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An Investigation into the Influence of Infrastructure Investment on Economic Development and its Spatial Distribution in South Africa

Theses of the Ph.D. Dissertation

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1. Research Background and Motivation

Sustained economic progress is of critical significance to policymakers and scholars globally, particularly in developing nations striving to bridge the standard of living gap with more advanced economies. South Africa, an exemplar of an emerging economy, is situated at the southernmost point of the African continent. The nation's official incorporation into the BRICS bloc in late 2010 augmented its global stature and notoriety. As the continent's most industrialized nation, South Africa maintains a moderate yet open economy that actively participates in international trade and finance. The country serves as a distinctive case study for examining economic performance within an emerging economy context. This is attributed to its colonial and apartheid legacies, persistent income inequality, chronically high unemployment rates, and the regional economic growth and development disparities within the country. South Africa's post-apartheid constitution emphasizes social and economic rights, positioning it among the most progressive globally. The nation benefits from strong institutional frameworks and a critical media, alongside a thriving civil society and an independent judiciary (Francis and Webster, 2019). Despite a substantial endowment of natural resources and relatively modern infrastructure, South Africa has encountered challenges in achieving sustained economic development and poverty alleviation. The country's GDP growth has been lacklustre, averaging 1.82% from 2010 to 2022 (World Bank, 2024), markedly below the thresholds necessary to surmount systemic inequality and unemployment. This dissertation investigated the role of infrastructure investment in propelling economic development and its spatial allocation within South Africa. Furthermore, it evaluated the country's capacity to converge with the per capita income levels of the Organisation for Economic Cooperation and Development (OECD) member countries.

Investment in infrastructure is broadly recognized as a crucial driver of economic growth and development, as it enhances productivity, supports commerce, and creates job opportunities (Aschauer, 1989; Romp and de Haan, 2005; Fedderke and Garlick, 2008; Estache and Fay, 2009; Heintz et al., 2009; Calderon and Serven, 2010; and Kumo, 2012). However, the effectiveness of infrastructure investment is contingent upon its distribution, quality, and maintenance. In South Africa, infrastructure investment has been distributed unevenly, with affluent regions such as Gauteng and the Western Cape receiving the majority, while less affluent provinces like Limpopo and the Eastern Cape fall behind (Statistics South Africa, 2023). This regional inequality exacerbates income disparities and obstructs national economic convergence. Moreover, South Africa's ability to reach OECD income levels is constrained by

structural challenges, including high unemployment, low skill levels, and inefficient service delivery by the government (Lewis 2002; World Bank 2018).

2. Actuality and Justification of the Study

In South Africa, the legacy of colonialism and apartheid, which was based on racial and spatial isolation, continues to result in entrenched disparity. The country is recognised as the most unequal society as its Gini coefficient of around 0.63 is the highest amongst the countries measured for income inequality (Sulla et al., 2023). Moreover, mining economy has been hampered by all of the barriers of the resource curse phenomenon, which is simply characterised as an intriguing situation in which a resource-rich country performs poorly economically. In general, these economies undergo structural adjustments and slower development than non-mineral exporters, and their industrial structures are more capital-intensive (Altman and Meyer, 2003). For structural advancement to take place in an economy, it is obliged to transition from output activities in the primary sector driving economic growth to those in the secondary sector. This transitional process is known as industrialisation and urbanisation (Kuznets, 1955).

The new democratic dispensation inherited an economy which had been in decline for over a decade. Following the democratic transition the African National Congress (ANC) after 1994, primary emphasis was placed on political enfranchisement, while significant economic transformation was largely in abeyance. Ownership within the economic sector has predominantly remained unaltered, thereby sustaining disparities in income and wealth created by colonialism, which was further entrenched during the apartheid regime. The initiative referred to as the "second phase of transition," which was intended to facilitate economic reform, has largely stagnated, serving the interests of a limited elite (Turok, 2019).

South Africa's constitution prioritises social and economic rights, making it among the most progressive in the world. The country has strong institutions, critical media, a thriving civil society, and an independent judiciary (Francis and Webster, 2019). Moreover, the country is at a crossroads between opposing forces, including a modest, open economy that participates in international commerce and finance, and a socio-economic scenario that necessitates significant policy changes. The country's employment market, with its split characteristics, lies at the heart of its socioeconomic predicament. The highly skilled segment experiences excess demand, while the poorly skilled segment is dominated by excess supply (Francis and Webster, 2019).

The South African government developed comprehensive policy documents identifying its challenges and earmarked investment in public infrastructure as critical to address socio-economic disparities. It's main policy framework, the National Development Plan 2030 (NDP), seeks to reduce income inequality from 0.70 to 0.60 and increase the infrastructure investment percentage of GDP to 20% by 2030.

Another element which hinders the country's economic performance is that since October 2007, Eskom, the national electricity provider of South Africa, has initiated a series of strategically planned power outages, known as loadshedding, have been a challenge for both businesses and households (Inglesi-Lotz, 2023). Individuals with lower incomes are disproportionately impacted due to unreliable electricity supply, rising energy costs, and limited financial capacity to mitigate such disruptions, given their socioeconomic conditions (Inglesi-Lotz, 2023). This ongoing deficit in power supply has notably affected employment rates within the manufacturing sector, which is highly dependent on energy. Enterprises lacking the resources to invest in costly diesel generators have been forced to halt production or completely shut down, causing significant harm to employment in a nation already grappling with severe income inequality. During the past two fiscal years (2023-2024), the frequency of load shedding occurrences has escalated to levels that seem to be incessant. In 2023, South Africans faced load shedding for a total of 332 days (Ballim, 2025).

Although institutional economics offers a robust framework for comprehending long-term developmental trajectories, this investigation purposefully foregrounded infrastructure investment in its analysis of South Africa's economic growth, in light of an amalgamation of theoretical, empirical, and policy-related considerations. The focus of this study on infrastructure investment represents a carefully selected, contextually relevant, and methodologically rigorous approach. It directly evaluates the South African state's primary economic policy, provides a quantifiable metric for assessing the redress of spatial apartheid inequalities, and produces definitive findings that hold immediate significance for budgetary and planning authorities. The findings, particularly the inverse relationship between total investment and growth, compellingly indicate that even the appropriate type of investment (infrastructure) can be ineffectual in an unsuitable institutional environment, thereby implicitly reinforcing the critical importance of institutions without them being the primary focus of analysis.

While acknowledging the contributions made of existing studies, we applied these theoretical frameworks to investigate the relationship between infrastructure investment, economic progress, and convergence. Using panel data econometric models, the study

investigated the implications of infrastructure investment on real GDP per capita throughout South Africa's provinces and examined the country's progress towards OECD values.

The policy recommendations are derived from the empirical findings, focus on infrastructure investment, inclusive growth, and structural reforms. We investigate the infrastructure investment and convergence phenomena in an African context using this approach. This study's research contribution to the greater discussion of economic development in an emerging economy setting in several ways: (i) empirical evidence of a relationship between infrastructure investment and per capita income, (ii) empirical evidence of regional income and investment disparities, (iii) identified regional limitations that hinder national and international convergence, (iv) developed context specific actionable policy recommendations to the South African government to address systemic challenges.

The research is of particular relevance in the context of South Africa's persistent electricity crisis, characterized by load-shedding and economic stagnation. The COVID-19 pandemic has further revealed and intensified existing vulnerabilities. With the government facing challenges in achieving its NDP objectives and addressing public dissatisfaction, this study provides actionable insights to inform future policy and investment decisions. This dissertation addresses a suggestive gap in the literature by offering empirical evidence on the role of infrastructure in economic development and convergence within a highly unequal emerging economy. Its findings emphasize the necessity for targeted, efficient, and equitable infrastructure investment to promote inclusive growth and mitigate spatial disparities. The study not only contributes to academic discourse but also bears practical significance for South Africa's socio-economic development and its ambitions to converge with advanced economies, thereby enriching the literature on emerging, resource-rich, middle to upper-middle income economies.

3. Objectives, Questions and Hypotheses of the Study

This study has two components both focused on five main topics: 1) real GDP per capita, 2) infrastructure investment, 3) regional economic development, 4) regional income and investment disparity, and 5) convergence. These topical concepts are presumed to be immensely independent but simultaneously sequential, which establishes the feasibility of developing a detailed panel dynamic model that can be used to model ongoing infrastructural, demographic changes, capital formation trends in South Africa. In accordance with these topical challenges, the study's overarching objective is to evaluate the link between

infrastructure investment and regional economic performance in South Africa. After rigorous interrogation of a vast body of literature the following research objectives, research questions and research hypotheses were formulated.

3.1 Part 1: Domestic Analysis of South Africa's 9 Provinces

Research objectives:

i) To determine the relationship between infrastructure investment and real GDP per capita in South Africa.

ii) To empirically estimate infrastructure investment effects on regional economic development in the 9 provinces in South Africa.

iii) To determine the provincial disparity in infrastructure investment allocation between the 9 provinces in South Africa.

iv) To determine the income disparity between the 9 provinces in South Africa.

Research question:

In alignment with these research objectives, this study answered the following research questions: Is the South African government's substantial strategic commitment to infrastructure yielding benefits in terms of economic development and spatial equity? What positive and negative effects does infrastructure investment have on economic development over the period 1996-2021? The critical focus of this research question is to identify any existing link between infrastructure investment and regional economic performance. As well as to determine the causal effects of these on themselves and on the total investment and employment, which in turn contributes to regional economic development. Moreover, testing three research hypotheses.

Research hypotheses:

> *H_1: Infrastructure investment has a long term significant positive effect on aggregate output i.e. real GDP per capita.*
> *H_2: A significant relationship exists between infrastructure investment and real GDP per capita.*
> *H_3: Income disparity in South Africa has widened.*

3.2 Part 2: International Comparative Analysis: South Africa-OECD

Research objectives:

i) To examine income per capita convergence or divergence between South Africa and the OECD.

ii) To empirically estimate the steady state long term relationship between SA and the OECD.

Research question:

In accordance with these research aims; this study addressed the following research question: To what extent could a steady state long term relationship in GDP per capita be observed between South Africa and the OECD over the period 1980-2019? The primary goal of this research question is to examine the income per capita of South Africa over the investigation period in order to ascertain whether the country is converging toward or diverging from the average GDP per capita of the OECD. Furthermore, testing the research hypotheses.

Research hypotheses:

> *H_4: The disparity in per income per capita convergence between South Africa and the OECD has decreased.*

The study examined the correlation between infrastructure investment and regional economic development in South Africa's 9 provinces using panel data from 1996 to 2019. Thereafter, it examined the extent to which a steady state long term relationship could be observed over the period 1980-2019 between South Africa and the OECD.

4. Empirical Strategy

4.1 Domestic Analysis of South Africa's 9 Provinces

Examination into the relationship between the dependent variable real GDP per capita and the independent variables employment, domestic investment, ICT investment, construction investment, electricity investment and transport investment are commonly performed through long and short run analysis. We applied three estimation methods to assess the various econometric approaches to investigate this relationship, as elaborated in earlier chapters. These methods included Pooled OLS, OLS with Fixed Effects, the and the one step system GMM method (Blundell and Bond, 1995). Our analysis mainly relies on the latter, as it has been widely used in recent studies on the topic (Santo, 2015; Kitonyo and Kathanje, 2018; Zhou *et*

al., 2021; Asanta *et al*., 2022; Dao and Le, 2024). Initially, the estimations were conducted using the Least Squares method, adept at handling country-specific heterogeneity. The Hausman test was then used to decide between fixed or random effects models.

In studies exploring the link between infrastructure investment and economic growth, the GMM estimations in both first difference and system forms are used to address the problem of variable endogeneity (Zhou et al., 2021). There are bidirectional relationships between these factors. The GMM System Estimator employs both difference and level equations: for the difference equation, lagged values of the variables in levels act as instruments, while in the level equation, instruments are derived from their first differences. This set of equations is jointly estimated using GMM. According to Monte Carlo simulations by Blundell and Bond (1998), the system estimator proves to be the most effective. Overidentification assessments include the Hansen test and Arellano and Bond's second-order serial correlation test. The statistical outcomes from the Hansen test verify the instrument validity. Regarding the serial correlation test, results confirm there is no second-order serial correlation in the residuals. Throughout all regressions, coefficient standard deviations are corrected using White's method to mitigate possible heteroskedasticity.

All multivariate econometric modelling was conducted using STATA and EViews 12 software. The relationship is tested using the series level values, the logical framework is shown in Equation 1 for the provincial analysis.

$$LnGDP = \beta_0 + \beta_1 LnGDP_{t-2} + \beta_2 LnEMP_{t-2} + \beta_3 LnGFCF_{t-2} + \beta_4 LnCON_{t-2} + \beta_5 LnICT_{t-2} + \beta_6 Ln\ TRA_{t-2} + +\beta_7 Ln\ Elec_{t-2} + u_t \quad (1)$$

4.1.1 Dynamic Pooled Panel Ordinary Least Squares (OLS)

Dynamic panel data estimation is utilized for the examination of datasets characterized by both cross-sectional and time-series dimensions, compiled from identical subjects across several temporal intervals. As stated by Gujarati (2003), the amalgamation of time-series and cross-sectional data not only augments the dataset's magnitude but also enhances its quality beyond the capabilities of either cross-sectional or time-series data alone. Within the context of panel analysis, control variables are employed to address heterogeneity concerns, acknowledging the intrinsic diversity of study units such as firms, countries, or regions. Pooled OLS is a statistical technique for estimating a linear regression model's parameter. Yu (2010) applied the methodology in the investigation of whether or not democratic institutions affect international trade and economic growth in 157 IMF member states between 1962-1998. The main purpose

of the OLS approach is to reduce the sum of the squared discrepancies between the values predicted by the linear model and the actual values. The elementary form of a linear regression model is illustrated by Equation 2 (Wooldridge, 2010:49).

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_K x_K + \varepsilon \quad (2)$$

where:

Y is the dependent variable.

$x_1, x_2, \ldots, x_K$ are the independent variables.

$\beta_0, \beta_1, \ldots, \beta_K$ are the parameters to be estimated.

ϵ is the error term.

4.1.2 Dynamic Panel Data Analysis: Generalised Method of Moments (GMM)

In static panel data models, the methodologies employed include Pooled Ordinary Least Squares (OLS), fixed effects (FE), and random effects (RE). The RE estimator was omitted due to the rejection of the null hypothesis RE versus FE by the Hausman test. Consequently, the regression coefficients are estimated utilizing fixed effects. Additionally, a dynamic panel data approach was introduced. Models are deemed dynamic when the values of the dependent variable from prior years, or lagged values, exert an influence on its current year's values. This indicates that the behaviour of economic variables in a given period is shaped by their historical behaviour. Consequently, lagged values ought to be considered as explanatory factors when analysing interactions. For instance, the Gross Domestic Product (GDP), as an indicator of economic production within a specified timeframe, relies on the metric from the preceding year, a phenomenon referred to as GDP persistence. This imparts the model with attributes of endogeneity and dynamic effects, which are ignored by static models. The economic and demographic diversity of each of the 9 South African provinces has been discussed in chapter (4). The multifaceted nature of this heterogeneity necessitates the consideration of effects specific to each province within the relatively short investigation period of 25 years (1996-2021). The methodology, frequently utilized within the growth literature to address the aforementioned, employs the System Generalized Method of Moments (GMM). The estimator employed, System GMM, addresses issues related to serial correlation, heteroskedasticity, and endogeneity of certain explanatory variables (Leitao, 2010). These econometric challenges were addressed by Arellano and Bond (1991), as well as Blundell and Bond (1998, 2000). To estimate the dynamic model, we adhered to the methodology proposed by Blundell and Bond (1998, 2000).

In the empirical assessment of the nexus between infrastructure investment and economic development, real gross domestic product (RGDP) was utilized as the dependent

variable. To quantify the level of infrastructure investment, four sub-categories of the total investment were specifically employed namely, construction, transport, information and communication technology (ICT), and electricity investment.

The study employs the generalized one-step system method of moments (GMM) estimators formulated for dynamic panel data models, as introduced by Holtz-Eakin et al. (1990), Arellano and Bond (1991), and Arellano and Bover (1995). Examine the subsequent regression equation:

$$Y_{it} - Y_{it-1} = (\propto -1)Y_{it-1} + \beta_0 X_{it} + \mu_i + \varepsilon_{i,t} \quad (3)$$

Where Y_{it} is the logarithm of the real GDP per capita, $Y_{it} - Y_{it-1}$ is the rate of income per capita growth, Y_{it-1} is the initial level of income per capita, X_{it} represents a vector of explanatory variables, μ_i is an unobserved country-specific effect, ε_i is the error term and the subscripts i and t represent country and time period respectively. Rewriting (3), we obtain:

$$Y_{it} = \alpha Y_{it-1} + \beta_0 X_{it} + \mu_i + \varepsilon_{i,t} \quad (4)$$

To eliminate the province specific effects, we take the first differences of (4):

$$Y_{it} - Y_{it-1} = a(Y_{it-1} - Y_{it-2}) + \beta_0 (X_{it} - X_{it-1}) + \varepsilon_{it} - \varepsilon_{it-1} \quad (5)$$

Levine et al. (2000) advocate for the utilization of instruments for two principal reasons: firstly, to address the probable endogeneity between infrastructure investment variables and economic growth; and secondly, due to the correlation of the newly formulated error term $(\varepsilon_{it} - \varepsilon_{it-1})$ in Equation 5 with the lagged dependent variable $(Y_{it-1} - Y_{it-2})$. The GMM panel estimator employs the subsequent moment conditions.

$$E[Y_{it} - s(\varepsilon_{it} - \varepsilon_{it-1})] = 0 \text{ for } s \geq 2;\ t = 3,\ldots,T$$

$$E[X_{it} - s(\varepsilon_{it} - \varepsilon_{it-1})] = 0 \text{ for } s \geq 2;\ t = 3,\ldots,T$$

Assuming the error term, ε, lacks serial correlation and the explanatory variables, X, exhibit weak exogeneity, the authors designate this as the difference estimator. Notwithstanding, there exist statistical limitations associated with this estimator. Alonso-Borrego and Arellano (1996) and Blundell and Bond (1998) indicate that, in instances where the explanatory variables exhibit persistence over time, the lagged levels of these variables serve as weak instruments for the regression equation formulated in differences. To mitigate the potential biases attributed to the difference estimator, the authors employ an innovative estimator that integrates within a systematic framework the regression in differences with the regression in levels. The authors adopt a GMM estimator which utilizes lagged differences of Y_{it} as instruments for the equation in levels, alongside lagged levels of Y_{it} serving as instruments for equations in first differences. Blundell and Bond (1998) propose that Monte

Carlo simulations and calculations of asymptotic variance demonstrate that this expanded system GMM estimator provides efficiency improvements in contexts where the first-difference GMM estimator is inadequately performing. The aforementioned instruments are deemed suitable under the assumption that, while there may exist a correlation between the levels of the right-hand side variables and the country-specific effect in the level equation, there is no correlation between the differences of these variables and the province-specific effect. The additional moment conditions pertinent to the second component of the system, which is the regression in levels, are:

$\mathrm{E}\left[(Y_{it-s} - Y_{it-s-1})(\mu_{it} - \varepsilon_{i,t})\right] = 0$ for s = 1

$\mathrm{E}\left[(X_{it-s} - X_{it-s-1})(\mu_{it} - \varepsilon_{i,t})\right] = 0$ for s = 1

Considering that the lagged levels serve as instruments within the difference's specification, solely the most recent difference is utilized as an instrument within the level's specification. Employing additional lagged differences would lead to superfluous moment conditions [see Arellano and Bover (1995)]. The authors apply the aforementioned moment conditions and implement a System GMM procedure to produce parameter estimates that are both consistent and efficient.

4.2 International Convergence Analysis: South Africa – OECD

The convergence hypothesis among nations has been predominantly employed to evaluate the validity of the neoclassical growth model. Moreover, the estimated rate of convergence across various economies was thought to provide insights into crucial growth theory parameters, particularly the contribution of capital within the production function. Nonetheless, a direct evaluation of beta convergence, which suggests that less affluent countries with limited capital will experience more rapid growth than wealthier countries with substantial capital reserves, did not substantiate the presence of convergence. Consequently, this result is regarded as a challenge to the neoclassical model (see Sala-i-Martin, 1996).

Sala-i-Martin (1996) posited that the neoclassical model's prognosis of convergence is contingent upon the fundamental premise that 'the only difference across countries lies in their initial levels of capital'. However, in practical terms, economies might display variations in their technological advancements, saving propensities, and population growth rates. Consequently, if economies exhibit diverse technological and behavioural parameters, they are likely to reach disparate steady states.

Instead of utilizing absolute beta-convergence to assess convergence, it is more appropriate to employ 'conditional beta-convergence,' as the premise that less affluent economies expand more rapidly than wealthier ones hold true only if all economies converge to a common steady state. Conditional beta-convergence facilitates the analysis of convergence among nations with different steady states. This analysis is realized by maintaining the steady state of each economy constant, achieved through incorporating a vector consisting of additional explanatory variables in the equation (Barro and Sala-i-Martin, 1995; and Mankiw et al., 1992). Assuming absolute convergence is applicable to a group of countries $i = 1, 2, \ldots, N$, the standard growth equation is articulated as (Barro and Sala-i-Martin, 1995):

$$\log(y_{it}) = a + (1 - b)\log(y_{i,t-1}) + v_{it} \quad (6)$$

In this context, y_{it} denotes the income of the ith country, while a and b represent constants, where $0 < \beta < 1$. Additionally, v_{it} signifies a disturbance term, and t refers to a temporal index. The stipulation that $b > 0$ denotes absolute convergence, as the annual growth rate, expressed as $log(y_{it}/y_{it-1})$, exhibits an inverse relationship with $log(y_{it-1})$. In instances where the economies exhibit distinct steady-state positions, a vector of explanatory variables is incorporated into Equation 7. The conventional growth model equation, which utilizes panel data, is represented as (e.g. Islam, 1995):

$$\log(y_{it}) = \eta_i + \beta\log(y_{i,t-1}) + \sum_{j=1}^{k}\pi_j\, log(x_{it}^{j}) + \xi_t + u_{it} \quad (7)$$

In this context, y_{it} denotes per capita income. The variable $\beta = e^{-\lambda}$represents convergence, where λ is the rate of convergence and τ represents the time period. The variables x_{it}^{j}, for $j = 1,2, \ldots k$ are the control or explanatory variables. The term η_i captures the country-specific effect, while ξ_t is defined as the period-specific constant. The term u_{it} represents the disturbance. A set of countries is characterized by conditional growth convergence if the condition $0 < \beta < 1$ holds. Applying this empirical strategy, the convergence phenomenon was examined between South Africa and the OECD.

5. Summary of Key Study Findings

5.1 Part 1: Domestic Analysis of South Africa's 9 Provinces

An extensive econometric inquiry was conducted into South Africa's nine provinces, concentrating on their economic performance, infrastructure investment, and geographical distribution of economic development during the research period. Three estimation techniques

were utilized to evaluate the different econometric methods explored in previous chapters concerning this relationship. These included Pooled Ordinary Least Squares (OLS), OLS with Fixed Effects, and the one-step system Generalized Method of Moments (GMM) method. Addressing the research question what positive and negative effects infrastructure investment had on economic development over the period 1996-2021. South Africa's population surged by 51.7% between 2011 and 2022, with Gauteng, KwaZulu-Natal, and the Western Cape being the most populated provinces. Internal migration is mostly concentrated in Gauteng and the Western Cape, whereas provinces such as Limpopo, Eastern Cape, and Free State undergo out-migration. Gauteng accounts for 33% of the national GDP, followed by KwaZulu-Natal (16.2%) and the Western Cape (14%). Despite being the largest province in terms of land area, the Northern Cape accounts for only 2.3% of GDP. The Eastern Cape and Limpopo provinces are among the poorest, with significant unemployment rates and a reliance on remittances. The provinces have distinct economic structures based on their natural resources and industrial activities. For example, Gauteng is a hub for finance and manufacturing, while the Free State and Limpopo are heavily reliant on mining and agriculture.

H_1: Infrastructure investment has a long term significant positive effect on aggregate output i.e. real GDP per capita.

The hypothesis posits that infrastructure investment exerts a significant long-term positive impact on aggregate output, specifically real GDP per capita. The findings partially support for the acceptance of this hypothesis. A 1% increase in construction investment results in a 0.088% augmentation in GDP (p=0.001), demonstrating strong significance. Similarly, a 1% increase in electricity investment leads to a 0.054% enhancement in GDP (p=0.000), which is also strongly significant. Transport investment shows that a 1% increase correlates with a 0.040% increase in GDP (p=0.036), indicating significance. However, a 1% increase in ICT investment only results in a 0.006% increase in GDP (p=0.218), which is not statistically significant.

The affirmative outcomes observed in the domains of construction, electricity, and transport exhibit a strong congruence with the foundational principles of Infrastructure Theory (Aschauer, 1989; Munnell, 1992). These findings corroborate the theory positing that infrastructure serves as a direct input into production processes, thereby enhancing productivity and reducing costs (Liu and Liu, 2011; Asturias *et al*., 2019). Furthermore, the outcomes are in alignment with empirical studies across both developed and developing countries (Romp and de Haan, 2005; Ferreira and Araujo, 2006; Fedderke and Garlick, 2008; Estache and Fay, 2009; Heintz *et al*., 2009 and Kumo, 2012). These categories of infrastructure demonstrate

distinct transmission mechanisms: Construction & Transport: Mitigate transaction and trade costs, augment logistical efficiency, and facilitate the mobility of goods and factors of production. Electricity: Directly energizes economic activities; its dependability constitutes an essential precondition for industrial and commercial output.

The absence of a significant outcome from ICT investment does not inherently diminish its significance; rather, it indicates a more intricate relationship. This can be elucidated by the following: (i) Complementarity Requirements: The advantages of ICT infrastructure could be dependent upon complementary investments in human capital (i.e., digital skills), research and development, and business process reorganization (Brynjolfsson and Hitt, 1998). In the absence of such investments, the infrastructure alone may not deliver quantifiable productivity enhancements. (ii) Measurement and Temporal Delay: The economic returns derived from digital infrastructure (such as broadband networks) might necessitate extended gestation periods or prove more challenging to encapsulate within aggregate GDP metrics relative to physical infrastructure. (iii) Suboptimal Utilization: The investment might not be deployed or utilized efficiently to realize its maximum potential; an issue highlighted within critiques of infrastructure theory (Kenny, 2007).

H_2: A significant relationship exists between infrastructure investment and real GDP per capita.

A considerable relationship is evident between infrastructure investment and real GDP per capita. The empirical results provide substantial support for the acceptance of this hypothesis. The principal finding of the GMM analysis indicates a statistically significant relationship. Three out of the four infrastructure variables exhibit a positive and significant coefficient. The System GMM model, constructed to account for endogeneity and persistence, corroborates a robust causal link between infrastructure investment and economic output. This finding serves as the primary empirical substantiation of the thesis articulated in the literature review. It offers tangible evidence for the extensive body of literature asserting that public capital is a crucial driver of growth. It directly supports the contributions of Aschauer (1989), Munnell (1990, 1992), Bougheas et al. (1999), and other works referenced in the theoretical synopsis. It substantiates the South African government's policy stance (as articulated in the NDP 2050, NIP 2030) that emphasizes infrastructure investment for economic development. The advanced econometric technique (System GMM) effectively disentangles the impact of infrastructure investment from other factors and reverse causality. The highly significant coefficients for

most types of infrastructure, together with strong model diagnostics (Hansen test, AR tests), assure that this relationship is not spurious.

H_3: Income disparity in South Africa has widened.

The empirical analysis provides substantial evidence supporting for the acceptance of this hypothesis. In terms of spatial income inequality, only two provinces, Gauteng and Western Cape, consistently recorded a GDP per capita exceeding the national average over the entire 25-year period. One province, Free State, remained approximately at the average level, while the remaining six provinces persistently fell below this benchmark. Concerning spatial investment inequality, the allocation of all forms of investment (GFCF, Construction, Transport, ICT, Electricity) was predominantly centred in the three leading economic provinces: Gauteng, KwaZulu-Natal, and Western Cape.

This finding profoundly resonates with the scholarly discourse on South Africa's enduring inequality (Sulla et al., 2022). It reflects the historical legacies of apartheid and colonialism which have engendered entrenched spatial and economic disparities. It corroborates the critiques of infrastructure theory (Gramlich, 1994; Kenny, 2007) positing that investment may be inefficiently allocated based on political motives as opposed to economic necessity, resulting in "white elephant" projects in certain areas and under-investment in others. It illustrates a Matthew Effect wherein already prosperous regions attract greater investment, thereby further exacerbating the disparity with poorer regions (Bourguignon and Morrisson, 1998; Piketty, 2006).

There exist several plausible explanations for this outcome. Path Dependency: The economic geography of South Africa was entrenched during the apartheid era. Post-1994, notwithstanding policy intentions, investment has predominantly adhered to pre-existing economic corridors, thereby reinforcing rather than alleviating these disparities. Political Economy: The distribution of infrastructure projects may be shaped by political economy considerations (e.g., lobbying, corruption) that give precedence to certain regions over others, as noted by Kenny (2007). Market Forces: Private investment tends to flow to regions with higher returns and lower perceived risk, which are generally the already-developed urban centres of Gauteng and the Western Cape.

Furthermore, a significant and pivotal discovery of the study pertains to the adverse effects of total domestic investment (GFCF). The empirical findings reveal that a 1% increase in GFCF is correlated with a -0.266% decline in GDP (p=0.000). This unexpected outcome bolsters the crowding-out argument regarding public investment, as posited by Erenburg

(1993). It implies that extensive public investment might be supplanting more efficient private investment by elevating interest rates or depleting limited capital and expertise. This observation is also in strong concurrence with critiques of inefficient resource allocation, budget overruns, and substandard project management (Flyvbjerg et al., 2003; Rioja, 2003). If a substantial fraction of GFCF is allocated to inadequately chosen or executed projects, the resultant effect on economic growth could potentially be detrimental. Possible explanations for such an observation may be that this finding likely mirrors the inferior quality and composition of aggregate investment in South Africa. It indicates a profound issue where the volume of investment fails to convert into productive quality, possibly attributable to factors criticized in the scholarly literature: corruption, state capture, and inefficiency in state-owned enterprises such as Eskom.

The provincial analysis furnishes a nuanced and critical elucidation of the research inquiry. It substantiates that infrastructure investment (H_2/H_3) holds a significant positive correlation with economic growth; however, this correlation is not consistent across all infrastructure categories. Significantly, the advantages of this growth have been geographically concentrated, resulting in an expansion of provincial income disparities (H_3). The disconcerting negative correlation between total investment and GDP indicates that the inefficiency and allocation of investment are profound issues, corroborating numerous criticisms directed at infrastructure-led growth strategies within the South African milieu. This sets a formidable stage for the convergence analysis: how might a nation achieve convergence with advanced economies if its growth is both inefficient and internally divergent?

5.2 Part 2: International Comparative Analysis: South Africa-OECD

This part of the investigation discussed in Chapter 5, delved into the growth patterns of 39 countries—South Africa, 32 OECD countries and 6 Latin American nations—comparing their performance for 39 years through the lens of convergence theory.

H_4: The per income per capita convergence disparity between South Africa and the OECD has narrowed.

This analysis scrutinized the outcomes of the international comparative study to evaluate whether South Africa is aligning with advanced economies, in accordance with the neoclassical growth and convergence theory delineated in the literature. The empirical analysis determined that the hypothesis receives conditional support and partial acceptance of this hypothesis based

on the evidence of conditional β-convergence, while absolute convergence is not evidenced. The absolute disparity between South Africa and the OECD has increased. The nominal income gap between South Africa and the OECD average has widened significantly. In 1980, the disparity was: OECD average ($8,708) - South Africa ($3,035) = $5,673. By 2019, this gap had expanded to: OECD average ($39,685) - South Africa ($6,073) = $33,612. The model postulates that it would require 34.11 years for South Africa to attain the OECD's 2019 average income level, ceteris paribus (Marais, 2024a, 2024b).

Provides evidence of conditional β-convergence. Despite the expanding absolute gap, the analysis indicates signs of conditional convergence. A classic neoclassical inverse relationship between initial income levels and subsequent growth rates was observed. South Africa, which had a low initial income, demonstrated a positive growth rate (0.55), aligning with the convergence hypothesis. Over time, South Africa's income per capita has risen, with its GDP per capita increasing from $3,035 to $6,073 within the period. This growth suggests progress; however, it was not sufficient to match the rapidly increasing OECD average. South Africa's economic performance was significantly lower than the OECD average GDP per capita, with an annual average growth rate in real GDP of 0.54% during the research period, which falls below the 2% 'iron law of convergence' hypothesis. Evidence that conditional convergence has been observed aligns with the Solow-Swan model (1956) and supports the findings of previous studies (Barro, 1991; Barro and Sala-i-Martin, 1992, 1996; Mankiw et al., 1992; Marais, 2024a, 2024b). The findings substantiate that convergence is not absolute; rather, it is contingent upon a nation's savings rates, population growth, institutional quality, and technological adoption, which collectively constitute its "steady state."

Steady state analysis demonstrated South Africa's GDP per capita in 2019 ($6,073) remains below its projected steady-state level ($16,282). This condition implies that the economy possesses the capacity for further catch-up growth, contingent upon its fundamental factors (capital, labour). In contrast, the majority of OECD nations are at or have exceeded their steady-state levels (Marais, 2024a, 2024b). To boost economic performance, South Africa should prioritise the effective use of available technologies and capital accumulation as the theory suggests. This may be accomplished by investing in R&D, innovation programmes and measures to close the technological divide. Additionally, by encouraging collaboration among the commercial sector, academia and government can help with technological transfer and adoption.

The economies of the OECD did not remain unchanged; they persisted in their growth through technological innovation—an essential component of endogenous growth theory—and

efficient allocation of capital. While South Africa was advancing, the OECD maintained a more accelerated pace. The potential equilibrium income (steady state) of South Africa is intrinsically inferior to that of OECD countries, attributed to factors critiqued within convergence theory, such as institutions, structural challenges, and human capital. Consequently, South Africa is progressing towards its own lower steady-state rather than aligning with the elevated level characteristic of OECD nations.

The findings robustly reinforce the "criticisms of convergence theory" delineated in literature. In particular, they underscore the significance of: Institutional and Structural Factors (North, 1990; Acemoglu and Robinson, 2012): The structural constraints faced by South Africa, such as inequality, a skills shortage, and an energy crisis, are likely to diminish its steady-state income level in comparison to the OECD. Initial Conditions and Path Dependence (Arthur, 1994; Pierson, 2000): The apartheid legacy has positioned South Africa on a diminished developmental trajectory, perpetuating an enduring disparity. Heterogeneity (Durlauf and Quah, 1999; Rodrik, 2011): The global economy is not comprised of uniform economies converging to a singular point; instead, convergence clubs emerge, and South Africa appears entrenched in a lower-income club.

The domestic analysis has elucidated the reasons for the deceleration of South Africa's economic growth. These include suboptimal investment characterized by crowding out, disparate developmental patterns, and the improper allocation of infrastructure resources. Such internal deficiencies directly inhibit the nation's growth trajectory and constrain its potential for absolute convergence with more developed and efficient economies. The projected GDP per effective worker, which accounts for technological advancements, exceeds the actual GDP per capita recorded in 2019 across all 39 examined countries. This robustly endorses the endogenous growth theories posited by Solow (1988) and Mankiw, Romer, and Weil (1992), which assert that technological innovation is pivotal to sustained economic growth, surpassing the limitations imposed by diminishing returns on capital within the fundamental Solow model. It demonstrates that the potential for economic expansion is achievable through the adoption and enhancement of technological advancements (enhancing the effectiveness of labour). In the context of South Africa, this discrepancy suggests that a crucial mechanism for expediting economic convergence and attaining its equilibrium status lies in the enhancement of total factor productivity. This involves not merely the accumulation of additional capital, but the more efficient utilization of capital and labour through advanced technology, improved skills, and superior management practices.

Moreover, the findings highlight the need for policy initiatives to promote convergence between South Africa and OECD nations. These interventions should focus on education and skill development, infrastructure investment and creating a favourable business climate. Implementing policies that encourage equitable growth and eliminate structural hurdles can help to close the development gap. South Africa should look at prospects for regional economic cooperation with other African countries. Collaborative efforts can help with information exchange, trade integration and cooperative infrastructure projects. Regional cooperation can provide synergies and boost South Africa's economic growth potential as suggested by the regional economic growth theory and interregional convergence hypothesis developed by Hecksher, Ohlin and Samuelson (1919, 1933, 1953). Given the scarcity of empirical studies on convergence in Africa, it is advised that further study be conducted in this field. Increased empirical study can shed light on the processes of economic development, convergence trends and policy implications unique to African nations. This study can help to shape evidence-based policy and decision-making processes.

6 Policy Implications

6.1 Policy Recommendations for South Africa's Provincial Economic Development

These policy recommendations are discussed in order of importance. It has been limited to those which are of highest priority. They are interdependent in nature and may be implemented simultaneously to complement the effectiveness of each.

(a) Increase and Diversify Infrastructure Investment

Literature has established that public infrastructure provision is the obligation of the government as it is a collective consumption good (Samuelson, 1954; Fourie, 2006). Numerous studies (Romp and de Haan, 2005; Fedderke and Garlick, 2008; Estache and Fay, 2009; Heintz *et al*., 2009; Kumo, 2012; Marais, 2025) concluded that there is a strong positive relationship between infrastructure investment and economic growth. Moreover, the findings of this research study concur with the conclusions and specifically identified that transport and ICT investments have a significant positive impact on real GDP per capita. The Chinese government is an example from an emerging economy that implemented large-scale

infrastructure investment in recent decades, which through an open economic policy and a series of institutional reforms had resulted in double digit annual growth rates (Zeng, 2015).

Therefore, the South African government should prioritise infrastructure investment in underdeveloped provinces such as Limpopo, the Eastern Cape, and Northern Cape to stimulate economic growth and reduce regional inequalities. Invest in road, rail, and port infrastructure in rural and underserved areas to boost connectivity and trade. For example, the N2 Wild Coast Road project in the Eastern Cape should be hastened to increase the region's economic activity. Expand broadband and digital infrastructure in rural regions to help close the digital divide and provide access to global markets, e-commerce, and remote employment possibilities. The Eastern Cape Broadband Project, and similar projects, should be scaled up. Encourage public-private partnerships (PPPs) which capitalise on private sector knowledge and funds for infrastructure projects. This might involve cooperative partnerships in the transportation, energy, and ICT sectors. Create risk-sharing structures for the public and private sectors to encourage investment in high-risk areas, such as undeveloped provinces. Further leverage PPPs through ISA to accelerate infrastructure development. Encouragement of economic decentralisation outside of the current geographical hubs is needed and actioned by incentivising enterprises to establish operations in undeveloped regions.

(b) Promote Inclusive Economic Development Through Education and Skills Development

South Africa's high Gini coefficient (0.63) is a significant impediment to economic growth and convergence with OECD nations. The country’s labour market is at the core of its socio-economic dilemma with its bifurcated characteristics. The highly skilled segment is acquiescent by excess demand and the low skilled segment by excess supply (Francis and Webster, 2019). Investment is needed in education and vocational training programs, especially in undeveloped areas, to boost human capital and employability particularly in labour intensive industries. This will assist to lessen the skills mismatch in the labour market, allowing more individuals to get higher-paying employment. Moreover, encouraging STEM (science, technology, engineering, and mathematics) education and digital skills. Importantly, capital investment projects such as the SIPs should not be developed, constructed or implemented in a haphazard manner. But coordinated with education and vocational development programmes to improve the efficiencies in labour to counter its negative impact on GDP per capita.

(c) Enhance Industrialisation and Diversification

A research study based on the Chinese economy identified the important role that the establishment of special economic zones (SEZs) played in the country's accelerated economic trajectory. Cities were earmarked to facilitate and accelerate its industrialisation in specific areas of manufacturing (Zeng, 2015). The authors further conclude that a "lack of infrastructure creates bottlenecks for sustainable growth and poverty reduction" (Sahoo, et al., 2010:3).

Manufacturing and value addition (also known as beneficiation) should be promoted in South Africa's economic development policies, learning from the Chinese example. South Africa's economy is strongly reliant on the mining and primary industries, limiting its potential to catch up with OECD countries. Its government should support industrialisation in high-unemployment provinces like the Eastern Cape and Limpopo, as well as promote value-added mining by incentivising local mineral processing (e.g., platinum, gold, and manganese) over exporting raw materials. Expand and enhance the efficacy of SEZs like the Coega Industrial Development Zone in the Eastern Cape and the Musina-Makhado SEZ in Limpopo. These zones should focus on attracting foreign direct investment (FDI) and developing export-oriented enterprises.

The research of South Africa's provincial economies indicates considerable differences in economic development and infrastructural investment. While some provinces grow, such as Gauteng and the Western Cape, others struggle owing to a lack of investment and restricted economic prospects. To solve these difficulties, the government has to take a comprehensive approach that includes infrastructure investment, regional development, and equitable growth policies. South Africa may achieve more balanced and sustainable economic growth by focussing on undeveloped regions, improving ICT and transport infrastructure, and encouraging public-private partnerships. Long-term planning and consistent policy execution will also be critical in ensuring that infrastructure investments benefit all provinces in the long run.

These policy recommendations have been identified and partly addressed by existing strategies, frameworks and policy documents of the South African government most recently by the National Development Plan 2030. Despite their existence, implementation thereof has been unsuccessful as shown by their meagre impact.

6.2 Policy Recommendations for South Africa's Catching up to the OECD

The policy recommendations in the previous sub-chapter are interdependent and in alignment with the policy priorities highlighted in this section for South Africa to achieve economic convergence with the OECD. Convergence theory, predicated on the neoclassical growth models of Solow (1956) and Swan (1956), argues that weaker countries may catch up with richer ones through capital accumulation, technological diffusion, and efficient resource allocation. The results of this study provide evidence that the South African economy is deficient in all three of these areas.

(a) Enhance Capital Accumulation and Investment

According to the convergence hypothesis (Solow, 1956; Sala-i-Martin, 1996), poor nations initially start farther away from their steady state equilibrium level, however as levels of capital increase, the economy grows rapidly then the growth rate starts to decline as it reaches its steady state. According to the findings of this study, South Africa is currently performing below its own steady-state equilibrium and the benchmark of the OECD. Moreover, the analysis finds that capital stock and total investment are the most important determinants of GDP growth. Therefore South Africa should enhance its capital accumulation capabilities and increase public investment in infrastructure, technology, and human resources. Public-private partnerships (PPPs) can be a mechanism to fund major infrastructure projects. To attract foreign direct investment (FDI), South Africa should remove regulatory bottlenecks, decrease corruption, and increase company efficiency. Policies that encourage long-term investment in critical industries (such as manufacturing, mining, and technology) should be prioritised.

(b) Enhance Labour Productivity and Employment Through Technology Application and Innovation

The Solow and Swan (1956) model centres around four variables: output, capital, labour and technology also known as the effectiveness of labour. Output changes over time only if the factors of production into the transformation process changes. The findings of this study provide evidence of the long-term negative impact of labour share on GDP, this indicates ineffectiveness of labour in the production process. Increases in capital per worker and technological augmentation are argued to be critical to long term growth and development. The

South African government should promote the use of digital technology in all sectors, including agriculture, industry, and services which have the potential for leapfrogging benefits. Coupled with investment in education and vocational training programs to improve the capabilities of its workers, particularly in high-growth industries like technology and services may counter the skills mismatch which is currently prevalent in its labour market.

This comparative examination of South Africa and the OECD finds that, while the country has made progress in closing the income per capita gap, considerable obstacles remain. The country's GDP per capita is still far lower than the OECD average, and its steady-state equilibrium implies space for development through increased capital accumulation, technical breakthroughs, and labour productivity. To achieve long-term economic development and close the income gap, South Africa must prioritise increasing investment, stabilising the currency rate, encouraging technological innovation, and strengthening governance. Furthermore, tackling social issues like inequality and unemployment will be critical to long-term growth. By implementing the proposed measures, South Africa may speed up its convergence to the OECD average and reach higher levels of economic development.

7. Study Limitations and Future Research

7.1 Study Limitations

There is an opportunity to extend the period of investigation to later years beyond 2019 and 2021. The research focuses exclusively on economic variables such as GDP per capita and infrastructure investment, while ignoring non-economic elements such as political instability, social discontent, and cultural dynamics. These factors have a considerable impact on economic development and convergence but are outside the scope of this research. The research focuses largely on economic variables, such as GDP per capita and infrastructure investment, while disregarding non-economic elements like political insecurity, social unrest, and cultural dynamics. The research looks at aggregate infrastructure investment (for example, transportation, ICT, and building), but it doesn't go into depth about specific industries or projects. This reduces our capacity to determine which forms of infrastructure have the greatest influence on economic growth. Moreover, did not take exogenous shocks such as the covid-19 pandemic into account.

7.2 Future Research

The findings of this dissertation provide various options for further study into the link between infrastructure investment, economic progress, and income convergence. Future study might broaden the analysis to cover previous years or forecast future changes. This would offer a more complete picture of the long-term consequences of infrastructure investment. Time-series analysis or dynamic panel data models can be used to examine the cumulative impact of infrastructure developments across decades. Investigate the impact of sector-specific infrastructure investments (such as electricity, water, healthcare, and education) on economic growth. Examine the geographical spillover effects of infrastructure investment between provinces and regions. Infrastructure projects in one province may have a beneficial or negative impact on surrounding provinces. Understanding these processes can lead to more equal resource distribution.

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