first-differenced variables, corresponding to the short-run dynamics in equations (9), (10b), and (13b).

3.5. Data Analysis

This study employs annual secondary time-series data for South Africa covering 1960 to 2022. Data are sourced primarily from the World Bank’s World Development Indicators (WDI), due to its extensive time-series data coverage. The WDI provides consistent and internationally comparable macro-economic and demographic data suitable for econometric time-series analysis.⁵ The study period spans major political and economic regimes, including apartheid, the democratic transition in 1994, and post-reform developments. This long sample enables analysis of both long-run relationships and short-run dynamics between population growth and economic growth. The 63-year timeframe captures major structural shifts in South Africa’s political, social and economic regimes. Below are the key variables used in the analysis based on the theoretical framework stated in this study in Chapter 2.

Table 10: Variables and Data Sources (1960–2022)

Data Name	Abbrev.	Unit of measurement	Database
Gross Domestic Product (Trillions of rands)	GDP	Real GDP at constant local currency units (Rands) in trillions of Rands, used as logged values in estimations	World Bank (WDI)
Total Population (Millions)	POP	Total number of persons regardless of citizenship in millions (logged for estimation).	World Bank, (WDI)
Life Expectancy at Birth (years)	LIFE	Average number of years a newborn is expected to live, given prevailing mortality rates.	World Bank, (WDI)
Gross Fixed Capital Formation (trillions)	CAP	Constant local currency units (Rands), used as logs in estimations. Capital formation is also referred as investment in this analysis.	World Bank, (WDI)
Crude Birth Rate (Percentages)	BIR	Number of births per 1000 population. Measured in percentages	World Bank, (WDI)
Crude Death Rate (Percentages)	DEA	Number of deaths per 1000 population. Measured in percentages	World Bank, (WDI)
Age Dependency Ratio (percentage)	DEP	Ratio of dependents (ages 0-14 and 65+) to the working-age population (ages 15-64), per 100 working-age persons.	World Bank, (WDI)
Educational Attainment (25 years and above)	EDU	Average years of total schooling for the total population aged 25 and over. Public source observations are five-year benchmarks; the annual estimation series is interpolated from 2011 to 2022.	Barro–Lee Educational Attainment

Source: Author’s compilation based on World Development Indicators (WDI, 2025) <https://data.worldbank.org/indicator>

Educational Attainment Dataset: <https://barrolee.github.io/BarroLeeDataSet/Data.html>

⁵ Although secondary data is generally reliable, it may present limitations, such as changes in definitions or data collection methodologies over time. To ensure consistency, this study applied data cleaning and validation procedures, and cross-checked anomalies against alternate sources where necessary.

In Table 10, GDP, population and gross fixed capital formation are transformed into natural logarithms for elasticity interpretation and to remove effects of inflation, while rates and ratios are retained in levels. Educational attainment is available in five-years intervals in the World Bank series. Barro and Lee's education source is a public average-years-of-total-schooling measure for the total population aged 25 and over, which reports country observations from 1950–2010 (Barro & Lee, 2013). The annual EDU working series for 2011 to 2022 was constructed by linear interpolation between the five-year benchmarks and extended through 2022 are used for the formal 1960–2022 estimation sample. The interpolation and extension are author transformations, not observations published by Barro and Lee. Because annualisation imposes smoothness and the terminal values are extended following Barro and Lee's procedure, Model 4 is interpreted only as a conditioning robustness specification, with stepwise and benchmark-only sensitivity reported in Table 24.

3.5.1. Data Quality

The study uses secondary data that is collected by reputable and credible organisations that have quality controls mechanism during collection of data. Measurement errors or inconsistencies in data collection methodologies over time could affect the results.⁶ A specific limitation concerns apartheid-era demographic and labour-market data. During the apartheid period, official statistical systems were shaped by racially fragmented administration, uneven population coverage and restricted reporting practices.

Demographic information for the Black majority and homeland populations may therefore be less complete or less comparable than post-1994 data. This is important because the study covers both apartheid and democratic periods, and population, employment, education and health-related indicators may reflect changes in statistical coverage as well as real demographic change. To reduce this limitation, the study uses internationally standardised secondary data from the World Bank, Statistics South Africa and United Nations sources where available. The analysis also applies structural-break tests, regime dummies, robustness checks and a post-1994 subsample feasibility check to assess whether the main population-growth relationship is driven by apartheid-era observations. Nevertheless, the findings should be interpreted with awareness that historical demographic data may contain measurement and comparability limitations.

⁶ This is particularly relevant for historical data from the apartheid era (1948-1993), when statistical reporting may have been incomplete or biased, especially regarding demographic indicators due to apartheid propaganda practices.

3.5.2. Structural breaks

The Perron and Zivot-Andrews tests help identify structural breaks, particularly around the 1994 democratic transition, there may be other unobserved breaks or gradual changes not captured by the model. South Africa experienced multiple economic policy shifts and external shocks during the 63-year period under study that might not be fully accounted for in the current specification. Hence the Perron and Zivot-Andrews identify structural break years in the data based on exogenous and endogenous assumptions.

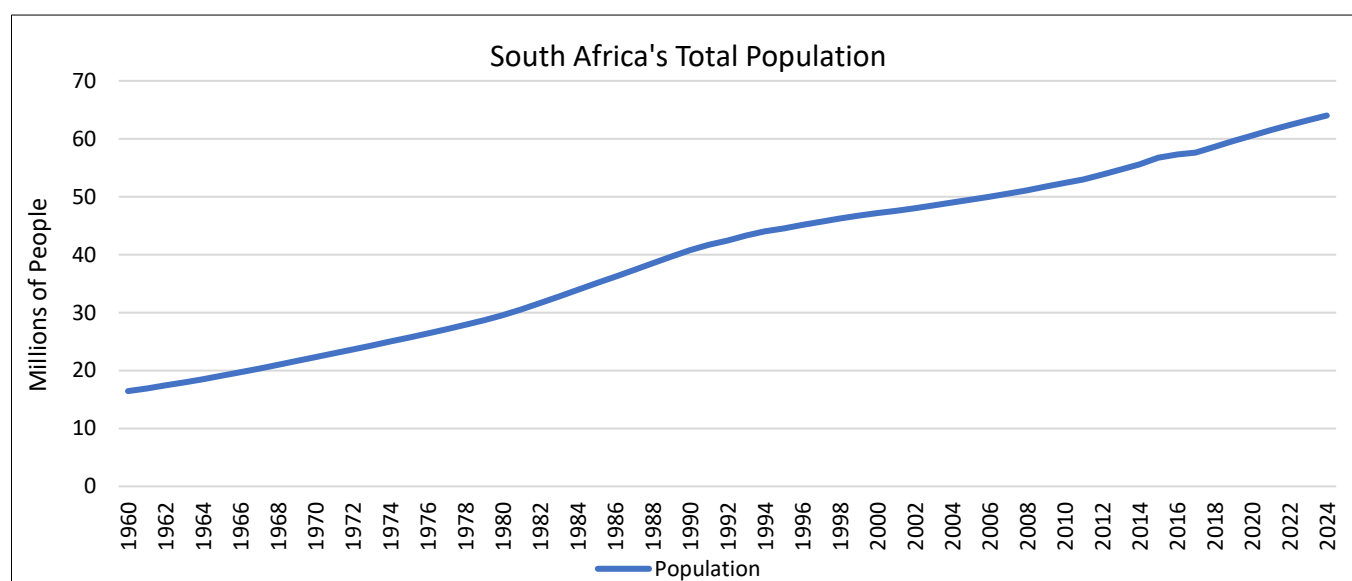
3.5.3. Ethical Considerations

The researcher accepts both the Confidentiality Acts and the University Procedures Act, which govern academic ethics and prohibits acts of plagiarism. The researcher acknowledges that it is important to identify relevant references for other people's work. The study relies exclusively on secondary data sourced from reputable institutions such as the World Bank and Statistics South Africa. As no primary data collection involving human participants was conducted, ethical concerns related to confidentiality or informed consent are minimised. The data collected from sources is for research purposes in this analysis and not for any harm or disrepute to any party.

3.6. Trend Analysis

This section presents historical trends in South Africa's key demographic and macro-economic variables over 1960–2022 to provide preliminary insights, evolution of variables, demographic transition dynamics, and possible structural breaks relevant to the population and economic growth analysis. All variables are shown in levels to visualise long-term patterns prior to formal econometric testing.

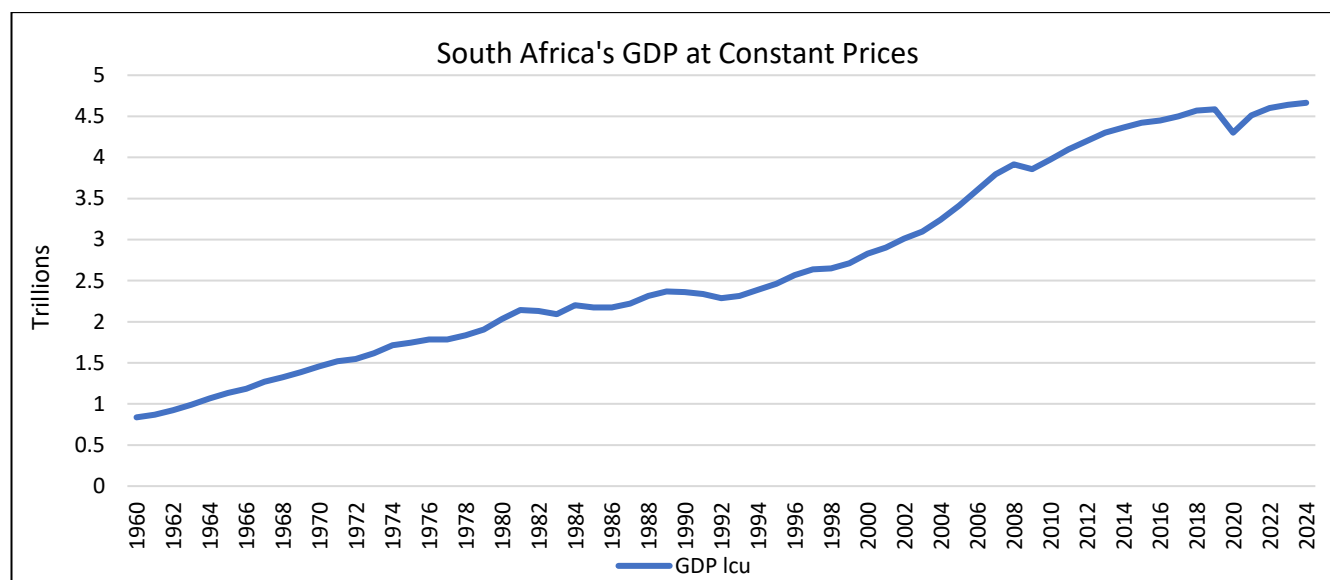
Figure 4: Population Series 1960–2022



Source: World Bank data.

In Figure 4, South Africa's population increased steadily from approximately 16 million in 1960 to over 62 million in 2022. Population growth accelerated during the 1970s and 1980s and moderated after the mid-1990s, reflecting declining fertility, increased urbanisation, and progression through the demographic transition. The persistent upward trend highlights sustained demographic expansion, which constitutes the core explanatory variable in this study.

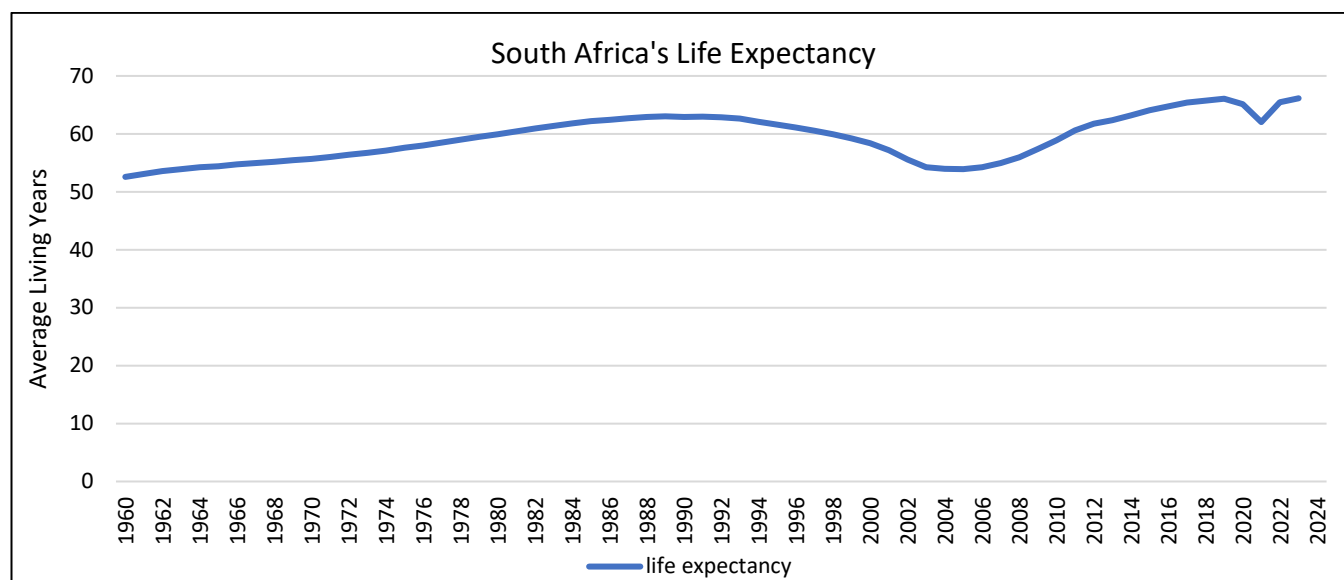
Figure 5: Gross Domestic Product Series 1960–2022



Source: World Bank data

Real GDP shows a pronounced long-run upward trend in Figure 5, interrupted by notable cyclical downturns. Strong growth during the 1960s and 1970s were followed by stagnation in the 1980s, with recovery after the democratic transition in 1994. Sharp contractions are observed during the 2009 global financial crisis and the 2020 COVID-19 shock. Although GDP increases over the long-term, growth is uneven, suggesting that demographic expansion has not translated uniformly into economic performance.

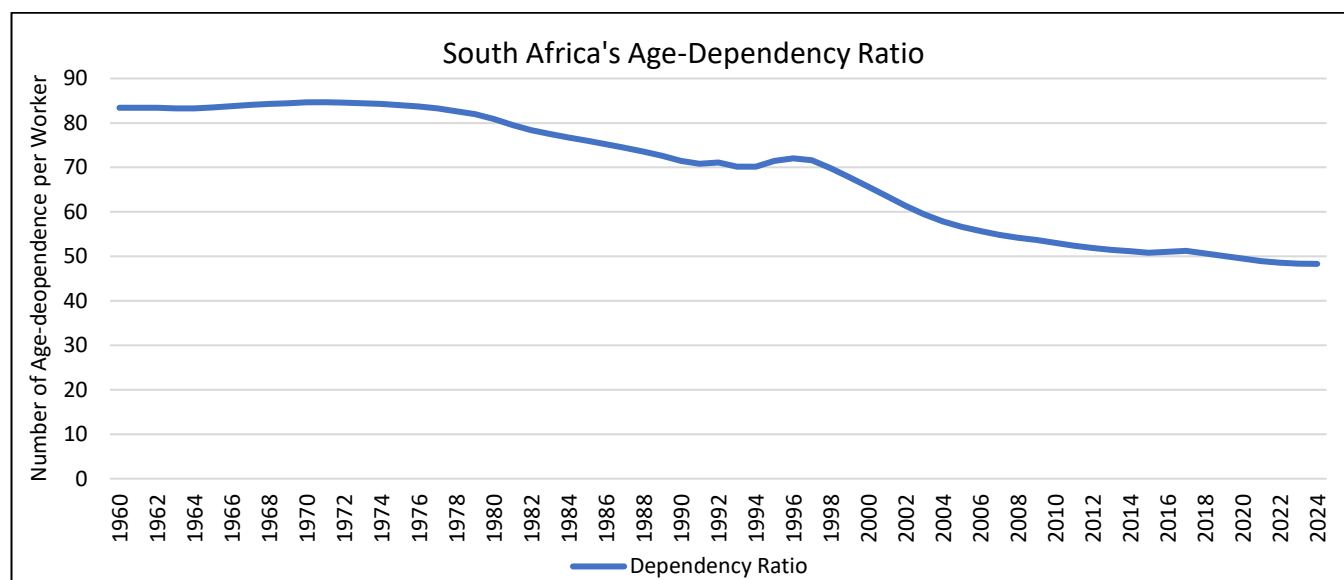
Figure 6: Life Expectancy Series 1960–2022



Source: World Bank data.

In Figure 6, Life expectancy improved steadily over most of the sample period, indicating long-run gains in health outcomes and human capital. A marked decline occurred in the late 1990s and early 2000s due to the HIV/AIDS epidemic, followed by recovery after the widespread rollout of antiretroviral therapy. A temporary decline is also visible in 2020, reflecting the impact of COVID-19. These demographic shocks may influence both labour productivity and growth dynamics.

Figure 7: Age-Dependency Ratio Series 1960–2022

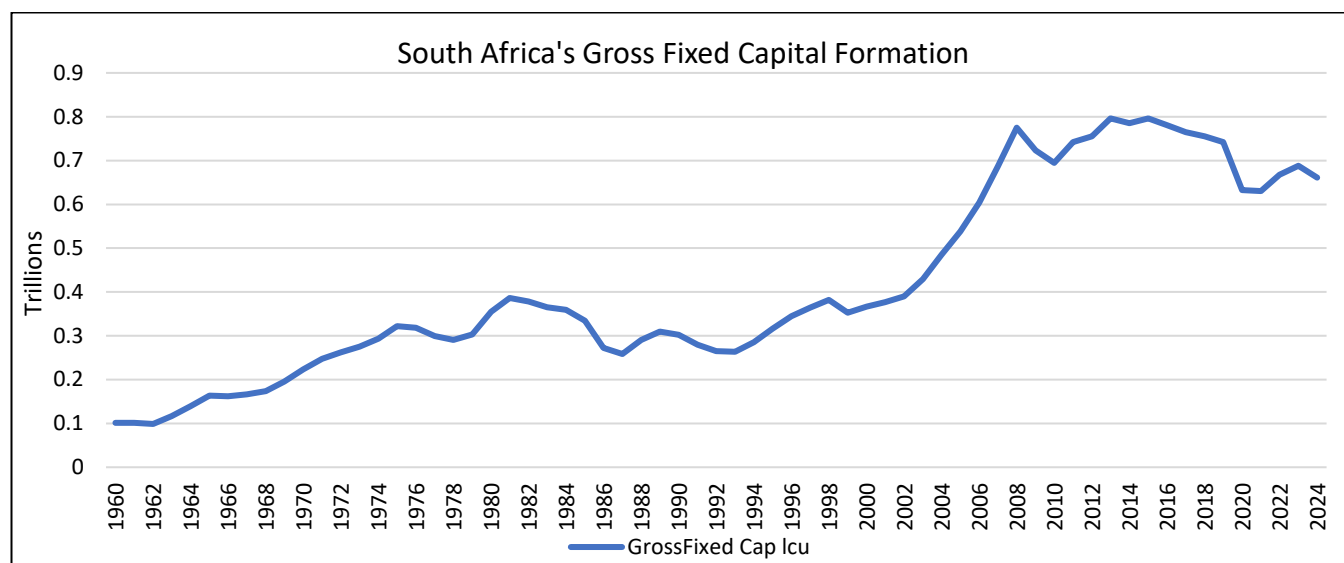


Source: World Bank data

The age-dependency ratio in Figure 7 declined from about 83% in 1960 to below 50% by 2022, reflecting falling fertility and a rising share of the working-age population. This trend signals the

emergence of a potential demographic dividend, increasing the scope for economic growth, conditional on adequate employment creation and capital accumulation.

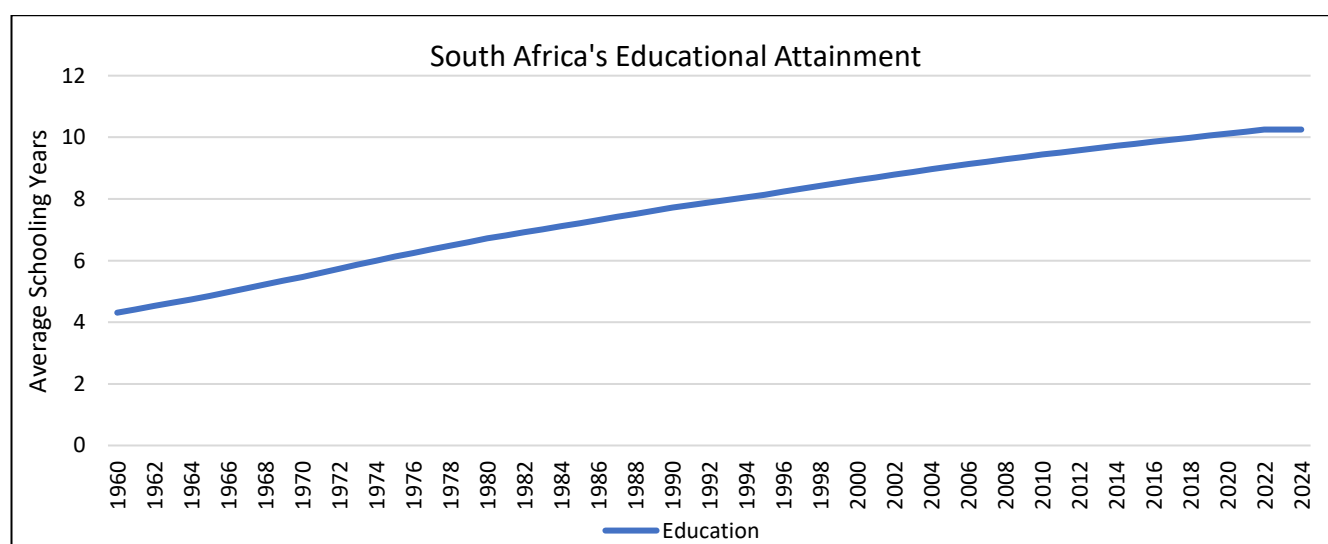
Figure 8: Gross Fixed Capital Formation Series 1960–2022



Source: World Bank data.

In Figure 8, Gross fixed capital formation fluctuates considerably over the sample period, despite a broadly rising long-run trend. Investment peaked in the early 1980s, declined sharply during the sanctions and transition period, and partially recovered after 2000 before weakening again after 2015. These fluctuations reflect episodes of political uncertainty, macro-economic instability, and shifting investor confidence, which may mediate the growth effects of population change.

Figure 9: Average Schooling Years Series 1960–2022

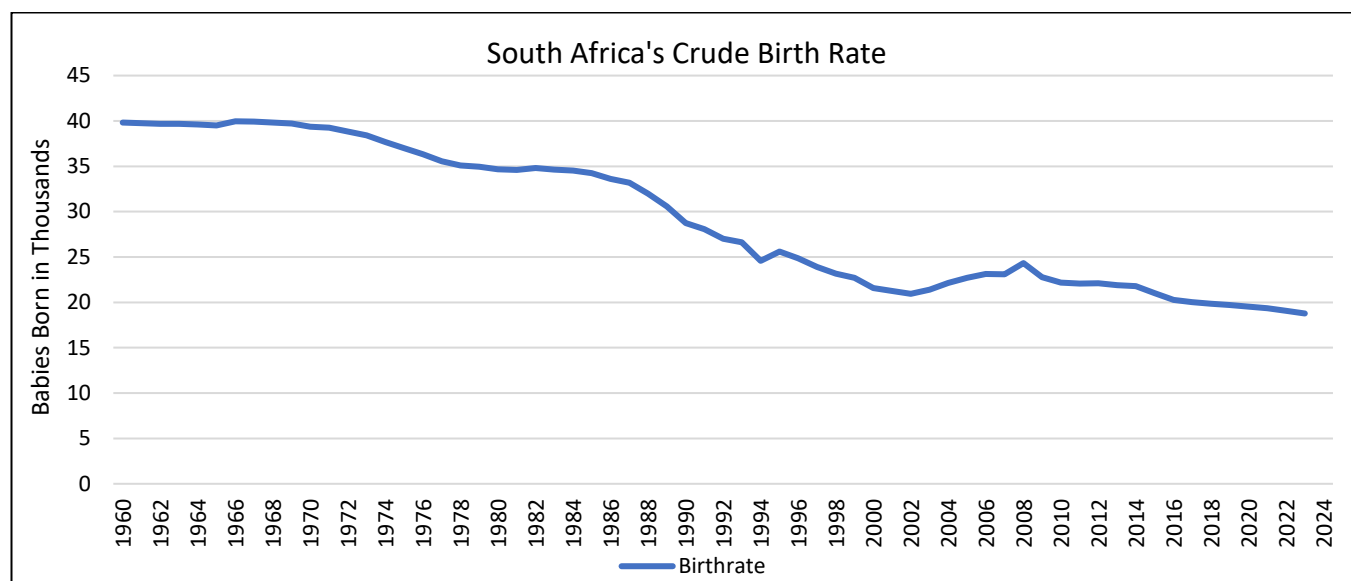


Source: World Bank data.

In Figure 9, average years of schooling increased consistently from about 4 years in 1960 to over 10 years by 2022, indicating long-run improvements in human capital. This trend supports

endogenous growth mechanisms through skill accumulation, although recent slowdowns suggest possible constraints related to education quality and labour-market absorption.

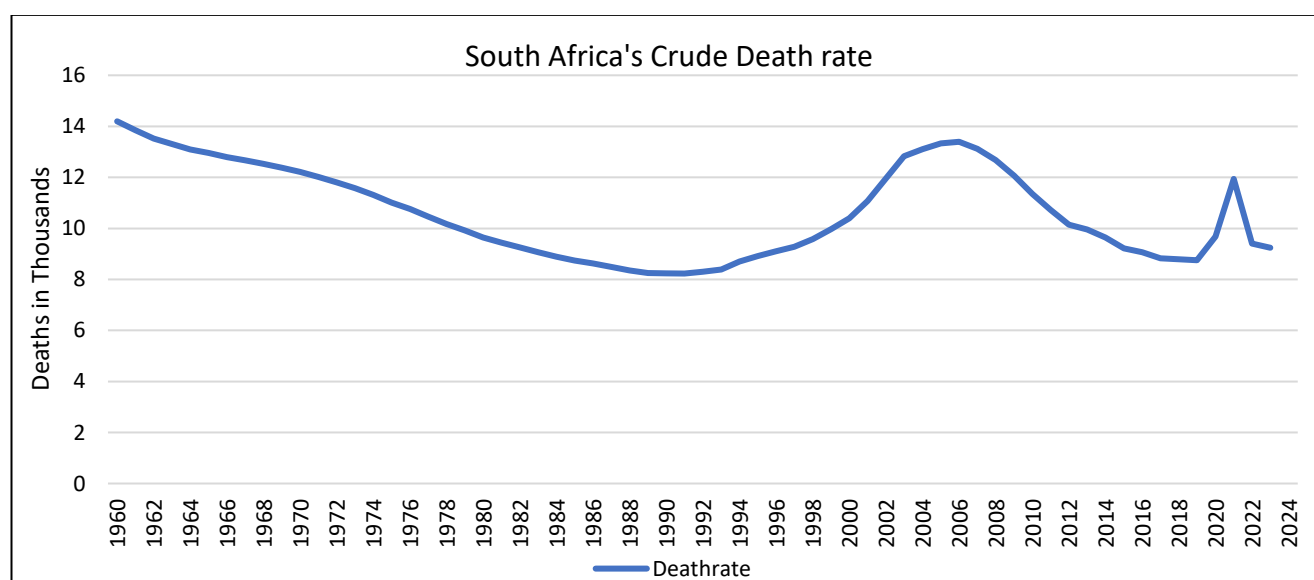
Figure 10: Crude Birth Rate Series 1960–2022



Source. World Bank data.

The crude birth rate, in Figure 10, declined sharply from nearly 40 births per 1,000 people in the 1960s to below 20 per 1,000 in recent years. This sustained decline reflects increased female education, urbanisation, and access to family planning and reinforces South Africa's transition toward lower fertility and a higher working-age population share.

Figure 11: Crude Death Rate Series 1960–2022



Source: World Bank data.

The crude death rate in Figure 11, shows a long-run downward trend, interrupted by a sharp increase during the early 2000s at the height of the HIV/AIDS epidemic and a temporary spike in

2020 due to COVID-19. The overall decline reflects improvements in healthcare access, disease management, and living standards.

Overall, South Africa has a clear demographic transition characterised by sustained population growth, declining fertility and dependency ratios, rising life expectancy, and improving educational attainment. However, economic growth and investment remain unstable, indicating that demographic gains have not been fully converted into sustained economic performance. These patterns motivate the formal econometric analysis that follows, which tests whether population dynamics influence growth through long-run structural channels, short-run adjustment mechanisms, and asymmetric responses to demographic shocks.

3.6.1. Descriptive Statistics Summary

Descriptive statistics summarise the behaviour of the variables used in the econometric analysis over 1960–2022. The statistics reported include the mean, median, minimum, maximum, and standard deviation, providing an initial overview of the distribution and variability of South Africa’s demographic and macro-economic indicators in Table 11.

Table 11: Descriptive Statistics of Variables (1960–2022)

Variable	Mean	Median	Minimum	Maximum	Std. Dev.	Obs.
Real GDP (R trillion)	2.619	2.337	0.837	4.603	1.152	63
Gross Fixed Capital Formation (R trillion)	0.407	0.345	0.099	0.796	0.215	63
Total Population (millions)	39.126	41.688	16.440	62.378	13.961	63
Life Expectancy (years)	59.227	59.472	52.575	66.071	3.824	63
Birth Rate (per 1,000)	29.431	28.075	19.079	39.959	7.636	63
Death Rate (per 1,000)	10.658	10.168	8.230	14.196	1.805	63
Age Dependency Ratio (%)	69.686	71.623	48.551	84.661	13.083	63
Educational Attainment Proxy (years)	7.609	7.804	4.310	10.252	1.782	63

Source: Author’s calculations

Notes: Monetary variables are reported in levels for descriptive purposes. In the econometric estimations, GDP, population and capital formation are expressed in natural logarithms to stabilise variance and allow elasticity interpretation.

The statistics in Table 11 indicate substantial fluctuating real GDP and capital formation, reflecting periods of economic instability and external shocks. In contrast, population, life expectancy, and educational attainment show smoother long-run movements, consistent with gradual demographic and human-capital improvements. Fertility and dependency indicators display greater dispersion, highlighting significant shifts in population structure over time. Despite declining dependency ratios, the average level remains relatively high, suggesting continued demographic pressure on the productive population. These patterns imply that demographic improvements alone may not guarantee sustained economic growth without supporting

investment and human-capital accumulation. Overall, the descriptive evidence motivates further econometric analysis to determine the nature, direction, and dynamics of the population-growth relationship, which is examined in the sections that follow.

3.6.2. Conclusion

This chapter discussed the data and econometric procedures used for analysing the relationship between population growth and economic growth in South Africa from 1960 to 2022. The study utilises secondary data from reputable sources from the World Bank and Statistics South Africa. The chapter acknowledges potential limitations related to data quality and structural breaks. Ethical standards are upheld by relying solely on secondary data, ensuring academic integrity, and minimising risks related to confidentiality or consent. In line with the study's identification limits, the empirical results are interpreted as evidence of long-run association, short-run adjustment, predictive causality and asymmetric response. The results are not interpreted as strict structural causal effects. This terminology is used consistently throughout the thesis to avoid overstating the causal meaning of the econometric findings.

CHAPTER FOUR: RESULTS ANALYSIS

4. Introduction

This chapter presents and interprets the empirical findings from the econometric procedures outlined in Chapter 3. The core objective is to determine whether population dynamics stimulate or constrain economic growth in South Africa over 1960–2022. The analysis evaluates both short-run and long-run relationships and explicitly accounts for major structural shifts associated with South Africa's political and economic transitions.

The empirical strategy is organised around five one-to-one question–objective–hypothesis chains: H_1 tests the long-run population to real GDP association; H_2 tests predictive causality; H_3 tests the direct short-run population response and error-correction speed; H_4 tests structural and regime sensitivity of GDP levels or growth; and H_5 tests equality of positive and negative trend-gap effects. Table 12 records the same mapping used throughout the results and conclusion.

Table 12: Research Questions and Hypotheses

Research Question (RQ)	Hypothesis	H_0 (Null Hypothesis)	H_1 (Alternative Hypothesis)
RQ1: What is the long-run relationship between total population size and aggregate real GDP in South Africa?	H1: Long-run association	H_{01} : Total population size has no statistically significant long-run association with aggregate real GDP.	H_{11} : Total population size has a statistically significant long-run association with aggregate real GDP.
RQ2: Do past values of population dynamics improve prediction of economic performance?	H2: Predictive causality	H_{02} : Population dynamics provide no statistically significant predictive information for economic performance.	H_{12} : Population dynamics provide statistically significant predictive information for economic performance.
RQ3: What are the direct short-run population effects, and how quickly is disequilibrium corrected after a shock?	H3: Short-run effect and adjustment	H_{03} : Population growth has no significant direct short-run effect, and the error-correction term is not negative and significant.	H_{13} : Population growth has a significant direct short-run effect and/or the error-correction term is negative and significant.
RQ4: Do structural and regime changes significantly affect the level or growth path of real GDP?	H4: Structural change	H_{04} : Structural and regime changes do not significantly affect the level or growth path of real GDP.	H_{14} : Structural and regime changes significantly affect the level or growth path of real GDP.
RQ5: Do positive and negative population trend deviations have unequal short- and long-run effects?	H5: Trend-gap asymmetry	H_{05} : Positive and negative deviations have equal short- and long-run effects.	H_{15} : Positive and negative deviations have unequal short- and/or long-run effects.

Source: Author's construction

To address these questions, the chapter follows a structured econometric sequence. It begins with trend analysis and descriptive statistics to provide preliminary insights into long-run movements and potential structural shifts. This is followed by unit root testing using KPSS tests, complemented by structural break unit root tests (Perron and Zivot-Andrews) to capture regime-linked shifts. Long-run relationships are examined using Dynamic Ordinary Least Squares (DOLS), as the cointegrating regression and Engle–Granger residual-based cointegration tests, followed by error-correction model (ECM) estimation to capture short-run dynamics and the speed of adjustment toward equilibrium. Granger causality tests then assess predictive causal direction

in both levels and growth rates. Finally, NARDL models are estimated to test whether population shocks have asymmetric effects on growth. The results are interpreted in relation to the theoretical and empirical literature and provide the basis for the policy implications and conclusions developed in Chapter 5.

4.1.1. Correlation Matrix Analysis

Some macro-economic and demographic variables trend strongly over time, the level correlations in Table 13 are interpreted as descriptive co-movement rather than evidence of causal association. High correlations between GDP, population, education and capital formation may partly reflect common trending behaviour. For this reason, the table reports both level correlations, first-difference and growth-rate correlations. The latter provide a more cautious indication of short-run association, while formal inference is based on the stationarity, cointegration, ARDL, ECM, Granger predictive-causality and NARDL results reported in the subsequent sections. Correlation analysis is used as a diagnostic test to examine the strength and direction of linear associations between economic growth and demographic variables. The Pearson correlation coefficient is employed and defined as:

$$r_{OY} = \frac{\sum_{t=1}^T (O_t - \bar{O})(Y_t - \bar{Y})}{\sqrt{\sum_{t=1}^T (O_t - \bar{O})^2} \sqrt{\sum_{t=1}^T (Y_t - \bar{Y})^2}} \quad (23)$$

Correlation coefficients are computed for the full sample period and for sub-periods corresponding to the apartheid and democratic eras to assess regime-specific patterns. While several demographic variables have strong correlations with economic growth, correlation does not imply causation. Accordingly, these results serve only to motivate formal econometric testing. The correlation analysis examines the association between economic growth (logGDP), income per capita (logGDPpc), and key demographic, human-capital, and structural variables over three periods: 1960–2022, 1960-1993, and 1994-2022. This sub-period analysis allows assessment of whether the population-growth relationship differs across political regimes. Correlation strength follows the thresholds proposed by Dancey and Reidy (2004) and Gujarati and Porter (2009). Table 13 presents descriptive and dynamic correlation evidence that motivates the formal econometric models specified in equation (23) tested per variable.

Table 13: Descriptive Correlations between Economic Output and Demographic Variables

Variables	Category	GDP in level			GDP per capita in level			Direction & Strength
		GDP (1960–2022)	GDP (1960-1993)	GDP (1994-2022)	GDPPC (1960–2022)	GDPPC (1960-1993)	GDPPC (1994-2022)	
logPOP _t	Population size	0.976***	0.960***	0.942***	0.522	0.105	0.805***	Very strong (+)

	GDP in level				GDP per capita in level			
DEP _t	Dependency ratio	-0.932***	-0.725***	-0.979***	-0.634**	0.341	-0.947***	Very strong (-)
BIR _t	Birth Rate Level	-0.930***	-0.824***	-0.716***	-0.456**	0.166	-0.541**	Strong to moderate (-)
DEA _t	Death rate Level	-0.422	-0.970***	-0.045	-0.056	-0.178	0.100	Strong to moderate (-)
EDU _t	Education Attainment	0.989***	0.971***	0.979***	0.597**	0.151	0.882***	Very strong (+)
LIFE _t	Life expectancy	0.621**	0.958***	0.473	0.313	0.132	0.292	Moderate (+)
logCAP _t	Capital Formation	0.967***	0.917***	0.956***	0.827***	0.680***	0.992***	Very strong (+)
	GDP growth rate				GDP per capita growth rate			
Variables	Category	GDP (1960–2022)	GDP (1960-1993)	GDP (1994-2022)	GDPPC (1960–2022)	GDPPC (1960-1993)	GDPPC (1994-2022)	Direction & Strength
ΔlogPOP _t	Population growth	-0.311	-0.239	-0.296	-0.552*	-0.566*	-0.495	Weak to moderate (-)
ΔDEP _t	Change in dependency	-0.125	0.092	-0.129	-0.005	0.415	-0.199	Weak/unstable (-)
ΔBIR _t	Change in fertility	0.287	0.257	0.277	0.316	0.340	0.283	Weak to moderate (+)
ΔDEA _t	Mortality change	0.017	-0.370	-0.006	0.041	-0.327	0.058	Weak (-)
ΔEDU _t	Education change	0.372	0.470	0.325	0.135	0.458 *	0.349	Moderate (+)
ΔLIFE _t	Life span change	-0.030	0.301	-0.139	-0.070	0.196	-0.108	Unstable correlation (±)
ΔlogCAP _t	Capital Change	0.725**	0.715**	0.774**	0.728**	0.718**	0.768**	Strong (+)

Source: Author's calculation

Notes: Correlations are reported between GDP measures and demographic variables in levels, and between ΔGDP growth rates and changes in explanatory variables. ***, **, * denote significance at 1%, 5%, and 10% levels respectively.

Table 13 shows that population size, education, life expectancy, and capital formation have strong positive correlations with economic growth, indicating that scale effects, human capital accumulation, and investment are closely associated with long-run output performance. Education and capital formation show particularly strong and stable correlations across all sub-periods. In contrast, population growth, fertility rates, and dependency ratios are negatively correlated with economic growth, especially in the post-1994 period. This suggests that rapid demographic expansion and high dependency burdens may constrain growth when not accompanied by sufficient employment creation and productivity gains. Short-run demographic changes display weak and unstable correlations with growth, implying that demographic influences materialise primarily through long-term structural channels rather than short-term fluctuations.

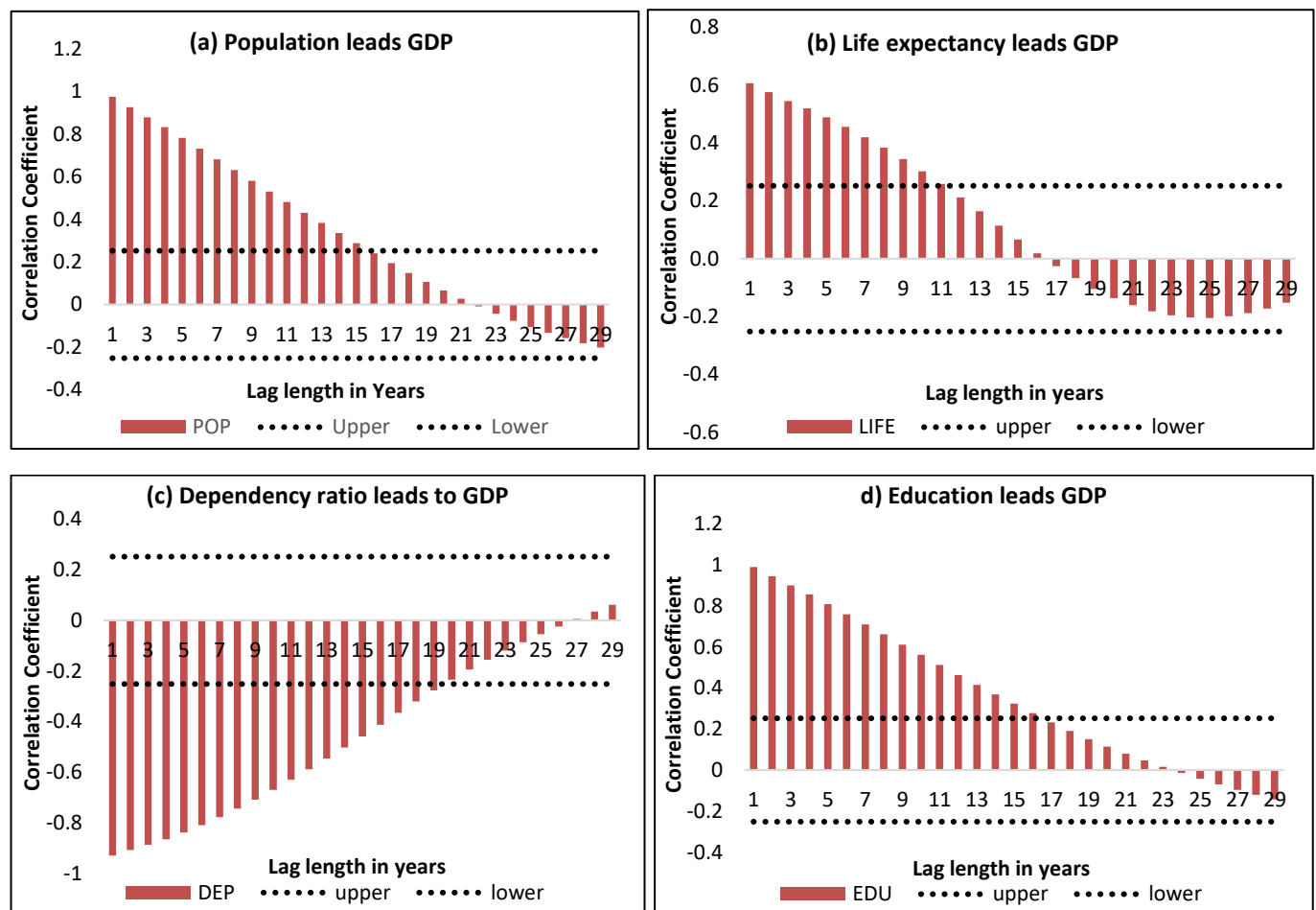
These correlation patterns in Table 13 are matching with the conditional strand findings of the literature reviewed in Chapter Two. They support the argument by Bloom et al. (2001) that demographic structure matters more than population size alone, and they also match with the South African evidence of Fedderke and Simkins (2012), which emphasises investment and productivity as central long-run growth drivers. The negative association between dependency

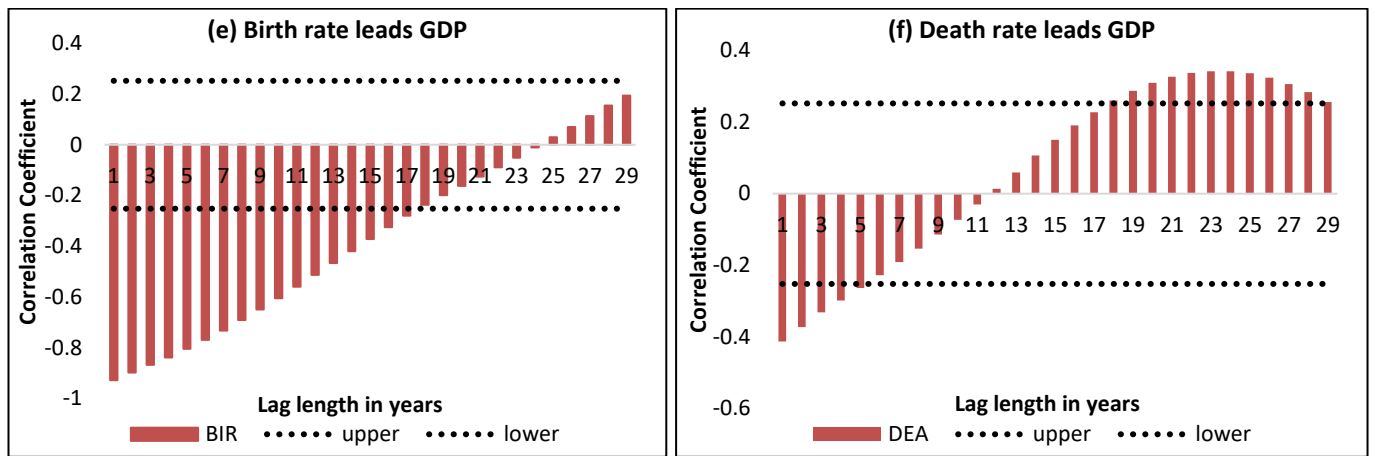
burdens and GDP further aligns with the capital-dilution and demographic-burden arguments advanced by Kelley and Schmidt (2005) and Lee and Mason (2010). Overall, the correlation results suggest that South Africa's growth performance is enhanced by human capital and investment but constrained by adverse population dynamics, justifying the subsequent sections on stationarity, cross-correlation analysis, cointegration, causality, and asymmetry tests.

4.1.2. Cross-correlation between Population dynamics and GDP

Cross-correlogram analysis is used to assess the timing of the relationship between demographic variables and economic performance in South Africa. Level series capture long-run co-movement between GDP and demographic structure, while first-differenced series reflect short-run interactions between population growth and economic growth, following standard time-series practice (Enders, 2015).

Figure 12: Cross correlation: Demographic Factors leading Economic output (GDP)



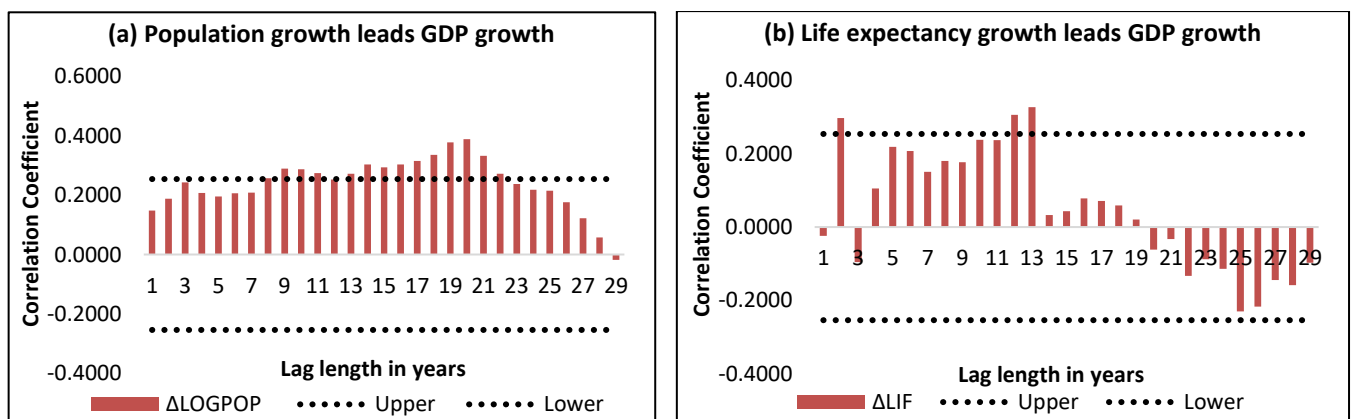


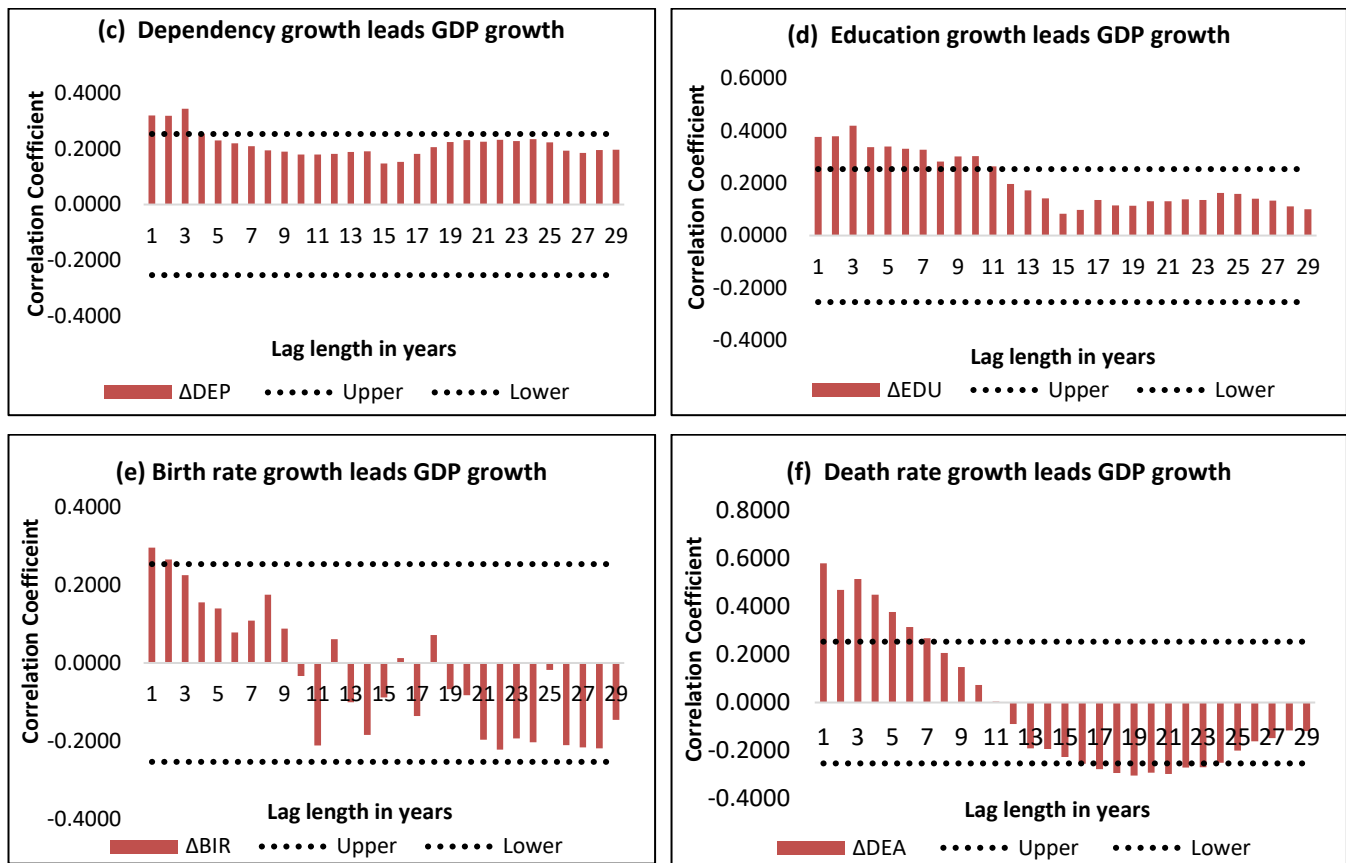
Source: Author's calculations

Notes: The figure shows cross-correlations between GDP and demographic variables with common 95% confidence bands ($\pm 2/\sqrt{T}$, $T = 63$). Bars outside the bands (dotted lines) indicate statistically significant lead relationships.

Figure 12 a) shows that population size strongly leads GDP at short horizons, with correlations around 0.97 at early lags remaining statistically significant up to 15 years before declining and turning slightly negative after 23 years, indicating a strong but fading growth effect. In Figure 12 b) life expectancy has positive correlations (≈ 0.60 at lag 1), significant up to 11 years, followed by small negative values, suggesting diminishing long-run influence. The dependency ratio c) displays large negative correlations (around -0.90 at early lags), indicating a strong adverse effect on output for 18 years. In Figure 12 d) Education shows very strong positive correlations (≈ 0.95 -1.00 at short lags), remaining significantly positive up to 16 years, confirming that education leads economic growth. In Figure 12 e), birth rates are strongly negatively correlated with GDP (about -0.90 to -0.40 at 1 to 17 years), with effects weakening only at later years. In Figure 12 f), death rates show negative short-run correlations for four years (≈ -0.40) that turn positive after 18 years (≈ 0.25 -0.35), reflecting delayed adjustment effects. Overall, population size and education are the strongest positive demographic drivers of GDP, while dependency burden, fertility, and mortality exert sustained negative pressure on economic performance, highlighting the central role of demographic structure in shaping South Africa's growth dynamics in the long term.

Figure 13: Cross correlations: Demographic changes lead Economic growth changes





Source: Author's Calculations

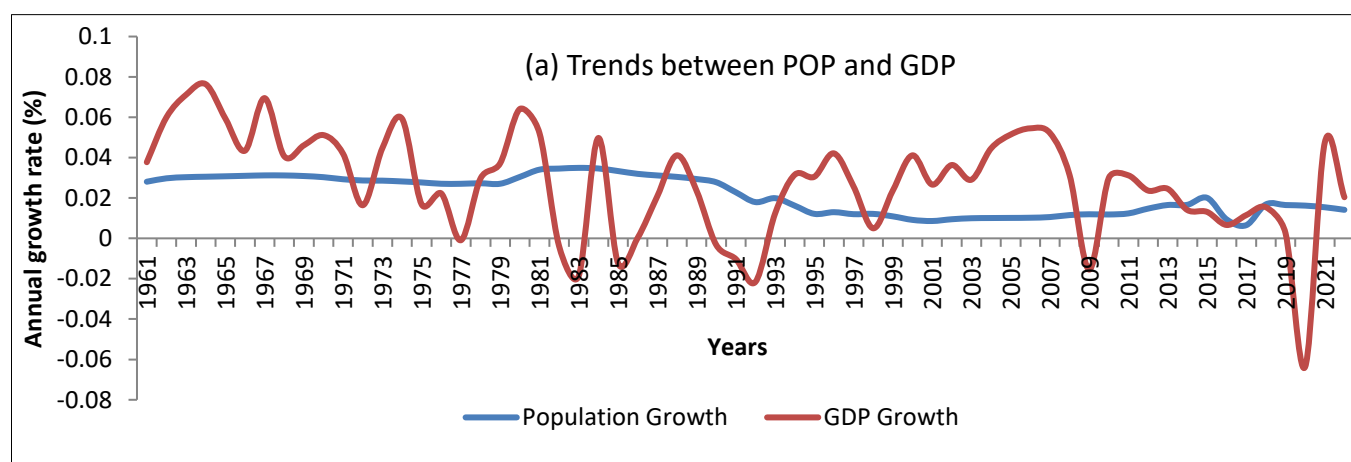
Notes: The figure shows short-run cross-correlations between changes in demographic variables and GDP growth. Dashed lines indicate 95% confidence bounds ($\pm 2/\sqrt{T}$). Bars outside the bands (dotted lines) are statistically significant lead relationships.

In the short run, in Figure 13 a) population growth ($\Delta \log POP$) shows a modest positive effect on GDP growth, peaking around 0.38 at lags (≈ 20) before declining toward zero, showing weaker effects than in levels. In Figure 13 b) Life expectancy growth ($\Delta LIFE$) has small and mixed correlations, with brief positive effects (≈ 0.30) that fade and turn negative at longer lags, indicating limited short-run transmission. In Figure 13 c) Dependency ratio growth (ΔDEP) is positively correlated with GDP growth in the short run (≈ 0.30 at 3 lags), but remains within narrow bounds, suggesting cyclical rather than structural effects. In Figure 13 d) Education growth (ΔEDU) displays the strongest short-run association, with correlations around 0.35-0.40 at 3-10 lags before gradually weakening. In Figure 13 e), birth-rate growth (ΔBIR) shows declining and eventually negative correlations, whilst in Figure 13 f), death-rate growth (ΔDEA) shifts from strong positive short-run correlations (≈ 0.55) from 1-6 lags and then exhibits persistent negative effects at longer lags. Overall, short-run demographic effects on GDP growth are transitory and smaller in magnitude, reinforcing the dominance of long-run demographic channels, confirming gradual demographic adjustment mechanisms. These short-run patterns motivate visual causality inspection to separate temporary co-movement from directional effects on growth.

4.1.3. Visual Causal Inspection

Figures 12 to 15 are presented as descriptive diagnostic evidence rather than formal causal tests. The cross-correlation figures help identify possible lead-lag patterns between demographic variables and economic output, while the trend and scatterplot figures show the short-run co-movement between population growth and GDP growth. However, because both demographic and macro-economic variables may be affected by common trends, shocks and structural breaks, the figures are interpreted cautiously. Formal inference is based on the stationarity tests, cointegration analysis, ARDL error-correction models, Granger predictive-causality tests and NARDL asymmetry results. This section presents a visual inspection of the relationship between population growth and GDP growth in South Africa. The analysis is descriptive and does not establish causality but serves to motivate the subsequent use of formal Granger causality tests.

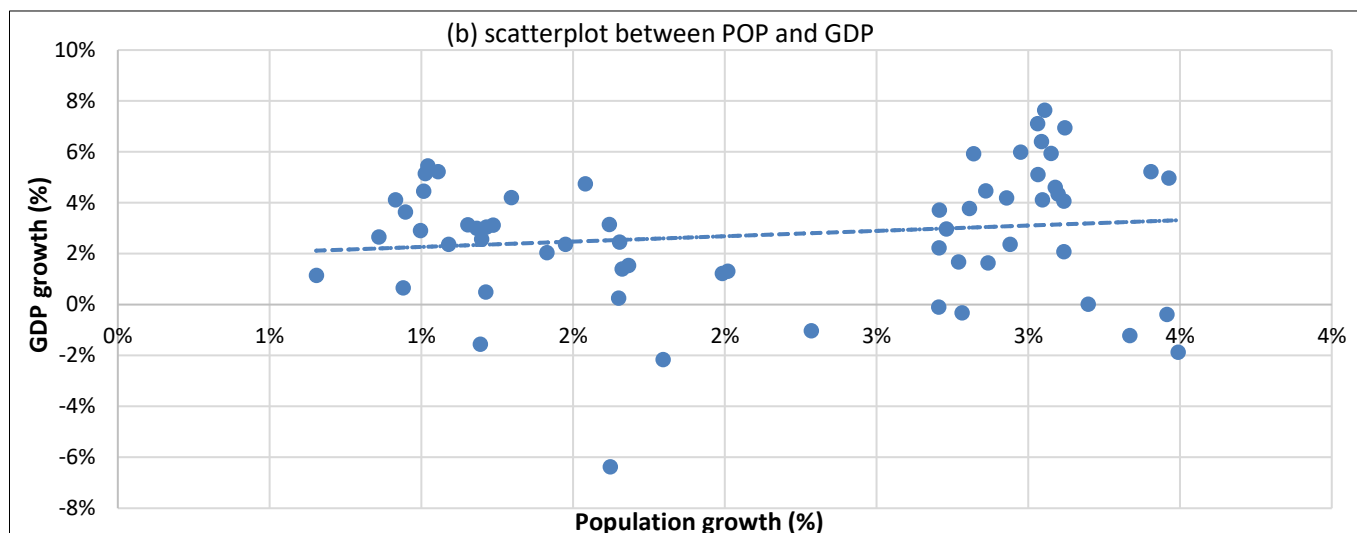
Figure 14: Trends in Population growth and GDP growth (1961-2022)



Source: Author's calculation

Figure 14 shows that population growth follows a smooth, gradually declining path, consistent with South Africa's demographic transition of decreased fertility, reduced mortality and increased female labour participation, while GDP growth is markedly more volatile. Major downturns are visible in the early 1980s, early 1990s, 2009 and 2020. These patterns suggest that population effects on economic growth operate through longer-term adjustment processes rather than immediate short-run responses, supporting the use of error-correction and structural-break models. Although periods of co-movement are evident, the trends do not reveal a clear direction of influence between the two variables. Below the scatterplot explores spread of the data between population growth and economic growth under study.

Figure 15: Scatterplot of Population Growth and GDP Growth



Source: Author's Calculation

Figure 15 displays data spread of population growth against GDP growth with a fitted linear trend. The relationship is weakly positive but highly detached, indicating that similar population growth rates are associated with very different economic growth outcomes. This scattering highlights that visual inspection is not enough in explaining the population-growth relationship. Both, the trend and scatter evidence depicts a bilateral relationship between population growth and economic growth, characterised by co-movement without a clear directional pattern. This motivates the use of dynamic time-series techniques, including error-correction models, Granger causality tests, and non-linear specifications, to distinguish short-run dynamics from long-run demographic effects. The next part, granger causality is tested for population, demographic factors against GDP.

4.1.4. Bivariate Granger Causality

This section investigates the direction of causality between population dynamics and economic growth in South Africa from 1960 to 2022 using pairwise Granger causality tests. Both short-run (growth rates) and long-run (levels) specifications are estimated to distinguish cyclical effects from structural relationships.

Table 14: Short-run and Long-run bivariate Granger Causality between Population and GDP output in the short term, medium and long term

Causal Direction test in growth	Lag	Obs.	F-stats	p-value	Causality Decision
$\Delta \log \text{POP}$ does not granger cause $\Delta \log \text{GDP}$	2	61	0.0094	0.9907	No predictive causality
$\Delta \log \text{GDP}$ does not granger cause $\Delta \log \text{POP}$	2	61	1.3635	0.2641	No predictive causality
$\Delta \log \text{POP}$ does not granger cause $\Delta \log \text{GDP}$	3	60	2.0691	0.1153	No predictive causality
$\Delta \log \text{GDP}$ does not granger cause $\Delta \log \text{POP}$	3	60	1.3439	0.2700	No predictive causality
$\Delta \log \text{POP}$ does not granger cause $\Delta \log \text{GDP}$	4	59	3.2675	0.0186 *	Weak short-run predictive causality

Causal Direction test in growth	Lag	Obs.	F-stats	p-value	Causality Decision
$\Delta \log \text{GDP}$ does not granger cause $\Delta \log \text{POP}$	4	59	1.0376	0.3972	No predictive causality
$\Delta \log \text{POP}$ does not granger cause $\Delta \log \text{GDP}$	5	58	2.3357	0.0565 *	Weak short-run predictive causality
$\Delta \log \text{GDP}$ does not granger cause $\Delta \log \text{POP}$	5	58	0.8822	0.5005	No predictive causality
Long-run Causal Direction test					
$\log \text{POP}$ does not granger cause $\log \text{GDP}$	2	62	6.0751	0.0041 ***	Strong long-run predictive causality
$\log \text{GDP}$ does not granger cause $\log \text{POP}$	2	62	3.0819	0.0536 *	Weak long-run predictive causality
$\log \text{POP}$ does not granger cause $\log \text{GDP}$	3	61	5.3244	0.0027 ***	Strong long-run predictive causality
$\log \text{GDP}$ does not granger cause $\log \text{POP}$	3	61	1.8698	0.1457	No predictive causality
$\log \text{POP}$ does not granger cause $\log \text{GDP}$	4	60	4.0400	0.0064 ***	Strong long-run causality
$\log \text{GDP}$ does not granger cause $\log \text{POP}$	4	60	2.6996	0.0407 **	Moderate long-run predictive causality
$\log \text{POP}$ does not granger cause $\log \text{GDP}$	5	59	6.6435	0.0009 ***	Strong long-run predictive causality
$\log \text{GDP}$ does not granger cause $\log \text{POP}$	5	59	1.7574	0.1397	No predictive causality

Source: Author's Calculation for Granger Causality (1960–2022)

Notes: *10%, **5%, ***1% denote significance levels. Lag length = 2 to 5 reflects business cycle of 2 to 5 years.

In Table 14, the short-run Granger predictive causality tests show no consistent causal relationship between population growth and GDP growth across lag lengths of two to five years. Except for weak and lag-specific effects at longer lags of 4 to 5 years, the null hypothesis of no short-run causality cannot be rejected at 10% significance level. This indicates that population growth does not drive short-term economic fluctuations in South Africa.

In contrast, in Table 14, the long-run Granger predictive causality results provide strong and robust evidence that population size Granger-causes economic growth. Across all lag specifications of 2-5 years business cycle, the null hypothesis that population does not Granger-cause GDP is rejected at the 1% significance level. Reverse causality from GDP to population is weak, inconsistent, and sensitive to lag length, suggesting limited feedback from economic growth to demographic change. Overall, the results indicate that population dynamics granger causes economic growth primarily through long-run structural channels rather than short-run cyclical mechanisms. To delve deeper into the population dynamics, the study explores Granger predictive causality between demographic factors and economic output into short-run and long-run in Table 15 and 16.

Table 15: Bivariate Granger Causality between demographic factors growth and GDP growth

Null Hypothesis: Short-Run causality	Lag	Obs.	F-Stats	p-value	Causality Decision
ΔLIFE does not Granger cause $\Delta \log \text{GDP}$	2	60	0.4330	0.6508	No causality
$\Delta \log \text{GDP}$ does not Granger cause ΔLIFE	2	60	9.5651	0.0003***	Strong short-run predictive causality
ΔLIFE does not Granger cause $\Delta \log \text{GDP}$	3	59	1.4845	0.2296	No predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔLIFE	3	59	7.4835	0.0003***	Strong short-run predictive causality
ΔLIFE does not Granger cause $\Delta \log \text{GDP}$	4	58	1.2282	0.3111	No predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔLIFE	4	58	4.9400	0.0020***	Strong short-run predictive causality
ΔLIFE does not Granger cause $\Delta \log \text{GDP}$	5	57	1.1495	0.3483	No predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔLIFE	5	57	3.9803	0.0044***	Strong short-run predictive causality
ΔDEP does not Granger cause $\Delta \log \text{GDP}$	2	60	0.1858	0.8310	No predictive causality

Null Hypothesis: Short-Run causality	Lag	Obs.	F-Stats	p-value	Causality Decision
$\Delta \log \text{GDP}$ does not Granger cause ΔDEP	2	60	0.3589	0.7001	No predictive causality
ΔDEP does not Granger cause $\Delta \log \text{GDP}$	3	59	0.6204	0.6049	No predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔDEP	3	59	0.3288	0.8045	No predictive causality
ΔDEP does not Granger cause $\Delta \log \text{GDP}$	4	58	1.2422	0.3055	No predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔDEP	4	58	0.2285	0.9211	No predictive causality
ΔDEP does not Granger cause $\Delta \log \text{GDP}$	5	57	0.9261	0.4728	No predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔDEP	5	57	0.2588	0.9332	No predictive causality
ΔEDU does not Granger cause $\Delta \log \text{GDP}$	2	60	3.6386	0.0328**	Moderate short-run predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔEDU	2	60	0.4871	0.6171	No predictive causality
ΔEDU does not Granger cause $\Delta \log \text{GDP}$	3	59	2.1719	0.1024	No predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔEDU	3	59	0.3064	0.8206	No predictive causality
ΔEDU does not Granger cause $\Delta \log \text{GDP}$	4	58	1.5942	0.1908	No predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔEDU	4	58	0.6284	0.6445	No predictive causality
ΔEDU does not Granger cause $\Delta \log \text{GDP}$	5	57	1.2109	0.3192	No predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔEDU	5	57	0.4740	0.7937	No predictive causality
ΔBIR does not Granger cause $\Delta \log \text{GDP}$	2	60	1.0180	0.3680	No predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔBIR	2	60	0.8517	0.4322	No predictive causality
ΔBIR does not Granger cause $\Delta \log \text{GDP}$	3	59	0.4950	0.6874	No predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔBIR	3	59	0.4712	0.7037	No predictive causality
ΔBIR does not Granger cause $\Delta \log \text{GDP}$	4	58	0.3455	0.8458	No predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔBIR	4	58	0.3174	0.8650	No predictive causality
ΔBIR does not Granger cause $\Delta \log \text{GDP}$	5	57	0.3323	0.8908	No predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔBIR	5	57	0.2816	0.9209	No predictive causality
ΔDEA does not Granger cause $\Delta \log \text{GDP}$	2	60	0.4109	0.6651	No predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔDEA	2	60	9.4287***	0.0003***	Strong short-run predictive causality
ΔDEA does not Granger cause $\Delta \log \text{GDP}$	3	59	0.7419	0.5319	No predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔDEA	3	59	6.2215***	0.0011***	Strong short-run predictive causality
ΔDEA does not Granger cause $\Delta \log \text{GDP}$	4	58	0.6470	0.6317	No predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔDEA	4	58	5.0364***	0.0018***	Strong short-run predictive causality
ΔDEA does not Granger cause $\Delta \log \text{GDP}$	5	57	1.0567	0.3965	No predictive causality
$\Delta \log \text{GDP}$ does not Granger cause ΔDEA	5	57	3.9283**	0.0048**	Strong short-run predictive causality

Source: Author's Calculation for Granger Causality (1960–2022)

Notes: *10%, **5%, ***1% denote significance levels. Δ denotes first-difference operator. Lag length = 2 to 5 reflects business cycle of 2 to 5 years.

Short-run causality results in Table 15, show strong and consistent unidirectional short-run causality from economic growth to health-related demographic variables, namely life expectancy (LIFE) and death rates (DEA), across all lag lengths (2-5 years). This indicates that short-term changes in GDP growth translate into immediate improvements in population health and mortality outcomes. No evidence found for reverse causality from life expectancy or death rate to GDP growth. By contrast, dependency ratios (DEP) and birth rates (BIR) show no short-run causal relationship with economic growth in either direction, reflecting the slow-moving nature of demographic structure and fertility behaviour. Educational attainment (EDU) shows moderate short-run causality to GDP growth at lag 2 only, but this effect is not robust across other lag specifications, and no feedback from GDP growth to education is detected. Overall, the short-run results suggest that economic growth is the primary driver of demographic adjustments, while demographic variables exert limited immediate influence on economic growth.

Table 16: Long-Run Granger Causality between demographic factors and GDP output

Null Hypothesis: long-run causality	Lag	Obs.	F-Stats	p-value	Causality Decision
LIFE does not Granger cause $\log \text{GDP}$	2	61	6.5284	0.0028***	Strong long-run predictive causality
$\log \text{GDP}$ does not Granger cause LIFE	2	61	4.5818	0.0144**	Moderate long-run predictive causality

Null Hypothesis: long-run causality	Lag	Obs.	F-Stats	p-value	Causality Decision
LIFE does not Granger cause logGDP	3	60	5.7788	0.0017***	Strong long-run predictive causality
logGDP does not Granger cause LIFE	3	60	7.0967	0.0004***	Strong long-run predictive causality
LIFE does not Granger cause logGDP	4	59	4.9488	0.0019***	Strong long-run predictive causality
logGDP does not Granger cause LIFE	4	59	5.7749	0.0007***	Strong long-run predictive causality
LIFE does not Granger cause logGDP	5	58	4.2882	0.0027***	Strong long-run predictive causality
logGDP does not Granger cause LIFE	5	58	3.6739	0.0069***	Strong long-run predictive causality
DEP does not Granger cause logGDP	2	61	3.7794	0.0289*	Weak long-run predictive causality
logGDP does not Granger cause DEP	2	61	2.4860	0.0924*	Weak long-run predictive causality
DEP does not Granger cause logGDP	3	60	2.6655	0.0571*	Weak long-run predictive causality
logGDP does not Granger cause DEP	3	60	1.9508	0.1326	No predictive causality
DEP does not Granger cause logGDP	4	59	2.5352	0.0516*	Weak long-run predictive causality
logGDP does not Granger cause DEP	4	59	1.8932	0.1262	No predictive causality
DEP does not Granger cause logGDP	5	58	2.0354	0.0908*	Weak long-run predictive causality
logGDP does not Granger cause DEP	5	58	1.6831	0.1572	No predictive causality
EDU does not Granger cause logGDP	2	61	2.7705	0.0712*	Weak long-run predictive causality
logGDP does not Granger cause EDU	2	61	0.0669	0.9353	No long-run predictive causality
EDU does not Granger cause logGDP	3	60	2.5643	0.0643*	Weak long-run predictive causality
logGDP does not Granger cause EDU	3	60	0.0743	0.9735	No long-run predictive causality
EDU does not Granger cause logGDP	4	59	1.8630	0.1316	No long-run predictive causality
logGDP does not Granger cause EDU	4	59	0.0895	0.9853	No long-run predictive causality
EDU does not Granger cause logGDP	5	58	1.5901	0.1813	No long-run predictive causality
logGDP does not Granger cause EDU	5	58	0.3196	0.8987	No long-run predictive causality
BIR does not Granger cause logGDP	2	61	4.1907	0.0201*	Weak long-run predictive causality
logGDP does not Granger cause BIR	2	61	2.3392	0.1058	No long-run predictive causality
BIR does not Granger cause logGDP	3	60	4.7793	0.0051***	Strong long-run predictive causality
logGDP does not Granger cause BIR	3	60	1.5457	0.2135	No long-run predictive causality
BIR does not Granger cause logGDP	4	59	3.5901	0.0119*	Weak long-run predictive causality
logGDP does not Granger cause BIR	4	59	1.0617	0.3853	No long-run predictive causality
BIR does not Granger cause logGDP	5	58	2.8125	0.0266*	Weak long-run predictive causality
logGDP does not Granger cause BIR	5	58	0.9043	0.4863	No long-run predictive causality
DEA does not Granger cause logGDP	2	61	7.4071	0.0014**	Strong long-run predictive causality
logGDP does not Granger cause DEA	2	61	2.5479	0.0873*	Weak long-run predictive causality
DEA does not Granger cause logGDP	3	60	5.4252	0.0025***	Strong long-run predictive causality
logGDP does not Granger cause DEA	3	60	5.7248	0.0018***	Strong long-run predictive causality
DEA does not Granger cause logGDP	4	59	4.6383	0.0029***	Strong long-run predictive causality
logGDP does not Granger cause DEA	4	59	3.5954	0.0119*	Weak long-run predictive causality
DEA does not Granger cause logGDP	5	58	4.1227	0.0035***	Strong long-run predictive causality
logGDP does not Granger cause DEA	5	58	2.8427	0.0253*	Weak long-run predictive causality

Source: Author's calculations

Notes: ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. Lag length = 2 to 5 reflects business cycle of 2 to 5 years.

Long-run causality results in Table 16, reveal strong bidirectional long-run causality between life expectancy (LIFE) and economic growth across all lag lengths. This indicates a reinforcing long-term relationship in which improvements in population health enhance economic performance, while sustained economic growth further supports gains in life expectancy. For the dependency ratio (DEP), the evidence points to weak but consistent unidirectional long-run causality running from dependency to economic growth, with little feedback from GDP to dependency. This suggests that demographic structure exerts a long-term influence on growth outcomes, while economic growth alone does not completely alter dependency dynamics. Educational attainment (EDU) has weak long-run causality to GDP at shorter lags only, with no evidence of reverse causality. This implies that education contributes to long-run growth, although the effect appears modest and lag-dependent.

Birth rates (BIR) in Table 16, display unidirectional long-run causality from fertility to economic growth, ranging from weak to strong depending on lag length, while no reverse causality from GDP to birth rate. This finding highlights the role of fertility dynamics in shaping long-run economic performance. Finally, death rates (DEA) show strong long-run causality to economic growth, alongside weaker but significant feedback from GDP to mortality. This indicates a long-term interaction in which mortality conditions affect growth, while sustained economic performance contributes to improved survival outcomes. Overall, the long-run results indicate that demographic variables exert a more pronounced and persistent influence on economic growth than in the short run, emphasizing that structural nature of population-growth linkages occur over time.

The causality results therefore refine the empirical debate rather than merely confirming one side of it. They differ from neutral findings such as Pritchett (2001), Jones (2002) and Mushtaq (2006), which find no systematic long-run population-growth link, but they are compatible with studies that stress demographic transition and labour-force composition as long-run predictors of growth, including Bloom et al. (2001), Bloom and Williamson (1998), and Cervellati and Sunde (2011, 2015). For South Africa, the evidence suggests that population dynamics provide predictive information for output only when examined over medium- to long-run horizons, which explains why simple short-run correlations understate the demographic-growth channel.

4.2. Stationarity Testing

Before estimating long-run and short-run relationships, it is essential to examine the stationarity properties of all variables to prevent spurious regression and invalid inference. Given the long sample period (1960-2022) and South Africa's history of structural change, the analysis applies both conventional and structural-break unit root tests: (i) Structural-Break Unit Root Tests: Perron (1989) and Zivot and Andrews (1992). (ii) Stationarity-based test: Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. The combined evidence from these tests informs the choice of econometric techniques, particularly the Engle-Granger cointegration approach, ARDL bounds testing, and error-correction modelling.

4.2.1. Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test

To further strengthen the stationarity assessment, the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test is employed. The KPSS test takes stationarity as the null hypothesis and therefore provides complementary evidence using equation (19).

Table 17: Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test based on equation 19

Variable	Level KPSS	1% CV	5% CV	10% CV	Decision (Level)	Order (Level)	Diff. ΔKPSS	1% CV	5% CV	10% CV	Decision (Δ)	Order (Final)
logPOP _t	0.713***	0.739	0.463	0.347	Reject	I(1)	0.364*	0.739	0.463	0.347	Fail to Reject	I(1)
logGDP _t	0.677***	0.739	0.463	0.347	Reject	I(1)	0.451*	0.739	0.463	0.347	Fail to Reject	I(1)
logCAP _t	0.878***	0.739	0.463	0.347	Reject	I(1)	0.256	0.739	0.463	0.347	Fail to Reject	I(1)
LIFE _t	0.371*	0.739	0.463	0.347	Fail to Reject	I(0)	0.312	0.739	0.463	0.347	Fail to Reject	I(0)
DEP _t	0.659***	0.739	0.463	0.347	Reject	I(1)	0.194	0.739	0.463	0.347	Fail to Reject	I(1)
EDU _t	0.727***	0.739	0.463	0.347	Reject	I(1)	0.653**	0.739	0.463	0.347	Reject	I(1)
BIR _t	0.556**	0.739	0.463	0.347	Reject	I(1)	0.145	0.739	0.463	0.347	Fail to Reject	I(1)
DEA _t	0.170	0.739	0.463	0.347	Fail to Reject	I(0)	0.264	0.739	0.463	0.347	Fail to Reject	I(0)

Source: Author's calculations

Notes: KPSS null hypothesis is stationarity. *, **, *** denote rejection of stationarity at the 10%, 5%, and 1% significance levels respectively. Diff=differenced. Integration order (Final) reflects integration used in subsequent modelling.

In Table 17, for logPOP, logCAP and logGDP, the null hypothesis of stationarity is rejected at levels but not rejected after first differencing, confirming I(1) behaviour. Life expectancy and mortality are stationary in levels, while dependency ratio, fertility, and educational attainment display I(1) dynamics once KPSS evidence is applied. Log population (LOGPOP) decisively fails the KPSS stationarity test at levels, confirming that population size is trend-driven and non-mean-reverting. After first differencing, the KPSS test fails to reject stationarity, indicating that population follows an I(1) stochastic trend. Next, structural break unit root tests are applied to capture breakpoint years in the data to ensure robustness on regime shifts, given South Africa's political, social and economic shifts.

4.2.2. Breakpoint Unit Roots Tests

To account for South Africa's major structural shifts, breakpoint unit root tests following Perron (1989) and Zivot and Andrews (1992) are applied. These tests allow for exogenous and endogenous breaks that other conventional tests may fail to detect, using equation (20).

Table 18: Structural Break Unit Root Results – Perron (P) & Zivot-Andrews (ZA) using equation 20

Variable	Test	Break Type	Year	Test stats	p-value	Integration	Stationarity
logPOP _t	ZA	Intercept	1980	-3.563*	0.0004***	I(1)	Stationary around a break.
LogGDP _t	ZA	Intercept	2005	-3.859*	0.0032***	I(1)	Stationary around a break.
logCAP _t	ZA	Intercept	1985	-3.560*	0.0466**	I(1)	Stationary after structural break.
BIR _t	P	Intercept	1994	-6.837***	<0.01***	I(1)	Stationary with break.
DEA _t	P	Intercept	2002	-7.098***	<0.01***	I(1)	Stationary with break.

Variable	Test	Break Type	Year	Test stats	p-value	Integration	Stationarity
EDU _t	P	Intercept	1965	-16.539***	<0.01***	I(0)	Level-stationary with break
LIF _t	P	Intercept	2021	-4.532**	0.0395**	I(1)	Stationary after structural break.
DEP _t	P	Intercept	1996	-4.258*	0.0831*	I(1)	Weak break-stationarity.

Source: Author's Calculations of Breakpoint Unit roots

Notes: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels respectively. Zivot and Andrews (1992) allows for an endogenous structural break, while Perron (1989) models exogenous breaks.

In Table 18, allowing for structural breaks reveals economically meaningful breakpoints. Log population becomes stationary once an endogenous break around 1980 is introduced, consistent with apartheid-era migration controls and the onset of demographic transition. Capital formation breaks in 1985, reflecting the debt crisis and international sanctions, while real GDP exhibits a break around 2005, capturing post-apartheid economic expansion. Demographic variables display regime-linked shifts. Fertility and dependency ratios break around 1994-1996, coinciding with democratic transition and demographic restructuring.

In addition, in Table 18, mortality exhibits a break in 2002, aligned with the peak of the HIV/AIDS epidemic, while life expectancy shows a break in 2021, reflecting the COVID-19 shock. Educational attainment remains level-stationary once early institutional effects are accounted for in 1965. Overall, all variables are integrated of order zero or one, even after accounting for structural breaks. These findings justify the use of cointegration and error-correction techniques. Structural breaks are incorporated into the empirical models through binary dummy variables coded 0 before and 1 after each break to capture permanent regime shifts and ensure parameter stability in subsequent ARDL, ECM, and NARDL estimations.

4.2.3. Johansen Cointegration Test Results

The study further determines the number of cointegrating long run relationship using the Johansen Cointegration test based on Trace and Maximum eigenvalue statistics. The test is based on variables in baseline model. The population, capital formation and GDP variables are each integrated of order one, I(1). The Johansen cointegration test is applied with assumption of an intercept and no deterministic trend. This specification captures long-run as specified in equation (3), results are in Table 19.

Table 19: Johansen Cointegration Results based on baseline equation 3

Trace Test					
Hypothesis	Eigenvalue	Trace Stat	5% Critical Value	p-value	Decision
None	0.3454	40.9277**	29.7971	0.0018**	Reject
At most 1	0.1714	15.0775	15.4947	0.0577	Do not reject
At most 2	0.0574	3.6085	3.8415	0.0575	Do not reject

Trace Test					
Maximum Eigenvalue Test					
Hypothesis	Eigenvalue	Max-Eigen Stat	5% Critical Value	p-value	Decision
None	0.3454	25.8502**	21.1316	0.0100**	Reject
At most 1	0.1714	11.4690	14.2646	0.1322	Do not reject
At most 2	0.0574	3.6085	3.8415	0.0575	Do not reject

Source: Author's calculations

Notes: The cointegrating vector is normalized on LOGGDP and estimated with an intercept (no trend) using 1-2 lags in first differences. Critical values and p-values are from MacKinnon, Haug, and MacKinnon et al. (1999). ***, **, and * denote significance at the 1%, 5%, and 10% levels.

In Table 19, both Johansen trace and maximum eigenvalue tests indicate one cointegrating relationship at the 5% level. The Johansen cointegration results confirm a single stable long-run relationship among real GDP, population, and capital formation at the 5% level. Rejection of the no-cointegration hypothesis by both the Trace and Maximum Eigenvalue tests indicates that these variables move together over time despite short-run fluctuations, supporting the role of demographic dynamics and capital accumulation in long-run economic performance. This validates the use of cointegration-based models to estimate long-run coefficients and short-run adjustment dynamics.

4.2.4. Vector Error Correction Model and Weak-Exogeneity Results

The Johansen cointegration results in Table 19 confirms one long-run relationship between real GDP, population and capital formation. However, cointegration alone does not indicate which variables responds when the system moves away from equilibrium. So, a Vector Error Correction Model (VECM) is estimated to examine the direction of long-run relationship, adjustment process and short-run predictive relationships among GDP, population and capital formation. The adjusted estimation sample covers 1963–2022, containing 60 annual observations. The model includes an intercept in the cointegrating relationship, no deterministic trend and two lags in first differences.

Table 20: VECM Long-Run Estimates and Weak-Exogeneity Tests based on equation 3

Long-run Coefficients Estimate Cointegration						
Long-run variable	Coefficient	Standard error	Absolute t-statistic	Inference		
logPOP _{t-1}	1.5218	0.3007	5.0615	Positive and statistically significant		
logCAP _{t-1}	0.5268	0.1463	3.6019	Positive and statistically significant		
Constant	−13.0908	3.8060	3.4395	Statistically significant		
Adjustment Coefficients & Formal Weak-Exogeneity Tests (H0: alpha_i = 0)						
Adjustment equation	Loading coefficient (a _i)	Standard error	t-statistic	LR chi-square (1)	p-value	Weak-exogeneity inference
ΔlogGDP _t	0.0788	0.01442	5.46478	15.356	0.0001***	Reject H0; GDP adjusts
ΔlogPOP _t	0.0012	0.00179	0.67697	0.3866	0.5341	Fail to reject H0; population is consistent with weak exogeneity
ΔlogCAP _t	0.1489	0.03919	3.79968	9.2480	0.0024***	Reject H0; capital formation adjusts

Source: Author's computation

Notes: Long-run estimates are based on the rank-one Johansen cointegration model reported in Table 19. The cointegrating vector is normalised on logGDP as dependent variable. The weak-exogeneity tests impose the restriction on $H_0: a_i = 0$, where a_i is the loading coefficient in each adjustment equation. Failure to reject the null indicates weak exogeneity with respect to the long-run cointegrating parameters. Loading coefficients are obtained from the unrestricted VECM, while the LR chi-square statistics and p-values are obtained from the corresponding zero-loading restrictions. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

In Table 20, the long-run results of population and capital formation coefficients are positive and statistically significant. A 1% increase in population is associated with an approximately 1.52% increase in aggregate real GDP, while a 1% increase in capital formation is associated with an approximately 0.53% increase in real GDP, holding the other variable constant. These estimates represent long-run associations effects of the baseline model. The weak-exogeneity results show that the null hypothesis cannot be rejected for $\Delta\log\text{POP}$. Therefore, population is consistent with weak exogeneity for the estimated long-run parameters and does not respond significantly to deviations from the long-run equilibrium. In contrast, the zero-loading restrictions are rejected for GDP and capital formation at 1% significance for both $\Delta\log\text{CAP}$ and $\Delta\log\text{GDP}$. Hence, GDP and capital formation adjust when the system moves away from equilibrium. The results indicate that population behaves as the non-adjusting variable in the estimated long-run system, whereas output and capital formation carry the adjustment burden. This identifies where equilibrium correction occurs but does not establish that population structurally causes economic output.

Table 21: Short-Run Predictive Tests Results based on equation 3

Short-run VECM block-exogeneity tests					
Dependent equation	Excluded variable(s)	Chi-square	df	p-value	Inference
$\Delta\log\text{GDP}_t$	$\Delta\log\text{POP}_t$	19.0816	2	0.0001***	Population growth predicts GDP growth.
$\Delta\log\text{GDP}_t$	$\Delta\log\text{CAP}_t$	1.33725	2	0.5124	Capital formation does not predict GDP
$\Delta\log\text{GDP}_t$	All short-run regressors	19.8555	4	0.0005***	Jointly significant
$\Delta(\log\text{POP}_t)$	$\Delta\log\text{GDP}_t$	1.34859	2	0.5095	GDP does not predict population
$\Delta\log\text{POP}_t$	$\Delta\log\text{CAP}_t$	0.88106	2	0.6437	Capital formation does not predict population
$\Delta\log\text{POP}_t$	All short-run regressors	1.35712	4	0.8516	Jointly insignificant
$\Delta\log\text{CAP}_t$	$\Delta\log\text{GDP}_t$	2.66494	2	0.2638	GDP does not predict capital formation
$\Delta\log\text{CAP}_t$	$\Delta\log\text{POP}_t$	16.9213	2	0.0002***	Population predicts capital formation
$\Delta\log\text{CAP}_t$	All short-run regressors	24.4497	4	0.0001***	Jointly significant

Source: Author's computation

Notes: The block-exogeneity Wald tests examine whether the lagged first differences of an excluded variable are jointly significant in each VECM equation. The null hypothesis is that the excluded variable does not provide short-run predictive information for the dependent variable. These tests assess short-run Granger or block exogeneity and are distinct from the formal weak-exogeneity restrictions reported in Table 20. "All short-run regressors" refers to the joint exclusion of the other differenced variables in the relevant equation. **, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

The short-run predictive results in Table 21 shows that changes in population provide significant short-run predictive information for changes in GDP, this results match granger causality short-run results at 4-5 lags and long-run results at 2-5 lags in section 4.1.4. The exclusion of $\Delta\log\text{POP}$

from $\Delta \log \text{GDP}$ equation is rejected, with a chi-square of 19.08 at 1% significance level. By contrast, the exclusion of capital formation is not rejected at chi-square of 1.34. The joint exclusion of population and capital formation is significant at chi-square 19.86, indicating that the short-run regressors are jointly relevant to the GDP equation.

In the population equation, neither GDP nor capital formation is statistically significant individually or jointly. The joint test has an insignificant p-value of 0.8516. This indicates that changes in GDP and capital formation do not provide significant short-run predictive information for population within the estimated system. In the capital formation equation, population is statistically significant at chi-square of 16.92 at 1% significance level, whereas GDP is not. The joint exclusion test is also significant at 1% level with a chi-square of 24.45. The findings indicate that the short-run predictive direction flows from population towards both GDP and capital formation. These results support the dissertation's broader findings that population dynamics provide predictive information for economic performance, as also reported in the Bivariate Granger causality at 4.1.4. However, the tests establish model-predictive ordering rather than structural causality.

Table 22: Residual Diagnostics based on equation 3

VECM residual diagnostics					
Diagnostic test	t-stats	Lag/df	p-value	Decision at 5% level	Inference
Adjusted Portmanteau Q-test	91.631	Lag 12; df = 97	0.6349	Fail to reject	No overall residual autocorrelation
Individual LM test	22.742	Lag 3; df = 9	0.0068***	Reject	Localised serial correlation at lag 3
Cumulative LM test	38.959	Lags 1-4; df = 36	0.3380	Fail to reject	No persistent cumulative serial correlation
Joint skewness test	4.977	df = 3	0.1735	Fail to reject	No significant joint skewness
Joint kurtosis test	190.057	df = 3	<0.001***	Reject	Excess kurtosis detected
Joint Jarque-Bera normality test	195.034	df = 6	<0.001***	Reject	Residuals are not multivariate normal
Heteroskedasticity: levels and squares	84.771	df = 84	0.4559	Fail to reject	No residual heteroskedasticity
Heteroskedasticity: including cross terms	210.007	df = 210	0.4869	Fail to reject	No system-wide residual heteroskedasticity

Source: Author's computation

Notes: The Portmanteau and LM tests examine the null hypothesis of no residual serial correlation. The normality tests examine whether the VECM residuals are jointly multivariate normal, while the heteroskedasticity tests examine the null hypothesis of constant residual variance. Although the individual LM test detects serial correlation at lag 3, the cumulative LM test through lag 4 and the adjusted Portmanteau test through lag 12 do not indicate persistent system-wide residual autocorrelation. **, * and * denote significance at the 1%, 5% and 10% levels, respectively. Degrees of freedom is df.

In Table 22, the adjusted Portmanteau test fails to reject the null hypothesis of no residual autocorrelation through lag 12. Similarly, the cumulative LM test through lags 1–4 is insignificant. Although the individual LM test identifies serial correlation at lag 3, this isolated result is not

supported by the cumulative LM and Portmanteau tests. The model therefore does not show evidence of persistent residual serial correlation. The joint skewness test is insignificant with a p-value of 0.174, indicating that residual skewness is not a major problem. However, the joint kurtosis test is significant at 1% significance level, and the joint Jarque-Bera test rejects multivariate normality at 1% significance level. The rejection of normality is therefore mainly attributable to excess kurtosis. Both heteroskedasticity tests fail to reject their respective null hypotheses. The levels-and-squares test records an insignificant p-value of 0.4559, while the more comprehensive test including cross terms records also an insignificant p-value of 0.4869. Thus, there is no evidence of system-wide residual heteroskedasticity. In brief, the VECM diagnostics are satisfactory regarding persistent serial correlation and heteroskedasticity, although residual normality is rejected. The VECM results are robustness results supporting the Johansen cointegration and are interpreted together with the DOLS, Engle-Granger, ARDL and NARDL findings rather than as stand-alone evidence of structural causality.

4.3. Engle–Granger Cointegration Analysis

Having established that all variables are integrated of order zero or one, the long-run relationship between economic growth, population dynamics, and capital accumulation is examined using the Engle–Granger cointegration framework. As a first step, long-run level relationships are estimated using Dynamic Ordinary Least Squares (DOLS). DOLS is preferred because it corrects for endogeneity and serial correlation by augmenting the cointegrating regression with leads and lags of first-differenced regressors (Stock & Watson, 1993). This approach provides unbiased and efficient long-run parameter estimates in small samples. To assess consistency, the analysis estimates the baseline models without dummies and then, as a robustness check, estimates models that include structural dummies, informed by the Perron and Zivot–Andrews breaks.

4.3.1. Baseline Long-Run Results

This section estimates baseline equation and its variants. long-run models linking real GDP to population size, capital accumulation, and selected demographic variables over the period 1960–2022. Log real GDP is the dependent variable in all specifications, while population size (logPOP) and capital formation (logCAP) are included as core regressors as in the baseline equation 3-9.

Table 23: Long-Run DOLS Estimation Results from baseline equation (3-9) without dummies

Variable	Model 1 Population & Capital	Model 2 Life Expectancy	Model 3 Dependency- ratio	Model 4 Education Attainment	Model 5 Birth & Death rates
logPOP _t	0.628 (0.000) ***	0.608 (0.000) ***	0.556 (0.000) ***	−0.160 (0.183)	0.476 (0.000) ***
LogCAP _t	0.419 (0.000) ***	0.419 (0.000) ***	0.369 (0.000) ***	0.233 (0.000) ***	0.413 (0.000) ***
LIFE-EXPECT _t	—	0.002 (0.722)	—	—	—

Variable	Model 1 Population & Capital	Model 2 Life Expectancy	Model 3 Dependency- ratio	Model 4 Education Attainment	Model 5 Birth & Death rates
DEPENDENCY _t	—	—	-0.005 (0.000) ***	—	—
EDUCATION _t	—	—	—	0.257 (0.000) ***	—
BIRTH RATE _t	—	—	—	—	-0.017 (0.016) *
DEATH RATE _t	—	—	—	—	0.014 (0.069) *
Constant (C)	6.404 (0.000) ***	6.688 (0.000) ***	9.324 (0.000) ***	22.938 (0.000) ***	9.402 (0.000) ***
R squared	0.996	0.996	0.998	0.999	0.998
Adjusted R ²	0.995	0.995	0.997	0.998	0.997
Leads/Lags	1/1	1/1	1/1	1/1	1/1
Long-run variance	0.0027	0.0029	0.0009	0.00058	0.0015
Observations	61	61	61	61	61
Diagnostic Tests					
Normality	0.50 (0.78)	0.39 (0.82)	0.10 (0.95)	0.87 (0.65)	1.16 (0.559)
CUSUM	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%
CUSUMSQ	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%

Source: Author's calculations using Dynamic Ordinary Least Squares Estimates (1960–2022)

Notes: Dependent variable is logGDP. Brackets () denotes the p-values. *** denotes significance at 1% significance level, ** denotes significance at 5% significance level, * denotes significance at 10% significance level. All models use HAC/Newey-West robust standard errors. Leads/Lags=1/1. Each column model depicts the variant according to variables added as discussed in theoretical framework.

Across all estimations and specifications in Table 23, capital accumulation is positive and highly significant, with elasticities ranging from 0.23 to 0.42, confirming its central role in sustaining long-run economic growth. Population growth has a positive impact on economic growth and is significant in most models, with coefficients between 0.48 and 0.63, indicating that a growing population is associated with higher long-run output. However, once educational attainment is introduced (Model 4), the population coefficient becomes statistically insignificant. This suggests that population growth via scale effects alone does not drive growth; rather, its effect operates primarily through human-capital accumulation.

Among additional demographic variables, the dependency ratio in Table 23 column 4 exerts a negative and highly significant effect on output, consistent with demographic-burden and capital-dilution arguments. In Table 23 column 4, education has a positive effect on GDP, and the impact is strongly significant, reinforcing endogenous growth mechanisms. In contrast, life expectancy, fertility, and mortality are weakly significant or insignificant once population and capital are controlled for, indicating that demographic flow variables do not exert independent long-run effects. The adjusted R² increases as additional independent variables are added to the baseline models, indicating improved explanatory power. Table 23 diagnostics indicate normal residuals and stable parameters across all models.

4.3.2. Multicollinearity Diagnostic and Interpolation Sensitivity Check

A multicollinearity diagnostic is conducted for Model 4 which has logPOP, logCAP and EDU because population size and educational attainment both follow strong upward trends over the sample period, this is to distinguish between conditional and mediation from collinearity effects.

Table 24: Multicollinearity and Interpolation Check for the Education-Augmented Long-Run Model

Panel A: Multicollinearity Diagnostics					
Variable		Centered VIF			Multicollinearity Decision
logPOP _t		88.59			High multicollinearity
logCAP _t		8.89			Moderate multicollinearity
EDU _t		120.73			High multicollinearity
Panel B: Education Interpolation Sensitivity Check					
Specification	Obs.	Key variable	Coefficient	p-value	Interpolation Decision
Current annual linear interpolation (1960–2022)	63	logPOP _t	0.1887	0.0162 **	Population, capital and education remain positive. High VIF values imply that coefficients share a strong collinearity.
		logCAP _t	0.3280	0.001 ***	
		EDU _t	0.1253	0.001 ***	
Stepwise five-year education series	63	logPOP _t	0.5038	0.001 ***	The positive population–capital relationship remains when education is not linearly interpolated annually.
		logCAP _t	0.3551	0.001 ***	
		EDU _{step_t}	0.0505	0.0080 **	
Five-year benchmark observations only	13	logPOP _t	0.3722	0.1377	All coefficients remain positive, but the smaller sample of 13 observations in education series reduces statistical precision for population and education.
		logCAP _t	0.3254	0.0001 ***	
		EDU _t	0.0952	0.1339	

Source: Author's sensitivity calculations based on alternative treatment of the education variable (1960–2022).

Notes: Obs. denotes observations. VIF stands for variance inflation factor. Panel A reports centred VIFs. Panel B compares the author-constructed linear annual series with a stepwise series and a five-year-benchmark-only specification. The 13-observation benchmark model has inherently low precision. The exercise supports the population–capital result but does not identify an isolated causal education effect. . ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively

The variance inflation factor results in Table 24 at panel A show high centred VIF values for population (88.59) and education (120.73), while capital formation records a lower but still notable centred VIF of 8.89. These results indicate substantial collinearity between population and education. Therefore, the reduced or weaker statistical significance of population after the inclusion of education should be interpreted cautiously. The finding remains consistent with the view that human capital accumulation has a positive association with economic output, which is consistent with the endogenous-growth interpretation. The population–growth relationship also reflects the difficulty of separating the population-size effect from the education trend in a long annual macro-economic series. Therefore, the education-augmented specification is treated as a robustness and conditioning model rather than definitive evidence that education fully absorbs the population channel.

Panel B in Table 24 evaluates sensitivity to annualisation. Linear interpolation, stepwise carry-forward and benchmark-only estimates yield the same positive population–capital pattern,

although the education coefficient's magnitude and significance vary and the benchmark-only model contains only 13 observations. Together with centred VIFs of 88.59 for population and 120.73 for education, this shows that population and schooling trends cannot be cleanly separated in Model 4. The education-augmented result is therefore treated as a conditioning and robustness check rather than evidence that education causally replaces the population channel.

4.3.3. Robustness Testing Through the Inclusion of Structural Breaks

To account for South Africa's major political, economic, and health-related regime shifts, the baseline long-run DOLS models are re-estimated with structural-break dummy variables. Break dates of 1980 represent apartheid-era restructuring, 1985 the debt crisis, 1994 democratic transition, 2002 the HIV/AIDS peak crisis, 2008 the global financial crisis and the 2020 COVID-19 shocks are drawn from the breakpoint unit roots results from 4.2.2, respectively. Dummies are equal to 0 before a break and 1 after. Including break dummies allows long-run intercept shifts while preserving the underlying cointegrating relationship specified in equation (9). DOLS remains appropriate as it corrects for endogeneity and serial correlation while accommodating exogenous structural changes.

Table 25: Results for the long-Run DOLS estimations from the baseline equation (3-7) with Structural Break Dummies

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
logPOP _t	0.780 (0.0001) ***	0.554 (0.0208) **	0.696 (0.002) ***	0.0647 (0.898)	0.851 (0.016) **
logCAP _t	0.312 (0.000) ***	0.411 (0.000) ***	0.360 (0.000) ***	0.194 (0.035) **	0.327 (0.003) ***
LIFE _t	—	-0.001 (0.823)	—	—	—
DEP _t	—	—	-0.007(0.234)	—	—
EDU _t	—	—	—	0.219 (0.087) *	—
BIR _t	—	—	—	—	0.0079 (0.3510)
DEA _t	—	—	—	—	0.0095 (0.3723)
Dum1980	-0.080 (0.058) *	-0.039 (0.375)	-0.106 (0.030) **	-0.012 (0.820)	-0.0496 (0.240)
Dum1985	0.0383 (0.437)	0.0811 (0.118)	0.0310 (0.554)	0.0109 (0.854)	0.027 (0.701)
Dum1994	0.0404 (0.332)	-0.006 (0.893)	0.031 (0.554)	-0.007 (0.883)	0.003 (0.951)
Dum2002	0.067 (0.012) **	0.087 (0.012) **	-0.0353 (0.638)	0.0376 (0.420)	0.072 (0.170)
Dum2008	0.0190 (0.428)	0.0432 (0.355)	-0.0321 (0.522)	0.0391 (0.282)	0.081 (0.060) *
Dum2020	0.0126 (0.747)	0.1182 (0.353)	0.0089 (0.828)	0.0325 (0.632)	0.170 (0.184)
Constant (C)	6.56 (0.000) **	7.87 (0.000) ***	7.33 (0.000) ***	20.23 (0.018) **	4.58 (0.188)
Observations	61	61	61	61	61
R-squared	0.999	0.999	0.999	0.999	0.999
Adjusted R-squared	0.998	0.998	0.998	0.998	0.998
Leads/lags	1/1	1/1	1/1	1/1	1/1
Bandwidth	4	4	4	4	4
Long-run variance	0.0005	0.0004	0.0005	0.0004	0.0003
Diagnostic Test					
Normality	0.37 (0.83)	1.34 (0.51)	0.19 (0.91)	1.44 (0.49)	0.76 (0.68)
Ramsey RESET	0.01 (0.92)	0.160 (0.69)	1.43 (0.24)	2.66 (0.11)	0.09 (0.76)
CUSUM	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%
CUSUMSQ	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%

Source: Author's calculations of Dynamic Ordinary Least Squares Estimates (1960–2022)

Notes: Dependent variable is logGDP. p-values in parentheses: All estimates using Dynamic OLS with HAC/Newey-West robust standard errors, Leads/lags=1/1. Dummies are 0 before a break and 1 after a break, they capture major historical shocks of 1980, 1985, 1994, 2008, and 2020. Each column model depicts the variant according to variables added. The model denotes the equation with variables from equation (3) to (7) as explained in the theoretical section.

In Table 25, the impact of capital formation on GDP remains positive and highly significant across all specifications, with elasticities ranging from 0.20 to 0.40, reaffirming its vital role in long-run GDP growth. Population size continues to exert a positive impact on GDP, and the impact is statistically significant in most models, with coefficients between 0.65 and 0.84, indicating the importance of scale and labour-supply effects. However, as in the baseline models, the population coefficient becomes insignificant once education is included, reinforcing the conclusion that population contributes to growth primarily when complemented by human-capital accumulation. The results confirm a robust long-run relationship between real GDP, population, and capital accumulation after controlling for structural breaks.

Amongst the effects demographic controls in Table 25, education is the only variable that consistently enhances long-run growth, while life expectancy, dependency ratios, fertility, and mortality are statistically insignificant once population and capital are controlled for. This suggests that demographic stocks, rather than demographic flows, drive long-run output dynamics. Structural-break dummies are largely insignificant, indicating that major shocks affected growth mainly through population, capital, and education channels rather than through permanent level shifts. The dummy1980 is negative and significant in the dependency-ratio model, reflecting apartheid-era distortions, while the dummy2008 is weakly positive in some specifications, consistent with post-crisis adjustment effects.

Table 25 diagnostics support residual normality; the RESET test indicates correct functional specification, while the CUSUM and CUSUMSQ tests confirm parameter stability at the 5% level across all models. Overall, the inclusion of structural breaks does not alter the core conclusions. Long-run growth in South Africa is driven by capital accumulation and human capital, with population size contributing conditionally.

These long-run DOLS findings speak directly to the theoretical debate. The positive population coefficient in baseline specifications supports population-driven growth arguments associated with labour supply and market-size expansion, while the weakening of the population coefficient after adding education and dependency controls supports the conditional view that population effects depend on human-capital quality and age structure as well as capital dilution caused by rising dependency burdens when the dependency ratio is controlled for. This is consistent with

Furuoka (2005), Bloom and Williamson (1998), and Bloom et al. (2001), but it also qualifies the positive strand by showing that population size alone is insufficient in South Africa without investment and skills formation.

The positive long-run relationship between population, capital formation and GDP output is consistent with the growth-accounting interpretation that aggregate output is linked to labour input and capital accumulation. However, the results should not be read as a mechanical growth-accounting decomposition because the study does not estimate factor shares or total factor productivity directly. Instead, the findings show that population and capital formation move together with aggregate real GDP in the long run, while education and life expectancy provide additional human-capital and productivity-related interpretation.

The two-sector structural transformation perspective helps explain why the population-growth relationship is conditional. South Africa's growing population creates potential labour supply and market demand, but the growth benefit depends on productive labour absorption. High unemployment, skills mismatch and high inequality mean that demographic expansion does not automatically become a demographic dividend. This supports the interpretation that population growth is associated with economic performance, but its benefits depend on capital formation, education, favourable demographic and structural transformation. These findings validate the DOLS estimates and motivate formal testing for cointegration using the Engle–Granger residual-based approach in the next section.

4.3.4. Second step in Engle–Granger Cointegration analysis

Having estimated the long-run relationships using Dynamic Ordinary Least Squares (DOLS), this section formally tests whether the variables are cointegrated using the Engle–Granger second step procedure. In the second step, these residuals are tested for stationarity using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The null hypothesis is that the residuals contain a unit root (no cointegration). Rejection of the null hypothesis indicates that a long-run relationship exists. The residual stationarity test is specified in equation (10a).

Table 26: Engle–Granger Residual Cointegration Results (ADF & PP) from equation 10a

Model Number	ADF Level	ADF p-value	ADF Stationarity	PP Level	PP p-value	PP Stationarity	Cointegration Conclusion
1	–2.155 **	0.0310 **	I(0)	–2.077 **	0.0372 **	I(0)	Cointegrated at 5%.
2	–4.728 ***	0.0003 ***	I(0)	–4.628 ***	0.0004 ***	I(0)	Cointegrated at 1%.
3	–4.802 ***	0.0002 ***	I(0)	–4.817 ***	0.0002 ***	I(0)	Cointegrated at 1%.
4	–4.751 ***	0.0002 ***	I(0)	–4.676 ****	0.0002 ***	I(0)	Cointegrated at 1%.
5	–5.822 ***	0.000 ***	I(0)	–5.582 ***	0.000 ***	I(0)	Cointegrated at 1%.

Source: Author's Residuals Stationarity on Augmented Dickey-Fuller & Philips-Perron (1960–2022)

Notes: *** denotes significance at 1% significance level, ** denotes significance at 5% significance level= 5%, * denotes significance at 10% significance level. Residuals were tested with a constant and no trend. Lag length selected automatically using the Schwarz Information Criterion (SIC). Each model depicts the variant according to variables added.

Both ADF and PP test statistics in Table 26 reject the null hypothesis of non-stationary residuals at conventional significance levels. Cointegration is confirmed at the 1% level for Models 2 to 5 and at the 5% level for Model 1. These findings indicate that real GDP, population, capital accumulation, and the associated demographic variables move together in the long run. The confirmation of cointegration validates the long-run DOLS estimates presented earlier and rules out spurious regression concerns. The results above provide strong evidence of cointegration across all five models. Importantly, the presence of cointegration justifies the estimation of error-correction models (ECMs) to analyse short-run dynamics and determine the speed at which deviations from long-run equilibrium are corrected. This adjustment process is examined in the following section.

4.3.5. Third step in Engle–Granger cointegration analysis Error-Correction Model (ECM)

The third step involves estimating the short-run error-correction model. Following confirmation of cointegration, this section examines short-run dynamics using error-correction models (ECMs) derived from the Engle–Granger framework. The ECMs capture how short-term deviations in economic growth adjust toward the long-run equilibrium relationship between real GDP, population dynamics, capital accumulation, and demographic variables. Each ECM includes the lagged error-correction term (ECT_{t-1}) which is derived from the residuals obtained from the corresponding long-run cointegration equations (3-7). A negative and statistically significant ECT coefficient indicates convergence toward the long-run equilibrium after departure from the equilibrium state. Equations (10a) and (10b) depict the short-run dynamics:

Table 27: Engle–Granger Short-Run Error-Correction Model Estimates on equation 10a-10b

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
$\Delta \log POP_t$	0.397 (0.120)	0.437 (0.077) *	0.428 (0.042) **	-0.014 (0.947)	0.467 (0.032) **
$\Delta \log CAP_t$	0.251 (0.000) ***	0.252 (0.000) ***	0.253 (0.000) ***	0.235 (0.000) ***	0.245 (0.000) ***
$\Delta LIFE_t$	—	-0.003 (0.204)	—	—	—
$\Delta DEPENDENCY_t$	—	—	-0.002 (0.599)	—	—
$\Delta EDUCATION_t$	—	—	—	0.233 (0.019) **	—
$\Delta BIRTH\ RATE_t$	—	—	—	—	0.004 (0.280)
$\Delta DEATH\ RATE_t$	—	—	—	—	0.004 (0.069) *
ECT_{t-1}	-0.108 (0.212)	-0.172 (0.279)	-0.397 (0.047) **	-0.348 (0.068) *	-0.451 (0.049) **
Speed of adjustment	10.8%	17.2%	39.7%	34.8%	45.1%
Constant	0.010 (0.035) **	0.010 (0.063) *	0.008 (0.047) **	-0.003 (0.713)	0.010 (0.013) **
R-squared	0.607	0.608	0.629	0.639	0.639
Adjusted R-squared	0.586	0.580	0.603	0.613	0.606

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
F-statistic	29.30	21.71	23.74	24.76	19.49
Prob. (F-statistics)	0.000	0.000	0.000	0.000	0.000
Akaike Info. Criterion	-5.286	-5.257	-5.312	-5.339	-5.307
Durbin-Watson	1.97	1.98	1.96	2.11	1.98
Observations	61	61	61	61	61
Diagnostic Test					
Normality	0.472 (0.79)	0.075 (0.96)	0.399 (0.82)	0.519 (0.77)	0.293 (0.86)
Ramsey RESET	0.118 (0.73)	0.232 (0.63)	0.247 (0.62)	0.600 (0.44)	0.102 (0.75)
CUSUM	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%
CUSUMSQ	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%

Source: Author's Calculations of Short-Run estimates (1961-2022)

Notes: Dependent variable is $\Delta \log \text{GDP}$. Models use HAC-robust standard errors, p-values are in brackets (). ECT terms are derived from long-run DOLS residuals. ***, **, * denote significance at 1%, 5%, and 10% levels respectively. Each column model depicts the variant according to variables added.

In Table 27, the short-run economic growth in South Africa is driven primarily by capital accumulation. Across all specifications, a 1% increase in capital growth raises real GDP growth by approximately 0.24-0.25%, with effects statistically significant at the 1% level. This confirms an investment-led short-run growth process. Population growth exhibits a conditional short-run effect. While insignificant in the simplest specifications, population growth becomes positive and statistically significant once demographic structure is controlled for, increasing GDP growth by about 0.43 to 0.47% in Models 3 and 5. This suggests that population dynamics influence short-run growth mainly through structural composition rather than sheer size.

In Table 27, the educational attainment contributes positively to short-run growth when included, whereas life expectancy, dependency ratios, birth rates, and death rates remain statistically insignificant in the short run. This implies that most demographic influences operate through long-run channels rather than immediate cyclical effects. The error-correction terms are negative and statistically significant in Models 3 to 5, with adjustment speeds ranging from 35% to 45% per year. This indicates relatively rapid convergence toward long-run equilibrium following short-run disturbances, reinforcing the stability of the long-run relationship. Overall, the ECM results confirm that short-run fluctuations in economic growth are dominated by investment dynamics, while population effects materialise gradually through longer-term structural adjustments. Again, models pass all models diagnostic tests in Table 27.

This section extends the baseline ECM analysis by incorporating structural-break dummy variables to capture major political, economic, and health-related shocks that may influence South Africa's short-run growth dynamics. Dummy variables for 1980, 1985, 1994, 2002, 2008, and 2020 are included to assess whether these events exert independent short-run effects beyond population growth and capital accumulation. Each dummy is 0 before a break and 1 otherwise.

Table 28: Structural Break Adjusted Short-Run (Engle–Granger) Error Correction

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
$\Delta \log \text{POP}_t$	0.942 (0.099) *	0.771 (0.349)	0.806 (0.244)	0.732 (0.253)	0.746 (0.386)
$\Delta \log \text{CAP}_t$	0.214 (0.000) ***	0.211 (0.000) ***	0.209 (0.000) ***	0.208 (0.000) ***	0.209 (0.000) ***
ΔLIFE_t	—	-0.002 (0.362)	—	—	—
ΔDEP_t	—	—	-0.002 (0.344)	—	—
ΔEDU_t	—	—	—	0.088 (0.144)	—
ΔBIR_t	—	—	—	—	0.0028 (0.3271)
ΔDEA_t	—	—	—	—	0.0028 (0.3270)
ECT_{t-1}	-0.166 (0.124)	-0.199 (0.2470)	-0.412 (0.033) **	-0.365 (0.00) ***	-0.454 (0.055) *
Dum1980	-0.018 (0.000) **	-0.010 (0.120)	-0.013 (0.171)	-0.0089 (0.098) *	-0.011 (0.115)
Dum1985	0.004 (0.333)	-0.0045 (0.324)	-0.0028 (0.573)	-0.0035 (0.343)	-0.0021 (0.739)
Dum1994	0.0149 (0.204)	0.0153 (0.403)	0.0174 (0.154)	0.0173 (0.107)	0.0157 (0.296)
Dum2002	0.012 (0.000) ***	0.009 (0.211)	0.007 (0.114)	0.008 (0.007) ***	0.004 (0.640)
Dum2008	-0.012 (0.006) ***	-0.010 (0.360)	-0.012 (0.028) **	-0.012 (0.019) **	-0.009 (0.317)
Dum2020	-0.002 (0.784)	-0.0103 (0.001) ***	-0.008 (0.002) ***	-0.006 (0.075) *	-0.010 (0.00) ***
Constant (C)	0.002 (0.891)	0.007 (0.774)	0.005 (0.796)	-0.003 (0.819)	0.009 (0.750)
Observations	61	61	61	61	61
R-squared	0.6540	0.6517	0.6770	0.6635	0.6772
Adjusted R-squared	0.5930	0.5820	0.6124	0.5962	0.6047
S.E. of regression	0.01653	0.01675	0.01613	0.01647	0.01629
F-statistic	10.71	9.36	10.48	9.86	9.34
Prob(F-statistic)	0.0000	0.0000	0.0000	0.0000	0.0000
Durbin-Watson	2.11	2.10	2.15	2.17	2.06
Wald F-statistic	205.06	90.68	319.30	251.00	200.00
Prob (Wald F)	0.0000	0.0000	0.0000	0.0000	0.0000
Diagnostic Test					
Normality	0.418 (0.812)	0.244 (0.886)	1.277 (0.528)	1.332 (0.514)	0.201 (0.904)
Ramsey RESET	0.359 (0.552)	0.698 (0.407)	0.485 (0.489)	0.477 (0.493)	0.456 (0.503)
CUSUM	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%
CUSUMSQ	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%

Source: Author's Calculations of Dummy Adjusted Short-Run (1961-2022)

Notes: Dependent variable is $\Delta \log \text{GDP}$. () denotes the p-values. *** denotes significance at 1% significance level, ** denotes significance at 5% significance level= 5%, * denotes significance at 10% significance level. All models used HAC/Newey-West robust errors. ECT_{t-1} indicates the lagged residual from long-run cointegration equations. Each column model depicts the variant according to variables added.

The inclusion of structural-break dummies in Table 28 does not alter the conclusion on core short-run dynamics. Capital accumulation remains the dominant short-run driver of economic growth, with a 1% increase in capital growth raising GDP growth by approximately 0.21-0.22% across all models. Population growth remains positive but generally weak and statistically insignificant, reinforcing the view that demographic effects operate mainly through long-run structural channels rather than short-run fluctuations. The error-correction terms remain negative and statistically significant in the more comprehensive models, with coefficients between -0.35 and -0.45, indicating that 35-45% of short-run disequilibrium is corrected within one year. This confirms rapid adjustment toward long-run equilibrium even in the presence of major shocks.

Structural shocks display temporary and selective effects. The dummy1980 captures apartheid-era distortions in some specifications, while the dummy2002 reflects post-HIV/AIDS recovery effects. The 2008 global financial crisis and 2020 COVID-19 shock generate short-run contractions, but these effects do not persist, indicating transitory disruptions rather than permanent growth losses. The 1994 democratic transition does not have a statistically significant short-run impact once macro-economic fundamentals are controlled for. Overall, the results confirm that South Africa's short-run growth process is investment-led and resilient, with structural shocks causing temporary deviations that are rapidly corrected through stable long-run adjustment mechanisms. Model diagnostic assessments of all models are reliable for inference.

4.4. Results from the Autoregressive Distributed Lags (ARDL) Long-Run Bounds Test

This section examines the long-run relationship between economic growth, population dynamics, and capital accumulation using the Autoregressive Distributed Lag (ARDL) bounds testing approach. The ARDL framework is well suited to this study as it accommodates a mixture of $I(0)$ and $I(1)$ variables and provides simultaneous estimation of short-run dynamics and long-run equilibrium relationships.

Five ARDL models are estimated for the period 1960–2022, with log real GDP (logGDP) as the dependent variable. Population size (logPOP) and capital accumulation (logCAP) are included in all specifications, while life expectancy, dependency ratio, education, and fertility-mortality variables are introduced sequentially to assess robustness across alternative demographic structures. All models are estimated under the assumptions of restricted constant, no deterministic trend and with HAC/Newey-West robust standard errors as shown in equation 12a and 12b.

Table 29: ARDL Conditional Error-Correction, Bounds Test, and Long-Run Estimates in equation 12a & 12b

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Selected Model	ARDL (1,2,2)	ARDL (1,0,2, 0)	ARDL (1,0,2,0)	ARDL (3,2,2,1)	ARDL (1,4,2,1,0)
logGDP _{t-1}	-0.092 (0.182)	-0.070 (0.306)	-0.322 (0.000) ***	-0.606 (0.000) ***	-0.201 (0.011) **
logPOP _{t-1}	0.019 (0.697)	0.032 (0.481)	0.139 (0.005) ***	-0.224 (0.002) ***	0.055 (0.332)
LOGCAP _{t-1}	0.039 (0.193)	0.030 (0.300)	0.116 (0.001) ***	0.131 (0.001) ***	0.089 (0.014) **
LIFE _{t-1}	—	-0.002 (0.008) ***	—	—	—
DEPENDENC _{t-1}	—	—	-0.002 (0.000) ***	—	—
EDU _{t-1}	—	—	—	0.182 (0.000) ***	—
BIRTH RATE _{t-1}	—	—	—	—	-0.005 (0.103) *
DEATH RATE _t	—	—	—	—	0.006 (0.007) ***
ΔlogGDP _{t-1}	—	—	—	0.148 (0.305)	—
ΔlogGDP _{t-2}	—	—	—	0.231 (0.053) **	—
ΔlogPOP _t	0.620 (0.484)	—	—	-0.152 (0.850)	0.699 (0.452)
ΔlogCAP _t	0.242 (0.000) ***	0.238 (0.000) ***	0.280 (0.000) ***	0.274 (0.000) ***	0.254 (0.000) ***
ΔlogPOP _{t-1}	-1.537 (0.076) *	—	—	0.995 (0.341)	0.475 (0.676)
ΔlogPOP _{t-2}	—	—	—	-1.603 (0.121)	-1.727 (0.144)
ΔlogPOP _{t-3}	—	—	—	2.891 (0.003) **	2.617 (0.012) *

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
$\Delta \log \text{CAP}_t$	—	—	—	0.274 (0.000) ***	-0.095 (0.005) **
$\Delta \log \text{CAP}_{t-1}$	-0.089 (0.009) ***	-0.093 (0.006) ***	-0.098 (0.002) ***	-0.106 (0.028) **	-0.095 (0.005) ***
ΔEDU_t	—	—	—	0.545 (0.0151) *	—
ΔBIR_t	—	—	—	—	0.0004 (0.940)
Constant (C)	1.312 (0.006) ***	0.772 (0.081) *	3.848 (0.000) ***	16.193*** (0.000)	2.461 (0.019) **
F-Bounds	5.77	22.92	28.73	6.51	4.84
Cointegration	<0.001 ***	<0.001 ***	<0.001 ***	<0.001 ***	<0.005 **
LONG RUN IMPACT					
$\log \text{POP}_t$	0.203 (0.575)	0.462 (0.024) *	0.432 (0.000) ***	-0.370 (0.003) ***	0.272 (0.246)
$\log \text{CAP}_t$	0.420 (0.000) ***	0.434 (0.000) ***	0.359 (0.000) ***	0.217 (0.000) ***	0.444 (0.000) ***
LIFE_t	—	-0.029 (0.243)	—	—	—
DEP_t	—	—	-0.007 (0.000) ***	—	—
EDU_t	—	—	—	0.3002 (0.000) ***	—
BIR_t	—	—	—	—	-0.024 (0.067) *
DEA_t	—	—	—	—	0.032 (0.021) *
Constant	14.264 (0.022) *	10.993 (0.009) ***	11.944 (0.000) ***	26.737 (0.000) ***	12.242 (0.001) ***
Observations	62	62	62	60	60
Diagnostics Test					
Normality	0.758 (0.685)	0.766 (0.682)	0.871 (0.647)	0.373 (0.830)	0.491 (0.782)
Ramsey RESET	0.252 (0.618)	0.336 (0.565)	0.226 (0.637)	2.010 (0.163)	0.528 (0.471)
CUSUM	Unstable	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%
CUSUMSQ	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%

Source: Author's Calculations of ARDL, Sample: 1960–2022

Notes: Dependent variable is $\Delta \log \text{GDP}$. Brackets () denotes the p-values. *** denotes significance at 1% significance level, ** denotes significance at 5% significance level, and * denotes significance at 10% significance level. Each column model depicts the variant according to variables added.

The ARDL bounds test results in Table 29 provide strong evidence of cointegration between economic growth, population, and capital accumulation. In all models, the computed F-statistics exceed the upper critical bounds, indicating the existence of a stable long-run relationship at conventional significance levels. Cointegration is very strong in Models 2 and 3, strong in Models 1 and 4, and moderate in Model 5, confirming robustness across alternative specifications. Capital accumulation consistently emerges as the dominant long-run driver of economic growth. The estimated long-run elasticity of GDP with respect to capital ranges between 0.22 and 0.44, implying that a 1% increase in investment raises long-run output by approximately 0.2-0.4%.

The long-run impact of population is conditional. In simpler specifications, population size contributes positively to economic growth. However, once education and dependency burdens are explicitly controlled for, the population coefficient becomes negative in some models, indicating potential dilution effects when population growth is not accompanied by improvements in human capital and age structure. Education exerts a strong and positive long-run effect, while the dependency ratio negatively affects growth, confirming that population quality and structure matter more than population size alone. Fertility and mortality variables display weaker and less stable effects, suggesting indirect rather than direct growth channels. All models are stable with only Model 1 having structural instability over time. Overall, the ARDL results reinforce earlier cointegration findings and highlight that South Africa's long-run growth path is driven by

investment and human-capital accumulation, with population dynamics influencing growth primarily through structural and demographic composition channels.

4.4.1. Results from ARDL Short-run Error Correction

Having established a stable long-run relationship through the ARDL bounds tests, this section examines the short-run dynamics using the associated error-correction models (ECMs). The ECM framework captures how short-term fluctuations in economic growth adjust toward long-run equilibrium following shocks to population and capital accumulation using equations 13a and 13b.

Table 30: ARDL Short-Run Error Correction based on equation 13a and 13b

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Selected ARDL	(1,2,2)	(1,0,2,0)	(1,0,2,0)	(3,4,2,1)	(1,4,2,1,0)
$\Delta \log \text{GDP}_{t-1}$	—	—	—	0.148 (0.222)	—
$\Delta \log \text{GDP}_{t-2}$	—	—	—	0.231 (0.014) **	—
$\Delta \log \text{POP}_t$	0.620 (0.445)	—	—	-0.152 (0.830)	0.699 (0.366)
$\Delta \log \text{POP}_{t-1}$	-1.537 (0.060) *	—	—	0.995 (0.312)	0.475 (0.655)
$\Delta \log \text{POP}_{t-2}$	—	—	—	-1.603 (0.103)	-1.727 (0.115)
$\Delta \log \text{POP}_{t-3}$	—	—	—	2.891 (0.001) ***	2.617 (0.002) ***
$\Delta \log \text{CAP}_t$	0.242 (0.000) ***	0.238 (0.000) ***	0.280 (0.000) ***	0.274 (0.000) ***	0.254 (0.000) ***
$\Delta \log \text{CAP}_{t-1}$	-0.089 (0.00) ***	-0.093 (0.002) ***	-0.098 (0.001) ***	-0.106 (0.013) **	-0.095 (0.002) ***
ΔEDU_t	—	—	—	0.545 (0.000) ***	—
ΔBIR_t	—	—	—	—	0.0004 (0.922)
ECM_{t-1}	-0.092 (0.00) ***	-0.070 (0.000) ***	-0.322 (0.000) ***	-0.606 (0.000) ***	-0.201 (0.00) ***
Observations	62	62	62	60	60
R-squared	0.689	0.689	0.735	0.798	0.751
Adj. R-squared	0.667	0.679	0.726	0.761	0.718
S.E. of regression	0.0150	0.0148	0.0136	0.0124	0.0135
AIC	-5.479	-5.546	-5.704	-5.784	-5.644
Durbin-Watson	2.29	2.27	2.20	2.14	2.12
F-Bounds	5.77	22.92	28.73	6.51	4.84
Cointegration	<0.001 ***	<0.001 ***	<0.001 ***	<0.001 ***	<0.005 **
Diagnostic Test					
Normality	0.758 (0.685)	0.766 (0.682)	0.871 (0.647)	0.373 (0.830)	0.491 (0.782)
Ramsey RESET	0.252 (0.618)	0.336 (0.565)	0.226 (0.637)	2.010 (0.163)	0.528 (0.471)
CUSUM	Unstable	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%
CUSUMSQ	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%

Source: Author's Calculation

Notes: Dependent variable: $\Delta \log \text{GDP}$. All models are estimated using Case 2 (restricted constant, no trend). ECM (-1) denotes the error-correction term. Variables marked “—” are excluded by optimal lag selection. p-values in brackets (). *, **, *** denote significance at the 10%, 5%, and 1% levels respectively. Durbin-Watson statistics close to 2 indicate no first-order serial correlation. Each column model depicts the variant according to variables added.

In Table 30, the error-correction term (ECM_{t-1}) is negative and highly significant across all ARDL specifications, confirming adjustment toward long-run equilibrium. The estimated adjustment speeds range from 7.0% to 60.6% per year, depending on model specification. The slower speeds in Models 1 and 2 indicate gradual adjustment in simpler specifications, while the faster adjustment in Models 3 and 4 reflects the inclusion of additional demographic-structure and human-capital controls and the selected lag structure. Short-run economic growth is driven

primarily by capital accumulation. A 1% increase in capital growth raises GDP growth by approximately 0.21-0.27% within the same year, with statistically significant effects across the specifications. Diagnostic tests reveal instability in model 1, other tests are well specified and for rest of models.

In contrast, population growth does not exert a systematic contemporaneous effect on GDP growth. Where population enters the model, its impact is lag-dependent and generally weak, indicating that demographic influences on growth materialise gradually rather than through immediate cyclical channels. Human capital improvements generate immediate short-run gains when included, while fertility changes remain statistically insignificant in the short run. Overall, these results confirm that investment is the primary short-run transmission mechanism, while population dynamics influence economic growth mainly through longer-term structural adjustment.

These results are important because they resolve the apparently mixed empirical literature. Short-run insignificance is consistent with studies that find weak or neutral population-growth effects once macro-economic fundamentals are controlled for, while the significant error-correction terms confirm that demographic variables still matter through the long-run equilibrium channel. In the South African case, the evidence therefore supports a conditional demographic-dividend interpretation rather than a simple Malthusian or population-driven growth conclusion.

4.4.2. Robustness to Structural Breaks and Demographic Shifts in ARDL Models

To assess whether the long-run relationship between population dynamics and economic growth is stable in the presence of major historical disruptions, the ARDL models are augmented with structural break dummy variables. These dummies capture key political, economic, and health-related shocks that may have shifted South Africa's growth path without necessarily altering the underlying equilibrium relationship. The break years incorporated include 1980 (early apartheid-era restructuring), 1985 (debt crisis and international sanctions), 1994 (democratic transition), 2002 (post-HIV/AIDS stabilisation), 2008 (global financial crisis), and 2020 (COVID-19 pandemic). Each dummy enters the model as an intercept shifter, allowing for temporary or permanent level changes in output while preserving the dynamic structure of the ARDL specification using equation 13a and 13b.

Table 31: ARDL Conditional Error-Correction, Bounds Test, and Long-Run Estimates 13a and 13b

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Selected Model	ARDL (1,0,2)	ARDL (1,0,2,0)	ARDL (2,0,2,0)	ARDL (2,1,1,0)	ARDL (1,4,4,0,0)
logGDP _{t-1}	-0.243 (0.036) **	-0.240 (0.051) *	-0.181 (0.175)	-0.244 (0.057) *	-0.253 (0.044) **
logPOP _{t-1}	—	—	—	-0.387 (0.014) **	0.099 (0.404)

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
$\log \text{CAP}_{t-1}$	0.086 (0.048) **	0.085 (0.074) *	0.083 (0.082) *	0.071 (0.063) *	0.101 (0.056) *
$\Delta \log \text{CAP}_t$	0.252 (0.000) ***	0.251 (0.000) ***	0.274 (0.000) ***	0.274 (0.000) ***	0.210 (0.000) ***
LIFE_{t-1}	—	-0.0004 (0.942)	—	—	—
DEP_{t-1}	—	—	-0.012 (0.259)	—	—
EDU_{t-1}	—	—	—	0.492 (0.043) **	—
BIR_{t-1}	—	—	—	—	-0.008 (0.529)
DEA_{t-1}	—	—	—	—	0.033 (0.178)
$\Delta \log \text{POP}_t$	—	—	—	0.549 (0.465)	—
$\Delta \log \text{CAP}_t$	0.252 (0.000) ***	0.251 (0.000) ***	0.274 (0.000) ***	0.274 (0.000) ***	0.210 (0.000) ***
$\Delta \log \text{CAP}_{t-1}$	-0.106 (0.003) ***	-0.106 (0.003) ***	-0.074 (0.077) *	—	-0.094 (0.025) **
Dum1980	0.007 (0.536)	0.007 (0.538)	0.006 (0.619)	0.009 (0.464)	0.014 (0.377)
Dum1985	0.004 (0.801)	0.003 (0.829)	0.008 (0.599)	0.034 (0.023) **	-0.008 (0.679)
Dum1994	0.015 (0.148)	0.015 (0.222)	0.016 (0.180)	0.010 (0.461)	0.026 (0.104)
Dum2002	0.025 (0.025) **	0.024 (0.109)	-0.004 (0.811)	-0.009 (0.493)	0.007 (0.672)
Dum2008	0.000 (0.978)	0.001 (0.947)	-0.016 (0.207)	-0.022 (0.044) **	0.007 (0.587)
Dum2020	0.004 (0.702)	0.004 (0.713)	0.004 (0.736)	—	-0.004 (0.813)
Constant	2.887 (0.002) ***	2.850 (0.008) ***	3.265 (0.002) ***	10.877 (0.000) ***	2.729 (0.090) *
F-Bounds	21.67	16.99	14.24	5.73	3.16
Cointegration	<0.001 ***	<0.001 ***	<0.001 ***	<0.001 ***	<0.005 **
LONG RUN IMPACT					
$\log \text{POP}_t$	0.409 (0.075) *	0.414 (0.093) *	-0.048 (0.943)	-1.584 (0.188)	0.393 (0.311)
$\log \text{CAP}_t$	0.356 (0.000) ***	0.355 (0.000) ***	0.458 (0.003) ***	0.290 (0.000) ***	0.399 (0.001) ***
LIFE_t	—	-0.0004 (0.942)	—	—	—
DEP_t	—	—	-0.012 (0.259)	—	—
EDU_t	—	—	—	0.492 (0.043) **	—
BIR_t	—	—	—	—	-0.008 (0.529)
DEA_t	—	—	—	—	0.033 (0.178)
Constant (C)	11.89 (0.000) ***	11.87 (0.000) ***	18.07 (0.053) *	44.54 (0.021) **	10.80 (0.024) **
Observations	62	62	62	62	62
Diagnostic Test					
Normality	3.269 (0.195)	3.303 (0.192)	5.638 (0.060) *	2.202 (0.333)	2.155 (0.340)
Ramsey RESET	1.792 (0.187)	2.018 (0.162)	0.329 (0.569)	0.004 (0.951)	6.803 (0.013) **
CUSUM	Stable at 5%	Stable at 5%	Unstable	Unstable	Unstable
CUSUMSQ	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%

Source: Author's Calculation, Sample: 1960–2022

Notes: Dependent variable is $\log \text{GDP}_{t-1}$. All models estimated under case 2: restricted constant, no trend. p-values in (brackets). ***, **, * denote significance at 1%, 5%, and 10% respectively. Dummy variables enter as fixed intercept shifters. Each column model depicts the variant according to variables added.

The bounds test statistics in Table 31 remain above the upper critical values across all model specifications, confirming that the long-run relationship between economic growth, population, and capital accumulation is robust to structural breaks. This indicates that major historical events altered the level of economic activity but did not fundamentally disrupt the long-run growth equilibrium. Capital accumulation continues to be the dominant long-run driver of economic growth. A 1% increase in capital stock raises real GDP by approximately 0.29-0.46%, with all coefficients remaining positive and statistically significant. This reinforces the central role of investment in sustaining long-term growth irrespective of regime changes or external shocks.

Population effects remain conditional and indirect. When population size is included without controls for demographic structure, its long-run effect is weak or insignificant. However, once education or dependency structure is accounted for, population coefficients become either positive or negative depending on demographic composition. This confirms that population influences growth through human-capital quality and age structure, rather than size alone. Most

structural-break dummies are statistically insignificant, suggesting that shocks such as the democratic transition and the global financial crisis caused temporary deviations rather than permanent changes in South Africa's long-run growth trajectory. Diagnostic results, however, are not uniformly stable across specifications: Model 5 rejects the Ramsey RESET null at the 5% level ($p = 0.013$), and the CUSUM test indicates instability in Models 3–5, while CUSUMSQ remains stable in all models and the normality tests are acceptable at the 5% level. Accordingly, the core cointegration and capital results remain robust, but the affected specifications are interpreted with appropriate caution.

4.4.3. Short-run ARDL Structural Break Models

This section extends the robustness analysis by examining short-run dynamics within the ARDL framework while explicitly accounting for major structural breaks. By incorporating break dummies into the error-correction models, the analysis evaluates whether historical shocks altered the short-run adjustment process or the transmission of population and investment effects to economic growth.

Table 32: Short-Run Structural Break based on equation 13a and 13b

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Selected Model	ARDL 1,0,2	ARDL 1,0,2,0	ARDL 2,0,2,0	ARDL2,1,1,0	ARDL 1,4,4,0,0
$\Delta \log GDP_{t-1}$	—	—	-0.223 (0.068) *	-0.371 (0.000) ***	—
$\Delta \log POP_t$	—	—	—	0.549 (0.013) **	0.372 (0.664)
$\Delta \log POP_{t-1}$	—	—	—	—	0.219 (0.836)
$\Delta \log POP_{t-2}$	—	—	—	—	-1.491 (0.178)
$\Delta \log POP_{t-3}$	—	—	—	—	2.825 (0.003) ***
$\Delta \log CAP_t$	0.252 (0.000) ***	0.251 (0.000) ***	0.274 (0.000) ***	0.274 (0.000) ***	0.210 (0.000) ***
$\Delta \log CAP_{t-1}$	-0.106 (0.001) ***	-0.106 (0.001) ***	-0.074 (0.036) **	—	-0.094 (0.010) ***
$\Delta \log CAP_{t-2}$	—	—	—	—	-0.040 (0.257)
$\Delta \log CAP_{t-3}$	—	—	—	—	-0.044 (0.177)
$\Delta LIFE_t$	—	—	—	—	—
ΔDEP_t	—	—	—	—	—
ΔEDU_t	—	—	—	—	—
ΔBIR_t	—	—	—	—	—
ΔDEA_t	—	—	—	—	—
Dum1980	0.007 (0.308)	0.007 (0.302)	0.006 (0.358)	0.009 (0.284)	0.014 (0.141)
Dum1985	0.004 (0.654)	0.003 (0.683)	0.008 (0.329)	0.034 (0.001) ***	-0.008 (0.441)
Dum1994	0.015 (0.051) *	0.015 (0.057) *	0.016 (0.035) **	0.010 (0.217)	0.026 (0.005) ***
Dum2002	0.025 (0.005) ***	0.024 (0.006) ***	-0.004 (0.575)	-0.009 (0.253)	0.007 (0.371)
Dum2008	0.000 (0.971)	0.001 (0.909)	-0.016 (0.039) **	-0.022 (0.003) ***	0.007 (0.464)
Dum2020	0.004 (0.607)	0.004 (0.615)	0.004 (0.647)	—	-0.004 (0.675)
ECM ($t-1$)	-0.243 (0.000) ***	-0.240 (0.000) ***	-0.181 (0.000) ***	-0.244 (0.000) ***	-0.253 (0.000) ***
Speed of adjust.	24.3%	24.0%	18.1%	24.4%	25.3%
R-squared	0.732	0.732	0.755	0.777	0.785
Adj. R-squared	0.691	0.691	0.712	0.743	0.718
Durbin-Watson	2.38	2.38	2.22	2.16	2.19
Observations	62	62	62	62	60
Diagnostic Test					
Normality	1.329 (0.515)	2.138 (0.343)	1.354 (0.508)	0.941 (0.625)	2.101 (0.350)
Ramsey RESET	0.342 (0.562)	0.226 (0.637)	0.359 (0.552)	1.127 (0.295)	0.551 (0.462)
CUSUM	Unstable	Stable at 5%	Unstable	Unstable	Stable at 5%

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
CUSUMSQ	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%

Source: Author's Calculations

Notes: Dependent variable: $\Delta \log \text{GDP}$. All models estimated with restricted constant, no trend. p-values in brackets (). ***, **, * denote significance at 1%, 5%, and 10%. Variables marked with “—” indicates exclusion by optimal lag selection. ECM ($t-1$) captures speed of adjustment to long-run equilibrium. Each column model depicts the variant according to variables added.

In Table 32, the error-correction term ECM_{t-1} remains negative and highly significant across all specifications, with coefficients ranging between -0.18 and -0.25. This indicates that approximately 18-25% of short-run disequilibrium is corrected within one year, confirming rapid and stable convergence toward long-run equilibrium even in the presence of major political, economic, and health-related shocks. Capital accumulation continues to dominate short-run growth dynamics. A 1% increase in capital growth raises GDP growth by roughly 0.21-0.27%, with all coefficients significant at the 1% level. Lagged investment growth enters negatively in some models, reflecting short-term adjustment costs following periods of accelerated capital formation. Models 1, 3 and 4 are minor instable due to multiple dummy effect capturing regime change effects over time, all other diagnostics are satisfied.

Population growth exerts weak and lag-dependent effects. Contemporary population growth is generally insignificant, while positive effects emerge only after several lags in selected models. This pattern reinforces the view that demographic influences on economic growth operate gradually through structural channels rather than immediate cyclical responses. The structural-break evidence also strengthens the study's contribution relative to earlier South African work. Fedderke and Simkins (2012) emphasise investment and productivity, while Bhorat and Oosthuizen (2008) and Bhorat et al. (2014) stress labour-market absorption. The present results integrate these channels by showing that political, health and global shocks affect short-run growth, but that capital formation and demographic structure remain the key transmission mechanisms in the long run.

Structural-break dummies capture temporary short-run disruptions. The democratic transition (1994) and the global financial crisis (2008) are significant in some specifications, while the COVID-19 shock (2020) consistently exhibits a negative short-run effect. However, these shocks do not alter the speed of adjustment or the underlying growth process, indicating that South Africa's economy absorbs shocks without long-term destabilisation. Overall, the short-run ARDL results confirm that investment-led growth remains resilient, with demographic effects emerging only over longer horizons and structural shocks producing transitory, rather than permanent impacts. Below, we test for if the core finding of population, capital and real output is resilient

against consolidated regime shifts under both domestic and external shocks in the sample period of the baseline model.

4.4.4. Consolidated structural-dummy robustness checks

To address the degrees-of-freedom concern arising from the inclusion of several event-specific structural-break dummies in a 63-observation annual sample, additional robustness checks are estimated using consolidated shock indicators with HAC/Newey-West standard errors. The original event-specific dummies for 1980, 1985 and 1994 are grouped into a domestic/regime-transition shock dummy, while the 2002, 2008 and 2020 dummies are grouped into an external/health-shock dummy. The purpose of this check is not to reinterpret the historical events causally, but to test whether the core population and capital coefficients of the baseline model remain stable across the five models when the structural-break specification is over parameterised.

Table 33: Consolidated Structural-Dummy Robustness Checks: Long-Run DOLS Results

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
logPOP _{t-1}	0.681 (0.000) ***	0.671 (0.000) ***	0.676 (0.000) ***	0.192 (0.263)	0.648 (0.000) ***
logCAP _{t-1}	0.339 (0.000) ***	0.345 (0.000) ***	0.334 (0.000) ***	0.259 (0.000) ***	0.356 (0.000) ***
LIFE _{t-1}	—	-0.0006 (0.834)	—	—	—
DEP _{t-1}	—	—	-0.005 (0.145)	—	—
EDU _{t-1}	—	—	—	0.151 (0.000) ***	—
BIR _{t-1}	—	—	—	—	0.00008 (0.989)
DEA _{t-1}	—	—	—	—	0.005 (0.484)
DOMESTIC Shocks	-0.0024 (0.839)	-0.0014 (0.943)	-0.029 (0.192)	0.0129 (0.260)	0.003 (0.850)
EXTERNAL Shocks	0.043 (0.000) ***	0.0498 (0.000) ***	0.008 (0.784)	0.033 (0.064) **	0.0514 (0.000) ***
Constant (C)	7.584 (0.000) ***	7.608 (0.000) ***	8.211 (0.000) ***	16.865 (0.000) ***	7.618 (0.000) ***
Lead / lag	1/1	1/1	1/1	1/1	1/1
Adjusted R ²	0.998	0.998	0.998	0.999	0.998
Observations	60	60	60	60	60

Source: Author's calculations using HAC/Newey-West standard errors. Adjusted DOLS Sample: 1962-2021

Note: Dependent variable is logGDP. Domestic shocks combine 1980, 1985 and 1994. External shocks combine 2002, 2008 and 2020. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. Brackets () are p-values. Specifications are estimated using (DOLS) with a constant, fixed (lead = 1, lag = 1) with HAC/Newey-West standard errors. Variables marked with “—” indicates exclusion by optimal lag selection.

Table 33 reports consolidated structural-dummy robustness checks that reduce six event indicators to two broader controls. Population remains positive and statistically significant in Models 1, 2, 3 and 5, while capital remains positive and significant in all five specifications. In Model 4, the population coefficient becomes statistically insignificant after education is added. Given the very high centred VIFs reported in Table 24, this is evidence of imprecise separation

between two strongly trending regressors, not proof that education fully replaces or mediates the population channel. Model 4 is therefore interpreted as a conditioning robustness specification, consistent with endogenous-growth theory but insufficient for a causal education claim.

The domestic/regime-transition dummy is statistically insignificant across all specifications, suggesting that the consolidated domestic shocks do not overturn the long-run relationship between population, capital and real GDP. The external/health-shock dummy is positive and statistically significant in Models 1, 2 and 5, and marginally significant in Model 4, indicating that external and health-related shocks affected GDP levels without breaking the core findings between population and capital formation. So, these results address the degrees-of-freedom concern by showing that the core findings are not driven by an over-parameterised structural-break specification. Therefore, the consolidated dummies serve as robustness controls and not causal estimates of specific historical events.

4.5. Apartheid to Democracy regime Transmission robustness

Split-sample Dynamic Ordinary Least Squares (DOLS) models are estimated to address concerns that apartheid-era data may bias the full-sample findings. This is because data inherited from the apartheid period may be unreliable due to pre-1994 propaganda practices, the sample-split test checks whether the results differ between the apartheid and democratic regimes. Results for both the pre-1994 and post-1994 sub-samples across the five core models are in Table 34.

Table 34: Split-Sample DOLS Robustness Results by Data Regime

Panel A: Apartheid data regime / pre-1994 sample (1962-1993 after DOLS adjustments)					
Variables	Model 1	Model 2	Model 3	Model 4	Model 5
LOGPOP _t	0.677 (0.000) ***	0.869 (0.051) *	1.706 (0.000) ***	0.931 (0.197)	0.517 (0.148)
LOGCAP _t	0.339 (0.000) ***	0.301 (0.000) ***	-0.033 (0.676)	0.243 (0.001) ***	0.298 (0.002) ***
LIFE _t	—	-0.012 (0.674)	—	—	—
DEP _t	—	—	0.037 (0.000) ***	—	—
EDU _t	—	—	—	-0.022 (0.913)	—
BIR _t	—	—	—	—	0.021(0.039) **
DEA _t	—	—	—	—	-0.055 (0.159)
Constant	7.585 (0.000) ***	5.997 (0.176)	-3.34 (0.114)	5.643 (0.647)	11.419 (0.051) *
Adjusted R-squared	0.995	0.996	0.998	0.997	0.997
Observations	32	32	32	32	32
Panel B: Democracy data regime / post-1994 sample (1994-2022)					
LOGPOP _t	1.018 (0.000) ***	1.053 (0.000) ***	0.959 (0.000) ***	-0.218 (0.434)	0.949 (0.000) ***
LOGCAP _t	0.378 (0.000) ***	0.375 (0.000) ***	0.356 (0.000) ***	0.261 (0.000) ***	0.295 (0.001) ***
LIFE _t	—	-0.001 (0.281)	—	—	—
DEP _t	—	—	-0.001 (0.624)	—	—
EDU _t	—	—	—	0.224 (0.000) ***	—
BIR _t	—	—	—	—	-0.019 (0.045) **
DEA _t	—	—	—	—	0.006 (0.154)
Constant	0.628 (0.315)	0.144 (0.923)	2.333 (0.439)	23.746 (0.000) ***	4.392 (0.056) **
Adjusted R-squared	0.997	0.997	0.998	0.998	0.997
Observations	29	29	29	29	29

Source: Author's calculations

Note: Dependent variable is logGDP. Brackets () are p-values. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. Estimated using DOLS with fixed leads and lags of one and HAC/Newey-West standard errors. The split-sample estimates are used as robustness checks and not as replacements for the full-sample results.

Table 34, Panel A reports the apartheid data regime, while Panel B reports the democracy data regime. The baseline results show that population and capital formation remain positive and statistically significant in both regimes. In Model 1, the population coefficient is 0.68 in the apartheid-period sample and 1.02 in the democracy-period sample, implying an improved demographic drive on output in recent years, with both coefficients statistically significant at the 1% level. Capital formation is also positive and significant in both regimes across all models, with stronger coefficient in recent years. This indicates that the long-run population, capital and output relationship is not confined to apartheid-era observations which eliminates data bias concerns of propaganda practices of apartheid in pre-1994 data, so results remain resilience to regime changes.

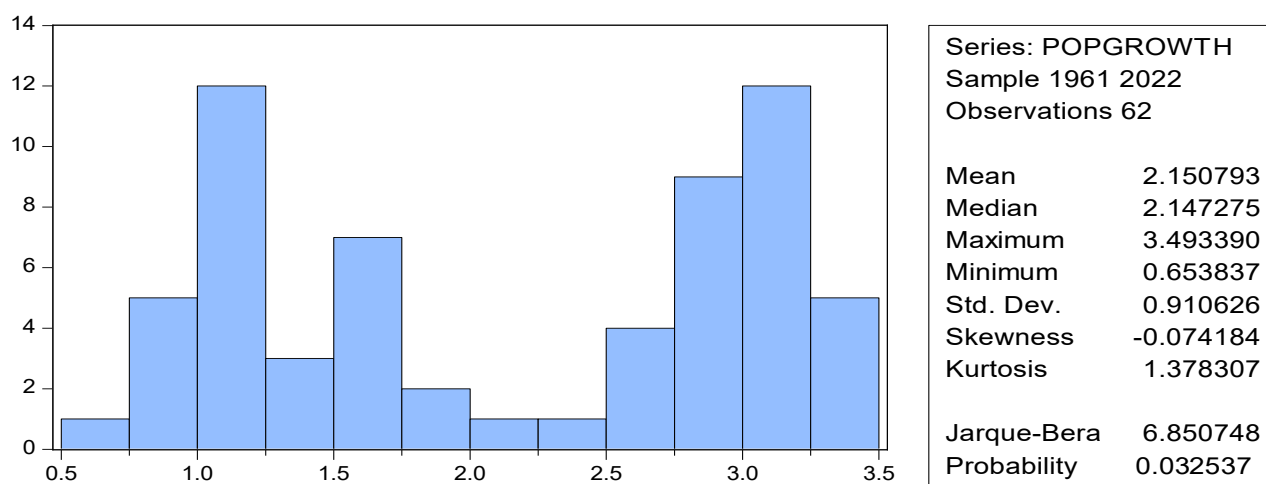
The extended specifications provide a slight difference in variables, but the sign and magnitude remain unchanged to the core conclusions. In the apartheid-period sample, population remains significant in Models 1, 2 and 3, but becomes statistically insignificant when education or fertility and mortality controls are included. In the democracy-period sample, population remains positive and significant in Models 1, 2, 3 and 5, but becomes insignificant when education is included. This pattern matches with the earlier evidence showing strong a positive drive of education to output than population. Capital formation remains positive and statistically significant in all specifications, confirming the robustness of the capital-accumulation channel. Overall, the split-sample results support the conclusion that the main long-run relationship is not driven only by the apartheid-era data regime. However, because each split sample contains relatively few annual observations after DOLS lead and lag adjustments, these results are robustness evidence and not replacements for the full-sample estimates and it should be noted that the ARDL sample-split could not be established because of sample size limits and lag powers reduced feasibility. The next section examines whether positive and negative deviations from the long-run population trend have asymmetric effects on economic growth over the 1960–2022 sample period.

4.6. Evidence from Non-Linear Autoregressive Distributed Lag Models

The linear models estimated earlier assume symmetric population effects on economic growth. However, population accelerations and slowdowns may influence growth differently. To capture this, the study employs the Non-Linear ARDL (NARDL) framework, which allows economic growth to respond asymmetrically to positive and negative deviations in population dynamics. This approach is particularly relevant for South Africa, where demographic transition, health shocks,

and migration patterns have caused population changes to deviate from long-run trends. NARDL therefore enables direct testing of whether demographic slowdowns impose different growth effects compared to population accelerations.

Figure 16: Distribution of Population Growth in South Africa (1961-2022)

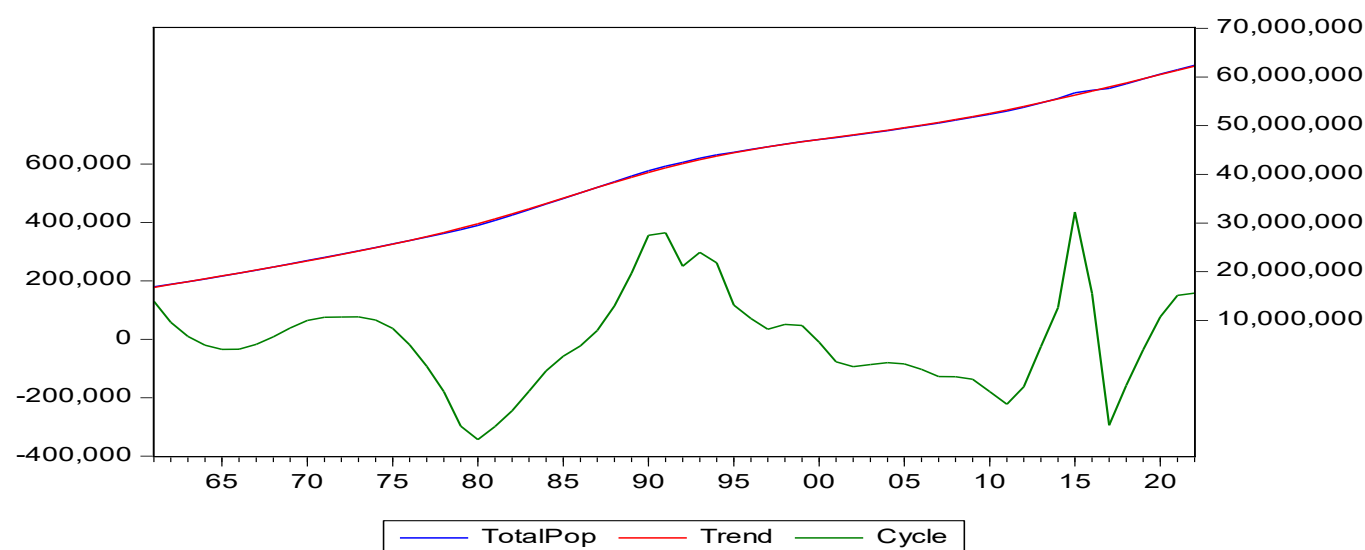


Source: Author's Decomposition of Total Population series

As shown in Figure 16, population growth remains strictly positive throughout the sample period. While this reflects South Africa's long-run demographic expansion, it limits the feasibility of directly decomposing the population-growth series within the NARDL framework. The population series is therefore decomposed into trend and cyclical components using the Hodrick-Prescott filter ($\lambda = 100$). This separates long-run demographic trends from short-run deviations around that trend.

Figure 17: Trend and Cycle Decomposition (of $\lambda = 100$)

Hodrick-Prescott Filter (lambda=100)

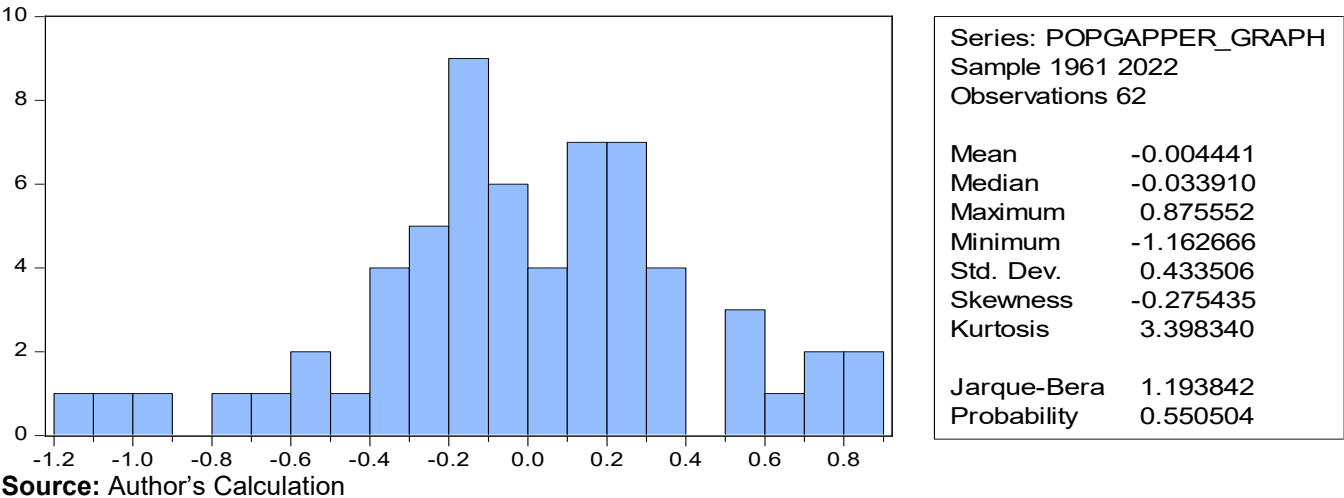


Source: Author's Calculation using HP filter, sample 1960–2022.

To overcome the limitation of partial-sum decomposition, the population series is scaled into trend and cyclical components using the Hodrick-Prescott (HP) filter with a smoothing parameter of $\lambda = 100$, appropriate for this study as it uses annual data as shown in Figure 17.

The HP filter isolates a long-run demographic trend (red line), reflecting structural population growth; and a cyclical deviation component (green line), capturing short-run fluctuations around the long-term trend. These deviations are scaled by total population and expressed in percentage terms. Importantly, the deviation series contains both positive (up) and negative (down) values, even though the original population growth rate is strictly positive. Hence, population deviations are captured in the Figure 18 below, clearly with negative (left-tail) and positive (right-tail) values.

Figure 18: Distribution of population deviation from trend using equation 14



Using trend deviations rather than raw population growth rates aligns with the interpretation of asymmetry in macro-economic adjustment. This is because people and policymakers respond not to absolute population levels, but to unexpected accelerations or decelerations relative to long-run demographic expectations, which causes movements in the total population.

Positive deviations represent periods when population growth exceeds its long-run demographic trend, implying upward pressure on labour markets, public services, and infrastructure beyond what is expected by long-term planning. Negative deviations capture periods of relative demographic slowdown, which arise from health shocks, economic stress, migration dynamics, or policy changes (Narayan & Narayan, 2010; Hatemi-J, 2012; Atil et al., 2020).

4.6.1. HP-Filter Endpoint Check for the Population Trend Gap

The Hodrick-Prescott filter can produce endpoint-sensitive cyclical components, so an endpoint-sensitivity check is conducted before interpreting the NARDL asymmetry results (Hamilton, 2018).

The standard HP filter uses a symmetric, two-sided moving average to extract the trend component. However, at the very beginning and the very end of a time series sample, for example 1960–1964 and 2018–2022, the filter may lack the historical or future data points required to calculate a balanced average. Therefore, trimming the outer edges (commonly 5 observations) ensures that the underlying data points used to interpret the NARDL model have been smoothed using a more stable, genuinely two-sided filter window. Hence, the full-sample HP-filtered population gap was compared with a trimmed-sample HP gap that excludes the first and last five observations as reported in Table 35 below.

Table 35: HP-Filter Endpoint-Sensitivity Check for the Population Gap

Diagnostic Sample Trim	Result	Interpretation
Correlation between full-sample 1960–2022 and trimmed-sample HP gaps, 1965-2017	0.9948	Very strong similarity
Maximum absolute gap, 1960-1964	0.1607	Small endpoint deviation observed.
Maximum absolute gap, 1965-2017	1.0257	Largest deviation occurs inside the sample
Maximum absolute gap, 2018-2022	0.2226	Small endpoint deviation observed

Source: Author's calculations from logPOP using HP filter ($\lambda = 100$).

Note: HP filter $\lambda = 100$ represents the smoothing parameter for annual time series data. The trimmed-sample HP gap excludes the first five (1960–1964) and last five (2018–2022) observations of the full sample to test for endpoint bias/tail instability for verifying the robustness of the cyclical component against tail distortions.

Table 35 reports deviations of the population series, showing how closely the positive and negative deviations move together over the common 1965-2017 period, with a correlation of 0.9948, indicating that the deviations are useful for symmetric testing. The largest absolute full-sample population-gap value occurs in the interior of the sample and not at the endpoints. The maximum absolute gap is 0.1607 during 1960-1964, 1.0257 during 1965-2017, and 0.2226 during 2018-2022. These results indicate that the non-linear population-deviation measure is not dominated by endpoints, making the following NARDL results robust against filter-driven artifacts. For this reason, asymmetric results are interpreted as robust time-series evidence of nonlinearity rather than strict structural causality. Based on equations (15a) and (15b), Table 33 shows results of positive and negative deviations on economic growth.

Table 36: Conditional Error-Correction, Long-Run Results and Wald Asymmetry Tests

Conditional Error-Correction Regression		
Selected Model: ARDL (3,4,4,1)		
Variable	Coefficient	p-value
$\log GDP_{t-1}$	-0.2789	(0.0006) ***
POP_{t-1}^-	-0.0116	(0.0037) ***
POP_{t-1}^+	0.0063	(0.0353) **
$\log CAP_{t-1}$	0.1097	(0.0023) ***

Conditional Error-Correction Regression		
$\Delta \log \text{GDP}_{t-1}$	-0.3835	(0.0004) ***
$\Delta \log \text{GDP}_{t-2}$	-0.1847	(0.0560) *
$\Delta \text{POP}^-_{t-1}$	0.0175	(0.4252)
$\Delta \text{POP}^-_{t-2}$	-0.0417	(0.2072)
$\Delta \text{POP}^-_{t-3}$	0.0184	(0.4987)
$\Delta \text{POP}^+_{t-1}$	0.0454	(0.0262) **
$\Delta \text{POP}^+_{t-2}$	-0.0033	(0.8397)
$\Delta \text{POP}^+_{t-3}$	-0.0256	(0.2317)
$\Delta \text{POP}^+_{t-4}$	0.0071	(0.7604)
$\Delta \text{POP}^+_{t-5}$	-0.0407	(0.0329) **
$\Delta \log \text{CAP}_t$	0.2885	(0.0000) ***
Constant (C)	4.9838	(0.0003) ***
Long-Run Impact & Cointegration		
POP^-_{t-1}	-0.0415	(0.0000) ***
POP^+_{t-1}	0.0227	(0.0078) ***
$\log \text{CAP}_{t-1}$	0.3934	(0.0000) ***
Constant (C)	17.8672	(0.0000) ***
F-Bounds statistic	14.3238	<0.001 ***
I(0) bound (5%)	2.79	<0.005 ***
I(1) bound (5%)	3.67	<0.005 ***
Cointegration decision	Very strong cointegration (reject H_0)	<0.001 ***
Wald Asymmetry Tests		
Long-run asymmetry	F (1,42) = 11.4837	0.0015 ***
Short-run asymmetry	F (1,42) = 21.4103	0.0000 ***
Diagnostic Test		
Normality (Jarque-Bera)	2.035	(0.362)
Ramsey RESET	0.016	(0.900)
CUSUM	Stable at 5%	(0.005)
CUSUMSQ	Stable at 5%	(0.005)

Source: Author's Calculations

Notes: Dependent variable is $\Delta \log \text{GDP}$. Brackets () are p-values. ***=1%, **=5%, *=10% significance levels. Models use restricted constant, no trend with HAC errors robustness. Additional Wald-test details: the long-run cumulative Wald test also gives $\chi^2(1) = 11.4837$ with $p = 0.0007$, while the short-run cumulative Wald test gives $\chi^2(1) = 21.4103$ with $p < 0.001$. Both tests reject the null hypothesis of symmetry.

The NARDL long-run results in Table 36 provide strong evidence of asymmetric population effects on economic growth in South Africa. Negative deviations of population from its long-run trend have a statistically significant adverse long-run effect, while positive deviations have a smaller positive effect. The long-run Wald asymmetry test rejects the null hypothesis that positive and negative population deviations have equal long-run effects on economic growth, $F(1,42) = 11.4837$, $p = 0.0015$. This confirms that the long-run effect of negative population deviations differs significantly from the effect of positive deviations.

The result strengthens the NARDL evidence that demographic slowdowns impose larger growth costs than the gains associated with population accelerations. Capital accumulation remains positive and highly significant, confirming its central role in sustaining long-run growth. The bounds test strongly rejects the null of no cointegration, validating a stable long-run relationship

between economic growth, population deviations, and investment. Overall, the results suggest that South Africa's economy is more vulnerable to adverse demographic shocks than it benefits from unexpected population expansions. Table 37 reports the long-run results based on equations 15a and 15b.

Table 37: Short-Run Dynamics and Wald Asymmetry Tests using equation 16

Selected Model: ARDL (3,4,4,1)		
Variable	Coefficient	p-value
$\Delta \log GDP_{t-1}$	-0.3835	(0.0002) ***
$\Delta \log GDP_{t-2}$	-0.1847	(0.0296) **
ΔPOP_t^-	0.0175	(0.3511)
ΔPOP_{t-1}^+	-0.0417	(0.1656)
ΔPOP_{t-2}^+	0.0184	(0.4772)
ΔPOP_{t-3}^+	0.0454	(0.0140) **
ΔPOP_t^+	-0.0033	(0.7981)
ΔPOP_{t-1}^+	-0.0256	(0.2004)
ΔPOP_{t-2}^+	0.0071	(0.7451)
ΔPOP_{t-3}^+	-0.0407	(0.0180) **
$\Delta \log CAP_t$	0.2885	(0.0000) ***
$ECT_{(t-1)}$	-0.2789	(0.0000) ***
Wald Asymmetry Tests		
Short-run cumulative asymmetry	F (1,42) = 21.4103	0.0000 ***
Diagnostic Test		
Normality (Jarque-Bera)	2.035	(0.362)
Ramsey RESET	0.016	(0.900)
CUSUM	Stable at 5%	(0.005)
CUSUMSQ	Stable at 5%	(0.005)

Source: Author's Calculations

Notes: Dependent variable is $\Delta \log GDP$. Brackets () are p-values. ***=1%, **=5%, *=10% significance levels. Models use restricted constant, no trend with HAC errors robustness.

The short-run NARDL results in Table 37 confirm asymmetric adjustment following population deviations. Negative population shocks significantly reduce economic growth in the short run, while positive deviations have weaker and more delayed effects. The short-run cumulative Wald asymmetry test rejects the null hypothesis of symmetric short-run adjustment, $F(1,42) = 21.4103$, $p < 0.001$. This indicates that the cumulative short-run effect of negative population deviations is statistically different from the cumulative effect of positive deviations. The finding confirms that South Africa's growth response to demographic shocks is asymmetric not only in the long run but also during short-run adjustment.

The asymmetric NARDL evidence extends the literature by showing that demographic slowdowns are more damaging than demographic accelerations are beneficial. This supports Lianos et al. (2023), who emphasise the growth risks of declining or below-trend population dynamics, and it complements Shin et, al. (2014) argument that macro-economic relationships may be

asymmetric. In South Africa, the asymmetry is economically possible because negative population deviations reflect health shocks, migration disruptions or labour-force losses, while positive deviations do not automatically raise output unless employment and investment expand at the same time with population increases. The next section compares speed adjustments.

4.7. Long-run equilibrium adjustment speed between Models

The error-correction terms $ECT_{(t-1)}$ are negative across the Engle–Granger error-correction models, autoregressive distributed lag ECM and Non-linear Autoregressive distributed lag ECM ARDL specifications, confirming adjustment toward long-run equilibrium after short-run deviations.

Table 38: Comparison of Error-Correction Adjustment Speeds Across Models

Model Number	Engle–Granger ECM	Engle–Granger ECM with dummy	ARDL ECM	ARDL ECM with dummy
Model 1	-0.108 (0.212) Speed: 10.8%	-0.166 (0.124) Speed: 16.6%	-0.092 (0.000) *** Speed: 9.2%	-0.243 (0.000) *** Speed: 24.3%
Model 2	-0.172 (0.279) Speed: 17.2%	-0.199 (0.247) Speed: 19.9%	-0.070 (0.000) *** Speed: 7.0%	-0.240 (0.000) *** Speed: 24.0%
Model 3	-0.397 (0.047) ** Speed: 39.7%	-0.412 (0.033) ** Speed: 41.2%	-0.322 (0.000) *** Speed: 32.2%	-0.181 (0.000) *** Speed: 18.1%
Model 4	-0.348 (0.068) * Speed: 34.8%	-0.365 (0.000) *** Speed: 36.5%	-0.606 (0.000) *** Speed: 60.6%	-0.244 (0.000) *** Speed: 24.4%
Model 5	-0.451 (0.049) ** Speed: 45.1%	-0.454 (0.055) * Speed: 45.4%	-0.201 (0.000) *** Speed: 20.1%	-0.253 (0.000) *** Speed: 25.3%
NARDL Error-Correction Estimate				
Model 6	ECT Coefficient		Adjustment Speed	
Short-run NARDL	-0.2789 (0.0000) ***		27.89%	

Source: Author's compilation from Engle–Granger ECM, ARDL ECM and NARDL ECM estimates.

Note: Adjustment speed is calculated as the absolute value of the ECT coefficient multiplied by 100. ***=1%, **=5%, *=10% significance levels. Brackets () are p-values.

Table 38 shows the speed of adjustment differs across the five models of the study. In the Engle–Granger ECM specifications, adjustment ranges from 10.8% to 45.4% per year, while the ARDL ECM specifications show a wider range of 7.0% to 60.6% per year. The NARDL model records an adjustment speed of 27.9% per year. This variation does not indicate inconsistency in the results; rather, it reflects differences in model specification, lag structure and the responses of demographic controls. The Engle–Granger ECM relies on residuals from long-run cointegrating equations, while the ARDL approach estimates short-run dynamics and long-run adjustment jointly within a selected lag structure. The NARDL model 6 further separates positive and negative population deviations, which changes the adjustment path by allowing asymmetric responses. Therefore, the differing magnitudes in error correction terms (ETC) show that the speed of adjustment is sensitive to how demographic dynamics, capital accumulation and structural features are modelled, but the common negative sign supports the conclusion that South Africa's

GDP adjusts toward a stable long-run equilibrium regardless of short-run fluctuations in the economy.

4.8. Summary of Key Findings

This chapter has shown that the relationship between population dynamics and economic growth in South Africa is neither automatic nor uniform. Population contributes positively to long-run economic performance when supported by capital formation and favourable structural conditions, but its short-run effects are weak and often delayed. The asymmetric results further indicate that demographic slowdowns impose greater economic costs than the gains associated with demographic accelerations. These findings support the view that the population-growth nexus in South Africa is dynamic, conditional and policy-sensitive.

Table 39: Summary of Empirical Findings

Hypothesis	Null & Alternative Hypotheses	Key Empirical Evidence	Decision	Conclusion
H1: Long-run association	H_{01}: Total population size has no statistically significant long-run association with aggregate real GDP. H_{11}: Total population size has a statistically significant long-run association with aggregate real GDP.	Tables 19–23 and 26–30 show cointegration and a positive, statistically significant long-run population–real-GDP association in the baseline and most augmented specifications.	Reject H_{01} and support H_{11} for the long-run association.	Population size is positively associated with aggregate real GDP in the long run, conditional on capital and specification.
H2: Predictive causality	H_{02}: Population dynamics provide no statistically significant predictive information for economic performance. H_{12}: Population dynamics provide statistically significant predictive information for economic performance.	Tables 14–16 show weak or inconsistent population-growth prediction at short horizons, but stronger and statistically significant predictive content from population size to real GDP at longer horizons.	Short horizons: fail to reject H_{02} . Longer horizons: reject H_{02} and support H_{12} .	Population dynamics have a delayed predictive influence on GDP. They are weak predictors at very short horizons but provide statistically significant predictive information over longer horizons.
H3: Short-run adjustment	H_{03}: No significant direct short-run population effect, and the error-correction term is not negative and significant. H_{13}: A significant direct short-run effect and/or a negative and significant error-correction term.	Tables 24–29 and 34–35 show that direct short-run population coefficients are weak or often insignificant, while error-correction terms are generally negative and statistically significant.	Fail to reject the no-direct-short-run-effect component; reject the no-adjustment component. H_{13} is supported through its adjustment condition.	The system adjusts towards long-run equilibrium, although population is not a robust immediate short-run driver; capital is the stronger short-run and long-run correlate.

Hypothesis	Null & Alternative Hypotheses	Key Empirical Evidence	Decision	Conclusion
H4: Structural change	H_{04}: Structural and regime changes do not significantly affect GDP levels or growth. H_{14}: Structural and regime changes significantly affect GDP levels or growth.	Structural-break and consolidated-dummy robustness results show that some shocks, especially external and health-related shocks, significantly affect GDP levels and short-run dynamics. However, the long-run population-capital-output relationship remains stable and cointegration is not overturned across long-run DOLS and ARDL bounds cointegration.	Reject H_{04} for significant GDP level and short-run shock effects; support H_{14} for those effects, while long-run cointegration remains stable.	Structural and regime shocks affect GDP levels and short-run dynamics, but they do not overturn the long-run population-growth relationship at both the short-run and long-run effects.
H5: Asymmetry	H_{05}: Positive and negative population deviations have equal short- and long-run effects. H_{15}: Their effects are unequal in the short run and/or long run.	NARDL Wald tests reject symmetry in both the long run and short run at the 1% significance level. Negative population deviations produce larger adverse effects on GDP than the gains generated by positive deviations at both the short-run and long-run.	Reject H_{05} and support H_{15} at both horizons.	Positive and negative population deviations have asymmetric effects on economic performance. The economy is more vulnerable to demographic slowdowns than it benefits from positive population deviations.

Source: Author's construction

Table 39 applies the five hypotheses without overlap. H_{01} is rejected for the positive long-run association. H_{02} is not rejected at the shortest predictive horizons but is rejected at longer horizons where population improves output prediction. For H_{03} , the no-direct-short-run-effect component is generally not rejected, whereas the no-adjustment component is rejected because the error-correction terms are negative and significant; and alternative is therefore supported through adjustment. H_{04} is rejected for significant level or short-run shock effects, while long-run cointegration remains stable. H_{05} is rejected by both long- and short-run Wald tests. These are separate claims about separate estimates and are not logically contradictory.

Overall, the empirical results show that population dynamics affect South Africa's economy mainly through long-run and delayed channels rather than immediate short-run effects. The long-run DOLS, ARDL and robustness results support a positive population-output association, while the short-run ECM and ARDL results show that capital accumulation is the stronger immediate driver of GDP growth. Granger causality evidence indicates that population dynamics provide stronger predictive information at longer horizons than at very short horizons. The negative and significant error-correction terms confirm adjustment toward long-run equilibrium, even though the direct short-run population coefficient is often weak. Structural-break and consolidated-dummy results show that historical shocks affect GDP levels and short-run movements, but they do not overturn the long-run population-capital-output relationship. Finally, the NARDL Wald tests confirm asymmetric effects, meaning negative population deviations have larger adverse economic effects than the gains associated with positive deviations.

The empirical results placed against the literature reviewed in Chapter Two; indicate that South Africa does not fit neatly into either a purely population-driven or purely population-constrained model. Instead, the evidence supports a conditional-effects framework, in which, population contributes to aggregate output when capital, human capital and labour-market institutions are supportive, but it can generate weaker or even adverse effects when dependency burdens, unemployment and weak investment dominate. This literature linkage strengthens the interpretation of the results and explains why policy must focus on converting demographic scale into productive capacity.

As summarised in Table 39, the hypothesis testing confirms that population dynamics matter for growth, but only in a conditional and long-term sense shaped by investment, human capital and favourable demographic structure so a demographic dividend can be realised. Population influences economic growth in South Africa mainly in the long run, while short-run growth is investment-driven. Adjustment is rapid, demographic effects are asymmetric, and regime changes cause temporary fluctuations and not structural disruptions.

4.9. Conclusion

This study investigates the relationship between population dynamics and economic growth in South Africa using linear and non-linear time-series approaches. The results indicate a stable long-run relationship in which population size supports economic growth when complemented by capital accumulation and human capital development, while short-run growth is predominantly investment-driven. Granger causality tests reveal that population influences economic growth mainly through long-run structural channels, with limited short-run feedback effects. Error-correction results confirm rapid adjustment toward long-run equilibrium following shocks. The non-linear analysis further shows that demographic slowdowns impose larger economic costs than the gains generated by population accelerations, highlighting asymmetric population-growth effects. Structural regime changes introduce temporary disruptions but do not alter the underlying long-run relationship. Overall, the findings suggest that demographic outcomes depend critically on investment capacity and human-capital absorption rather than population growth alone.

5. Introduction

This chapter summarises and interprets the empirical findings of the study on the relationship between population dynamics and economic growth in South Africa over the period 1960–2022. It evaluates how the results address the research questions, objectives, methods, and hypotheses, and explains their broader economic meaning within South African macro-economic stability. The chapter then discusses the policy implications arising from the findings, acknowledges important limitations, and offers recommendations for future research and policy.

5.1. Summary of Key Findings

The empirical evidence yields a consistent and robust set of findings across all econometric techniques employed. The central result is that population dynamics influence economic growth in South Africa primarily through long-run structural channels, rather than through short-run cyclical mechanisms. First, population size has a statistically significant positive effect on economic growth in the long run, conditional on capital accumulation and human capital development. This aligns with the population-driven and demographic-dividend literature, including Bloom et al. (2001), Bloom and Williamson (1998), and Furuoka (2005), but it also qualifies that literature by showing that the South African effect is not automatic. By contrast, population growth rates exert weak and delayed short-run effects, consistent with the conditional and neutral strand of the literature that emphasises institutions, productivity and labour-market absorption capacity as conditions for accommodating a growing population.

Second, the causality analysis shows strong and robust long-run Granger causality running from population size to economic growth, while short-run causality is weak and occurs at longer lags. This confirms that population dynamics act as a long-term driver of growth rather than responding to short-term economic fluctuations. Third, the error-correction results reveal rapid adjustment toward long-run equilibrium following shocks. Although South Africa experiences considerable short-run volatility, deviations from long-run equilibrium are corrected relatively quickly, indicating stable underlying relationships between population, capital accumulation, and output.

Fourth, the non-linear analysis uncovers important asymmetries. Negative demographic deviations, such as population slowdowns associated with health crises, job losses or migration disruptions, reduce economic growth more strongly than positive deviations increase it. This demonstrates that adverse demographic shocks impose disproportionately large economic costs.

Finally, the structural-break analysis indicates that major political and economic regime changes affect short-run growth outcomes but do not alter the long-run population-growth relationship.

Despite institutional and political transitions, the long-run demographic-economic linkage remains structurally stable. In short, the findings confirm that population dynamics matter for growth in South Africa, but only in a conditional and long-term sense, shaped by investment, human capital, and demographic structure. Altogether, the results demonstrate that population growth is not an autonomous engine of economic expansion, and nor inherently harmful or beneficial on its own. Its growth effects depend critically on complementary factors, particularly capital accumulation, education, labour-market absorption, and broader structural conditions.

5.2. Discussion of Findings in Relation to the Literature

The finding that population size is positively associated with aggregate real GDP in the long run is consistent with the population-driven and conditional-growth strand of the literature. Bloom, Canning and Sevilla (2003) argue that demographic change can support economic growth when it is accompanied by human-capital development, labour absorption and institutional capacity. Similarly, Kelley and Schmidt (2005) show that the economic effect of population growth depends on age structure, savings, dependency burdens and policy conditions. The South African results support this conditional interpretation. Population size is positively related to output in the long run, but the strength of the relationship depends on capital formation, education, demographic structure and structural shocks. This means that population growth is not automatically growth-enhancing; it becomes beneficial when the economy has the productive capacity to absorb and employ the growing population.

The results also align with South African evidence that investment, human capital and labour-market absorption are central to translating demographic change into economic performance. Fedderke and Simkins (2012) emphasise the importance of capital accumulation and productivity in South Africa's long-run growth process, while Bhorat et al. (2014) show that labour-market structure and employment absorption shape the distribution of growth. The present study extends this literature by showing that the population-output relationship is positive in the long run but weaker and more unstable in the short run. The NARDL results further show that negative deviations of population from its long-run trend have stronger adverse effects than positive deviations, suggesting that demographic slowdowns may impose larger growth costs than the gains from demographic accelerations.

The finding that the apartheid-to-democracy transition did not overturn the long-run population-growth relationship requires careful interpretation. The 1994 transition represented a major political and institutional break, but it did not immediately remove the structural economic constraints inherited from apartheid. Labour-market segmentation, spatial inequality, uneven education quality, skills mismatch, concentrated ownership of economic-assets and weak labour absorption continued to shape how population growth translated into economic performance after democracy. As a result, the transition affected the policy environment and short-run level dynamics, but it did not fully transform the underlying long-run relationship between population, capital formation and aggregate real GDP.

This explains why the structural-break and robustness results show some significant dummy effects, while the core population and capital coefficients remain positive and significant. The regime transition changed the conditions under which population growth operated, but the basic macro-economic channel remained: population growth contributes to output when supported by capital accumulation, human-capital development and productive employment absorption. Therefore, the results should not be interpreted as saying that the 1994 transition was economically unimportant. Rather, they suggest that the transition did not create a complete structural break in the long-run population-output relationship because demographic expansion, capital formation and labour absorption remained linked through persistent structural constraints.

The findings are also theoretically consistent with the growth-accounting framework. From a growth-accounting perspective, the positive long-run association between population, capital formation and real GDP suggests that labour-supply and capital-accumulation channels are important for South Africa's aggregate output. However, because the study does not estimate factor shares or total factor productivity directly, the results are interpreted as supportive of growth-accounting logic rather than as a formal growth-accounting decomposition.

From a two-sector structural transformation perspective, the findings suggest that population growth becomes growth-supporting only when the economy can absorb additional labour productively. South Africa's structural unemployment, skills mismatch and spatial inequality limit the conversion of population growth into a full demographic dividend. Therefore, the dissertation concludes that population growth is not automatically beneficial or harmful; its effect depends on capital accumulation, human-capital formation, labour absorption and structural transformation. Hence, these theories are used to strengthen the theoretical foundation and interpretation of the empirical findings, and not to introduce additional empirical models.

5.3. Policy implications

The policy implications follow directly from the dissertation's estimates. Capital is positive and statistically significant in the baseline and augmented long-run specifications (Tables 20, 23 and 29) and is the stronger immediate correlate in the short-run models (Tables 27–28, 30, 32 and 37). This pattern matches with Fedderke and Simkins (2012), who identify investment and productivity as central to South Africa's long-run performance. Therefore, the evidence supports maintaining productive public infrastructure, electricity reliability and conditions that crowd in private capital; it does not estimate the causal return to any single project, it is a broader advice.

The human-capital and labour-absorption recommendation is conditional rather than mechanically inferred. Table 24 shows that the education-augmented population coefficient is unstable under severe population–education collinearity, so the dissertation does not claim an isolated causal schooling coefficient. Instead, the result is read alongside South African evidence that education quality, skills matching and employment absorption condition growth (Burger & von Fintel, 2014; Bhorat et al., 2014; Spaull, 2013). The predictive-causality direction from population to aggregate GDP (Tables 14–16 and 21) indicates that demographic conditions contain useful forecasting information and supports incorporating population paths into macro-economic planning; it does not, by itself, establish a structurally causal or labour-intensive growth mechanism.

The resilience recommendations are likewise tied to reported evidence. Negative and significant error-correction terms (Tables 27–28, 30, 32 and 37–38) support timely stabilisation when the system departs from equilibrium. Consolidated-dummy results (Table 33) show sensitivity to external and health-related shocks without overturning the long-run relationship, while the NARDL Wald tests (Tables 36–37) show that negative population deviations carry larger output costs than positive deviations yield gains. These findings justify protecting health and education capacity, monitoring migration and working-age participation, and maintaining investment continuity across shocks. They do not identify a policy-specific treatment effect. The recommendations align with the National Development Plan's emphasis on employment, capabilities, infrastructure and inclusive growth (National Planning Commission, 2012).

Table 40: Alignment of Hypotheses, Empirical Insights and Policy Implications for South Africa

Hypothesis	Core Empirical Insight	Policy implications for South Africa
H ₁ : Long-run association	Population size is positively associated with aggregate real GDP mainly in the long run; short-run growth is more strongly investment-driven.	Prioritise long-term absorption capacity through capital formation, infrastructure, and skills development rather than relying on population expansion alone.

Hypothesis	Core Empirical Insight	Policy implications for South Africa
H ₂ : Predictive causality	Population size provides strong predictive information for GDP in the long-run, while short-run population growth is weaker to GDP growth.	Integrate demographic trends into macro-economic planning, labour-market policy and long-term development strategies.
H ₃ : Short-run Adjustment	Error-correction terms show adjustment toward long-run equilibrium following shocks, although short-run population coefficients are weaker.	Use timely countercyclical investment, employment and health policies to stabilise short-run shocks.
H ₄ : Structural change	Structural shocks affect GDP levels and short-run dynamics, but do not overturn the core long-run population-capital-output relationship.	Institutionalise long-term development policies so that demographic planning and investment remain stable across regimes and shocks.
H ₅ : Trend-gap asymmetry	Demographic slowdowns or below-trend deviations impose larger economic costs than population accelerations in the NARDL results.	Strengthen resilience to negative demographic shocks through healthcare, migration management, labour-force participation and employment-absorption policies.

Source: Author's compilation

Table 40 shows that South Africa's growth performance depends not only on population size, but also on how effectively demographic change is absorbed through investment, skills development, labour-market opportunities and stable institutions. Policy should therefore focus on long-term capital deepening, stronger human-capital formation, improved labour absorption and better demographic planning.

Actionable policy recommendations aligned with these implications are presented in Table 41, which identifies specific policy themes, key empirical findings and policy recommendations to support implementation and monitoring based on the empirical evidence.

Table 41: Actionable Policy Recommendations based on Empirical Findings

Policy Theme	Key Empirical Finding	Policy Recommendation
Investment-Led Growth	Capital is positive in long-run Tables 20, 23 and 29 and dominates the immediate short-run evidence in Tables 27–28, 30, 32 and 37; consistent with Fedderke and Simkins (2012).	Scale up infrastructure investment; crowd-in private capital; strengthen regulatory certainty.
Human Capital Conditionality	Tables 23–24 show education conditioning, with Table 24 reporting severe logPOP–EDU collinearity; interpretation is supported by Burger and von Fintel (2014), Bhorat et al. (2014) and Spaul (2013).	Improve education quality; expand apprenticeships; align skills supply with industrial demand. Support skill acquisition with employment needs.
Demographic Dividend	Dependency-ratio effects are modelled in Tables 23, 25, 29 and 31, while labour-absorption implications are interpreted with South African labour-market evidence in Bhorat et al. (2014).	Promote labour-absorbing sectors; reduce hiring costs; support Small-Medium Enterprise expansion and entrepreneurship to absorb labour force from population so unemployment stays low.
Asymmetric Demographic Shocks	Tables 36–37 reject long- and short-run symmetry; negative population deviations have the larger output cost.	Protect health and education spending; strengthen shock-response capacity. Improve education quality with skills training.
Demographic Quality	Tables 23–24 show that education is positively associated with GDP in the education-augmented specification, while severe population–education collinearity prevents clean separation of the population and education effects.	Expand early childhood development; support female labour participation; ensure family-planning access.
Policy Monitoring & Data	Tables 18, 25, 28 and 31–34 show structural-break and regime sensitivity, while Tables 19, 26, 29 and 31 support stable long-run cointegration; this motivates continuous monitoring.	Institutionalise monitoring and evaluation; integrate administrative data systems. Integrate the informal sector into the formal economy and reduce scarce skills gaps.

Source: Author's Construction

Table 41 suggests actionable recommendations based on empirical results; the policy matrix reinforces the study's core finding that population dynamics influence growth only when supported by sustained investment, human-capital development, labour-market absorption, and effective institutions. The recommendations are therefore evidence-led rather than generic, and they flow directly from the empirical results reported in this dissertation.

5.4. Study limitations

This study has some limitations. First, the analysis relies on annual time-series data, which may conceal short-term fluctuations, contextual factors and adjustment dynamics that could be captured using higher-frequency data. Second, the use of aggregate national data means that regional and provincial demographic differences within South Africa are not explicitly examined. Third, although the study incorporates structural breaks and a nonlinear framework, the selected variables may not fully capture all institutional, social, and demographic dimensions that shape economic growth. Fourth, the single-country design strengthens contextual relevance but limits broad generalisation to other countries without comparative analysis.

Fifth, a limitation of the aggregate population variable is that it does not distinguish between natural population increase (births minus deaths) and net migration. These components may have different economic effects. Immigration can directly expand the working-age labour force, while natural increase initially raises the dependency burden. Decomposing these channels would require migration-specific time-series data, which are not consistently available for the full sample period. The results should therefore be interpreted as reflecting the aggregate population effect, encompassing both channels of natural increase and increased immigration.

A further limitation relates to historical data quality, especially during the apartheid period. Official demographic and labour-market data from that period may be affected by racially fragmented administration, incomplete coverage of homeland populations and changes in statistical definitions over time. Although the study uses standardised international and national data sources and applies structural-break robustness checks, the results may reflect some long-run variation changes in measurement coverage as well as real demographic-economic change.

5.5. Future Research Agenda

The limitations of this study create several clear directions for future research. First, future studies could extend the analysis from national time-series data to provincial panel data using Statistics South Africa provincial profiles, regional census data and community survey data. A provincial panel approach would allow researchers to examine whether the population-growth relationship

differs across provinces such as Gauteng, Western Cape, KwaZulu-Natal, Eastern Cape and Limpopo, where migration, employment absorption, urbanisation and industrial structure differ substantially.

Second, future research should incorporate migration more explicitly. Internal migration and cross-border migration are important in South Africa, but they are not fully captured by total population figures. Data from Statistics South Africa, the Southern African Migration Programme and census-based migration modules could be used to distinguish natural population growth from migration-driven population change. This is important because migration may affect economic performance differently from fertility-driven population growth, especially in urban labour markets, informal settlements and border provinces.

Third, future studies could use spatial econometric methods to test whether population growth in one province affects economic outcomes in neighbouring provinces. South Africa's economy is spatially interconnected: migration to Gauteng or Western Cape or KwaZulu-Natal may affect labour supply, housing demand and service pressure in destination provinces, while also affecting household income, remittances and labour availability in sending provinces. Spatial lag, spatial error or spatial Durbin models could therefore provide a deeper understanding of population-growth spillovers.

Fourth, future research could apply panel ARDL or panel NARDL methods using provincial data. A panel ARDL framework would allow researchers to distinguish short-run provincial differences from long-run common relationships, while a panel NARDL model could test whether positive and negative population shocks affect provincial economic outcomes asymmetrically. Future studies could also explore quasi-experimental or instrumental-variable strategies using historical migration restrictions, changes in provincial settlement patterns, policy-induced migration shifts or census-based demographic shocks, provided the relevance and exclusion restrictions can be defended carefully.

5.6. Conclusion

This study examined the effect of population dynamics on economic growth in South Africa with econometric estimation covering 1960–2022. The analysis incorporated key variables, including total population, population growth, gross domestic product (GDP), capital formation, education (human capital), life expectancy, dependency ratio, fertility and mortality indicators, to capture the multidimensional nature of the population-growth relationship. This study shows that population dynamics are a long-run structural determinant of economic growth in South Africa rather than a

short-run growth engine. In the long run, population size contributes positively to economic growth only when supported by sustained capital accumulation, human-capital development, labour-market absorption, and a favourable demographic structure. In the short run, economic growth is driven primarily by investment, and population growth has no systematic immediate effect. The results further demonstrate that demographic slowdowns impose larger economic costs than the gains associated with demographic accelerations.

Although political and economic regime changes affect short-term growth outcomes and level movements of macro-demographic factors, they do not disrupt the long-run population-growth relationship. Therefore, population growth is not a substitute for sound economic policy. South Africa's long-term growth prospects depend on its ability to convert demographic trends into productivity gains through sustained investment, quality education, labour-absorbing growth, and institutional stability. By integrating demographic theory, rigorous econometric analysis, and policy interpretation, the study provides evidence that the population-growth nexus in South Africa is dynamic, conditional, and highly policy-sensitive and should be integrated into development planning.

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UNIVERSITY OF SOUTH AFRICA

Title of thesis/dissertation:

The Effect of Population Growth on Economic Growth in South Africa for the Period of
1950 to 2022.

KEY TERMS:

Population dynamics; Population growth; Economic growth; South Africa; Demographic change; Demographic transition; Fertility rates; Mortality rates; Life expectancy; Age structure; Dependency ratio; Human capital; Capital accumulation; Education attainment; Long-run economic growth; Development economics; Time-series analysis; Cointegration analysis; Autoregressive Distributed Lag (ARDL) models; Nonlinear ARDL (NARDL); Granger causality.