Ph.D. DISSERTATION

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Szeged, 2025

UNIVERSITY OF SZEGED
FACULTY OF ECONOMICS AND BUSINESS ADMINISTRATION
DOCTORAL SCHOOL OF ECONOMICS

AN INVESTIGATION INTO THE INFLUENCE OF INFRASTRUCTURE INVESTMENT ON ECONOMIC DEVELOPMENT AND ITS SPATIAL DISTRIBUTION IN SOUTH AFRICA

Ph.D. Dissertation

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DECLARATION AND APPROVAL

Candidate's Declaration

I hereby declare that all sections and contents of this Ph.D. dissertation and thesis are my original work and have not been presented or used to award any diploma or conferment of a degree in this university or any other institution of higher learning. All books, journal articles, and organisational websites have been correctly acknowledged through in-text citations and reference list.

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Supervisor approval

This confirms that the Ph.D. candidate conducted the work in this thesis under my guidance and direction. Therefore, this dissertation and thesis have been examined, passed, and submitted with my approval as the candidate's supervisor.

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Toewyding

Alle eer, lof en danksegging aan U, Soewereine Heer Jesus Christus, vir hierdie Ph.D.-reis en die voltooiing daarvan. Hierdie werk word opgedra aan mnr. Cecil John Marais, my oorlede oupagrootjie, wat as 'n klein dogtertjie die saadjie in my jong gemoed geplant het dat ek kon 'n dokter word.

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2. **Marais, S.-L.** (2025): An examination of economic development causation through time series analysis in South Africa. *Acta Universitatis Sapientiae: Economics and Business*, 13(2025), pp.70-96.
3. Alwago, W.O., David, D., Sgardea, F.M., and **Marais, S.-L.** (2025): The effect of environmental tax on CO_2 emissions in Romania: an ARDL-linked cointegration approach, *Journal of Risk Finance*, 26(3), pp.367-392. https://doi.org/10.1108/JRF-07-2024-0188
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1. **Marais, S.** (2024). A non-stationary panel data approach for examining convergence in South Africa. The 1st International Conference on Sustainable Economy-Sustainable Society, 16-17 May 2024, Debrecen, Hungary.
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3. **Marais, S.** (2023). Catching-up Theory: Examining South Africa's economic development. Economic, Diplomatic, and Cultural Challenges International Conference, 2 June 2023, Budapest, Hungary.
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1. Introduction

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).

This dissertation addresses these challenges by investigating the impact of infrastructure investment on economic development across the nine provinces of South Africa and by comparing the nation's economic performance with that of OECD countries. According to convergence theory, less developed economies grow at a faster rate than wealthier counterparts, eventually narrowing the income disparity due to their greater potential for capital accumulation (Solow, 1956; Swan, 1956; Barro and Sala-i-Martin, 1992).

The theoretical foundation of this empirical investigation is situated within the framework of neoclassical endogenous growth theories, particularly infrastructure theory (Samuelson, 1954; Aschauer, 1989; Munnell, 1992) and convergence theory (Solow and Swan, 1956; Barro and Sala-i-Martin, 1992; Sala-i-Martin, 1996). Infrastructure theory, as developed by Samuelson (1954), Aschauer (1989) and Munnell (1992), emphasises the significance of public infrastructure in increasing productivity and economic growth. Infrastructure is divided into two categories: economic overhead capital (EOC), which supports economic activity, and social overhead capital (SOC), which improves human capital (Eberts, 1990). Infrastructure investment in South Africa has mostly concentrated on EOCs, such as transport, information, communication and technology (ICT), but the gains have been unevenly dispersed, resulting in economic development discrepancies between regions (Fedderke and Garlick, 2008).

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. However, convergence is not automatic; it is determined by factors such as institutional quality, human capital, and infrastructure investment (Barro and Sala-i-Martin, 1992; Sala-i-Martin, 1996). Structural impediments to South Africa's convergence with OECD nations include high inequality, inadequate human capital investment, and inefficient infrastructure allocation (World Bank, 2018).

This dissertation applied these theoretical frameworks to investigate the relationship between infrastructure investment, economic progress, and convergence. Using panel data econometric models, the study investigated the causal implications of

infrastructure investment on real GDP per capita throughout South Africa's provinces and examined the country's progress towards OECD values. The study was guided by two main following research questions. Firstly, is the South African government's substantial strategic commitment to infrastructure yielding benefits in terms of economic development and spatial equity? Moreover, what positive and negative effects did infrastructure investment have on economic development over the period 1996-2021? This question is addressed in Chapter 4, which analyses the impact of infrastructure investment on GDP per capita across South Africa's nine provinces using panel data econometric models. Secondly, 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? This question is addressed in Chapter 5, which applies convergence theory to compare South Africa's economic performance with that of OECD countries.

To achieve these objectives, our focus is directed towards the increasingly expanding corpus of literature in conjunction with the latest panel data. We utilize a dynamic panel model estimated by employing methodologies such as Pooled Ordinary Least Squares (Pooled OLS), Fixed Effects (FE), and System Generalized Method of Moments (Sys_GMM). All econometric modelling in this study was performed using the STATA and EViews 12 software. The policy recommendations are derived from the empirical findings in Chapters 4 and 5, which focus on infrastructure investment, inclusive growth, and structural reforms.

To the best of our knowledge, there is a lack of empirical studies investigating 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 the significant 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. Therefore, expanding the literature on emerging, resource-rich, middle to upper-middle income economies.

Moreover, this dissertation aims to improve our understanding of the role of infrastructure investment in economic development, as well as its consequences for income convergence. By examining South Africa's provincial differences and comparing its economic performance to that of OECD nations, the report sheds light on the

difficulties and potential for long-term progress. The findings of this study are especially significant for South African policymakers because they underscore the need for targeted infrastructure investment in underdeveloped regions, stronger governance, and structural changes to address systemic difficulties. South Africa can boost its economic development and get closer to OECD income levels by further entrenching infrastructure investment with the aims of the National Development Plan (NDP) and harnessing global trends like digitalisation and expanding its value-added activities.

The dissertation is structured as follows: Chapter 2 provides a review of current literature, discussing infrastructure theory, convergence theory, and the political economy in South Africa. Chapter 3 describes the research methodology, including the theoretical models, data sources, and econometric techniques used in the analysis. Chapter 4 presents the South African provincial demographic and economic overview, its empirical estimation examining the impact of infrastructure investment on economic development in its nine provinces. Chapter 5 presents the South Africa-OECD comparative empirical estimation, assessing the country's convergence or divergence from OECD per capita income levels. Chapter 6 discusses the key findings, and Chapter 7 provides contextual policy recommendations for improving economic development in South Africa.

2. Literature Review

This chapter provides a theoretical synopsis based on theories and conjecture that serve as the foundation for the study's expounding of its relevant concerns. It is concentrated on empirical literature and adheres to a refined background anchoring theory, from which an empirical model is constructed for each set hypothesis. The theoretical synopsis lays the groundwork for empirical investigations on the objectives, allowing us to base our research in later empirical chapters on valid theoretical concepts and empirical substantiations from earlier studies. This chapter conceptualises, examines theoretical notions, and gives an extensive literature review to introduce the contextual empirical methodologies discussed and hypotheses formulated in Chapter 3 and its results in Chapter's 4 and 5. Therefore, this chapter provides an overview of the thematic notions of the dissertation, and their theoretical implications to the hypotheses.

2.1 Infrastructure Theory

The seminal work of Paul A. Samuelson (1954) on public expenditure lays the foundation of the public good theory, where the two categories of private consumption goods and

collective consumption goods were developed. The central premise of public good theory is that the market will not provide enough public goods to maximise social welfare since the benefits of public goods are not limited to a single consumer, as they are with private goods, but are available to all. Consumption is thus a kind of competition for private commodities, but not for pure public benefits. Instead of questioning why the government exists, he asks, "*How should government decide*?" (Samuelson, 1954:388). Infrastructure is an example of a collective consumption good, which has non-excludability and nonrivalry qualities. It contends that the provision of infrastructure is the government's obligation due to its public benefit characteristics (Fourie, 2006).

Research on the central role of public infrastructure on economies did not begin until the late 1980s, as noted by Munnell (1992); Bougheas *et al*. (1999); Cálderon and Servé (2010). Munnell (1992) cites David Aschauer (1989a; 1989b; 1990) as the inspiration for analysing the impact of public capital expenditure on output using regression analysis. Aschauer's early research concludes that "*much of the decline in US productivity that occurred in the last two decades is due to the that which occurred in the 1970s and was precipitated by declining rates of public capital investment"* (Munnell, 1992:190). Initial studies employing econometric modelling found that public capital investment had a significant impact on private sector output and productivity (Munnell, 1990). Aschauer's original analysis indicates that a 1% increase in public capital investment results in a 0.39 percent rise in private sector production (Munnell, 1992). Academics have criticised previous estimates for their huge coefficients, false connection, and probable endogeneity related to the variables (Munnell, 1992; Aaktar *et al*., 2017).

According to Egberts (1990) economic development primarily depends on location leverage when making evaluations between countries, regions, or cities. In their pursuit of economic profit, firms look for locations that offer potential opportunities. These opportunities are enhanced through the adequate supply of public infrastructure. This notion is supported by Ascani *et al.* (2012) that through globalisation a regional world has emerged in which economic development occurs in spatial clusters within a defined locality, therefore fostering a growing comprehension that this process highlights the important role that local actors play in setting the developmental path. The authors further state that globalisation is the catalyst that established the concept of regional development.

Numerous studies (Romp and de Haan, 2005; Fedderke and Garlick, 2008; Estache and Fay, 2009; Heintz et al., 2009; Kumo, 2012; Marais 2025) carried out in the 20th century by economists have concluded that there is a strong positive relationship between infrastructure investment and economic growth. Heintz et al. (2009) applied the autoregressive distributed lag (ARDL) model to estimate the production function for the USA from 1951 to 2006. The study found long-term links between public capital investment and private productivity, with infrastructure having a crowding-in effect on private investment. Romp and de Haan (2005:15) after reviewing the evidence, 32 out of 39 studies in OECD countries establish a "positive effect of infrastructure on some combination of output, efficiency, productivity, private investment, and employment". Furthermore, 9 out of 12 investigations conducted in developing countries found a significant positive impact (Estache and Fay, 2009:15).

Research conducted by Bougheas *et al.* (2000) supports the long-term link between infrastructure investment and growth. The authors applied the ordinary least squares (OLS) and instrumental variable estimation (IV) models to categorised physical infrastructure as a technology that reduces the fixed costs of generating intermediate input.

Ferreira and Araujo (2006) examined the influence of infrastructure expenditure in Brazil, including paved roads, telephone lines, and energy production capacity, on capital variation and growth between 1960 and 1996. The authors applied cointegration analysis and vector autoregression models (VAR) to assess the long run relationship between output and infrastructure investment. Their results indicate that the long-term correlation between investment in physical infrastructure (roads, telephone lines, and energy generation) and output was nearly one. Regression studies indicate that a 10% increase in public infrastructure would enhance long-run production per capita by 2.2 to 3.3%.

Bose *et al*. (2007) found in their study of 30 developing countries over 1970-1980 that government capital expenditure as a percentage of GDP was positively and significantly related to the growth in income per capita.

Measuring whether or not a relationship exists between the aforementioned is no easy feat, as there are various perspectives in which it could be investigated. Moreover, significant econometric issues arise in the estimation of macroeconomic models, problems such as common trends in capital and output per capita, poor data quality, reverse causality, and omitted variable bias (Gramlich, 1994; Estache and Fay, 2009).

Several transmission mechanisms exist through which infrastructure can affect growth; that public infrastructure enhances the productivity of the private sector, which was first described by Ascher (1989), and Barro (1990) is the most conventional channel. This demonstrated the direct productivity effect of infrastructure investment, where an 'increase in public capital stock (relative to private capital) has a positive but decreasing impact on the marginal product of all factor inputs (such as labour and capital)' (Dissou and Didic, 2013:7). Therefore, as the cost of the factors of production decreases, the level of private production increases. Subsequently, complementarity and crowding out effects were identified as other types of transmission mechanisms, the former 'promotes growth through private capital formation' (Dissou and Didic, 2013:7).

As *"public infrastructure raises the marginal productivity of private inputs, thereby raising the perceived rate of return on private capital and possibly also increasing private sector demand for physical capital"* (Agenor and Moreno-Dodson, 2006:9). The latter crowding out concept is when the increase in public investment displaces private investment in the short run, this may have a long run negative effect if it occurs over a longer period. Studies by Richaud *et al*. (1999), Fourie (2006), and Fedderke et al. (2006) found that several positive externalities are induced through public investment in infrastructure. The authors have identified them as improvements in competitiveness, increased regional and international trade, extended FDI, and higher profitability of domestic and foreign investment flows; this in turn increases income per capita.

According to Kumo (2012), infrastructure plays a direct input role in production processes, making it a factor of production. Infrastructure adds value to the industrial process by cutting costs and promoting human capital development. Enhancing aggregate demand by increasing spending on building and operations. Furthermore, it may help drive industrial policy by investing in specific infrastructure projects to influence private sector investment decisions (Fedderke and Garlick, 2008; Kumo, 2012).

Infrastructure exerts a substantial impact on the efficiency of economic growth by primarily reducing transportation costs and facilitating the movement of factors and goods. Liu and Liu (2011) identified in their study that the construction of highways led to decreased inventory costs for manufacturing firms during that period, thereby contributing to the enhancement of economic growth efficiency. Consequently, it augments resource allocation and factor productivity. Research conducted by Asturias, Garca-Santana, and Ramos (2019) on India's "Golden Quadrilateral" highway project

revealed an 8% improvement in resource allocation efficiency, highlighting the beneficial implications of infrastructure development. The study by Liu, Zhang, and Fang (2015) in China illustrated that infrastructure encourages the transition of agricultural labour to non-agricultural sectors, thereby raising marginal productivity in agriculture and increasing labour income for rural inhabitants. Furthermore, Liu and Zhao (2010) found that infrastructure can reduce inter-regional trade costs, promoting industrial concentration and economies of scale.

Infrastructure constitutes a fundamental component in the stabilization of economic growth. Initially, by diminishing regional isolation, infrastructure enables the integration of small, closed markets, thereby augmenting the market size. According to Chen and Miao (2010), transportation infrastructure significantly enhances economic spatial aggregation. This phenomenon of industrial clustering allows economic growth to transcend critical thresholds, ameliorate excessive fluctuations, and promote economic development. Moreover, infrastructure strengthens regional cooperation and spillover effects. Hu and Li (2015) utilized the Dubin model to investigate the externalities associated with transportation hubs and identified significant positive spillover effects. Such regional spillover and diffusion facilitate the distribution of industrial labour across diverse areas, thus reinforcing the structural stability of growth. Jin et al. (2021) conducted an analysis of the impact of infrastructure investment on the quality of economic growth within China's regional development, drawing on empirical data collected from 29 provinces. The analysis utilized regional panel data originating from 29 provinces within China. An exhaustive index evaluating the quality of economic growth was formulated through Principal Component Analysis (PCA). The findings indicate that although infrastructure investment remains beneath the optimal threshold, the quality of economic growth has significantly enhanced. Robustness assessments conducted with instrumental variables (2SLS and system GMM) corroborate these conclusions. Infrastructure investment facilitates economic growth through resource circulation, market integration, and the development of knowledge capital.

Investment in infrastructure is poised to serve as a key catalyst for sustained economic growth by markedly enhancing productivity, facilitating the accumulation of human capital, promoting innovation and the dissemination of knowledge, and supporting the concentration of economic activities. Within the framework of endogenous growth posited by Romer (1990), technological advancement (A) is endogenously generated

through deliberate and profit-oriented investments in research and development by enterprises. This body of accumulated knowledge is characterized as non-rival. Infrastructure, particularly pertaining to digital networks and transportation facilities, acts as the medium through which this knowledge is disseminated, thereby engendering positive knowledge spillovers essential to the model, ultimately leading to a reduction in the costs associated with innovation and idea dissemination. Furthermore, Agénor (2010), within the theory of infrastructure-led development, identifies multiple channels through which infrastructure investment impacts growth. These include the Direct Productivity Effect, which reduces production costs for firms, and Human Capital Complementarity, where improved health infrastructure enhances labour productivity and improved educational infrastructure enhances skill acquisition. Synergistic Effects arise from the integration of various types of infrastructure (e.g., power and telecommunications), creating synergies that amplify the overall growth impact. Duranton and Turner (2012) contend that investment in transportation infrastructure propels urban economic growth by enabling agglomeration economies which are integral to endogenous growth, through enhanced matching of jobs and workers, the sharing of suppliers, and accelerated learning and knowledge spillovers.

2.1.1 Criticisms of Infrastructure Theory

The previous Subchapter 2.1 discussed the arguments in favour of investment in public economic infrastructure and presented empirical evidence from studies in developed and developing countries to support their findings. However, despite the evidence in support of this activity, numerous studies highlight criticisms that cannot be ignored (Erenburg, 1993; Gramlich, 1994; Flyvbjerg *et al*., 2003; Rioja, 2003; Kenny, 2007). The authors reached consensus in listing five areas of concern when public funds are invested in infrastructure.

Inefficient allocation of resources: According to Gramlich (1994), investment in public infrastructure can result in inefficient resource allocation conceivably due to governments prioritising projects based on political rather than economic grounds. This may lead to investments in projects that provide low economic returns or do not address the most pressing infrastructure requirements. Furthermore, governments may prioritise infrastructure projects based on political concerns, such as obtaining voter support or satisfying special interest groups, rather than economic ones, such as maximising societal

gains. Consequently, this might result in the building of "white elephant" projects with little economic value, whereas more economically advantageous initiatives are ignored. A proposal of employing multi-criteria cost-benefit analysis and other rigorous assessment approaches to enhance infrastructure project selection and prioritisation (Gramlich, 1994).

Cost overruns and delays: Flyvbjerg *et al.* (2003) state that numerous public infrastructure projects have incessant cost overruns and delays, resulting in higher than anticipated expenses and delayed benefits for the citizenry. Moreover, the majority of large-scale infrastructure projects suffer huge cost overruns of 50% or more. Factors contributing to this include underestimating the complexity of the project, changing the scope of the project, technological obstacles, and political interference. Delays in project completion can sometimes result in considerable economic losses, since the advantages of the infrastructure are not realised as anticipated. Improving project management, risk assessment, and institutional capability have been advocated as solutions to these difficulties (Flyvbjerg *et al.,* 2003).

Crowding out of private investment: Erenburg (1993) asserts that public infrastructure investment can crowd out private investment because government expenditure raises interest rates and reduces the availability of funds for private initiatives. Capital demand causes interest rates to rise, thus discouraging private investment in other industries. This "crowding out" effect can decrease total investment in the economy and slow economic development. In contrast, well-planned public infrastructure expenditures can "crowd in" private investment by boosting productivity and economic circumstances, especially where private and public investments are complementary (Erenburg, 1993).

Lack of proper maintenance and upkeep: Rioja (2003) reveals that governments may underinvest in the maintenance and upkeep of existing infrastructure, resulting in asset degradation and increased long-term expenditures. In addition, governments can prioritise the development of new infrastructure above the maintenance and repair of old assets, resulting in the degradation of roads, bridges and other essential infrastructure. This may result in increased long-term expenses if the demand for total reconstruction or replacement grows. Furthermore, the establishment of comprehensive asset management systems, dedicated financing streams for infrastructure maintenance, and the use of life-

cycle cost analysis to better assess the long-term costs and benefits of infrastructure projects can be main factors (Rioja, 2003).

Political influence and corruption: Kenny (2007) describes political influence and corruption, and it can have a negative impact on public infrastructure projects, resulting in poor investment decisions and resource misallocation. Infrastructure projects may be subject to political interference, with decision makers allocating money based on political rather than economic concerns. Corruption, such as bribery and kickbacks, can also result in the selection of subpar projects and the misuse of public funds. To address these concerns, the proposals include increasing openness, strengthening supervision and accountability structures, and improving procurement methods. Researchers have emphasised the necessity of strong governance frameworks and the need to protect infrastructure decision making from political interference and corruption (Kenny, 2007).

This Sub-chapter presented the genesis of infrastructure theory with its roots firmly entrenched in Samuelson's (1954) seminal work on public good theory and the use of public funds to invest in collective consumption goods. Thereafter, it went on to elaborate on the scholarly investigations on the role of public infrastructure in numerous economies spanning from the 1980s to the present day. The authors largely found in their empirical analysis that infrastructure has a strong positive influence on some combination of production, efficiency, productivity, private investment, employment, and growth. The Sub-chapter concluded by highlighting the criticisms of scholars when public funds are used to invest in infrastructure.

2.1.2 Theoretical Justification: Analytical Lens of Infrastructure Investment

In light of the aforementioned critiques pertaining to infrastructure investment, it is imperative to justify the selection of this theoretical rationale for the present research undertaking. 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.

Direct Policy Leverage and Measurability: The fundamental justification is embedded in the realm of practical policy intervention. Investment in infrastructure constitutes a direct

and tangible mechanism available to governmental authorities. Policymakers undertake specific annual budgetary allocations towards particular infrastructure projects (e.g., the N2 Wild Coast Road, broadband rollouts, power plants). Such investments encompass measurable inputs (ZAR expended) and as evaluated in the study, potentially measurable outputs (impact on GDP, employment rates during the construction phase). Although institutions—encompassing governance quality, corruption levels, or societal trust—are undeniably crucial (as recognized within the study's limitations), they remain amorphous, evolve slowly, and present significant challenges in terms of measurement and direct influence through distinct policy actions. By emphasizing infrastructure, the research aligns itself with the immediate priorities and tools accessible to the National Treasury, the Department of Public Works, and Infrastructure South Africa (ISA). The research corresponds with a positivist methodological framework that prioritizes quantifiable and actionable policy variables. As documented in the literature through the seminal contributions of Aschauer (1989) and Gramlich (1994), infrastructure capital constitutes a directly measurable input factor for which economic returns can be systematically modelled. This is in contrast to institutions, which are more expansive, exhibit gradual evolution, and are frequently regarded as components of the unexplained "residual" in growth models or necessitate intricate proxying.

Testing a Core Tenet of the Official Policy Doctrine: Since 1994, and particularly following the implementation of the National Development Plan (NDP) and the National Infrastructure Plan (NIP 2030/2050), the South African government has strategically committed to infrastructure-led growth as its principal approach for economic stimulation and transformation. This research serves as a critical empirical evaluation of this foundational policy hypothesis. The inquiry posits: "Is the government's substantial strategic commitment to infrastructure yielding benefits in terms of economic growth and spatial equity?" The results—which indicate positive yet inconsistent returns alongside a concerning crowding-out effect—offer a direct, evidence-based assessment of the state's primary economic strategy. While the analysis of institutions remains significant, it does not directly evaluate the effectiveness of this particular, predominant policy choice.

The research design actively engages with and critically examines the explicit growth strategy prescribed by the national policy documents of South Africa. This is consistent with the framework of policy evaluation research (Estache and Fay, 2009).

Addressing a glaring Spatial Legacy: The historical legacy of apartheid in South Africa orchestrated a state of underdevelopment through the deliberate imposition of spatial and infrastructural inequalities. The allocation of economic overhead capital (EOC), encompassing roads, railways, power grids, and ports, was meticulously structured to favour white minority interests while actively hindering the economic progress of the black population. Consequently, the post-apartheid redistribution of infrastructure is not merely an economic concern but constitutes a fundamental constitutional and moral obligation for rectification. The study's concentration on the spatial allocation of investment is a direct response to this singular historical context. It transcends the inquiry of whether infrastructure investment stimulates growth and addresses the more pivotal question: "Where is it occurring, and who stands to benefit?" This spatial analysis serves as a more precise instrument for gauging the progress, or lack thereof, in dismantling the economic geographical remnants of apartheid than would a broader institutional analysis. South African political economists posit that the spatial economic distortions left by apartheid persist as the principal economic challenge for the country, asserting that targeted infrastructure investment serves as a fundamental mechanism for rectification (Fedderke and Garlick, 2008; Turok, 2019).

Theoretical Parsimony and Model Specification: From a methodological perspective, infrastructure investment presents a more tractable variable for the specified econometric models. This can be operationalized either as a financial flow (e.g., Gross Fixed Capital Formation in construction) or as a physical stock, facilitating its integration into regression equations alongside other macroeconomic variables such as GDP and employment. The integration of complex institutional constructs would necessitate robust, time-variant proxies (e.g., World Governance Indicators), which are typically accessible solely at the national level, thereby hindering the study's invaluable provincial-level analysis. By concentrating on infrastructure, the study sustains a more refined, parsimonious model capable of distinctly isolating the macroeconomic and spatial effects of capital investment.

Complementarity, Not Exclusion: It is imperative to recognize that the study does not disregard institutions; rather, it implicitly maintains them as constant to isolate the variable of interest. The adverse finding that aggregate investment (GFCF) correlates with a decline in GDP serves as a significant indictment of the institutional environment

in which that investment transpires. The authors accurately interpret this as indicative of "corruption, state capture, and inefficiency." Consequently, the infrastructure-focused analysis inadvertently yields some of the most compelling evidence for the very institutional failures an institutional economics perspective would underscore. The infrastructure lens functions as an exact mechanism to disclose institutional deficiencies.

In summary, 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. The next Sub-chapter 2.2 presents the definition of infrastructure and states the category this study employs.

2.2 Defining Infrastructure

In the field of economics, infrastructure denotes the essential physical and organizational frameworks, facilities, and systems requisite for the functioning of a society, enterprise, or the economy in its entirety. It constitutes the foundational capital that facilitates productive activities, aids the movement of goods and individuals, and delivers vital services to households and businesses (Aschauer, 1989; Munnell, 1992; Gramlich, 1994). Infrastructure is divided into two broad categories, public infrastructure and private infrastructure; their respective classifications are determined by their sources of funding. The former is funded through public financial mechanisms and the latter by private sources (Aschauer, 1989; Eberts, 1990). This investigation delves into the domain of public infrastructure, which is further divided into two subcategories: economic overhead capital (EOC) and social overhead capital (SOC). EOC directly supports the movement of goods and facilitates economic activity; public works projects such as transportation networks and systems, energy generation facilities, telecommunication networks, and so forth (Eberts, 1990; Munnell, 1992; Gramlich, 1994). Fedderke and Garlick (2008) further add that it is universally accepted that infrastructure spending is regarded as

capital expenditure, with infrastructure being acknowledged as a capital good. SOC invests in the enhancement of human capital through the establishment of healthcare and education facilities, policing, frail care homes, and so on and so forth (Eberts, 1990). The classification of infrastructure by Fedderke and Garlick (2008) agrees with Aschauer (1989) and Ebert (1990), with the addition of cultural and recreational facilities to the social overhead capital of the subcategory. Several authors recognise that economic and social infrastructure development is one of the prominent determinants of economic development, and especially the case in developing countries (Munnell, 1992; World Bank, 1994; Richaud *et al*., 1999; Röller and Waverman, 2001; Sahoo et al. 2010). For the purposes of this investigation, economic (public) infrastructure that supports the performance of economic activities will be further dealt with.

There is a consensus amongst studies that public infrastructure possesses two characteristics: firstly, that they provide a rudimentary bedrock for economic activity; secondly, the societal benefits generated called positive spillovers greatly exceed the price any economic actor would be willing to pay (Aschauer, 1989; Eberts, 1990; Richaud *et al*., 1999). These positive spillovers arise for a number of reasons, for example largely they are nonexcludable services, where their usage by person 'A' does not decrease the derived benefits of usage from person 'B'. Certain types of infrastructure (pollution abatement facilities) counter the negative externalities generated by the private sector. Other types of public infrastructure, such as telecommunication networks, unveil opportunities for economies of scale (Aschauer, 1989; Eberts, 1990; Gramlich, 1994; Röller and Waverman, 2001).

Public infrastructure projects are largely implemented by the lowest sphere of government, which is the local or regional municipality within a country. Globalisation has been influenced and identified as a vital driver of change in the way local economic development (LED) projects are planned and executed. LED initiatives are implemented largely through infrastructure investment and research conducted by Sahoo et al. (2010:3) observes that *"Direct Investment on infrastructure creates (i) production facilities and stimulates economic activities; (ii) reduces transaction costs and trade costs improving competitiveness and (iii) provides employment opportunities to the poor"*. Zeng (2015) illustrates China as an example of large-scale infrastructure investment in recent decades, which through and open economic policy and a series of institutional reforms have been on a double digit (10% annually) growth trajectory second to none resulting in a mammoth increase in GDP per capita from US$40 to US$3,400 between 1978 and

2008. The application of an open economic policy has not been applied throughout the country, but specific regions have been identified and special economic zones (SEZs) have been established, such as in the case of Shenzhen, Zhuhai, Shantou, and so forth (Zeng, 2015). The authors further conclude that a *"lack of infrastructure creates bottlenecks for sustainable growth and poverty reduction"* (Sahoo, *et al*., 2010:3).

There is a general consensus that LED practices emerged in cities in the global North during the 1960s, where there was a shift towards decentralisation and underpinned by an environment of global economic restructuring (Rogerson and Rogerson, 2010). The authors further mention that there are numerous definitions for LED; one of them is defined by the World Bank as 'a process by which public, business and nongovernmental sector partners work collectively to create better conditions for economic growth and employment generation' (Rogerson and Rogerson, 2010:466).). Each of the other definitions quoted highlights various aspects of this concept; however, there is an agreement that the main objective of LED is to foster an environment for economic growth and create employment opportunities in a defined locality.

This section defined infrastructure in its two broad categories that are social and economic in nature. It went on to emphasise that the objective of this study, the public economic infrastructure that supports the performance of economic activities, will be further assessed. There is a consensus amongst studies that public infrastructure possesses two characteristics: firstly, that they provide a rudimentary bedrock for economic activity; secondly, the societal benefits generated called positive spillovers greatly exceed the price any economic actor would be willing to pay (Eberts, 1990). Public infrastructure investments are made through public expenditure and are operationalised through the lowest sphere of government, closest to the population, that is, a local municipality. This investment is the catalyst for further local economic development. The next Sub-chapter 2.3 discusses convergence theory, the theoretical framework for this study.

2.3 Convergence Theory

Over the past 30 years literature highlights that there is a lack of consensus amongst policy makers and academics in defining economic development and understanding what it entails. This obscurity stems from the inability of macroeconomic policy to satisfy both the individual and the collective needs of society (Feldman, *et al*., 2016). It is often

bundled with economic growth, a short to medium term indicator that is quantifiable and measurable as emphasis is placed on increasing aggregate output, employment, or population regardless of whether they can be linked to advances in the standard of living. A measurement of the standard of living of a population is represented by real GDP per capita which estimates the average earning per person adjusted to inflation. Scholars such as Ricardo et al. (1819) and Solow (1956) developed the foundational theories of economic growth where an economy was conceptualised to be mechanistic which produces an output as a function of the factors of production inputs. Economic agents or actors go through a process of effectively allocating scarce resources to an economic activity in order for an output to be produced efficiently at the lowest possible cost. The concept of economic development is focused on a longer term usually beyond a 10-year period and is grounded on the collaboration between public, private sectors and civil society (Feldman, et al., 2016). The authors further add that this is dependent on the government's ability to foster environmental conditions that will enable long run economic growth through public investments in infrastructure, institutions, education, attracting domestic and foreign capital and so on and so forth.

Within the framework of neoclassical growth models, particularly the Solow-Swan model (1956) and its subsequent extensions by Barro (1991) and Sala-i-Martin (1996), convergence denotes the hypothesis that economies with lower per capita income will experience accelerated growth rates compared to wealthier economies. As a result, over time, the income levels of various economies are expected to converge towards a uniform steady-state level. The fundamental mechanism underpinning this phenomenon is the diminishing returns to capital. Wealthier economies possess a high capital-to-labour ratio, resulting in a relatively low return on additional capital investment. In contrast, poorer economies exhibit a low capital-to-labour ratio, thus additional capital investment yields substantial returns, enabling them to grow at a faster pace and "catch up."

The Solow-Swan model (1956) is the basis framework for enquiries into economic development and convergence when determining nations' steady-state equilibria. 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 (Sala-i-Martin, 1996). The steady state constitutes the fundamental organizing principle of the Solow model. It represents the long-term equilibrium position toward which the economy converges, irrespective of its initial conditions (e.g., whether it commenced as impoverished or affluent). The Solow-

Swan model centres around four variables: output (Y), capital (K), labour (L) and 'knowledge' or the 'effectiveness of labour' (A). Output changes over time only if inputs into the production process changes. If output increases over time t, with the given levels of capital and labour, this is seen as technological progress in terms of improvements in the effectiveness of labour (labour augmenting or Harrod-neutral). Meaning that improved allocation of resources in the production process has resulted in increases in output. The basic assumptions of the Solow-Swan model (1956) are that.

- Time is continuous.
- A single good is produced with constant technology.
- There is no government or international trade.
- All factors of production are fully employed.
- Labour grows at a constant rate.
- Initial values for capital, K_0 and labour, L_0 are given.
- Savings rate is constant. If there is no consumption, then savings will take place.
- Depreciation rate is constant.
- Constant returns to scale in capital (K) and effective labour (A).

Moreover, the model concentrates on three principal variables per worker: capital (K), output (Y), and investment (I). The Production Function: Output per worker (Y) is determined by the capital per worker (K) through a function Y = f(K). This function demonstrates diminishing returns to capital, wherein each additional unit of (K) results in a progressively smaller increase in (Y). Investment (I): A constant proportion (s) of the output is saved and subsequently invested; thus, the investment per worker is ($I = s * f(K)$. This represents the investment line in the graph, illustrating the amount of new capital being accumulated. Depreciation (δK): The current capital stock is subject to depreciation as it deteriorates and becomes obsolete. Depreciation per worker is considered to be a constant proportion delta of the capital stock, equating to ΔK. This embodies the depreciation line, which inclines upward. The Steady-State Condition: The alteration in the capital stock (ΔK): is equivalent to investment minus depreciation: $\Delta K = i - \delta K = s * f(K) - \delta K$. An economy is considered to be in a steady state when the capital stock per worker remains unchanged, implying ($\Delta K = 0$). Consequently, the steady-state condition is established as: $sY = (n + \delta)K$. At this stage, investment precisely counterbalances depreciation, ensuring that both the capital stock and output per worker remain constant.

There are two primary types of convergence (Baumol, 1986; Barro, 1991; Mankiw et al., 1992; Sala-i-Martin, 1996). Absolute Convergence (Unconditional Convergence) posits that less affluent economies will invariably expand at a more rapid pace than wealthier counterparts, irrespective of their distinct characteristics, ultimately achieving an equivalent per capita income level in the steady state. This denotes that all economies are characterized by identical foundational parameters, including the uniformity of savings rates, population growth rates, accessibility to technology, and institutional frameworks. Consequently, they converge to an identical steady state. The initial per capita income level remains the only distinctive factor. Conditional Convergence hypothesis posits that an economy exhibits accelerated growth, contingent upon its distance from its intrinsic steady state. Economies with lower wealth levels will surpass wealthier counterparts in growth rate only if they possess analogous steady-state attributes, such as savings rates, institutional quality, and human capital. This represents a fundamental assertion of the Solow model. Each economy gravitates towards a distinct steady state, delineated by its idiosyncratic parameters. A nation experiencing low initial income levels will achieve accelerated 'catch-up' growth solely if it is underpinned by fundamentals, including substantial investment in physical and human capital, stable institutional frameworks, and minimal population growth, which facilitate a high steady-state income level.

It is imperative to differentiate between beta (β), which represents the concept of convergence, and sigma (σ), which denotes convergence as an observable outcome. Beta-convergence describes the process of economic catch-up, characterized by an inverse relationship between initial levels of income and subsequent rates of growth. This form of convergence serves as a necessary prerequisite for sigma-convergence. Both absolute and conditional convergence are manifestations of beta-convergence, tested by assessing the presence of a negative coefficient (β) in a regression analysis of growth rates against initial income levels. Sigma-convergence, in contrast, pertains to the reduction in cross-sectional dispersion—such as the standard deviation, σ—of income levels across various economies over time. It is the observable phenomenon whereby incomes become increasingly similar. The examination of sigma-convergence involves assessing a decline in the logarithmic variance or standard deviation of per capita income across nations. While β-convergence is essential, it alone is insufficient for achieving σ-convergence. Economies may exhibit catch-up growth through beta-convergence; however, other variables, including stochastic shocks that disproportionately impact less affluent

countries, can exacerbate inequality among countries, thereby obstructing sigma-convergence. An advancement beyond the traditional neoclassical model, frequently linked with endogenous growth theories, is the concept of club convergence. This paradigm posits that economies do not converge towards a singular steady state or their own distinct state, but rather towards one of multiple potential steady states, or "clubs." For instance, a "rich club" composed of developed countries and a "poor club" consisting of developing nations, indicating convergence within each club but divergence between them. This phenomenon can occur due to factors such as coordination failures, technological traps, or institutional path dependence (Galor, 1996; Sala-i-Martin, 1996).

For an economy to achieve convergence, particularly conditional convergence, it is imperative that specific prerequisites are fulfilled (Hall and Jones, 1999). These prerequisites constitute the factors that enable an economy to leverage its "backwardness" and advance towards catching up with more developed economies. In their absence, convergence is unlikely to occur, potentially causing the economy to remain in a state of poverty trap. *Technology and Knowledge Accessibility*: A less developed country is unable to experience rapid growth through the process of reinventing existing technologies. It is essential for such a country to have the means to adopt and implement existing technologies from more technologically advanced nations, as this approach is considerably more cost-effective and expeditious than pursuing innovation. This necessitates: *Openness to Trade and Foreign Direct Investment* (FDI), which serves as a principal conduit for technology transfer. Education and Human Capital: A workforce endowed with skill is crucial to comprehend, operate, and sustain emerging technologies. Basic Infrastructure: The presence of reliable electricity, internet connectivity, and transportation networks is indispensable for the effective utilization of modern technology. *Capital Accumulation*: The principal mechanism driving convergence in the Solow model is an increasing capital-to-labour ratio. This necessitates: Investment: An adequate portion of national income must be allocated towards savings and subsequently invested in physical capital (such as machinery, factories, and infrastructure) rather than being consumed. *Functioning Financial System*: A robust banking and financial system are essential to facilitate the channelling of savings into productive investments. Sound Institutions and Economic Policies: This represents perhaps the most vital prerequisite. It entails: *Property Rights and Rule of Law*: It is imperative that investors (both domestic and foreign) have confidence that their capital and profits will not be subject to arbitrary appropriation. *Political Stability*: The absence of significant conflict or civil unrest is

crucial for long-term planning and investment. *Macroeconomic Stability*: Maintaining control over inflation, securing sustainable government debt, and ensuring a stable currency are necessary to create a predictable environment for business operations. *Limited Market Distortions*: Excessive regulation, corruption, and trade barriers can inhibit the efficient allocation of resources to their most productive uses. Although not a direct prerequisite, lower population growth rates facilitate the achievement of a high capital-to-labour ratio. An expanding population necessitates considerable investment merely to sustain the current capital-to-labour ratio, a process referred to as capital widening, thereby reducing the amount of investment available to enhance it per worker, known as capital deepening. For convergence to transpire, a developing nation must possess the capability to assimilate technology and maintain an institutional environment that fosters investment and productivity growth. In the absence of these factors, the diminishing returns to capital cannot be surmounted, and the nation remains impoverished.

Analysis on a growth equation using the Solow-Swan model (1956) is "*derived as a log-linear approximation, from the transition path of the neoclassical growth model for closed economies*" (Barro and Sala-i-Martin, 1991:108). The Cobb-Douglas production function, $Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}$, is applied and "*convergence coefficient, β, depends on the productivity of capital and the willingness to save. In particular, the source of convergence in the neoclassical growth model is the assumed diminishing returns to capital. If the ratio of capital (and hence output) to effective labor declines relative to the steady-state ratio, then the marginal product of capital rises. Therefore, for a given saving behavior, an economy grows faster the further it is below the steady state*" (Barro and Sala-i-Martin, 1991:109).

The steady-state equilibrium levels of each country are calculated following the Solow-Swan model (1956). Sala-i-Martin (1996:1020) extrapolates the classical methodology in his work and describes "*$\gamma_{i,t,t+T} \equiv log\ (y_{i,t+T} \div y_{i,t}) \div T$ be economy i's annualised growth rate of GDP between t and $t+T$, and let $log\ (y_{i,t})$ be the logarithm of the economy i's GDP per capita at time t*". Equation 1 is the model's regression estimation and Equation 2 depicts the effective worker output. Where Y is the total output, L is the number of workers, and A represents the level of technology or labour-augmenting technology.

$$\gamma_{i,t,t+T} = \alpha - \beta log\ (\gamma_{i,t}) + \epsilon_{i,t} \quad (1)$$

$$GDP\ per\ effective\ worker = \frac{Y}{L \times A} \quad (2)$$

Using the aforementioned as a theoretical base, contemporary economic growth theory has made use of aggregated models to measure economic growth. These approaches focus on whether or not there has been an increase in equilibrium gross domestic product GDP per capita over a period of time, identifying the economic factors which exerts an influence (Ascani, et al., 2012). Infrastructure is accurately investigated as either a stock or flow variable, where the former focuses on the "stock of infrastructure" at a certain point in time; and the latter examines if it has increased or decreased over a given period of time (Fedderke and Garlick, 2008). The authors Fedderke and Garlick (2008) further expand to say that these variables should be coupled with the appropriate macroeconomic measurement; infrastructure stock linked with aggregate output and infrastructure flows with GDP per capita as both are 'non-cumulative measures' as it is improbable for to display time trends. Enumerating infrastructure can be done either physically or financially are the two leading approaches. Physical measurement therefore depends on the type of infrastructure being investigated for example the kilometres of a road network. These studies applied the financial approach which computes the 'depreciated value of the accumulated investment' (Eberts, 1990; Fedderke and Garlick, 2008).

Moreover, the neoclassical Solow-Swan growth model of the 1950's has been the blueprint for the furtherance of economic theory and the drafting of policies for institutions around the world, where economic development was viewed as being a linear process which could be influenced by adjusting certain factors. This simplified view pays no attention to the multiplex social, institutional, or historical elements which are qualitative in nature that contribute to the advancement of an economy. Proponents of endogenous growth theory, including Solow (1988) and Mankiw, Romer, and Weil (1992), posited that technological innovation is central to the processes of economic growth in the long term (Ascani, et al., 2012). This study employs the principles and assumptions articulated within the framework of endogenous growth theory.

Economic development can be characterised as growth in the standard of living of individual citizens, where they have greater access to goods and services that improve their quality of life and the advancement of their social and economic stature (Bolganbayev et al., 2022). On the contrary, the authors describe regional development as improving the welfare of the region through the expansion of human resource

capabilities and the use of economic and social abilities (Bolganbayev et al., 2022). Francois Perroux (1950) published his seminal work on the growth pole theory that argues that economic development does not occur uniformly over an area, but rather is focused on certain businesses or sectors that act as "poles" of growth. These poles stimulate economic activity and growth in the surrounding areas through agglomeration and diffusion. Spatial development varies between nations and regions within them. Some regions can become more attractive than others in terms of factor of production, increasing their production capacity by attracting more capital and competent human resources, and therefore developing more quickly (Bolganbayev et al., 2022). The disparities in development across regions grow with time, to the detriment of undeveloped areas. Moreover, the developed, developing, and underdeveloped categories that form between nations throughout the world also exist between regions inside a country (Bolganbayev *et al.*, 2022).

Regional studies have long explored the question of whether GDP per capita converges or diverges between areas. Neoclassical economics holds that free movement of factors of production and comparative advantages leads to long-term convergence of labour and capital flows in inverse directions. Less developed nations and regions experiencing rapid growth converge near the prosperity levels of more developed regions. Regional economic growth theory and the interregional convergence hypothesis is illustrated by the Hecksher-Ohlin-Samuelson (1919, 1933, 1953) model which is an augmentation of David Ricardo's (1817) theory of comparative advantage. According to the model, specialisation in factor-abundant production combined with free interregional trade results in equivalent per capita incomes across areas for people with comparable skills (Dawkins, 2003). The idea of dynamic or static interregional convergence has apparent consequences for regional development theory: trade and investment will eventually result in wage equality across areas. It is crucial to note, however, that this does not necessarily mean equalisation of per capita incomes, because per capita incomes are affected by other factors such as population skill level and labour force participation rate (Dawkins, 2003).

Neoclassical growth models are dynamic by design; their convergence hypotheses refer to the convergence of growth rates rather than the static convergence of factor prices as is the case with its predecessor. Solow (1956) and Swan (1956) developed two types of convergence. First, convergence towards a steady-state growth rate resulting in stable per capita incomes, consumption levels, and capital/labour ratios is referred to as

conditional convergence. This is coined as conditional convergence, since savings rates, depreciation rates, and population growth rates vary between countries. As a result, conditional convergence may not always imply similar per capita income levels between countries. Secondly, absolute convergence arises when all countries' growth model parameters are equal, implying that richer countries would develop slower than poorer countries, and per capita incomes will eventually equalise between countries, as in the Hercksher-Ohlin-Samuelson (HOS) model of international trade (Solow and Swan, 1956). Although both models predict long-run convergence of per capita incomes across regions, the mechanism in which this occurs differs between the neoclassical trade and growth models.

Sala-i-Martin and Barro (1992) analysed the convergence of gross incomes in 92 countries. Their findings show convergence only if the factors influencing steady-state income remain stable. They observed a convergence rate of approximately 2% annually, which is known as the 'iron rate' (Barro and Sala-i-Martin, 1992). Mankiw et al. (1992) employed a cross-sectional technique based on the Solow growth model, examining the income convergence of 98 nations. The authors observed that conditional convergence occurs when population growth and capital accumulation do not change. McCoskey (2002) highlights a limitation of earlier convergence studies, the manner in which time was dealt with. The author further elaborates that the use of cross-section data sets is "constructed from observations averaged over time" (McCoskey, 2002:819).

Islam (1995) was at the forefront in the use of non-stationary panel estimating techniques to assess convergence in terms of per capita real income. The study also concluded that there is conditional convergence in per capita real income. Using nonstationary time series tools provides a better understanding of the series' course, which is important for analysing probable convergence over time, as stated by McKoskey (2002). Several researchers, namely Quah (1996a, 1996b, 1996c), Lee *et al*. (1997), Pedroni (1997), St Aubyn (1999), and McCoskey and Kao (1999), have applied these sophisticated econometric tools. Time series tools can prevent the possibility of misleading regressions since incomes have frequently tested non-stationary, or I(1). While not directly addressing the convergence axiom, Pedroni (1997) and McCoskey and Kao (1999) both continue to employ heterogeneous panel methodologies to examine the effects of urbanisation and human capital on development, respectively.

In a more recent study McCoskey (2002) investigated income convergence among 37 Sub-Saharan African countries from 1960 to 1990, testing the hypothesis of club

convergence using a nonstationary panel data approach, but did not detect any convergence in real GDP. Furthermore, a study by Fedderke et al. (2006) examined the link between investment in economic infrastructure and long-run economic growth. By evaluating the experience of South Africa in a time series setting from 1875 to 2001 through the vector error correction model (VECM) approach. Saba and Ngepah (2020) investigated the convergence in military spending and economic growth (real GDP per capita) of 35 African countries between 1990 and 2015. The analysis demonstrates that little to no income convergence can be observed between African countries. Ouattara and Zhang (2019) investigated long-run steady-state relationships between 29 Chinese provinces. Moreover, it studies the impact of infrastructure investment on output elasticities by applying causality tests by Dumitrescu and Hurlin (2012).

Moving onto the European context, Lengyel and Kotosz (2018) compared the success of catching up of NUTS3 areas in the four countries of the Visegrad group (Czech Republic, Hungary, Poland and Slovakia) with the average of the 15 founding member states of the European Union (EU) from 2000 to 2014. This was done by examining their respective real GDP per capita based on purchasing power parity. These countries acceded to the European Union (EU) in 2004. The integration of these economies into the EU began prior to this and was bolstered by monies from the Structural Fund following accession. The goal is to help less developed areas catch up and converge to the average of the more senior member states. The authors observed that all four nations were catching up, however, at different rates. The Czech and Hungarian economies declined between 2006 and 2008, but the Slovakian and Polish economies grew steadily throughout the period.

Kanó and Lengyel (2021) further explored this group and investigated the phenomenon of club convergence among the Visegrad group of four countries (Czechia, Poland, Hungary, and Slovakia) during the period 2000-2016. The authors examined whether convergence can be observed amongst the group, given that they have a shared socioeconomic historical context. Their analysis found that in spite of the substantial cohesion subsidies provided by the EU, there was no convergence among these countries.

Kung (2009) took a nontraditional approach by examining the interaction between economic growth and the financial system and assessing if convergence could be detected. The panel comprised 57 countries and was divided into three groups categorised as top, middle, and bottom based on their real GDP per capita between 1967 and 2001. The findings give strong support for conditional convergence. Middle- and high-income

countries have comparable growth paths in terms of GDP per capita and the development of their financial systems (Kung, 2002). The mutually reinforcing relationship between financial development and economic growth is highest in the early phases of economic development, but it decreases when sustained economic growth occurs. As a result, low-income countries with a moderately established financial sector are more likely to catch up with their middle- and high-income counterparts, whereas those with a less developed financial sector are more likely to remain impoverished. In addition, this result accounts for the significant divergence observed between impoverished and rich countries. Saba and Ngepah (2020) investigated the hypothesis of club convergence in military spending and economic growth (real GDP per capita) of 35 African countries from 1990 to 2015, applying the Phillips and Sul (2009) methodology. The analysis showed that little to no income convergence can be observed between countries.

This subchapter discussed the fundamental rationale of convergence theory and its link to Ricardo's (1819) theory of comparative advantage, its augmentation by Hecksher-Ohlin-Samuelson (1919, 1933, 1953), and its evolution into neoclassical growth models by Solow and Swan (1956). Then it went on to present the application of the convergence hypothesis by scholars investigating the phenomenon in both developed and developing economies. The literature produced results that support and contradict convergence theory, with emphasis placed on the practicality in using homogenous nations in the population. The next subchapter 2.3.1 discusses the criticisms of convergence theory.

2.3.1 Criticisms of Convergence Theory

The previous Subchapter 2.3 discussed studies in favour of the application of the convergence hypothesis to assess the economic development of a country and detailed their findings. However, despite the evidence in support of its use, it is necessary to mention its shortcomings as highlighted by several studies (North, 1990; Arthur, 1994; Pierson, 2000; Acemoglu, 2008, 2009; Rodrik, 2011; Acemoglu and Robinson, 2012). The convergence hypothesis is a fundamental idea in development economics, implying that economies of impoverished nations evolve quicker and catch up with affluent, more advanced economies over time (Barro and Sala-i-Martin, 1992). This hypothesis is predicated on the assumption that developing nations have the capacity to attain faster economic development rates as a result of technology, capital accumulation, and knowledge transfer from more sophisticated economies. One of the main criticisms is the

simplicity of the development mechanism and the assumption of a straight and universal path to economic advancement (Acemoglu, 2008; 2009). Researchers (North, 1990; Arthur, 1994; Pierson, 2000; Acemoglu, 2008, 2009; Rodrik, 2011; Acemoglu and Robinson, 2012) argue that the convergence theory does not account for the manifold and unique attributes of development, which is impacted by a variety of factors such as institutional, political, social, and cultural oscillation.

Heterogeneity and Divergence: a principal criticism levelled at the convergence theory by Durlayf and Quah (1999) is its failure to explain the continual heterogeneity and divergence detected among countries and regions. According to empirical research, a few nations and areas have seen significant economic development and convergence, whilst others have stalled or lagged behind (Rodrik, 2011). Furthermore, Rodrik (2011) postulated that the variance in development paths indicates that the convergence theory's assumed universal trajectory is unable to capture the diverse and multidimensional character of growth.

Institutional and Structural Factors: another key deficiency in the convergence theory is its inadequacy to take institutional and structural elements into account when determining a country's growth journey (North, 1990). Acemoglu and Robinson (2012) identifies the quality of governance, the strength of property rights, the extent of corruption, and the presence of inclusive political and economic institutions as important factors of economic growth and development. Moreover, according to the authors the convergence hypothesis places an enormous weight on capital and technology transmission but ignores the role of institutional and structural variables in promoting sustainable development.

Path Dependence and Initial Conditions: Arthur (1994) asserts that the convergence hypothesis also omits to consider the impact of route dependency and the onset conditions in a country's growth course. A country's historical legacies, cultural norms, and present power arrangements all have a significant influence on its economic trajectory and ability to compete with more sophisticated economies. These initial conditions might cause self-reinforcing systems that perpetuate inequality and impede catch-up efforts (Pierson, 2000).

Geopolitical and Global Factors: furthermore, Rodrik (2011) concludes that the convergence hypothesis is generally inadequate to account for geopolitical and global components that influence a country's growth. Moreover, the author states that the components such as global power distribution, trade agreements, financial flows, and technological advancement can all have a substantial influence on a country's capacity to catch-up with more advanced economies. The convergence hypothesis's limited focus on national-level determinants and neglects the complexity and interdependence of the global economic structure (Rodrik, 2011).

This subchapter discussed the convergence hypothesis and highlighted its invaluable foundation for the comprehension of the possibility for economic catch-up. It then presented the convergence theory as applied by researchers studying the issue in both established and emerging countries. The literature generated data that support and contradict convergence theory, with a focus on the practicality in employing homogeneous nations in the population. It has been broadly criticised for oversimplifying and its inability to capture the multifaceted and intricate character of advancement. A dynamic approach is needed that considers the role of institutions, structural variables, path dependency, and global dynamics. This will enhance the comprehension of the varying development paths observed amongst countries and regions. Despite these criticisms the convergence hypothesis is still widely utilised by scholars to investigate such a complex phenomenon. Econometric modelling requires a simplification of the real world by reducing it to a handful of variables for analysis and to draw conclusions from what the results reveal. The numeric results when linked to actual policy documents or projects can assist in the determination of what works and what does not. Therefore, its continual use is justified and necessary as was the case in this study. The next subchapter 2.4 introduces the concept of income inequality and its elements within the Southern African Customs Union and then discusses it in the South African context.

2.4 South Africa’s Political Economy

Political economy refers to the intersection of economic and political factors. It encompasses the examination of the evolution of societies over time, considering socio-economic and political dynamics (Gumede, 2015). 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).

2.4.1 Income Inequality

Kuznets (1955) seminal work on income inequality defines the phenomenon as an uneven income dissemination across groups, households, countries, or regions. Income inequality is specifically associated with malfeasance since the vast share of income is concentrated in the hands of a small number of people, while the majority of the population has the lowest share of income (Todaro, 1977; Hardoon *et al*., 2016). Sulla *et al.* (2022). The authors identify four sources of high and persistent inequality in the Southern African Customs Union (SACU), also the world's oldest functioning customs union established in 1910, comprises of Botswana, Eswatini, Lesotho, Namibia and South Africa.

- Pre-income distribution refers to the inequality of opportunity caused by differences in birth and childhood circumstances, such as gender, race, location, parental education, and family wealth. These differences can lead to inequalities in income distribution even before factor markets are involved.
- Primary income distribution examines how inequality affects access to assets including education, skills, land, and money, as well as their usage and market returns.
- Secondary income distribution, which refers to the inequality that remains after subtracting or adding taxes and government transfers from primary income.
- Tertiary income distribution, which refers to income inequalities after accounting for social expenditure on public goods including education, health, and infrastructure services, as well as taxes and subsidies.

The authors observed that Inequality of opportunity accounts for one-fifth of total inequality in the SACU. Disparities at birth are a significant source of inequality in the area, although their entire relevance cannot be reliably quantified due to insufficient data on people's situations, albeit less so in South Africa (Sulla *et al*., 2022). Over the last two decades, inequality of opportunity has grown in all SACU nations except Namibia. Moreover, SACU's history of geographical segregation, including the rural-urban split, continues to contribute to inequality of opportunity. Factors related to where people are

born and raised have a much greater impact on their life chances than gender (Sulla *et al*., 2022).

In South Africa, the legacy of colonialism and apartheid, which was based on racial and spatial isolation, continues to result in entrenched disparity. South African data enable for a more detailed investigation of opportunity inequality, including the influence of race and family characteristics. Disparity of opportunity accounts for over half, 47.7 percent of total disparity in consumption per capita, with race accounting for around 38.9 percent (Sulla *et al*., 2022). South Africa's 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 foundational framework of Keynesian economics emphasises the importance of aggregate demand in driving economic activity. Keynes' established standpoint was that government intervention through its tool of fiscal expansion was crucial to confront economic volatility, achieve full employment, stabilise prices, and reduce income inequality (Keynes, 1936).

South Africa 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). Several researchers (Leibrandt *et al*., 2012; Younsi and Bechtini, 2018; Mdingi and Ho, 2023; Sheunesu and Niyitegeka, 2023; Sulla *et al*., 2023; Choga *et al*., 2024; Sabella *et al*., 2024) have been motivated to study this phenomenon in this unique context from different aspects. Younsi and Bechtini (2018) empirically examined the causal relationship between income inequality, financial development and economic growth in the BRICS (Brazil, Russia, India, China and South Africa) group of countries from 1995-2015. The results confirm the financial Kuznets hypothesis of an inverted U-shaped relationship between economic growth, financial sector expansion, and inequality in the BRICS nations over the research period. Furthermore, the authors reported that the Granger causality test results indicate a unidirectional relationship between financial development index and income inequality, whereas inflation and income inequality have

a bidirectional relationship. However, no direct link exists between income disparity and economic growth (Younsi and Bechtini, 2018).

Mdingi and Ho (2023) investigated the link between income inequality and economic growth in South Africa over the period 1989-2018. The authors used the autoregressive distributed lag (ARDL) bounds test approach to examine the long-term link between economic growth and income disparity. The study found that income disparity has a negative long-term impact on economic growth but has no effect in the short run.

Sheunesu and Niyitegeka (2023) examined the link between domestic household debt and income inequality in South Africa from 1980-2021. The linkage was estimated using the vector error correction model (VECM). The results of the study demonstrated a long-term negative and significant association between domestic household debt and income inequality.

Choga *et al*. (2024) investigated the manner in which globalisation impacts income inequality in the South African economy from 1980-2022. The autoregressive distributed lag (ARDL) method was applied to the Gini index, the Konjunkturforschungsstelle (KOF) globalisation index, GDP per capita, unemployment rate, inflation rate, and government spending. The ARDL test results showed that globalisation has a negative long-run equilibrium connection with income inequality. Implying that globalisation often leads to increased economic disparity. The Granger causality results demonstrated a unidirectional association between globalisation and income disparity. This shows that changes in globalisation have a direct impact on income disparity.

Seabela *et al*. (2024) investigated the interconnection between South Africa's economic disparities and their factors. The study applied the Vector Error Correction Model (VECM) to empirically analyse the impact of government expenditure on social assistance payments, gross savings, population growth, and economic development on income inequality between 1975 and 2017. Their findings indicate that there is an empirically significant negative correlation between government spending on social handouts and economic disparity. Income disparity has a detrimental impact on both gross savings and economic development.

Further exploration of Kuznets' theory of income inequality is necessary in order to grasp the mechanics of the phenomenon. The theory states that when an economy grows, income disparity initially rises, reaches a peak, and then gradually decreases as the economy matures. The key assumption is that economic expansion generates a U-

shaped curve of income disparity. Income disparity grows throughout the early phases of industrialisation as wealth becomes concentrated among industrialists and capital owners (Kuznets, 1955). The shift from an agricultural economy to an industrial economy is prone to result in income inequalities because various sectors expand at different rates. Initially, people who own wealth or have in-demand skills profit disproportionately. As economies grow, educational possibilities expand, which can help reduce inequality over time as more people are afforded the opportunity to access higher-paying employment positions. Moreover, as development proceeds, factors such as increased education, social mobility, and government redistribution programs help to reduce inequality in later phases of development (Kuznets, 1955).

Growth in the sizes of cities occurs due to internal migration movements. It emerges as a necessary process influencing income dissemination and generally, contributing to income disparity. However, income disparity rises during the early phase of urban agglomeration, while structural advancement is progressing. Moreover, income disparity increases during the early phase of urban agglomeration, while structural development is still in progress. Furthermore, income disparity diminishes with equitable urban infrastructure expansion and industrial dispersion (Piketty, 2006). Developing countries are currently experiencing a period of increasing urbanisation where rural regions have lower per capita incomes than cities. Studies by Bourguignon and Morrisson, (1998) and Piketty (2006) demonstrated that economic performance may improve when industrial per capita production capacity grows faster than in the agricultural sector. This growth in one sector will broaden income inequality in the other sectors (Bourguignon and Morrisson, 1998; Piketty, 2006). Furthermore, the expansion of cities owing to internal migratory patterns has emerged as an essential process impacting income distribution and, in general, contributing to income disparities (Bourguignon and Morrisson, 1998; Piketty, 2006).

Francis and Webster (2019) argue that the economic, political, and social power systems that perpetuate poverty and inequality in South Africa have not received adequate attention. Moreover, the authors expound that one possible factor is the state's lack of political authority to bring about significant change. Focussing on technical aspects of poverty and inequality, such as measurement and quantification, has diverted attention away from the ways that change could be effected.

This section expanded upon the theory of income inequality by Kuznets (1955) and discussed the phenomenon in a Southern African context and provided sources for its persistence in these countries. It then focussed on South Africa and presented existing literature that empirically examined income inequality using several econometric techniques. Subsequently, Section 2.4.2 delineates the historical backdrop of energy generation in South Africa and articulates its contemporary condition.

2.4.2 Electricity Supply Crisis

When electricity demand exceeds the available supply, the stability of the grid is compromised. This situation may lead to the shutdown of generation units, further deteriorating system performance. In such circumstances, a reduction in generation capacity imposes additional stress on the remaining units and, in the worst-case scenario, may initiate a cascade of failures across multiple power stations, culminating in a nationwide power outage. Such an event could result in a nation experiencing several days without electricity (Walsh *et al*., 2020). To mitigate this, utilities or system operators implement load shedding when national electricity demand threatens to surpass supply, and when short-term measures to augment supply have been fully exhausted. This mechanism is formulated to regulate the spatial and temporal occurrence of outages to prevent a comprehensive failure of the power grid (Ballim, 2025). Load shedding is largely executed in rotational intervals lasting two to four hours, with different sections of the network being sequentially impacted (Walsh *et al*., 2020). Since October 2007, the South African national electricity provider, Eskom, has implemented a series of strategically planned power outages. In which both business and households have contended with (Inglesi-Lotz, 2023). Those with lower incomes are disproportionately affected by unreliable electricity supply, escalating energy costs, and their constrained financial capacity to mitigate such disruptions, given their socioeconomic conditions (Inglesi-Lotz, 2023). This persistent deficit in power supply has significantly affected employment rates within the energy-dependent manufacturing sector. Enterprises unable to allocate resources towards expensive diesel generators were compelled to cease production or completely shut down, inflicting a substantial detriment to employment in a nation already contending with profound income inequality. During the last two fiscal years (2023-2024), the frequency of load shedding occurrences has reached levels that render it seemingly perpetual. In 2023, South Africans experienced load shedding for a total of 332 days (Ballim, 2025).

The commencement of South Africa's electricity crisis in 2007 was primarily attributed to the government's failure to implement the comprehensive reforms of the electricity sector as outlined in the 1998 Energy Sector White Paper. This reform model proposed the separation of Eskom into distinct entities to differentiate the competitive elements, such as generation, from natural monopoly components, namely transmission and distribution. The central objectives of the policy paper were to attract private sector involvement in electricity generation, transition to cost-reflective pricing, expand basic electricity access, and harmonize the fragmented municipal distribution network (Walsh *et at*., 2020). Nevertheless, the South African Government did not fully comprehend the implications of Eskom's significantly subsidized electricity pricing on private sector investment within the energy industry. For over a decade, the government implicitly subsidized electricity prices, which did not accurately reflect the genuine costs of production, transmission, and distribution. As a result, there was limited financial incentive for private sector investment (Walsh *et at*., 2020).

In 2007, Eskom issued a cautionary notice indicating potential constraints within the energy system projected to occur in the subsequent five to six years. The utility called upon all stakeholders to collaborate in mitigating the risk of power disruptions. In response to this advisory, October 2007 marked the initiation of Eskom's first instance of load shedding. Then-President Mbeki assumed responsibility for this lapse in planning and, on December 12, 2007, issued a public apology, recognizing that "Eskom was right, the government was wrong." As a result, the Eskom board in 2007 was able to accelerate the approval of a substantial capacity expansion program, entailing the construction of two large coal-fired power plants, Medupi and Kusile (Walsh *et at*., 2020). The initiation of load shedding occurred in 2007, coinciding with the commencement of construction on the new Medupi and Kusile power plants by Eskom, albeit too late to pre-empt the escalating electricity crisis. The need for new power stations arose in conjunction with a governmental shift in public spending policy. During President Thabo Mbeki’s tenure in the 1990s, South Africa adopted fiscal austerity aimed at stabilizing the financial conditions burdened by debt inherited from the apartheid era. However, in 2004, Mbeki announced the National Development Plan (NDP), signifying a transition towards augmented public expenditure. The NDP prioritized the development of new infrastructure through state-owned entities such as Eskom, reversing prior austerity measures that had inhibited investment in additional power generation (Ballim, 2025).

The sophisticated technological requirements of Eskom necessitate a complex interaction between the government and the corporation. Government officials lack the technical proficiency required to construct and operate power plants, whereas Eskom's engineers do not possess the political mandate necessary to implement public infrastructure projects (Ballim, 2025). Consequently, they are engaged in an intricate web of inevitable conflict and cooperation. Since its establishment in 1923, Eskom grew into an immense entity, by the 1980s equating in asset-replacement value with South African mining operations. Irrespective of the governing regime—whether under apartheid or the democratic governance established in 1994—any governmental endeavour involving electricity had to negotiate through Eskom, often resulting in deviations from the initial plan (Ballim, 2025).

Between 2007 and 2019, load shedding was responsible for a cumulative decline in GDP amounting to R34.5 billion. Specifically, during the second quarter of 2015, load shedding resulted in 809 GWh of energy being shed, which corresponded to a GDP loss of R7 billion. The manufacturing sector bore nearly 40% of this economic impact, while the agricultural sector suffered a reduction of over 5% in its production between 2013 and 2015 as a consequence of load shedding (Walsh *et al*., 2020). The sectors of manufacturing, transport and communication, retail trade, and agriculture collectively accounted for more than 80% of the total expenses. The manufacturing sector, in particular, was responsible for nearly 40% of the load shedding costs. Conversely, the financial and business services sector experienced a relatively minor loss of merely R0.07 per kWh, constituting less than 1% of the overall impact. Relative to its contribution to the GDP, the agriculture sector suffered the most significant impact, experiencing an output loss 4.2 times greater per kWh of load shedding (Walsh *et al*., 2020). The incongruity between electricity supply and demand has led to economic losses and hindrances to industrial growth (Mabugu and Inglesi-Lotz, 2022).

This section expanded upon the concept of load shedding and discussed the phenomenon in a South African context and expounded on its genesis and the impact it had on its economy over the last decade. Next, section 2.4.3 provides an in-depth discussion of the important policies, frameworks, plans and strategies developed by the South African government, in order to address its social ills.

2.4.3 Democratic Developmental Pledges and Priorities

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). In the 1980s, Carnegie Two, investigated poverty and focused primarily on the black population. Wilson and Ramphele (1994) succinctly described their impressions of this work.

"Poverty is a profoundly political issue…there are four reasons why poverty is significant. The first is because of the damage it inflicts upon individuals who must endure it; the second is its sheer inefficiency in economic terms. Hungry children cannot study properly; malnourished adults cannot be fully productive as workers; and an economy where a large proportion of the population is very poor has a structure of demand that does not encourage the production and marketing of those goods that are most needed. The third reason relates to the consequences for any society where poverty is also the manifestation of great inequality. As Raymond Aron has reminded us, the existence of too great a degree of inequality makes human community impossible. Finally, there is the fact that poverty in many societies is itself symptomatic of a deeper malaise. For it is often the consequence of a process which simultaneously produces wealth for some whilst impoverishing others." (Wilson and Ramphele, 1994:4)

In 1994, the African National Congress (ANC) a freedom movement, led the tripartite liberation alliance and won 63% of the votes casted on 27 April 1994. This resulted in a majority parliamentary victory, moreover the political party now and to transition from a movement into a governing party led by President Nelson Rolihlahla Mandela (Wehner, 2000). Moreover, the new democratic dispensation inherited an economy which had been in decline for over a decade. It responded by publishing its main policy framework, the Reconstruction and Development Plan (RDP) in 1994. Wehner (2000) further highlighted that this was recognised as a fundamental policy pledge to its constituency and dealt with social and economic challenges as being interrelated, it identified its first priority as meeting basic needs of access to water, sanitation and housing. This was coupled with the development of human capital through the provision of education and training (Wehner, 2000).

The RDP met its end in June 1996, and the Growth, Employment and Redistribution (GEAR) strategy was launched by the Department of Finance which emphasised the need for consistent and high levels of growth to be achieved through a *"competitive outward-oriented economy"* (Department of Finance, 1996:1). Targets were set using macro econometric methodologies for the period 1996-2000 and highlighted the need for the *"moderation of wage demands to avoid a vicious circle of wage and price increases leading to instability in the financial markets and a decline in competitive advantage"* (Department of Finance, 1996:20). President Thabo Mbeki took office in 1999 and led the implementation of GEAR which was widely criticised by the tripartite alliance members (Congress of South African Trade Unions and South African Communist Party) who claimed that its development was done in isolation and lacked adequate consultation.

In 2005 the Accelerated and Shared Growth Initiative for South Africa (ASGiSA) was launched and builds on the foundations of the RDP's goals of building a united, democratic, non-sexist and non-racial society, and a single integrated economy. Subsequently, President Jacob Zuma took office in 2009, ASGiSA was scrapped and led the implementation of the New Growth Path in 2010 which then transformed into the National Development Plan (NDP) in 2013 and is the country's current policy blueprint driving for the elimination of poverty and reducing inequality by 2030 (Wehner, 2000). The strategies, plans and frameworks mentioned all achieved marginal successes but failed in the training and education of the large percentage of low skilled workers in the population, endemically high levels of unemployment continue, consistent low levels of economic growth. This and the lack of structural changes to the economy are resultant of political instability which has ravaged the ruling party since President Mandela left office in 1999 (Wehner, 2000).

The National Infrastructure Plan was adopted by the South African government in 2012 and is discussed separately due to the magnitude of its impact on infrastructure investment response by the country. The NDP's Chapters 4 (Economic Infrastructure), 6 (Inclusive Rural Economy), and 8 (Transforming Human Settlements) aim to improve the country's infrastructure. Priority investment sectors include transportation and port capacity, electricity, water and sanitation, housing, and broadband. The NDP aims to achieve a gross fixed capital-to-GDP ratio of 30% by 2030, with public investment at 10% of GDP. According to the NDP, the government's involvement in infrastructure supply should focus on social infrastructure, regulation and governance, and financial aid

through guarantees and subsidies (National Planning Commission, 2012). The ERRP reinforces the objectives of the NDP by highlighting the need to enhance the state's technical, project preparation, and financial engineering skills. The report emphasises the value of using private sector expertise. The 2020 ERRP committed to establishing Infrastructure South Africa (ISA) as a centralised government body to coordinate and deliver infrastructure investments (South African Government, 2020). ISA was founded in May 2020 and is now managed by the Ministry of Public Works and Infrastructure (Msimango *et al.*, 2024).

The Presidential Infrastructure Coordinating Committee (PICC) was established by cabinet and has been tasked with the role of oversight of 18 Strategic Integrated Projects (SIPS) all of which have the objective of being catalytic projects to fast-track development and growth (Presidential Infrastructure Coordinating Commission, 2012). These infrastructure projects cover each of the nine provinces and are categorised into geographic, energy, spatial, social infrastructure, knowledge, regional and water and sanitation. These projects aim to address infrastructure shortfalls, be a catalyst for economic growth, and generate employment opportunities. The establishment of Infrastructure South Africa (ISA) in May 2020, the publication of the National Infrastructure Plan (NIP) 2050, and the operationalisation of the Infrastructure Fund are expected to aid in post-pandemic recovery by providing blended finance solutions and co-financing mechanisms for increased investment of the SIPs (Msimango *et al*., 2024). To date 276 projects have been earmarked from all three spheres of government (national, provincial, and municipal) and state-owned enterprises, funding these projects is a gargantuan undertaking, the agency Infrastructure South Africa's (ISA) is mandated to explore domestic and international funding mechanisms with the support of the Development Bank of Southern Africa and National Treasury. ISA's mandate is to accelerate the execution of social and economic infrastructure projects by overseeing their preparation, assessment, and evaluation, resulting in a market-ready pipeline (Infrastructure South Africa, 2022). ISA attempts to address governmental and regulatory barriers that hinder infrastructure development and implementation in the country. ISA aims to support the implementation of South Africa's Infrastructure Investment Plan and National Infrastructure Plan (NIP) 2050 (Msimango *et al.*, 2024). For our research purposes the completed projects for the sub-categories transport and ICT infrastructure in each of the provinces are summarised in Table 1 that fall within the period of investigation 1996-2021. They serve as examples of the types of infrastructure projects

the South African government developed for each of the 9 provinces in an attempt to address their socio-economic challenges.

Table 1 Provincial Transport and ICT infrastructure SIPs summary.

Province	Sub category	Project name	Start date	End date	Initial capital	Total capital	Employment no.	Agent
Eastern Cape Province	Transport infrastructure	N2 Wild Coast Road	2014	2025 (estimated)	ZAR 15 billion	ZAR 20 billion	Approx. 8,000 during construction	South African National Roads Agency
	ICT infrastructure	Eastern Cape Broadband Project	2017	2022 (Phase 1)	ZAR 800 million	ZAR 1 billion	Approx. 200 during implementation	Eastern Cape Provincial Government
Free State Province	Transport infrastructure	Maluti-a-Phofung Special Economic Zone (SEZ)	2017	2025 (estimated)	ZAR 5 billion	ZAR 10 billion	Approx. 3,000 during construction	Free State Provincial Government
Gauteng Province	Transport infrastructure	Gauteng Freeway Improvement Project	2008	Ongoing in phases	ZAR 20 billion	ZAR 30 billion	Approx. 12,000 during construction	South African National Roads Agency
	ICT infrastructure	Broadband Network Project (Siyakha)	2015	2020 (Phase 1)	ZAR 1.2 billion	ZAR 1.5 billion	Approx. 500 during implementation	Gauteng Provincial Government
KwaZulu-Natal Province	Transport infrastructure	Durban - Free State-Gauteng Logistics and Industrial Rail Corridor	2012	Ongoing in phases	ZAR 25 billion	ZAR 30 billion	Approx. 15,000 during construction	Transnet
	ICT infrastructure	KwaZulu-Natal Broadband Network	2016	Ongoing in phases	ZAR 1 billion	ZAR 1.2 billion	Approx. 400 during implementation	KwaZulu-Natal Provincial Government

Limpopo Province	Transport infrastructure	Musina - Makhado Special Economic Zone (SEZ)	2016	2030 (estimated)	ZAR 10 billion	ZAR 10 billion	Approx. 5,000 during construction	South African National Roads Agency
Mpumalanga Province	ICT infrastructure	Moloto Rail Corridor	2015	2026 (estimated)	ZAR 12 billion	ZAR 15 billion	Approx. 10,000 during construction	Passenger Rail Agency of South Africa
Northern Cape Province	ICT infrastructure	Northern Cape Broadband Project	2019	2022 (phase 1)	ZAR 300 million	ZAR 400 million	Approx. 100 during implementation	Northern Cape Provincial Government
Western Cape Province	Transport infrastructure	Cape Town International Airport Expansion	2017	2022	ZAR 7 billion	ZAR 7.5 billion	Approx. 2,000 during construction	Airports Company South Africa
	ICT infrastructure	Western Cape Broadband Initiative	2014	2021	ZAR 1.5 billion	ZAR 2 billion	Approx. 300 during implementation	Western Cape Provincial Government

Source: Author's construction from reports by the South African National Roads Agency (SANRAL), Eastern Cape Provincial Government, Free State Provincial Government, Gauteng Provincial Government, Transnet, KwaZulu-Natal Provincial Government, Passenger Rail Agency of South Africa (PRASA), Airports Company South Africa (ACSA), Northern Cape Provincial Government, Western Cape Provincial Government.

Table 2 National energy infrastructure SIPs summary (2014-2035).

Programme	**Description**	**Estimated CAPEX (ZAR)**
Electricity transmission and distribution	The "Electricity Transmission and Distribution for All" SIP Program seeks to expand the network to correct past imbalances, ensure universal electricity access, and boost economic growth. The Transmission Development Plan (TDP) calls for over 14,000 km of new power lines by 2034, requiring substantial investment in transformation capacity.	63,1 Bn
Embedded Generation National Programme	Embedded Generation National Programme (EGNP): This program encourages private investments in large-scale renewable energy projects, aiming for over 10,000 MW of new capacity in diverse industrial sectors.	340,9 Bn

Green Energy in Support of The South African Economy	Green Energy in Support of The South African Economy: This SIP Program supports national sustainable green energy initiatives through diverse clean energy options in the Integrated Resource Plan (IRP), including the Renewable Energy Independent Power Producer Projects (REIPPP).	83,3 Bn
Green Hydrogen National Programme	Green Hydrogen National Programme (GHNP): South Africa intends to produce 500 kilo tonnes of green hydrogen annually by 2030 under the 2021 Hydrogen Society Roadmap, aiming to lead the market.	1,285.8 Bn
Integrated Resource Efficiency and Renewable Energy Programme (IREREP)	The national programme for improving Resource Efficiencies and Renewable Energy in Government facilities to achieve Government and South Africa's sustainability targets.	387 Bn
Just Energy Transition National Programme	The Just Energy Transition Investment Plan (JETIP) outlines Priority Investments in Electricity, New Energy Vehicles, and Green Hydrogen sectors over the next five years (2023-2027).	146,3 Bn
Oil and Gas National Programme	In line with the Gas Utilization Master Plan and IRP, this initiative focuses on supporting energy security through Upstream Production and Downstream Use in Gas to Power applications.	150,5 Bn
Solar Water Initiatives Programme	This SIP Program aligns with the National Development Plan (NDP) objectives and includes three sub-components: (i) Load Reduction to decrease national grid electricity demand, (ii) Industrial Sustainability for repair/replacement, and (iii) a fiscally driven socioeconomic Component.	42,7 Bn

Source: Author's construction from reports by Infrastructure South Africa.

The literature review reveals a central issue characterized as a trilemma: South Africa is endeavouring to employ a mechanism, infrastructure investment, that is theoretically robust yet flawed in practical application, in order to address a challenge, economic stagnation, which is intricately linked to extreme inequality, a substantial issue. This is all in the pursuit of an objective convergence with developed nations, that its inherent structural deficiencies render exceptionally challenging to attain. Consequently, the study emerging from this review is not solely concerned with whether infrastructure influences growth, but rather with understanding why its anticipated benefits have not manifested to

the extent and equity necessary for transformative development within the South African context.

This chapter elaborated on the South African frame of reference for infrastructure investment through its numerous strategies, plans, policy frameworks and legislation since the inception of its democracy. The South African government developed comprehensive documents identifying its challenges and attempts to find solutions through its investment in public infrastructure. The South African government, under the National Development Plan (NDP), seeks to reduce income inequality from 0.70 to 0.60 and increase the infrastructure investment percentage of GDP to 20% by 2030. Severe income disparity has persisted throughout the previous century, highlighting the importance of broad economic reforms, whether by policy or legal mandates. Existing policies and frameworks are inadequate in the face of rising income disparity, necessitating a rethinking of the variables that contribute to income inequality Seabela *et al*. (2024). The ongoing increasing trend in income inequality underlines the difficulty of resolving its fundamental causes by policy and intervention strategies, despite the extensive adoption of social expenditure programs (Seabela *et al.*, 2024).

Next, chapter 3 is concentrated on the empirical strategy of this study. It presents this study's methodology and theoretical for investigating the research objectives, questions and hypotheses.

3. Research Methodology and Theoretical Model

3.1 Theoretical Model

The primary objective of this research is to augment the extant body of knowledge by employing econometric methods to analyse South Africa's economic development. This research is executed in two phases. The first phase scrutinizes the economic performance across South Africa's nine provinces, assessing the impacts of infrastructure investment, whether beneficial or detrimental, over the period from 1996 to 2021, and determines the spatial distribution of economic development. Data for this phase was sourced from the South African Reserve Bank database, encompassing seven variables for each province, including the national average, and was transformed into panel data. The second phase explores the convergence phenomenon by evaluating South Africa's growth trajectory

relative to the OECD over a 39-year timeframe, from 1980 to 2019. This analysis entailed examining the long-term steady-state relationship in GDP per capita over the said period, employing the OECD average GDP per capita as a benchmark. To mitigate potential data distortions, the Covid-19 pandemic is considered an exogenous shock and has been excluded, as it led to a global cessation of economic activities from March 2020 for approximately two years. Data for the convergence analysis was derived from the Penn World Table 10.0, detailing six variables for 39 countries from 1980 through 2019. It was likewise transformed into panel data to compute the α-convergence and β-convergence.

Table 3 summarises the literature review, the variables investigated and the linkage to the hypotheses tested.

Table 3: Study Variables, Empirical Literature and Hypotheses.

Variable	Literature	Hypothesis
real GDP per capita	Solow and Swan (1956), David Aschauer (1989a; 1989b; 1990), Barro and Sala-i-Martin (1991), Munnell (1990, 1993), Mankiw et al. (1992), Islam (1995), Sala-i-Martin (1996), Bougheas et al. (1999), Monfort and Nicolini (2000), McCoskey (2002), Dawkins (2003), Blonigen (2005), Bose et al. (2007), Head and Rise (2008), Kung (2009), Cálderon and Servé (2010), Tshepo (2014), Göçer and Erdal (2015), Grigoras (2015), Vida and Dudás (2017), Egri and Tánczos (2018), Lengyel and Kotosz (2018), Saba and Ngepah (2020), Kanó and Lengyel (2021), Bolganbayev et al. (2022), Gbadamosi et al. (2022)	H_1 H_2 H_3 H_4
Domestic investment / Gross Fixed Capital Formation	David Aschauer (1989a; 1989b; 1990), Munnell (1990, 1993), Bougheas et al. (1999), Kung (2009), Cálderon and Servé (2010), Zeng (2015), Niftiyev (2025)	H_1 H_2 H_3 H_4
Construction investment	Richaud et al. (1999), Bougheas et al. (2000), Romp and de Haan (2005), Fedderke et al. (2006), Ferreira and Araujo (2006), Fourie (2006), Fedderke and Garlick (2008), Estache and Fay (2009), Heintz et al. (2009), Sahoo et al. (2010), Kumo (2012), Zeng (2015), Ouattara and Zhang (2019)	H_1 H_2 H_3
Transport investment	Richaud et al. (1999), Bougheas et al. (2000), Romp and de Haan (2005), Fedderke et al. (2006), Ferreira and Araujo (2006), Fourie (2006), Fedderke and Garlick (2008), Estache and Fay (2009), Heintz et al. (2009), Sahoo et al. (2010), Kumo (2012), Zeng (2015), Ouattara and Zhang (2019)	H_1 H_2 H_3
ICT investment	Bougheas et al. (2000), Ferreira and Araujo (2006), Sahoo et al. (2010), Szirmai (2012), Lavopa–Szirmai (2014), Zeng (2015), Rodrik	H_1 H_2 H_3

Variable	Literature	Hypothesis
	(2016), Lambregts et al. (2017), Ouattara and Zhang (2019); Mitra and Raghunathan, 2020; Szanyi (2021)	
Electricity investment	Fedderke et al., 2006; Fedderke and Garlick, 2008; Fedderke and Bogetić, 2009; Mbanda and Chitiga-Mabugu, 2016; Mbanda and Bonga-Bonga, 2023; Msimango et al., 2024	H_1 H_2 H_3
Employment	Rogerson and Rogerson (2010), Dissou and Didic (2013), Tshepo (2014), Göçer and Erdal (2015), Zeng (2015), Kanó and Lengyel (2021), Bolganbayev et al. (2022), Niftiyev (2025)	H_1 H_2 H_3
Capital stock PPP	Solow and Swan (1956), Ascher (1989), Barro (1990), Barro and Sala-i-Martin (1991), Sala-i-Martin and Barro (1992), Sala-i-Martin (1996), Agenor and Moreno-Dodson (2006), Dissou and Didic (2013)	H_4
Labour share	Dawkins (2003), Dissou and Didic (2013), Zeng (2015), Niftiyev (2025)	H_4
GDP per capita PPP chained	Blonigen (2005), Bose et al. (2007), Head and Rise (2008), Kung (2009), Cálderon and Servé (2010), Tshepo (2014), Göçer and Erdal (2015), Grigoras (2015), Vida and Dudás (2017), Egri and Tánczos (2018), Lengyel and Kotosz (2018), Saba and Ngepah (2020), Kanó and Lengyel (2021)	H_4

Source: Author's construction.

This research investigates the long-term relationships among the variables delineated in Chapters 4 and 5. The principal component of this analysis scrutinizes economic development and its spatial distribution across the nine provinces of South Africa by employing the one step system GMM method (Blundell and Bond, 1995). The secondary component explores the convergence hypothesis through the examination of α-convergence, β-convergence, and the steady state equilibrium. Furthermore, the estimation of the β-coefficient provides an approximation of the duration required for South Africa to achieve convergence.

3.2 Research Objectives, Research Questions and Research 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 interdependent but simultaneously sequential, which establishes the feasibility of developing a detailed dynamic panel model that can be used to examine

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 causal link between infrastructure investment and regional economic performance in South Africa. The study aimed to address the following distinct research objectives:

3.2.1 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 Questions:

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 assess 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.

This hypothesis examines the concept of long-term elasticity or the multiplier effect. It inquires: "Does a 1% augmentation in infrastructure investment result in a statistically significant enhancement of real GDP per capita over the extended period?". This

hypothesis explicitly pertains to Research Objective (i) and constitutes the foundation of the Research Question.

If H_1 is accepted. The research offers substantial empirical evidence corroborating the hypothesis that infrastructure acts as a fundamental catalyst for economic expansion in South Africa. This substantiates policy recommendations advocating for continuous and strategic infrastructure investment as a mechanism for enhancing national output and improving living standards.

If H_1 is rejected. this discovery would constitute a notable contribution, potentially suggesting that:

i. Infrastructure investment in South Africa has been characterized by inefficiency or misallocation, often resulting from corruption, suboptimal project selection, or failures in maintenance.
ii. The potential advantages of infrastructure development are negated by concomitant adverse economic factors, such as political instability, energy shortages, and additional constraints like skills deficiencies.
iii. The nature of the infrastructure investments does not lead to an immediate increase in GDP in the short-to-medium term; for instance, investments in social infrastructure, such as educational institutions and healthcare facilities, may enhance social welfare but do not directly yield higher GDP statistics in the immediate term.

H_1 linkage with theoretical literature:

The initial hypothesis, H_1, posits that infrastructure investment exerts a significant and enduring positive impact on aggregate output, specifically measured in terms of real GDP per capita. This inquiry constitutes a direct examination of the fundamental proposition of infrastructure theory as delineated in subchapter 2.1, this is the primary theoretical link. Numerous studies (Aschauer, 1989; Munnell, 1992; Romp and de Haan, 2005; Fedderke and Garlick, 2008; Heintz *et al*., 2009) have identified a robust positive correlation between public capital investment and output productivity. The transmission mechanisms have been delineated clearly, illustrating that infrastructure functions as a direct input, augments private sector productivity, reduces costs (e.g., transportation, inventory), and enables economies of scale (Liu and Liu, 2011; Asturias *et al*., 2019). The research

conducted by Ferreira and Araujo (2006) is of particular significance, demonstrating an almost one-to-one long-term correlation between infrastructure and output in Brazil.

H_1 has a secondary linkage is with convergence theory. The acceptance of H_1 is a prerequisite for achieving conditional convergence (H_4). In order for South Africa to align with the OECD, it is imperative to have a substantial and positive growth driver, such as infrastructure. Should H_1 be dismissed, the likelihood of achieving convergence is significantly diminished, highlighting the prevailing critiques of infrastructure theory in the South African context, namely inefficiency, corruption, and crowding out.

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

The inquiry examines the relationship between infrastructure spending and GDP growth. Specifically, it explores whether infrastructure spending induces GDP growth, whether GDP growth facilitates increased infrastructure spending, or if both phenomena occur simultaneously. This elaborates on H_1 by investigating the dynamic relationship. It addresses the "sequential" nature of the subjects discussed in the introduction.

If H_2 is accepted. This validates a virtuous cycle, wherein economic growth, evidenced by an increased Gross Domestic Product (GDP), leads to the generation of tax revenues and fosters the political resolve to invest in new infrastructure. Such investments subsequently promote additional economic growth, thus providing a compelling rationale for the presence of a positive feedback loop within the South African economy.

If H_2 is rejected.

i. No causality: This implies that the two variables lack a causal relationship, a notion that is highly improbable and would contravene fundamental economic principles.
ii. Unidirectional causality: The likelihood of this outcome is greater than that of complete rejection. The implications vary significantly depending on the causative direction: Infrastructure → GDP: There is evidence to suggest that infrastructure propels economic growth; however, economic growth does not inherently result in increased infrastructure, potentially due to fiscal limitations or political decisions. GDP → Infrastructure: It appears that governmental investment in infrastructure occurs predominantly during periods of economic

growth, treating it as a luxury rather than a catalyst for growth. This finding would be of critical significance for policymakers, as it indicates a reactive rather than a proactive strategy.

H_2 linkage with theoretical literature:

This hypothesis is fundamentally associated on a theoretical level with infrastructure theory. It scrutinizes the dynamic feedback loop through the transmission mechanisms postulated by infrastructure theory. The effect of 'complementarity' is crucial in this context. As articulated by Agenor and Moreno-Dodson (2006), public infrastructure enhances the marginal productivity of private capital, thereby augmenting the rate of return and triggering increased demand for private investment. This initiates a virtuous cycle. Furthermore, public investment in infrastructure has the potential to 'crowd in' private investment (Fedderke *et al*., 2006), which in turn contributes to the GDP, establishing a bidirectional relationship. Conversely, the literature also recognizes the 'crowding out' effect (Erenburg, 1993), where government expenditure leads to elevated interest rates, thus dissuading private investment. H_2 critically examines which of these forces prevails within the context of South Africa.

H_3: Income disparity in South Africa has widened.

Whilst H_1 and H_2 are characterized by their relational and causal nature, H_3 is fundamentally diagnostic in nature. It pertains directly to Research Objective (iv) and holds significant importance due to its interconnection with the other hypotheses. The study suggests that infrastructure investment (central to H_1 and H_2) may serve as a potential mechanism to address the disparity referenced in H_3.

If H_3 is accepted.

The research empirically substantiates a common socio-economic hypothesis concerning South Africa. This finding establishes a robust foundational reference: regardless of any national growth gained from infrastructure (if H_1 is confirmed), the benefits have not been evenly distributed. This necessitates the conclusion that the pattern of infrastructure investment (as examined in Objective iii) is of paramount importance. It is likely concentrated in affluent areas, thereby exacerbating inequality.

If H_3 is rejected.

An unexpected outcome emerges, indicating that the disparity in income across provinces has either diminished or remained constant over the 25-year span from 1996 to 2021. This implies that various governmental policies, such as social grants and educational initiatives, have successfully mitigated any adverse distributional effects associated with economic growth and investment. Such findings could profoundly influence the discourse surrounding economic development in the post-apartheid era.

H_3 linkage with theoretical literature:

The literature review provides a comprehensive analysis of the origins of extreme inequality in South Africa as detailed by Sulla et al. (2022), tracing its foundations to apartheid and colonialism, and its continued existence despite democratic advancements. South Africa's Gini coefficient of 0.63, is identified as the highest among countries assessed for this inequality globally. The empirical works of Leibrandt *et al*. (2012), Younsi and Bechtini (2018), Mdingi and Ho (2023), and others corroborate the magnitude and enduring nature of inequality within South Africa. The Kuznets curve hypothesis is primarily linked to H_3 presented, but the South African case seems to be stuck on the upward-sloping part of the curve, unable to transition to the point where inequality decreases.

The pattern of infrastructure investment (Objective iii) is of significant importance. Should investment be concentrated in provinces that are already affluent (e.g., Gauteng, Western Cape), it has the potential to exacerbate inequality (supporting H_3), as suggested by the prevailing criticisms concerning inefficient allocation and political influence (Gramlich, 1994; Kenny, 2007). This scenario would imply that growth driven by infrastructure is not inclusive.

Expanding and escalating internal inequality (H_3 accepted) poses a significant impediment to external convergence (H_4). A country cannot achieve convergence with affluent nations if a substantial segment of its populace is marginalized from the development process. This is directly linked to the "criticisms of convergence theory," particularly the institutional and structural elements (Acemoglu and Robinson, 2012) that obstruct equitable growth. South Africa's inequality exemplifies an "initial condition" (Arthur, 1994) that constrains catch-up.

3.2.2 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 disparity 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 aim 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 Hypothesis:

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

This hypothesis examines the fundamental concept of beta-convergence. It explores not merely whether South Africa has become wealthier over time, but whether the discrepancy between its income per capita and the average income per capita of the OECD has lessened throughout the 39-year timeframe. A reduction in disparity indicates convergence. An increase in disparity indicates divergence.

If H_4 is partially accepted.

Implies conditional convergence. The assertion that disparity has decreased is supported solely when controlling for additional variables. In the absence of such controls, there may be an absence of convergence or even an occurrence of divergence; however, after accounting for variations in factors such as education, institutional quality, infrastructure, political stability, and investment rates, a distinct trend towards convergence becomes evident.

If H_4 is rejected.

The data indicates that the income disparity between South Africa and the OECD has either expanded (divergence) or remained consistently stable (no convergence). South Africa is increasingly lagging behind or is ensnared in a middle-income trap in relation to the most advanced economies. The finding is worrisome, highlighting South Africa's lag in global technological and productivity advancements despite domestic economic progress. It reveals structural impediments hindering progress, such as perceptions of corruption, challenges in property rights, bureaucratic inefficiency, deficiencies in education, skill mismatches, inefficient utilization of resources, and lack of competitiveness in industries. These concerns necessitate a fundamental re-assessment of the national economic strategy.

H_4 linkage with theoretical literature:

This constitutes a direct examination of the neoclassical convergence hypothesis. The theoretical literature reviewed encompasses a comprehensive theoretical framework for evaluating this phenomenon, drawing from the Solow-Swan model and extending to the methodologies introduced by Sala-i-Martin (1996) for assessing β-convergence. It elucidates varied empirical evidence: a number of studies, such as those by Barro and Sala-i-Martin (1992) and Mankiw *et al*. (1992), identified evidence supporting conditional convergence, whereas research focusing on African countries (McCoskey, 2002; Saba and Ngepah, 2020) frequently reports minimal to no convergence. The case of the Visegrad countries (Lengyel and Kotosz, 2018; Kanó and Lengyel, 2021) serves as an illustrative example: despite the provision of substantial EU cohesion funds, convergence was not assured, underscoring the significance of additional factors.

It's linkage to infrastructure theory stems from the position that investment in infrastructure serves as a crucial determining factor for a nation's steady-state income level and consequently its potential for conditional convergence. The review of the literature asserts that infrastructure constitutes a fundamental component in the stabilization of economic growth and enhances resource allocation and factor productivity (Aschauer, 1989; Munnell, 1992; Romp and de Haan, 2005; Fedderke and Garlick, 2008; Heintz *et al*., 2009). Therefore, the results from Part 1 (H_1, H_2, H_3) directly inform the anticipated outcome for H_4. If H_1 is affirmed (i.e., infrastructure enhances growth) and infrastructure is allocated efficiently, it is expected to support conditional convergence (H_4). Conversely, if H_1 is disproved or H_3 is confirmed (i.e., inefficient

allocation exacerbating disparity), it provides substantial justification for anticipating divergence or absence of convergence (H_4 rejected), as the principal mechanism for catch-up growth is either impaired or misdirected.

The research analysed the causal relationship between infrastructure investment and regional economic development across the nine provinces of South Africa, utilizing panel data from 1996 to 2019. Subsequent to this, the study assessed the degree to which a long-term steady state relationship could be identified during the period 1980-2019 between South Africa and the OECD. To achieve the objectives of the research study in the first part, multivariate dynamic panel data models were employed, deploying the one-step System Generalized Method of Moments (GMM) for empirical estimation. Furthermore, the second part's convergence modelling was conducted using the Barro and Sala-i-Martin (1996) methodology.

3.3 Conceptual Framework

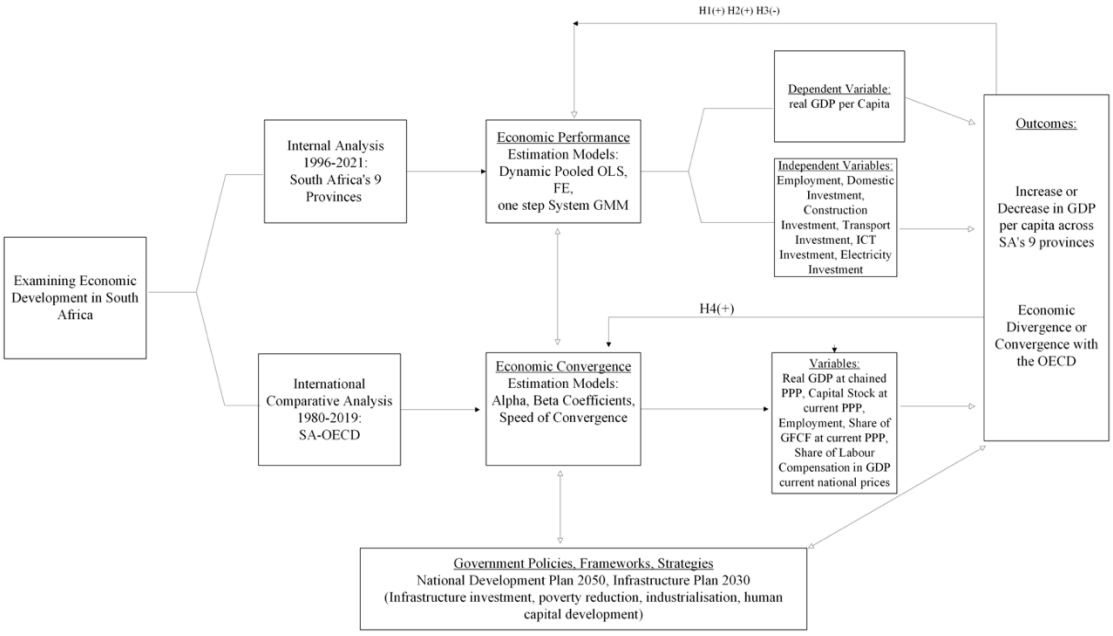
A conceptual framework is a visual depiction of the factors and concepts that are expected to interact and generate an outcome. To address the study questions and objectives discussed in chapter 2, a conceptual framework, Figure 1, was constructed to illustrate the interaction of the independent and dependent variables. The arrows show the direction of the relationship effect. It is a collection of interconnected components and variables that aid in addressing a real-world situation. It is the ultimate lens utilised to observe the logical solutions of an identified problem (Imenda, 2014). The formation of a conceptual framework begins with the logical premise that a problem exists, and issue resolution may be achieved through the use of processes, procedures, functional approaches, models, or theories (Zackoff *et al*., 2019). Traditional theoretical research uses theory to comprehend, explain, and predict occurrences (Swanson, 2013).

In applied research, the use of theory in problem solving focuses on how theory, in conjunction with practice (applied action) and procedures (functional approach), frames vision, thinking, and action towards issue resolution. The use of theory in a conceptual framework is not intended to validate or devalue applied theories. A simple approach to see the conceptual framework is as a set of understood fact-based conditions presenting the researcher's recommended reasoning for solving the identified problem. These requirements give a methodological framework for starting, carrying out, and characterising the outcome of problem-solving activities (Leshem and Trafford, 2007).

Grant and Osanloo (2014) argue that the terms conceptual framework and theoretical framework are often and incorrectly used synonymously. Just as a theory cannot or should not be expected to explain all phenomenal situations, a conceptual framework is not a haphazard collection of diverse concepts intended to incise a problem. Instead, it is a method of recognising and developing for both the researcher and the reader an epistemological mentality and a functional holistic approach to the recognised issue.

In this study, South Africa's historical economic development over the period 1980-2021 is examined in two steps. Firstly, a domestic analysis of its 9 provinces was conducted examining the dependent variable gross domestic product per capita's positive and/or negative relationship with the independent variables total investment, employment, brent crude, labour share, and foreign exchange rate to ascertain the spatial distribution of earnings in the country and their influencing factors. The outcome of which concludes whether there has been an increase or decrease in the GDP per capita of its citizens. Secondly, the country's economic performance is compared to the average GDP per capita of the OECD group of countries to determine if South Africa is catching up developmentally to its peers and the speed of which it is taking place. The outcome of this analysis demonstrates economic convergence or divergence. This study takes a deductive research approach, drawing conclusions based on theoretical assumptions and hypotheses supported by past research. Figure 1 depicts the interplay of factors using a conceptual framework.

Figure 1 Conceptual Framework: Examining Economic Development in South Africa.



Source: Author's construction. Note: Here, $H_1 - H_4$ denote the key hypotheses and the expected relationship between economic performance, economic convergence and South Africa's national economy.

This section provided a detailed discussion of the theoretical background and models of this study and its relevant theories. Furthermore, it provided an overview of the panel data sets from part one, the 9 Provinces in South Africa and part two, South Africa and the OECD. It then went on to elaborate on the tests, methods and approaches applied in this sophisticated econometric analysis. Laying out the logical framework followed when analysing the research questions what positive and negative effects infrastructure investment had on economic development over the period 1996-2021. Moreover, it discusses the extent to which it was able to catch up to the per capita income levels of the OECD over the period 1980-2019. Next, chapters 4 (South Africa's provincial analysis) and chapter 5 (South Africa-OECD comparative analysis) discuss each part of the empirical analysis, the data, the methods of testing and the empirical findings.

3.4 Methods

3.4.1 Domestic Analysis: 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, 1998, 2000). 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 and Dao and Le, 2024). Initially, the estimations were conducted using the Least Squares method, adept at handling country-specific heterogeneity.

In studies exploring the link between infrastructure investment and economic development, 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. The relationship is tested using the series level values the logical framework is shown Equation 3 for the provincial analysis.

$$LnGDP = \beta_0 + \beta_1 LnGDP_{t-2} + \beta_2 LnEMP_{t-2} + \beta_3 LnGFCF_{t-2} + \beta_4 LnCON_{t-2} + \beta_5 LnICT_{t-2} + \beta_6 Ln\ TRA_{t-2} + \beta_7 Ln\ Elec_{t-2} + u_t \quad (3)$$

3.4.1.1 Cross-sectional Dependence and Panel Unit Root Tests

As estimation issues are caused by the non-stationarity of data, this section applies a unit root test and cointegration methods. Kiss and Ampah (2018) applied three panel unit root tests Levin-Lin-Chu (LLC), Im-Pesaran-Shin (IPS) and the Fisher-type chi square to investigate the non-stationary features of their 1990-2012 series examining the

macroeconomic unpredictability viewed by domestic investors contributing to capital flight in highly indebted poor countries (HIPC) countries. Moreover, Göçer and Erdal (2015) applied the same methodologies to test for stationarity in their study into the relationship between economic growth and youth unemployment of 18 Central and Eastern European countries from 2006-2012. Firstly, the LLC unit root test was applied in this study which was developed by Levin et al. (1992), to gauge if the time series data set is stationary or if it has a unit root as used. If a unit root is detected it indicates that the series is non-stationary. The purpose of the test methods is to assess the alternative hypothesis—that each person's time series is stationary—with the null hypothesis, which states that each subject in the panel has an integrated time series. The pooling method results in increased test power when compared to doing individual unit root tests for each subject (Levin et al., 2002).

The Levin, Lin and Chu (LLC) unit root test works under the assumption of homogeneity of the unit root coefficient ($p_i = p$) and involves fitting an augmented Dickey–Fuller (ADF) regression for each panel. Individual intercepts and temporal trends can be analysed using the panel-based unit root test. Furthermore, the error variance and pattern of higher-order serial correlation can vary widely between subjects under investigation. The authors developed this methodology to address panels of modest size and gave the example of "between 10 and 250 persons, with 25-250 time series observations per individual" where such populations are classified as an industry-level or cross-country econometric investigation (Levin et al., 2002:3). The model specification for the LLC test is depicted in the regression model Equation 4.

$$Y_{it} = \alpha_{it} + \beta y_{it-1} + \sum_{j=1}^{p} \gamma_j \, x_{it-j} + \epsilon_{it} \quad (4)$$

where:

Y_{it} is the time series of interest for unit root testing.

x_{it} represents other variables (if any).

α_i is the individual effect.

β denotes the autoregressive parameter.

ϵ_{it} is the error term.

The model operates under the main assumption of homogeneity of the unit root coefficients, where $p_i = p$. The null hypothesis (H_0) states that if $\gamma = 0$, the series has a unit root, meaning it is non-stationary as the p-value equals one $(p = 1)$. The alternative hypothesis (H_1) states that no unit root is present, and the series is stationary when its p-value is less than one $(p < 1)$. An advantage of this technique is that it accounts for

looming cross-sectional dependencies and does not directly pool the autoregressive parameter in the unit root regression, also known as the AR(1) process (Levin, et al., 2002). The test analyses how much the value of the series in the current (t) period is affected by its value in the previous $(t-1)$ period.

To further test the results of the LLC, the IPS test was conducted. McCoskey (2002) investigated income convergence in 37 Sub-Saharan African countries from 1960 to 1990 and applied the IPS to test the stationarity of the series. Im, Pesaran and Shin (2003) developed a unit root test for dynamic heterogeneous panels based on the mean of individual unit root statistics in which the standardised t-bar test statistic based on the ADF statistics averaged across the groups. For every distinct time series, the IPS test is based on the regression model in Equation 5.

$$\Delta y_{it} = \alpha_i + \rho y_{it-1} + \sum_{j=1}^{p} \beta_j \Delta y_{it-j} + \epsilon_{it} \quad (5)$$

where:

y_{it} is the time series for unit root testing for individual i at time t.

Δ denotes the difference operator.

α_i captures individual effects.

ρ is the autoregressive parameter.

ϵ_{it} is the error term.

The model operates under the main assumption of heterogeneity of the unit root coefficients (p_i). The null hypothesis (H_0) states that if γ = 0, the series has a unit root, meaning it is non-stationary as the p-value equals one (ρ = 1). The alternative hypothesis (H_1) states that no unit root is present, and the series is stationary when its p-value is less than one (ρ < 1).

The examination of cross-sectional dependence has become imperative in dynamic panel analysis owing to global economic phenomena such as recessions, inflation, pandemics, and financial crises. These phenomena influence the global economy, engendering significant interdependence among different countries or regions (cross-sectional units), model regressors, and the error term (Pesaran, 2006). Nevertheless, prevalent panel estimation methods, including Pooled OLS, Fixed Effects (FE), Random Effects (RE), and generalized method of moments (GMM) estimators, typically neglect the potential cross-sectional dependence among countries, regions, or cities, which can result in biased inferential statistics.

This analysis aims to evaluate the presence of cross-sectional dependence within panel data by employing the Breusch-Pagan LM test (1980), the Pesaran LM test (2008),

and the Pesaran CD test (2004). Detection of cross-sectional dependence in the panel dataset renders traditional unit root tests, such as the Augmented Dickey-Fuller (ADF) test, Philips-Perron (PP) test, Im, Pesaran, and Shin (IPS) test, and Levin, Lin, and Chu (LLC) test, potentially unsuitable for assessing stationarity. Consequently, to address cross-sectional dependence, the "CIPS" unit root test as developed by Pesaran (2007) is utilized, being specifically designed for this context.

3.4.1.2 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 6 (Wooldridge, 2010:49).

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_K x_K + \varepsilon \quad (6)$$

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.

The OLS methodology comprises five main assumptions as summarised by Greene (2008: 11-19) and Kennedy (2008:41-42).

I. According to linearity, the dependent variable is expressed as a linear function of the error (disturbance) term and a selection of independent variables.

II. Exogeneity states that there is no correlation between disturbances and any regressors or that the anticipated value of disturbances is zero.

III. Disturbances are unrelated to one another (3.b non-autocorrelation) and have the same variance (3.a homoscedasticity).
IV. The independent variable's observations are stable over several samples with no measurement errors rather than stochastic.
V. According to the full rank assumption, independent variables do not have a precise linear connection with one another (no multicollinearity).

If individual effect u_i is not nil in long term data, heterogeneity (individual specific traits such as intellect and personality that are not collected in the regressors) may affect assumption 2 and 3. Specifically, disturbances may differ among individuals (heteroskedasticity, violation of assumption 3.a) and/or be connected to one another (autocorrelation, violation of assumption 3.b), rather than having the same variance. Nonspherical variance-covariance matrix of disturbances is an obstacle. The infringement of assumption 2 renders random effect estimators skewed. As a result, the best unbiased linear estimator is no longer the OLS estimator. Panel data models offer a solution to these obstacles.

3.4.1.2b F-test, LM-test and Hausman test

Fixed versus Random Effects: Furthermore, Green (2008) and Kenny (2008) elaborate that panel data models inspect the random and/or fixed effects of time or individuals. The purpose of dummy variables is the prime distinction between fixed and random effect models. A dummy variable's parameter approximation is a component of the error component in a random effect model and the intercept in a fixed effect model. In either a fixed effect model or a random effect model, slopes stay constant across groups or time periods. One-way fixed and random effect models have the following functional forms shown in Equation 7 and 8.

Fixed effect model: $y_{it} = (\alpha + u_i) + X'_{it}\,\beta + v_{it}$ (7)

Random effect model: $y_{it} = \alpha + X'_{it}\,\beta + (u_i + v_{it})$ (8)

Where, u_i is a fixed or random effect specific to an individual (group) or time period that is not included in the regression, and errors are independent identically distributed, $v_{it} \sim IID(0, \sigma_v^2)$.

Assuming identical slopes and constant variance for each person (group and entity), a fixed group effect model approximates individual fluctuations in intercepts. As an individual effect is time invariable and treated as being a part of the intercept, u_i is

permitted to be correlated with other regressors. During which the second OLS assumption is not infringed. Within effect estimating techniques and least squares dummy variable (LSDV) regression (OLS with a collection of dummies) is used to estimate this fixed effect model (Green, 2008; Kenny, 2008).

A random effect model presumes that individual effects (heterogeneity) are uncorrelated with any regressor and then approximates error variance specific to groups or times. As a result, u_i can be either a component of the composite error term or an individual specific random heterogeneity. For this reason, an error component model is another name for a random effect model. Every individual or group has the same regression intercept and slope. The distinction among individuals or durations of time lies within their individual unique errors and not in the intercepts (Green, 2008; Kenny, 2008).

When an individual's covariance structure, i, Σ (sigma), is known, the generalised least squares (GLS) method is used to approximate a random effect model. The complete variance-covariance matrix V (Σ in all diagonal members and 0 in all off-diagonal elements) is approximated when Σ is unknown using the feasible generalised least squares (FGLS) or estimated generalised least squares (EGLS) methodologies. For FGLS, there are several approximation techniques, such as simulation and the maximum likelihood approach (Baltagi and Chang, 1994). Random effect models decrease the number of parameters that need to be evaluated, although it will generate irregular estimates when a single random effect is correlated with regressors (Greene, 2008: 200–201).

The F-test examines the possibility that fixed effects may affect the panel data and a determination is made between the pooled panel OLS and fixed effects model. The null hypothesis (H_0) is that there are no fixed effects influencing the panel. If the null hypothesis is rejected, we conclude that indeed the time and/or individual effects are possibly fixed and further investigation ensues (Breusch and Pagan, 1980). The Lagrange multiplier (LM) test examines the presence of random effects by contrasting the panel pooled OLS and random effects model. The null hypothesis (H_0) is that there are no random effects impacting the panel. If the H_0 is rejected, we conclude that indeed the time and/or individual effects are possibly random and further investigation continues. It is important to note that if neither of the H_0 are rejected then the pooled OLS regression is selected.

The Hausman specification test measures a fixed model against a random effect model (Hausman, 1978). The null hypothesis (H_0) is that there are random effects

impacting the panel. If the H_0 is rejected, we conclude that indeed the time and/or individual effects are fixed. If the H_0 cannot be rejected, we conclude that indeed the time and/or individual effects are random. All three of these tests are performed to determine whether or not there are fixed or random effects influencing the panel data.

The conclusion is drawn from the rejection of the various H_0 , if the results present two out of the three tests detecting either fixed or random effects then the results are deemed to be robust and accepted. Moreover, when one cross-sectional or time-series variable is taken into account (for example, nation, firm, and race) it is referred to as a one-way fixed or random effect model. Therefore, two-way effect models have certain estimating and interpretation problems since they consist of two sets of dummy variables for individual and/or temporal variables (such as region and year). This investigation applied the fixed effects modelling approach, as evidenced in sub-chapter 4.3.

3.4.1.3 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:

$$Y_{it} - Y_{it-1} = (\propto -1)Y_{it-1} + \beta_0 X_{it} + \mu_i + \varepsilon_{i,t} \quad (9)$$

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 (9), we obtain:

$$Y_{it} = \alpha Y_{it-1} + \beta_0 X_{it} + \mu_i + \varepsilon_{i,t} \quad (10)$$

To eliminate the province specific effects, we take the first differences of (10):

$$Y_{it} - Y_{it-1} = a(Y_{it-1} - Y_{it-2}) + \beta_0 (X_{it} - X_{it-1}) + \varepsilon_{it} - \varepsilon_{it-1} \quad (11)$$

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 12 with the lagged dependent variable $(Y_{it-1} - Y_{it-2})$. The GMM panel estimator employs the subsequent moment conditions.

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

$E[X_{it} - s(\varepsilon_{it} - \varepsilon_{it-1})] = 0$ for s ≥ 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.

Table 4 provides a summary of the panel data tests and methods, alongside the examined hypotheses and the corresponding theoretical framework. The selection of these methods, tests, or approaches was informed by the attributes of the panel dataset, specifically the number of observations, time period, order of integration, among other factors.

Table 4: South African Provincial Analysis: Study Econometric Tests, Methods, Hypotheses and Theoretical Linkage.

	Test/Method	**Hypothesis**	**Theory**
Dynamic Panel Data Estimation	Pooled OLS FE	H_1 H_2 H_3	Neoclassical Endogenous Growth Theory: Public Good Theory (Samuelson, 1954). Infrastructure Productivity Effects (Aschauer, 1989a; 1989b; 1990), (Munnell, 1992)
	One-step System GMM	H_1 H_2 H_3	

Source: Author's construction.

3.4.2 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 (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):

$$\log(y_{it}) = a + (1 - b)\log(y_{i,t-1}) + v_{it} \quad (12)$$

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 13. The conventional growth model equation, which utilizes panel data, is represented as (e.g. Islam, 1995):

$$\log(y_{it}) = \eta_i + \beta\log(y_{i,t-1}) + \sum_{j=1}^{k}\pi_j\, log(x_{it}^{j}) + \xi_t + u_{it} \quad (13)$$

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. Table 5 presents an overview of panel data analyses and techniques, together with the hypotheses explored and the related theoretical framework.

Table 5: SA-OECD Analysis: Econometric Tests, Methods, Hypothesis and Theoretical Linkage.

	Test/Method	**Hypothesis**	**Theory**
Convergence Estimation	Alpha, Beta Coefficients, Speed of Convergence	H_4	Neoclassical Endogenous Growth Theory: Convergence Theory (Solow and Swan, 1956); (Barro and Sala-i-Martin, 1991)

Source: Author's construction.

This chapter delineated the empirical strategy underpinning this research, offering a discourse on the methodologies and tests employed to scrutinize the economic development of South Africa. Subsequent chapters, specifically Chapters 4 and 5, will

elaborate on the findings derived from the implementation of these aforementioned methods.

4. Domestic Analysis: South Africa's 9 Provinces

The purpose of this study is to contribute to the current body of knowledge by using econometric approaches to examine South Africa's economic progress over the period 1996-2021. However, it is necessary to provide an economic and demographic overview of each of its 9 provinces as each territory is endowed with factors of production to varying degrees. This sets the contextual stage for the analysis and the interpretation of the results. The core analysis investigated the economic performance of South Africa's nine provinces, the positive or negative effects of infrastructure investment over the study period, and the spatial distribution of economic development. Figure 2 provides a graphic illustration of the provincial borders and their geographic location of each of the nine provinces in democratic South Africa.

Figure 2: Provincial Boundaries of South Africa

Source: Author's construction.

4.1 South Africa's 9 Provinces: Demographic and Economic Overview

4.1.1 Demographic Overview

South Africa is located at the southernmost part of the African continent, with a shoreline that spans over 3,000km from the arid border with Namibia on the Atlantic coast to the subtropical Mozambique border on the Indian Ocean (GCIS, 2023). Prior to its present

democratic dispensation, the country was divided into four provinces: Cape, Transvaal, Orange Free State, and Natal; however, after 1994, the number was increased to nine, with three national capital cities to establish a power distribution as listed in Table 2.

According to the national statistics office, Statistics South Africa, in the latest census conducted in 2022, the country's population expanded by 51.7% to over 62 million people since the previous census conducted in 2011. That is an annual population growth rate of 1.8% over the period 2011-2022, this is more than triple the annual average population growth rate of 0.49% in OECD countries. The population split is approximately 51.5% female and 48.5% male. Gauteng, KwaZulu-Natal and the Western Cape have the largest populations of 15 million, 12.4 million, and 7.4 million respectively (Statistics South Africa, 2023). South Africa's internal migration is concentrated between two provinces. Gauteng continues to receive the majority of internal migrants, accounting for more than one-third of the flow, followed by 15% advancing to the Western Cape. During the intercensal era, people left four provinces: Limpopo, Eastern Cape, KwaZulu-Natal, and Free State (Statistics South Africa, 2023).

Furthermore, in the Census 2022 report, there were over 2.4 million foreign migrants, accounting for slightly more than 3% of the overall population. The majority, 86%, originated from the Southern African Development Community region, with Zimbabwe accounting for 45.5%, Mozambique for 18.7%, and Lesotho for 10.2%. Zimbabwe, Mozambique, Malawi, Lesotho, and the United Kingdom are the top five migration nations into South Africa and have remained so since the last census in 2011 (Statistics South Africa, 2023).

South Africa is a cosmopolitan society known for its diverse languages. Language plays a crucial role in promoting democracy, enhancing social, cultural, intellectual, economic, and political well-being in South Africa. The country has 11 official languages, all of which are granted equal status. Most South Africans are multilingual, speaking at least two official languages. English is widely understood across the country and serves as the primary language for commerce, politics, and media. It is also the country's lingua franca (GCIS, 2023).

This section provided a high-level overview of South Africa's geographical land mass, its population distribution, migration and its languages. The next section summarises the economic activity and endowments of each of the nine provinces.

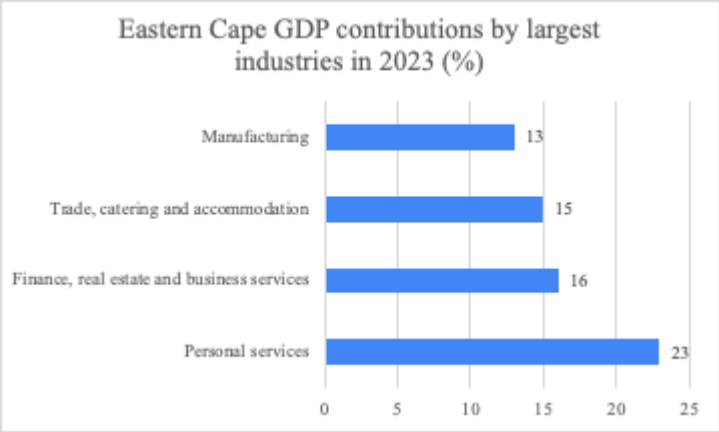
4.1.2 Economic Overview Per Province

South Africa's 9 provinces are endowed with factors of production to varying degrees. The structure of the economy in each province is distinct, to an extent in accordance with their endowments. The natural resources of South African provinces have a considerable impact on their socioeconomic landscapes. According to Statistics South Africa, Gauteng and the Western Cape are economically wealthy, the Eastern Cape and Limpopo are poorer provinces confronted with significant obstacles. Gauteng is the largest provincial contributor of 33% to the national GDP, subsequently followed by KwaZulu-Natal's 16.2% and the Western Cape's 14.0% whilst the smallest contributor is the Northern Cape at 2.3%. All economic activities conducted in South Africa are categorised according to the System of National Accounts (SNA) 2008, which is published jointly by the European Commission, International Monetary Fund, OECD, United Nations and the World Bank. The system is the basis and fundamental methodological source used by Statistics South Africa to calculate South Africa's GDP (Statistics South Africa, 2023).

4.1.2(a) Eastern Cape

The Eastern Cape, a coastal province with 168 966km^2, is South Africa's second-largest territory after the Northern Cape, accounting for 13.9% of the total land area. It is rich in agricultural land and forestry resources, with some mineral deposits, including coal. The capital city is Bhisho, and the province's population exceeds 6.6 million, with the majority speaking isiXhosa, followed by Afrikaans and English. It is one of the poorest provinces, with a significant unemployment rate and a dependency on remittances (personal services 23%). Figure 3 illustrates the Eastern Cape's top industry composition in 2023 that contributes to the provincial GDP (Statistics South Africa, 2023). Its economy is largely built on personal services contributing 23% and finance, real estate and business services 16% (Statistics South Africa, 2023). There are two industrial development zones: the West Bank in East London and Coega at Gqeberha, which includes the Ngqura deepwater port. Gqeberha and East London's urban economies rely heavily on manufacturing (13%), particularly in the automotive industry as the province is the country's centre of this industry (GCIS, 2023).

Figure 3: Eastern Cape Composition of Provincial Economy.



Source: Author's construction from Statistics South Africa data.

4.1.2(b) Free State

The provincial capital Bloemfontein is also South Africa's judicial capital, that houses the Supreme Court of Appeal. The provincial economy's largest contributor is finance, real estate and business services 18% and personal services contributing 16% (Statistics South Africa, 2023). The Free State landscape is dominated by agriculture, with 32,000km^2 of cultivated land and 87, 000km^2 of natural veld and pasture. With a population exceeding 2.9 million people, the majority speak Sesotho followed by Afrikaans and isiXhosa. Field grain crops account for about two-thirds of the province's gross agricultural income. Horticulture makes up the remaining proportion, with animal products accounting for another 30%. The province has natural endowments of gold and diamonds (GCIS, 2023).

Mining: The National Development Plan, the country's current national blueprint, has identified Matjhabeng, a goldfields region in the Lejweleputswa District, as a possible employment intervention zone for mining. The Presidential Infrastructure Coordinating Commission is considering possible development projects such as the De Bron-Merriespruit Gold Project and Bloemhoek Gold Project. The province is home to 12 gold mines, which accounts for 30% of South Africa's total output and the country ranks as the world's fifth largest gold producer (GCIS, 2023). The Free State's gold mines contribute significantly to the country's overall silver production. Uranium, found in gold-bearing conglomerates, is removed as a by-product. Free State Consolidated Goldfields is South Africa's largest gold mining complex, covering an area of 330km^2. Sasolburg mines bituminous coal and converts it into petrochemical products. The province's kimberlite

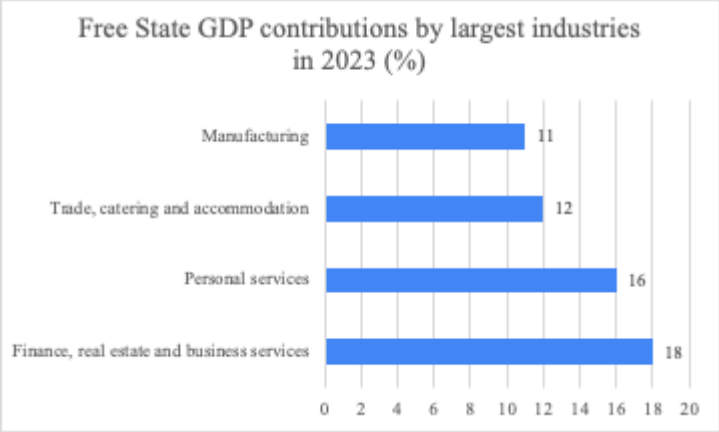
pipes and fissures generate high-quality diamonds, while the Koppies area has the country's biggest bentonite resource (GCIS, 2023).

Manufacturing and industry: Trade and manufacturing sectors contribute 12% and 11% respectively to the provincial GDP (Statistics South Africa, 2023). Maluti-a-Phofung Special Economic Zone represents the Free State's portion of the logistical and industrial corridor. A vehicle distribution centre was created in collaboration with the German Bremen Logistics Group, who contributed R60 million to the project. The Harrismith Food Processing Park is part of a larger manufacturing development effort. The Xhariep district's green economic solar zone aims to construct the Xhariep Solar Park, which will capture solar radiation in the southern Free State (GCIS, 2023).

The Ingula Pumped Storage Scheme is part of Eskom the national utility's Capital Expansion programme. The energy infrastructure project is situated on the boundary of Phumelela and Maluti-a-Phofung Local Municipalities in the Free State, and eMnambithi Local Municipality and uThukela District Municipality in KwaZulu-Natal (GCIS, 2023).

Sasol South Africa is the largest manufacturer of synthetic fuels on the subcontinent, and it continues to play a significant role in the Free State economy. The Omnia Nitric Acid Complex, part of the Sasol Industrial Complex, has a nitric acid factory, an ammonium nitrate plant, a porous ammonium nitrate facility, a fleet of 145 specialist ammonia rail tankers, and additional facilities (GCIS, 2023). Figure 4 illustrates the Free State's top industry composition in 2023 that contributes to the provincial GDP (Statistics South Africa, 2023).

Figure 4: Free State Composition of Provincial Economy.



Source: Author's construction from Statistics South Africa data.

4.1.2(c) Gauteng

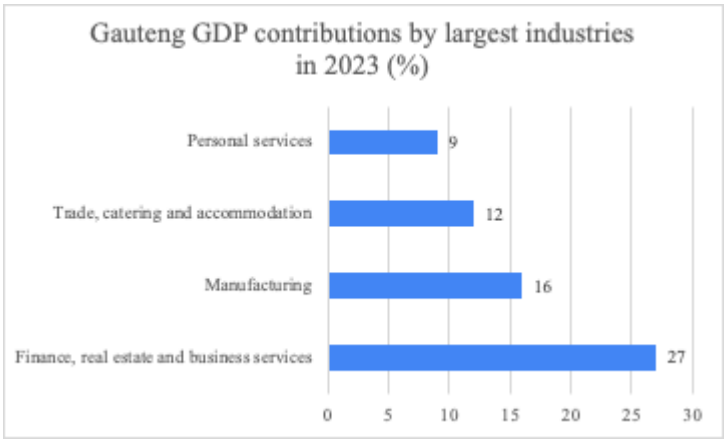
According to South Africa's Census 2022, the Gauteng province has the largest population exceeding 15 million who earn the highest per capita income in the country. The province contributes 33% to the national GDP. Moreover, it is the country's smallest province by land mass and is landlocked. Pretoria, South Africa's administrative capital and is the location of the national executive arm of government. Johannesburg is the country's economic hub and hosts the African headquarters of a plethora of multinational organisations across sectors. The top 3 principal languages spoken are isiZulu, Sesotho and Sepedi respectively, with English being the business language and lingua franca (GCIS, 2023).

Mining and manufacturing: Manufacturing includes basic iron and steel, manufactured metal items, food, equipment, electrical appliances, automobile components and accessories, and chemical products. Johannesburg is home to the headquarters of major gold and diamond mining companies, including Anglo American and De Beers. Although gold mining and allied businesses create employment for thousands of people, their importance is decreasing compared to manufacturing (16%) and finance (27%). Gauteng leads the South African economy in all major sectors except agriculture, mining, and quarrying. Mining accounts for just 6% of Gauteng's overall income and 31% of export revenue (GCIS, 2023; Statistics South Africa, 2023).

Technology: Gauteng accounts for about 60% of South Africa's research and development activity. The Council for Scientific and Industrial Research (CSIR) is a premier research, development, and implementation institution for science and technology in South Africa. The CSIR, headquartered in Pretoria, conducts research and development in biosciences, the built environment, information and communication, materials science and manufacturing, natural resources and the environment, mineral resources, space technology, nanotechnology and synthetic biology. The Innovation Hub in Pretoria is Africa's first fully authorised scientific park and a member of the International Association of Scientific Parks. This community is a hub for innovation and knowledge production, connected to global interconnectivity, comprising small, medium, and micro-enterprises as well as multinational corporations (GCIS, 2023).

Industry: The province has an integrated industrial complex with considerable economic activity in three subregions: the Vaal Triangle, the East, West, and Central Rand, and Pretoria. Johannesburg houses the Johannesburg Stock Exchange Limited, Africa's largest securities exchange. The city of Johannesburg is the most populous and the economic centre of South Africa with its key economic sectors are financial and commercial services, logistics, manufacturing, property, telecommunications, and commerce (GCIS, 2023). Figure 5 illustrates Gauteng's top industry composition in 2023 and their contribution to the provincial GDP (Statistics South Africa, 2023).

Figure 5: Gauteng Composition of Provincial Economy.



Source: Author's construction from Statistics South Africa data.

4.1.2(d) KwaZulu-Natal

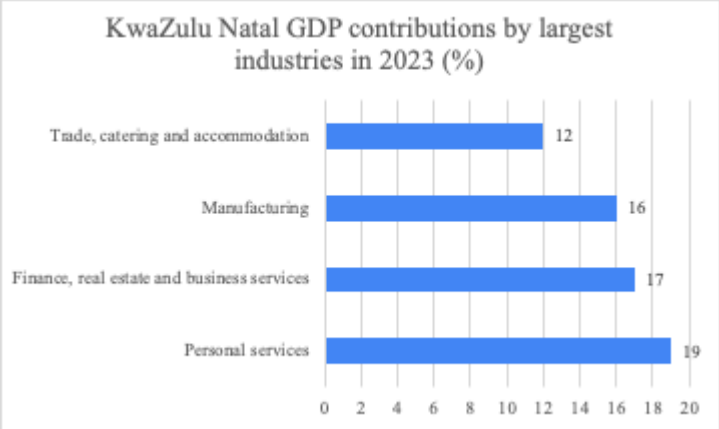
KwaZulu-Natal is home to 11.1 million people making it the country's second most populous province, its contribution to the national GDP is 16%. The sectors that contribute the largest proportion of the provincial GDP are personal services (19%), finance, real estate and business services (17%), manufacturing (16%) and trade, catering and accommodation (12%). South Africa's subtropical east coast extends from Port Edward in the south to Mozambique in the north. The Drakensberg Mountain range spans KwaZulu-Natal's western frontier. The Drakensberg Mountain range separates South Africa and Lesotho. The region has two large harbours: the port of Durban, Africa's busiest, and the port of Richards Bay, a significant coal-export port. The top 3 principal languages spoken are isiZulu, English and isiXhosa respectively (GCIS, 2023).

Industry and agriculture: KwaZulu-Natal's industrial sector is varied, with large industries concentrated around Durban's port. The province's principal industries include agriculture, forestry, aluminium, petro-chemicals, automobile manufacture, steel

production, plastics and packaging, paper and board manufacturing, and import/export through Durban and Richards Bay ports (GCIS, 2023).

The coastal belt produces subtropical fruit and sugar, while farmers in the interior focus on vegetables, dairy, and livestock cultivation. Forestry is an important source of revenue in the Vryheid, Eshowe, Richmond, Harding, and Ngome regions, which are also noted for their tea plantations (GCIS, 2023). Figure 6 illustrates KwaZulu-Natal's top industry composition in 2023 that contributes to the provincial GDP (Statistics South Africa, 2023).

Figure 6: KwaZulu-Natal Composition of Provincial Economy.



Source: Author's construction from Statistics South Africa data.

4.1.2(e) Limpopo

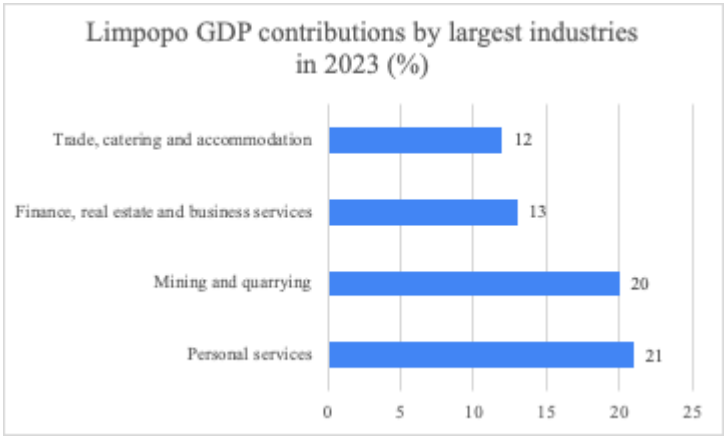
South Africa's northernmost province borders Mozambique, Zimbabwe, and Botswana, giving it an attractive entryway to the rest of the African continent. Named after the Limpopo River, which flows along its northern boundary. Limpopo is connected to the Maputo Development Corridor via the Phalaborwa Spatial Development Initiative, a network of rail and road corridors connecting major seaports, facilitating commerce and investment opportunities. Polokwane, the province's capital, the top languages spoken in the province are Sepedi, Tshivenda and Xitsonga respectively. The province's population is 6.5 million people and the economy's largest sectoral contributors are personal services (21%), mining and quarrying (20%), finance, real estate and business services (13%) and trade, catering and accommodation (12%) (GCIS, 2023; Statistics South Africa, 2023).

Agriculture: Limpopo produces a variety of agricultural goods. It produces 75% of the country's mangoes, 65% of its papayas, 36% of its tea, 25% of its citrus, bananas, and litchis, 60% of its avocados, and two-thirds of its tomatoes. Additional goods include

coffee, almonds, guavas, sisal, cotton, tobacco, sunflower, maize, wheat, and grapes. In addition, around 170 plantations generate timber. The higher-lying sections are mostly used for cattle and game ranches, known for producing high-quality biltong (GCIS, 2023).

Industry and mining: Limpopo's economy is heavily reliant on mining, which accounts for 20% of the province's GDP due to its extensive mineral resources. Metals consist of platinum, chromium, nickel, cobalt, vanadium, tin, limestone, and uranium clay. Other mineral deposits include antimony, phosphates, fluorspar, gold, diamonds, copper, emeralds, scheelites, magnetite, vermiculite, silicon, mica, black granite, corundum, feldspar, and salt. The Medupi Power Station, a dry-cooled coal-fired power plant in Lephalale, is currently under development. Medupi, a Sepedi term, translates to "gentle rain". The station is estimated to offer over 40,000 work possibilities (GCIS, 2023). Figure 7 illustrates Limpopo's top industry composition in 2023 and their share of contributions to the provincial GDP (Statistics South Africa, 2023).

Figure 7: Limpopo Composition of Provincial Economy.



Source: Author's construction from Statistics South Africa data.

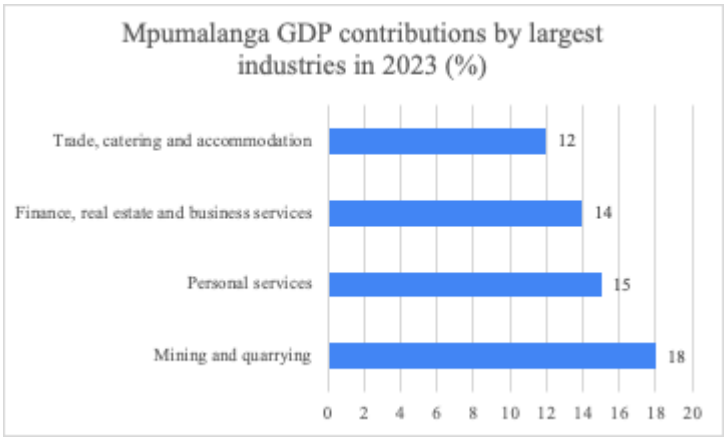
4.1.2(f) Mpumalanga

The province is home to 4 million people, the principal languages are Siswati, and isiZulu and its capital city is Mbombela. Despite its modest size of 76 495km^2, the province boasts the fourth-largest economy in South Africa. The province, bordered by Mozambique and Eswatini to the east and Gauteng to the west, is primarily located in the Middleveld plateau grasslands (GCIS, 2023). The provincial economy in 2023 comprised mining and quarrying (18%), personal services (15%), finance, real estate and business (14%) and trade, catering and accommodation (12%) (Statistics South Africa, 2023).

Agriculture and forestry: Mpumalanga is a summer-rainfall area split by the escarpment into two regions: the Highveld, with cold icy winters, and the Lowveld, with moderate winters and subtropical temperature. The escarpment area may see snowfall on higher ground. Summers are hot and humid, resulting in thick mist. The province's economy relies heavily on agriculture, which employs 8.1% of the workforce (GCIS, 2023). The province produces a wide range of subtropical fruits, including citrus, mangoes, avocados, litchis, bananas, papayas, granadillas, guavas, nuts, and vegetables. Mbombela is the second-largest citrus growing area in South Africa, accounting for one-third of the country's orange exports. The Institute for Tropical and Subtropical Crops is located in the city. Groblersdal is a significant irrigation region that produces citrus, cotton, tobacco, wheat, and vegetables. Carolina-Bethal-Ermelo is mostly a sheep-farming area, but also produces potatoes, sunflowers, maize, and peanuts (GCIS, 2023).

Industry and manufacturing: Mpumalanga's manufacturing sector is mostly concentrated in the southern Highveld area, particularly at Highveld Ridge, which has major petrochemical factories like Sasol 2 and Sasol 3. The northern Highveld region is known for large-scale manufacturing, notably of chrome-alloy and steel products. The Lowveld subregion's industries mostly produce agricultural and forestry products. Increased demand for goods and services for export through Maputo is predicted to boost industry in the area. Mpumalanga has abundant coal deposits, including eMalahleni, Africa's largest coal producer (GCIS, 2023). This province hosts the majority of South Africa's power plants. Kendal power plant has the world's biggest cooling towers. The Kusile Power Station in Delmas is the country's largest, generating 4800 megawatts of energy for the national grid. Ngodwana is home to one of the country's major paper mills, conveniently located near the timber supply. Columbus Stainless, South Africa's sole producer of stainless-steel flat goods, is located in Middelburg, a city known for its steel and vanadium production (GCIS, 2023). Figure 8 illustrates Mpumalanga's top industry composition in 2023 that contributes to the provincial GDP (Statistics South Africa, 2023).

Figure 8: Mpumalanga Composition of Provincial Economy.



Source: Author's construction from Statistics South Africa data.

4.1.2(g) Northern Cape

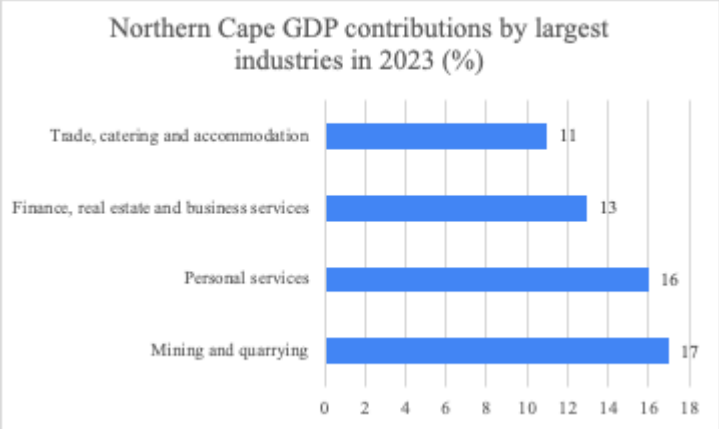
The Northern Cape is South Africa's biggest province, accounting for over a third of the total land area with Kimberly as its provincial capital city. The province has a population of around 1.2 million people spread over 372 889km^2 of territory. Approximately 68% of the population speaks Afrikaans, with Setswana, isiXhosa, and English also widely spoken (GCIS, 2023). The Northern Cape shares borders with Namibia and Botswana, as well as the Atlantic Ocean in the west. The Swartberg mountain range forms its southern boundary. The province's interior is easily accessible from South Africa's major towns, harbours, and airports, thanks to its strong road network and two large airports at Kimberley and Upington (GCIS, 2023).

Agriculture and industry: The Karoo region's economy is based on sheep farming, and the Gordonia district relies heavily on the karakul-pelt business. The province boasts excellent agricultural territory, particularly in the Orange River Valley. Upington, Kakamas, and Keimoes produce various fruits. The Vaalharts Irrigation Scheme in Warrenton supports the cultivation of wheat, fruit, peanuts, maize, and cotton (GCIS, 2023). The Niewoudtville Rooibos Tea Processing Initiative focuses on the economic empowerment of smallholder growers (GCIS, 2023).

Mining: Mining and quarrying accounts for 17% of the total provincial GDP. Despite the global crisis, iron-ore mining in the province's northeast is booming, mostly due to China's steel demand. Kumba Iron Ore, the owner of Sishen, is expanding with a new project in Kolomela. New manganese developments are also underway. Diamond mining

has seen diminishing volumes and employment losses. Diamond mining is shifting from older mines to alluvial mining on the Orange River, its tributaries, and the Atlantic Ocean. The province also contains copper, asbestos, fluorspar, semi-precious stones, and marble (GCIS, 2023). Figure 9 illustrates the Northern Cape's top industry composition in 2023 that contributes to the provincial GDP (Statistics South Africa, 2023).

Figure 9: Northern Cape Composition of Provincial Economy.



Source: Author's construction from Statistics South Africa data.

4.1.2(h) North West

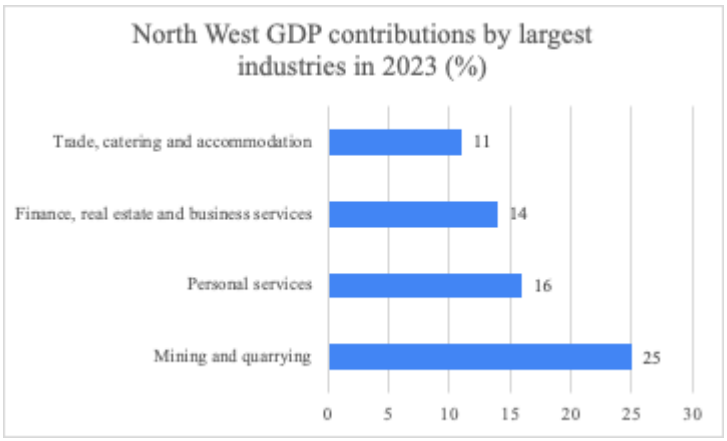
The North West province is landlocked, bordered by Botswana in the north, the Kalahari Desert in the west, Gauteng in the east, and the Free State in the south. It is referred to as the 'Platinum Province' due to its healthy endowment of the precious metal, mining and quarrying contributed 23% to the provincial economy followed by personal services (16%), finance, real estate and business services (14%) and trade, catering and accommodation (11%). The province has a population of almost 4 million people who largely speak Setswana (GCIS, 2023; Statistics South Africa, 2023).

Mining and manufacturing: The Rustenburg and Brits districts produce 94% of the country's platinum, surpassing any other single location in the globe. The province not only produces granite, marble, fluorspar, and diamonds, but also 25% of South Africa's gold reserves. The Platinum Corridor, stretching from Pretoria to eastern Botswana, employs more than one-third of the province's workforce. North West's manufacturing industry is concentrated in the municipalities of Brits, Rustenburg, Potchefstroom, Klerksdorp, and Mahikeng, accounting for almost 50% of total production. Brits' industries mostly focus on manufacturing and construction, whereas Klerksdorp's focus

is on mining. Local materials are used in the creation of car components, machinery, electronics, and medical equipment (GCIS, 2023).

Agriculture: Stellaland in Vryburg hosts some of the world's largest cow herds. North West is South Africa's leading producer of white maize. Rustenburg is surrounded by lush, mixed-crop farming terrain, with maize and sunflowers being the main crops (GCIS, 2023). Figure 10 illustrates the North West's top industry composition in 2023 that contributes to the provincial GDP (Statistics South Africa, 2023).

Figure 10: North West Composition of Provincial Economy.



Source: Author's construction from Statistics South Africa data.

4.1.2(i) Western Cape

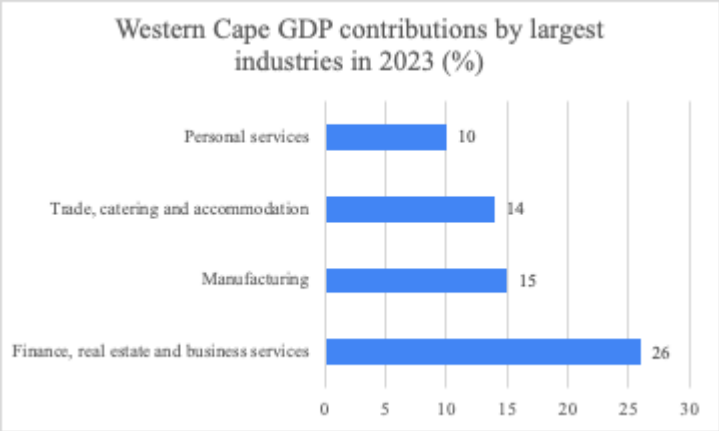
The Western Cape, located on the south-western corner of Africa, with Cape Town is South Africa's legislative capital, housing Parliament. The province has a population of over 7.2 million people, has the highest adult education level in the country, and the top 3 languages spoken are Afrikaans, isiXhosa and English respectively (GCIS, 2023). The largest sectors contributing to the provincial economy in 2023 were finance, real estate and business services (26%), manufacturing (15%), trade, catering and accommodation (14%) and personal services (10%) (Statistics South Africa, 2023).

Agriculture and fisheries: The Western Cape produces export-grade fruit such as citrus and deciduous fruits of which accounts for 60% of exports. Other exports include fruit, wine, wool, and ostrich. Approximately 75% of South African fishing occurs along the Western Cape coastline. A 200 km commercial fishing zone and rigorous quotas preserve the west coast's rich fishing grounds from exploitation. These waters provide a variety of delicacies, including snoek, Cape lobster, abalone, calamari, octopus, oysters and

mussels. The combination of high-quality exports and a weak local currency positions them competitively globally (GCIS, 2023).

Industry: The Saldanha Bay Industrial Development Zone is strategically located to serve as a service, maintenance, fabrication and supply hub for the booming African oil and gas sector, due to the increasing number of oil rigs requiring maintenance, and their traffic flow passing from the west to the east coast of Africa (GCIS, 2023). Figure 11 illustrates the Western Cape's top industry composition in 2023 that contributes to the provincial GDP (Statistics South Africa, 2023).

Figure 11: Western Cape Composition of Provincial Economy.



Source: Author's construction from Statistics South Africa data.

4.2 Data: South Africa's 9 provinces

In this empirical study the panel dataset comprises of a sample of South Africa's 9 provinces is regarded as one population in Table 6. The macroeconomic variables for this investigation are summarised in Table 7 below. The choice of these variables was guided by the literature as mentioned in Chapter 2. The extracted data from the South African Reserve Bank database was manually converted into a balanced panel dataset which resulted in a sample of 234 observations for the period 1996-2021 as seen in the descriptive statistics in Table 8. The investigation period for this analysis was originally planned to commence from 1980 to coincide with the convergence analysis but was amended to 1996 due to a lack of data. South Africa's 9 provincial boundaries were legally designated when the country became a democratic republic in 1994. Prior to this the country had four provinces namely, the Cape of Good Hope, Orange Free State, Transvaal and Natal (Mabin *et al.*, 2024).

Table 6: 9 Provinces in South Africa.

Code	Province	Provincial Capital City
EC	Eastern Cape	Bhisho
FS	Free State	Bloemfontein (national constitutional capital)
GAU	Gauteng	Pretoria (national administrative capital)
		Johannesburg (national economic centre)
KZN	Kwa-Zulu Natal	Pietermaritzburg
LP	Limpopo	Polokwane
MP	Mpumalanga	Mbombela
NC	Northern Cape	Kimberly
NW	North-West	Mahikeng
WC	Western Cape	Cape Town (national legislative capital)

Source: Author's construction.

Table 7: Domestic Analysis: Study variables.

Macroeconomic variable	EViews reference	Measurement	Source
real GDP per capita	Real GDP	Millions in ZAR	South African Reserve Bank
Employment	Emp	Millions of persons	South African Reserve Bank
Domestic investment	GFCF	Millions in ZAR	South African Reserve Bank
Construction investment	Cons	Millions in ZAR	South African Reserve Bank
Transport investment	Transp	Millions in ZAR	South African Reserve Bank
ICT investment	ICT	Millions in ZAR	South African Reserve Bank
Electricity investment	ELEC	Millions in ZAR	South African Reserve Bank

Source: Author's construction.

The dependent variable GDP per capita is defined as an important economic metric that measures the average economic production per capita in a certain geographic location. It is computed by dividing the total GDP by the population (Samuelson and Nordhaus, 2009; Mankiw, 2020). This metric provide insight into the country's economic performance and is oftentimes used to assess the standard of living and economic welfare of its citizens. Real GDP per capita is the total production value adjusted for inflation, and it is applied in this analysis. GDP per capita purchasing power parity (PPP) is an inappropriate measure to consider using as this is an investigation of 9 provinces within the borders of a single country. The PPP measure is more appropriately applied when comparatively analysing a cross section of countries as in the case of the second part of this study.

Six independent variables were investigated; employment or the number of people employed is defined as "working for at least one hour per week for some payment, either for a wage or profit, or commission, or without pay in a family business" (Junankar, 2004:42). This salary or compensation is the individual's remuneration for services done,

with the total indicated as a proportion of GDP (Rogerson and Rogerson, 2010; Dissou and Didic, 2013; Zeng, 2015; Kanó and Lengyel, 2021; Bolganbayev *et al*., 2022).

The OECD (2022) defines domestic investment, or gross fixed capital formation, in real terms as the acquisition of newly produced, purchased, and second-hand assets, including the production of such assets by producers (industries, producers of government services, and producers of private non-profit services to households) for their own use, minus assets that have been sold or written off. These assets are inputs into the manufacturing process of other commodities and services with an economic life of more than a year.

Construction investment refers to the allotment of monetary resources particularly aimed at the development, upgrading or maintenance of physical structures. This investment includes a wide range of activities, including residential, non-residential and infrastructure construction (Richaud *et al*., 1999; Bougheas *et al*., 2000; Romp and de Haan, 2005; Fedderke *et al*., 2006; Ferreira and Araujo, 2006; Fourie, 2006; Banister, 2008; Fedderke and Garlick, 2008; Glaeser and Gyourko, 2008; Estache and Fay, 2009; Heintz *et al*., 2009; Sahoo *et al*., 2010; Kumo, 2012; Zeng, 2015; Litman, 2017; Ouattara and Zhang, 2019).

Transport investment is defined as the allocation of monetary resources to develop, advance and maintain transportation infrastructure and services. These investments are crucial to promote the movement of people and goods and include various means of transportation such as road, rail, air and sea transport (Richaud *et al*., 1999; Bougheas *et al*., 2000; Romp and de Haan, 2005; Fedderke *et al*., 2006; Ferreira and Araujo, 2006; Fourie, 2006; Banister, 2008; Fedderke and Garlick, 2008; Estache and Fay, 2009; Heintz *et al*., 2009; Sahoo *et al*., 2010; Kumo, 2012; Zeng, 2015; Litman, 2017; Ouattara and Zhang, 2019).

Information and communication technology (ICT) investments are monetary resources allocated to the procurement, advancement and maintenance of technologies that promote communications and information management. This investment includes a broad scope of technologies, including hardware, software, telecommunications and related services (Brynjolfsson and Hitt, 1998; Bougheas *et al*., 2000; Ferreira and Araujo, 2006; Sahoo *et al*., 2010; Szirmai, 2012; Lavopa and Szirmai, 2014; Zeng, 2015; Rodrik, 2016; Lambregts *et al*., 2017; Ouattara and Zhang, 2019; Mitra and Raghunathan, 2020; Szanyi, 2021).

Lastly, investment in energy generation infrastructure, hereafter referred to as electricity investment, is defined as the allocation of financial capital into initiatives, enterprises, and technologies involved in the production, distribution, and utilization of energy. It includes conventional energy sources, such as fossil fuels, as well as renewable energy sources, encompassing solar, wind, and hydropower (Sustainability Directory, 2025).

Table 8 summarises the descriptive information of the 9 provinces from 1996 to 2021. The table outlines the descriptive data for central tendency and variability. The mean values represent the average value of the variables in the overall model. The standard deviation represents the dispersion of data around the mean value. It also indicates the data's proximity to the average value throughout the specified period. The range of data can be assessed by the highest and minimum values in each model. The range indicates the amount of variance in variables. Variables with broader range values exhibit more variance and vice versa.

Table 8: Domestic Analysis: Descriptive Statistics

Variable	N	Mean	Median	Maximum	Minimum	Std. Dev
real GDP per capita	234	4.8185	4.8061	5.1026	4.5355	0.1347
Employment	234	6.0445	6.0062	6.7111	5.3478	0.3275
Total investment	234	4.5417	4.6173	5.4287	3.4665	0.4255
Construction investment	234	2.7285	2.7428	3.8296	1.3821	0.5369
Transport investment	234	3.6347	3.6433	4.5211	2.6097	0.4354
ICT investment	234	3.3278	3.3369	4.3003	2.2529	0.4057
Electricity investment	234	3.3987	3.4325	4.5015	2.2053	0.5622

Source: Author's construction from EViews 12 output (2025).

4.3 Empirical Estimation Findings

The primary analysis examined the economic performance of the 9 provinces within South Africa and analysed the positive or negative effects of infrastructure investment over the period 1996-2021 and determined the spatial distribution of economic development in cities. This section provides the outcomes of both static and dynamic Ordinary Least Squares (OLS), and Generalized Method of Moments (GMM) regressions based on empirical assessments of the link between infrastructure investment and economic growth. The optimal lag selection was cross checked by applying the Vector Autoregression model which determine it to be VAR(2) and supports the GMM procedure as summarised in Table A1 in the Appendix. The preliminary stage in the estimation process of this dissertation entails evaluating the presence of cross-sectional

dependence (CD) among the analytical units (provinces). As illustrated in Table 9, all of the variables display cross-sectional dependence, thus the null hypothesis of panel homogeneity is not accepted.

Table 9: Cross sectional Dependence Results

Test	real GDP per capita	Cons	Elect	Trans	ICT	GFCF	Emp
Breusch-Pagan LM	80.212 (0.000)	927.042 (0.000)	930.332 (0.000)	929.442 (0.000)	924.547 (0.000)	930.617 (0.000)	790.265 (0.000)
Pesaran scaled LM	90.299 (0.000)	105.010 (0.000)	105.398 (0.000)	105.293 (0.000)	104.716 (0.000)	105.431 (0.000)	88.891 (0.000)
Bias-corrected scaled LM	90.1190 (0.000)	104.830 (0.000)	105.218 (0.000)	105.113 (0.000)	104.536 (0.000)	105.251 (0.000)	88.711 (0.000)
Pesaran CD	28.239 (0.000)	30.447 (0.000)	30.501 (0.000)	30.486 (0.000)	30.406 (0.000)	30.505 (0.000)	28.019 (0.000)

Source: Author's construction from EViews 12 output (2025).

In light of the observed cross-sectional dependence among all of the selected variables, the ensuing step entails the verification of stationarity or the order of integration by employing second-generation unit root tests, which adeptly manage cross-sectional dependence within the models being estimated. This investigation employed two panel unit root tests, those developed by Levin *et al*. (2002), known as LLC, and Im *et al*. (2003), referred to as the IPS test. These stationarity assessments prove highly effective in short panels characterized by a limited temporal dimension (T). The justification for selecting panel unit root tests (IPS and LLC) over first-generation unit root tests (ADF and PP) resides in their enhanced robustness, which is especially beneficial for short panels, as is the case in this study. The results from the stationarity tests align with the null hypothesis, indicating the presence of a unit root within the variables. According to the results presented in Table 10, the null hypothesis is rejected for construction, transport, ICT investment and employment at the level form, denoted as I(0) under all tests. The exception of the variables concerning real GDP per capita, GFCF and electricity investment. For these exceptions, the null hypothesis is only rejected at the first difference, indicated as I(1), suggesting the lack of non-stationary characteristics.

Table 10: Panel Stationarity Unit Root Test Results

Variable	Method	t-statistics	p-value	Order of integration	Cross sections
Real GDP	LLC	-2.512	0.00	I(1)	9
	IPS	-2.996	0.00	I(1)	9
Emp	LLC	-6.385	0.00	I(0)	9
	IPS	-4.668	0.00	I(0)	9
GFCF	LLC	-5.466	0.00	I(1)	9
	IPS	-3.569	0.00	I(1)	9
Cons	LLC	-9.043	0.00	I(0)	9
	IPS	-4.806	0.00	I(0)	9
Trans	LLC	-5,377	0.00	I(0)	9
	IPS	-2,232	0.00	I(0)	9
ICT	LLC	-5.565	0.00	I(0)	9
	IPS	-2.322	0.00	I(0)	9
Elect	LLC	-2.385	0.00	I(1)	9
	IPS	-3.092	0.00	I(1)	9

Source: Author's construction from EViews 12 output (2025).

4.3.1 Dynamic Pooled OLS and Fixed Effect OLS Estimation

Employing the logarithm of real GDP as the dependent variable, the results derived from the static panel estimation, pooled OLS and the fixed effects estimator in Table A2 in the Appendix exhibit positive and highly statistically significant outcomes. The coefficient relating to the infrastructure investment variables remains consistent, exhibiting no systematic alterations upon the inclusion of control variables within the model as reported in Table A2. These coefficients persist as positive and highly statistically significant, substantiating a long-term positive correlation between infrastructure investment and economic growth as postulated by the majority of theoretical models. The outcomes are congruent with previous scholarship, which identifies a significant positive relationship between infrastructure investment and economic growth (Romp and de Haan, 2005; Fedderke and Garlick, 2008; Estache and Fay, 2009; Heintz *et al*., 2009; Kumo, 2012; Zhou *et al.,* 2021). However, this does not consider any time effects in the dataset. Therefore, dynamic panel estimation was applied which accounts for time and provincial fixed effects. Table 11 presents the results and diagnostics of the dynamic Pooled OLS and Fixed Effect OLS analyses. The model's fitting adequacy is demonstrated by the F-statistic values of 2696.73 (0.000) for the Pooled OLS and 14646.44 (0.000) for the Fixed Effects OLS, along with their respective probability values, which meet the model stability requirements, thus affirming the results' credibility. The lagged GDP (L.lnrGDPpc) illustrates persistence, with a coefficient of 0.979 (0.000) in the Pooled

OLS and 0.929 (0.017) in the Fixed Effect OLS, denotive of significant persistence where GDP shocks display near-perfect continuation. This finding substantiates the path dependence in the regional GDP of South Africa. The subsequent findings from the Pooled OLS analysis indicate that the independent variables exhibit a negligible impact on real GDP per capita. These assessments are unable to comprehensively account for the lagged effects these variables may impose on the dependent variable. A similar pattern is observed in the Fixed Effect OLS analyses. The utilized tests are insufficient for a comprehensive examination of the relationship between these variables.

Table 11: Dynamic Panel Estimation

Dependent variable: lnrGDPpc		
Variable	Pooled OLS	FE OLS
L.lnrGDPpc	0.979 (0.000)	0.929 (0.017)
LnCon	0.003 (0.577)	0.026 (0.023)
LnElec_con	0.002 (0.651)	0.006 (0.017)
LnTrans	0.002 (0.691)	-0.019 (0.026)
LnICT	0.022 (0.147)	0.022 (0.147)
LnEmp	-0.148 (0.355)	-0.031 (0.022)
LnGFCF	-0.147 (0.201)	0.006 (0.020)
F-statistic	9696.73 (0.000)	14646.44 (0.000)
Constant	0.171 (0.043)	0.000 (0.000)
R-squared	0.998	0.998
Observations	225	225
Cross sections	9	9
Lag	2	2
Year FE	YES	YES
Province FE	YES	YES

Source: Author's construction.

4.3.2 One step System General Methods of Moments (GMM)

Table 12 delineates the outcomes and diagnostics of the one-step system GMM analysis. The adequacy of the model fit is evidenced by the F-statistic, 2.77e+07 (0.000), along with its associated probability value, fulfilling the model stability prerequisites, thereby deeming the results credible. It is imperative to underscore that the system GMM modelling procedure adjusts the variable nomenclature and elucidates the lag effect of each independent variable (instruments) on the dependent variable, namely real GDP per capita. The lagged GDP (L.lnrGDPpc) encapsulates persistence, with a coefficient of 0.998 (0.000) indicating pronounced persistence where shocks to GDP exhibit near-perfect continuation. This finding corroborates the path dependency in the regional GDP

of South Africa. An augmentation in investment in the built environment (L1_LnCon) by 1% precipitates a 0.088% (0.001) increase in GDP, demonstrating the catalytic role of physical infrastructure investment in fostering growth. A 1% escalation in electricity investment (LnElect_con) engenders a 0.054% (0.000) increase in GDP, underscoring that energy access and supply constitute a growth multiplier, rendering them indispensable for economic advancement. A 1% enhancement in transport infrastructure investment (L1_LnTrans) induces a 0.040% (0.036) increase in GDP, reflecting gains achieved through augmented efficiency in logistical networks and the facilitation of goods movement within the nation. The statistically insignificant impact of a 1% increase in ICT investment, 0.006 (0.218), indicates that investment in digital infrastructure should not be implemented in isolation but instead in conjunction with complementary elements such as research and development activities. A 1% rise in employment level (L1_LnEMP) results in a 0.054% (0.021) increase in GDP, suggesting an economy driven by labour expansion in South Africa. An unanticipated result pertains to the impact of total domestic investment on the national GDP, wherein a 1% increase in gross fixed capital formation (L1_LnGFCF) results in a -0.266% decrease in GDP. This phenomenon may be attributed to the crowding out effect of private capital by public investment or potentially to capital depreciation, illustrating the phenomenon of reverse causality.

Table 12: One-Step System GMM Results and Diagnostics.

Variable	Coefficient	p-value			
L.lnrGDPpc	0.998	0.000			
L1_LnEmp	0.112	0.021			
LnElec_con	0.054	0.000			
L1_LnICT	0.006	0.218			
L1_LnCon	0.088	0.001			
L1_LnTrans	0.040	0.036			
L1_LnGFCF	-0.266	0.000			
F-statistic	2.77e+07	0.000			
Constant	0.141	0.772			
Instruments	27		Observations	225	225
Hansen test	0.28	(1.000)	Cross sections	9	9
AR(1)	-2.52	(0.012)	Lag	2	2
AR(2)	-1.07	(0.285)	Year FE	YES	YES
AR(3)	-0.93	(0.350)	Province FE	YES	YES

Source: Author's construction.

A general guideline suggests that the number of instruments should be lower than the number of groups. However, in the present findings, the number of instruments (27)

surpasses the group count (9). The Hansen test p-value (1.000) confirms the exogeneity assumption, while the AR(2) tests p-value (0.285) assures the absence of autocorrelation. These results demonstrate robustness against alternative specifications. The robust Hansen test 0.28 (1.000) does not reject the null hypothesis regarding the validity of the instruments. The elevated p-value (1.000) is a consequence of the proliferation of instruments, which can render the Hansen test less potent and result in a p-value of 1. Nevertheless, in this instance, the issue is not problematic as the test fails to reject the null hypothesis.

When examining the Difference-in-Hansen tests, the following observations are made: For the GMM instruments applied to levels, the Hansen test excluding a group result in a chi-square statistic (chi2) of 18 with a value of 0.28, and the difference is chi2(1)=0.00 with a p-value of 1.000. This indicates an inability to reject the hypothesis that the level instruments are exogenous. For the GMM applied to gmm(L.lnrGDPpc, collapse lag(2 2)), the Hansen test excluding a group yields chi2(17)=1.08, with a difference reported as chi2(2)=-0.80. The negative value is attributed to an artifact of the generalized inverse; nonetheless, the reported p-value remains 1.000, indicating the validity of the subset of instruments for the lagged dependent variable.

Upon examination of the Arellano-Bond tests for autocorrelation it demonstrates that AR(1), the test yields z = -2.52 and Pr > z = 0.012, indicating significance. This result aligns with expectations for first differences, given that errors in levels are likely to exhibit serial independence, thus their differences should manifest correlation at the first order. Now turning to AR(2), z = -1.07 and Pr > z = 0.285, indicating non-significance. This is pivotal, as it denotes the absence of second-order serial correlation in the first-differenced errors, thereby affirming the validity of the instruments. In AR(3), z = -0.93 and Pr > z = 0.350, again indicating non-significance, thus confirming the absence of higher-order autocorrelation.

As indicated in Table 12, there is an absence of significant second-order autocorrelation, except for the GMM-System in the estimated model lacking control variables. Overall, our test statistics suggest a properly specified model. This finding aligns with Zhou *et al*. (2021), who investigated the relationship between infrastructure investment and economic growth across 29 Chinese provinces using the dynamic panel method. The

authors concluded that a statistically significant relationship exists between infrastructure investment and economic growth.

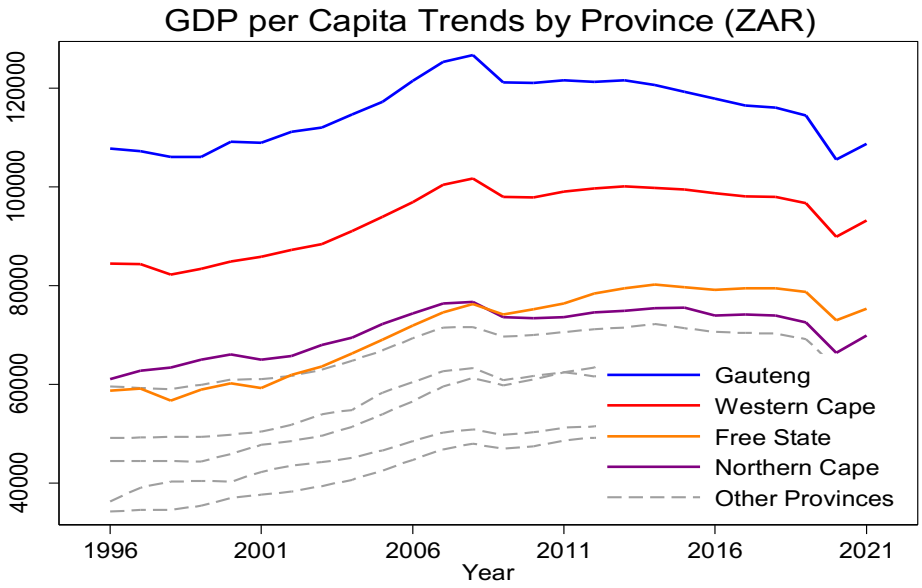
4.3.3 Spatial Distribution of Income and Investment in South Africa

The preceding subchapters provided a comprehensive examination and interpretation of the regression and causal relationships amongst the variables over the investigation period 1996-2021. It demonstrated the analysis of the panel of 9 provinces in South Africa, through the application of several econometric tests, methods and approaches. Thereafter it presented empirical evidence of the positive, negative causal relationships and dynamic interactions between the dependent variable real GDP per capita and the independent variables domestic investment, construction investment, transport investment, ICT investment and employment. The purpose of this final subchapter within the primary analysis section is to spatially plot the empirical results in a meaningful manner for further interpretation and discussion in chapter 6.

4.3.3a National versus Provincial Income

Figure 12 depicts the annual provincial real GDP per capita expressed in the local currency, the South African Rand (ZAR), presented in denominations of a thousand. In the accompanying text, when specific values are mentioned, the currency conversion to U.S. dollars (USD) is provided in parentheses for an international reference context. The average annual exchange rates for the period 1996-2021 were acquired from the South African Reserve Bank. The observed variations in the ZAR/USD exchange rates during the investigation period are attributed to the principle of purchasing power parity of the local currency, ZAR, in a particular year in relation to the international trade currency, the USD. Only two provinces have earnings that exceed the national average over the period, with Gauteng represented by the yellow line and the Western Cape by the brown. In contrast, earnings in the Free State province are relatively aligned with the national average. In 1996, Gauteng's populace earned an average of R107,792 ($25,101); their income experienced gradual increases, reaching its peak in 2008 at R126,655 ($7,352). The Western Cape's aggregate income in 1996 was R84,517 ($19,681), ascending to R93,223 ($6,305) by 2021. The average per capita income in the Free State in 1996 was R58,710 ($13,671), rising to R75,333 ($5,095) by 2021. The remaining six provinces consistently earned below the national average income throughout the entire investigation period.

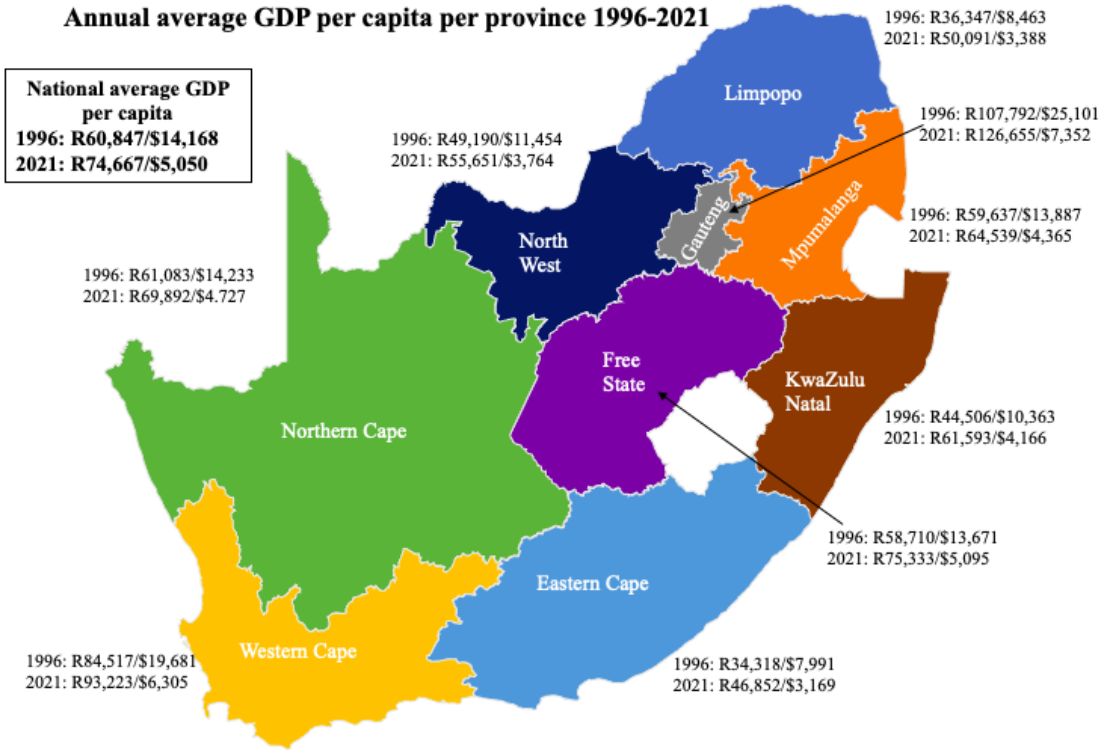
Figure 12: Annual Provincial real GDP per capita 1996-2021.



Source: Author's construction from SARB data (2024).

Moreover, Figure 13 illustrates a spatial visualization of the distribution of earnings across South Africa's provinces in the years 1996 and 2021. Each province demonstrated an increase in income per capita, alongside a reduction in purchasing power parity relative to the U.S. dollar. The disparity in income among the nine provinces is attributed to the composition of their local economies, as thoroughly examined in subchapter 4.1.2. Gauteng, the Western Cape, and the Free State are identified as the provinces with the highest income per capita. The former two, including KwaZulu-Natal (but excluding the Free State), are the most significant contributors to the national GDP of the country.

Figure 13: National, Provincial GDP per capita 1996 and 2021

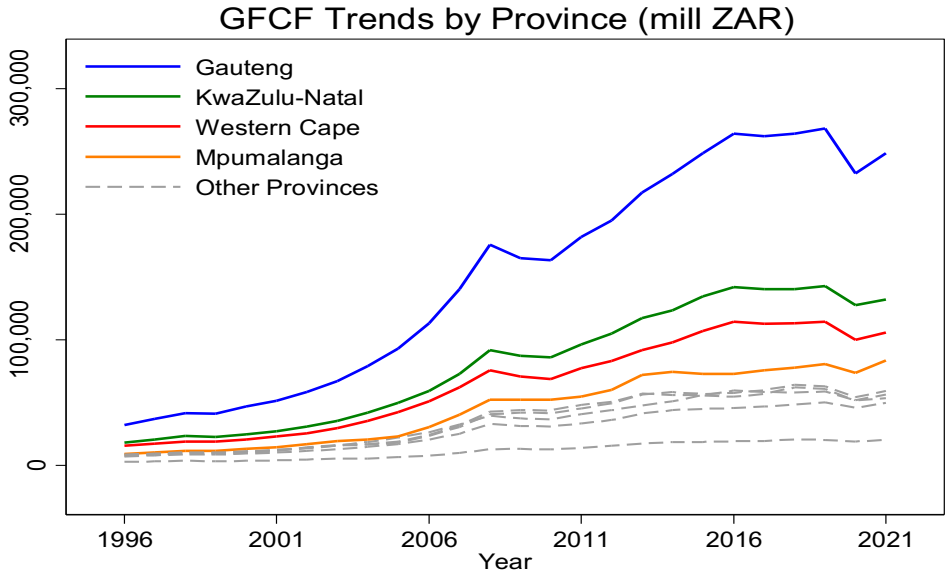


Source: Author's construction from SARB data (2024).

4.3.3b Provincial Investment

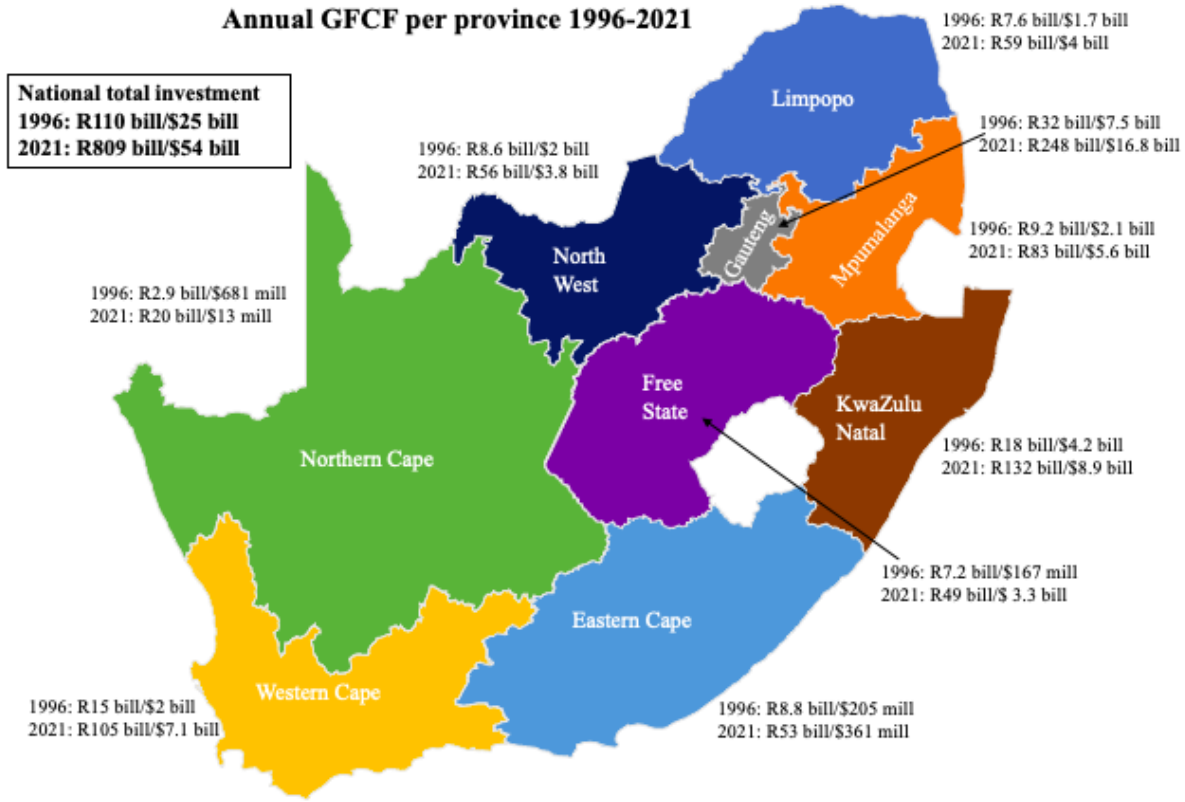
Figure 14 illustrates the annual provincial domestic investment in gross fixed capital formation (GFCF) for the period from 1996 to 2021. Notably, the Gauteng province received the largest portion of the investment, with R32 billion ($7.5 billion) in 1996, escalating to R248 billion ($16.8 billion) by 2021. The second highest investment was recorded in KwaZulu-Natal, amounting to R18 billion ($4.2 billion) in 1996 and increasing to R132 billion ($8.9 billion) in 2021. The Western Cape province, ranking third in investment reception, obtained R15 billion ($2 billion) in 1996 and R105 billion ($7.1 billion) in 2021. The data elucidates the trend of GFCF investment throughout the analysis period, highlighting that the remaining six provinces receive comparatively lower GFCF investments than the top three provinces mentioned. Furthermore, Figure 15 presents a spatial depiction of the domestic investment distribution across South African provinces in the years 1996 and 2021. Capital investment is predominantly concentrated in the Gauteng, KwaZulu-Natal, and Western Cape provinces, which collectively contribute the most significant share to the national income.

Figure 14: Provincial Total Investment 1996-2021.



Source: Author's construction from SARB data (2024).

Figure 15: National, Provincial GFCF Investment 1996 and 2021.

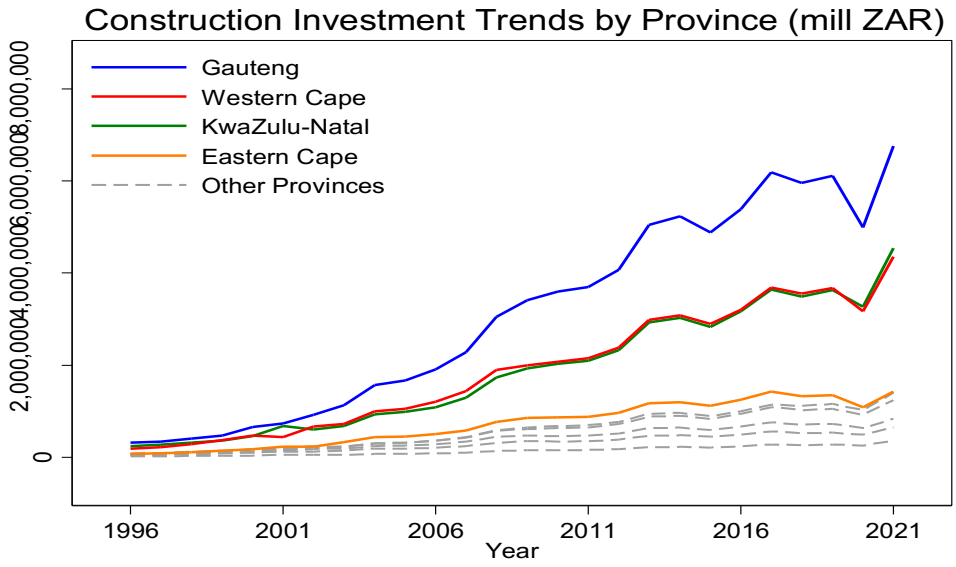


Source: Author's construction from SARB data (2024).

Figure 16 elucidates the provincial allocation of construction investment over the period 1996-2021. The most substantial proportion of this investment is allocated to the Gauteng province, with an allocation of R319 million ($74 million) in 1996, escalating to R6.7

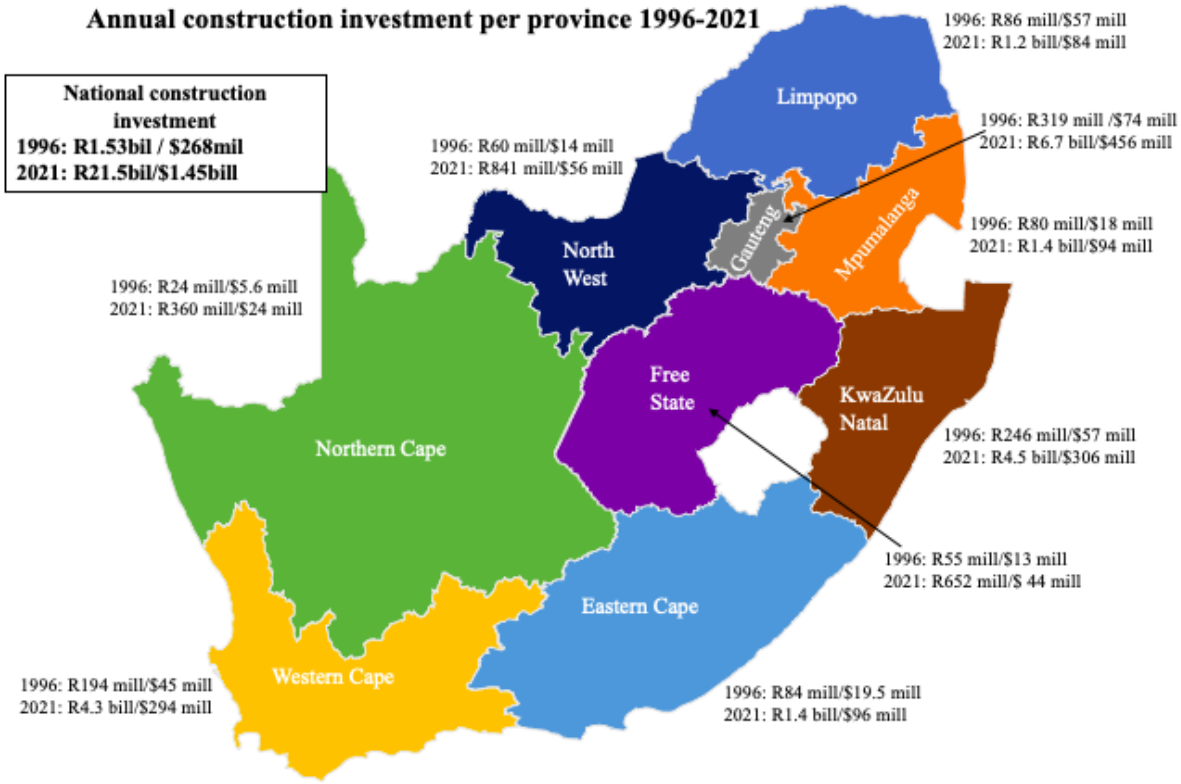
billion ($456 million) in 2021. The second highest allocation was directed to KwaZulu-Natal, amounting to R246 million ($57 million) in 1996 and increasing to R4.5 billion ($306 million) in 2021. The Western Cape province, identified as the third largest beneficiary of investment in 1996, received R194 million ($2 million), which surged to R4.3 billion ($294 million) by 2021. This data outlines the construction investment trends observed during the specified period of analysis. Moreover, it indicates that the remaining six provinces receive significantly lesser construction investments compared to the leading trio mentioned above. Figure 17 represents the spatial distribution of overall investment in South Africa by province for the years 1996 and 2021. Construction investment, as a constituent element of GFCF, is predominantly focused on provinces that significantly contribute to the national GDP.

Figure 16: Provincial Construction Investment 1996-2021.



Source: Author's construction from SARB data (2024).

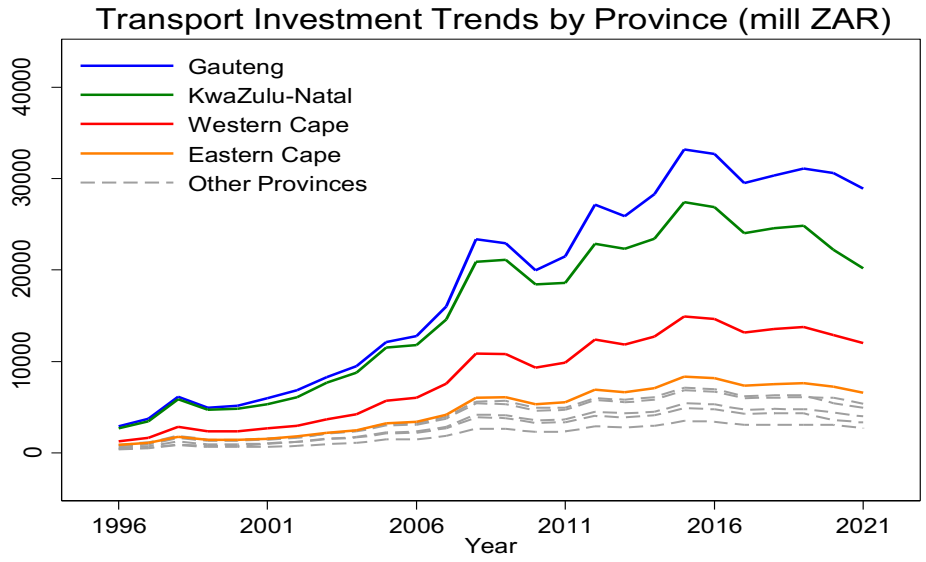
Figure 17: National, Provincial Construction Investment 1996 and 2021.



Source: Author's construction from SARB data (2024).

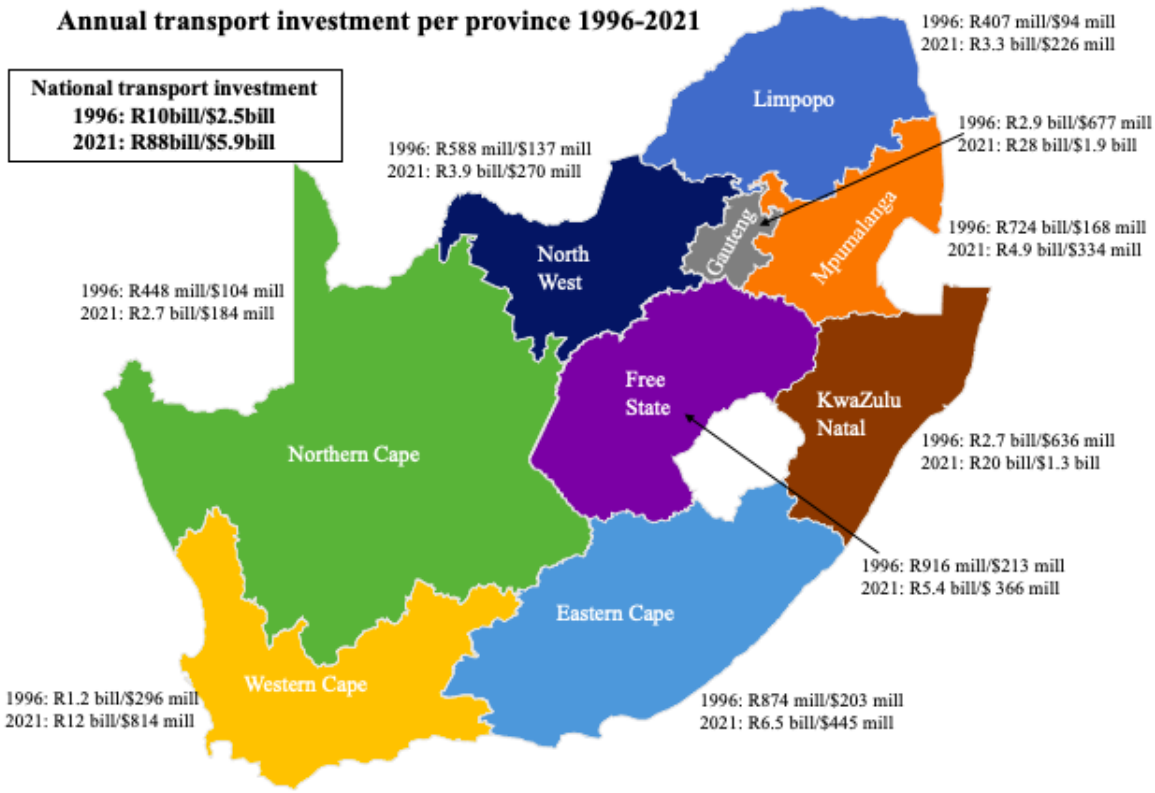
Figure 18 illustrates the annual provincial transport investment for the period of 1996-2021. The most substantial portion of the investment is allocated to the Gauteng province, amounting to R2.9 billion ($677 million) in 1996 and R28 billion ($1.9 billion) in 2021. In KwaZulu-Natal, the second largest investment was recorded at R2.7 billion ($636 million) in 1996 and R20 billion ($1.3 billion) in 2021. The Western Cape province, as the third largest beneficiary of investment in 1996, received R1.2 billion ($296 million), increasing to R12 billion ($814 million) by 2021. The data presented highlights the trend of transport investment throughout the investigation period, which is further depicted in Figure 19. Additionally, it is evident that the remaining six provinces receive transport investments to a lesser extent than the previously mentioned leading three. This pattern aligns with the trends observed in GFCF and CON, indicating a concentration of transport investment in provinces that contribute the highest percentage to the national GDP.

Figure 18: Provincial Transport Investment 1996-2021.



Source: Author's construction from SARB data (2024).

Figure 19: Provincial Transport Investment 1996 and 2021.

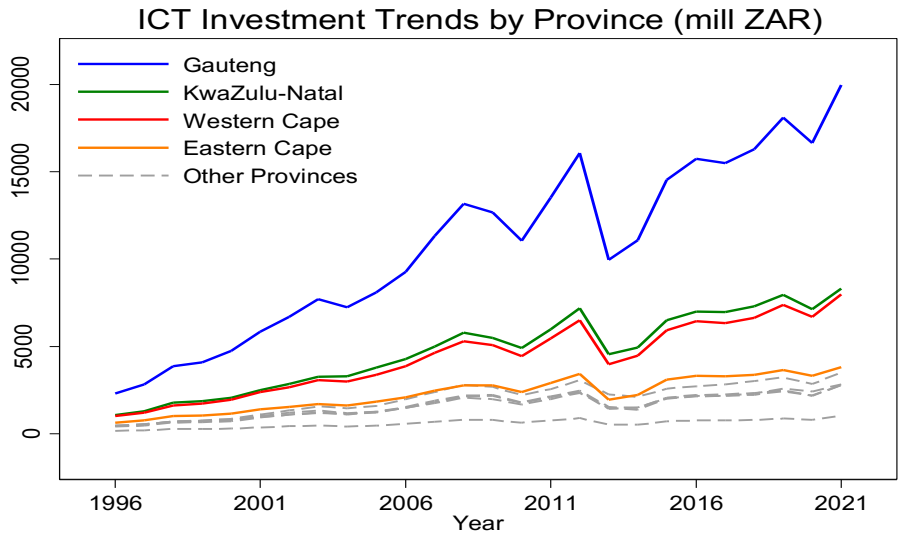


Source: Author's construction from SARB data (2024).

Figure 20 illustrates the provincial ICT investment over the period from 1996 to 2021. In 1996, the largest proportion of ICT investment was allocated to Gauteng province, with an investment of R2.3 billion ($536 million), which increased to R20 billion ($1.3 billion)

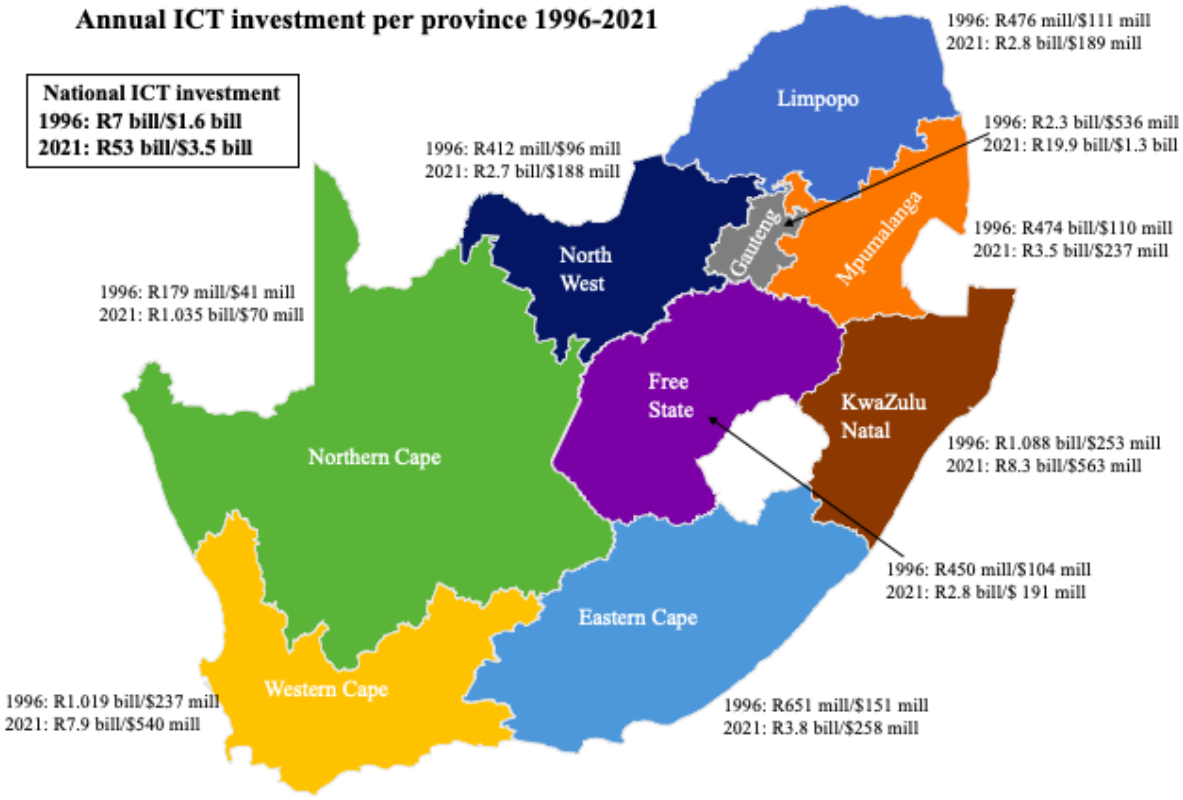
in 2021. The second largest investment was recorded in KwaZulu-Natal, where the figures were R1.088 billion ($253 million) in 1996 and R8 billion ($563 million) in 2021. The Western Cape province, as the third-largest beneficiary of investment in 1996, received R1.019 billion ($237 million), reaching R7.9 billion ($540 million) in 2021. The collected data reveals the trajectory of transport investment during the review period, which is further depicted in Figure 21. Moreover, the remaining six provinces received less transit investment compared to the top three. Consistent with the patterns observed with GFCF, CON, the TRANS investment is predominantly concentrated in the provinces that make the most substantial contributions to the national GDP.

Figure 20: Provincial ICT Investment 1996-2021.



Source: Author's construction from SARB data (2024).

Figure 21: National, Provincial ICT Investment 1996 and 2021.

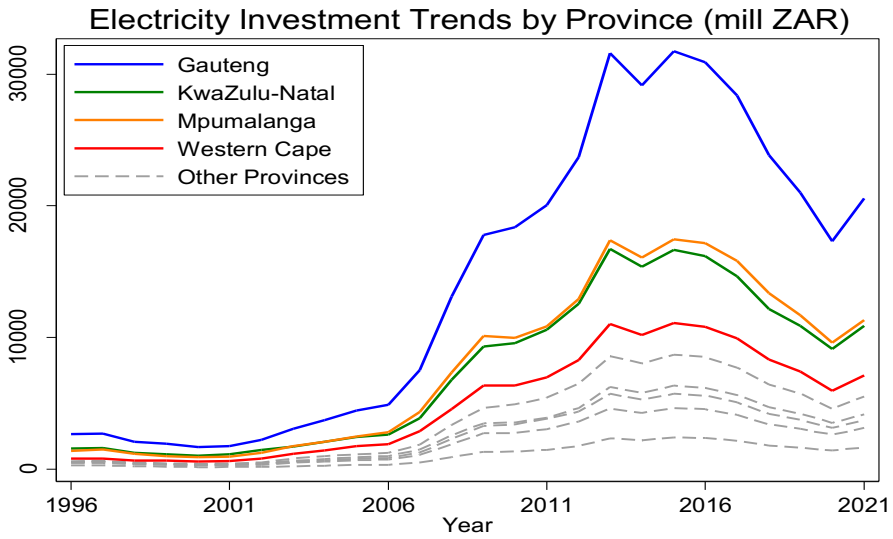


Source: Author's construction from SARB data (2024).

Figure 22 provides a depiction of the annual regional investment trends in electricity from the year 1996 to 2021. In the year 1996, the national expenditure on electricity investment was recorded at R8.8 billion ($2 billion). This figure experienced an initial decline during the early 2000s, followed by a progressive rise until 2007, where it attained R24 billion ($3.5 billion). Commencing in 2008, there was a significant and sustained increase over almost a decade, culminating at a peak of R104 billion ($8.2 billion) in 2015, before experiencing a reduction to R68 billion ($4.6 billion) by the year 2021. The largest allocation of electricity investment was directed to the Gauteng province, recording R2.6 billion ($61 million) in 1996 and R20 billion ($1.3 billion) in 2021. KwaZulu-Natal was the recipient of the second-largest proportion of investment, receiving R1.5 billion ($36 million) in 1996 and R10.8 billion ($73 million) in 2021. Mpumalanga, identified as the third-largest beneficiary in 1996, received investments amounting to R1.3 billion ($32.5 million) in 1996 and R11.3 billion ($76 million) in 2021. The data analysed captures the trend in electricity investment over the specified period, which is further examined in Figure 23. Moreover, the other six provinces were recipients of comparatively smaller transit investments in contrast to the leading three, reflecting patterns analogous to those observed in Gross Fixed Capital Formation (GFCF), Construction (CON), and

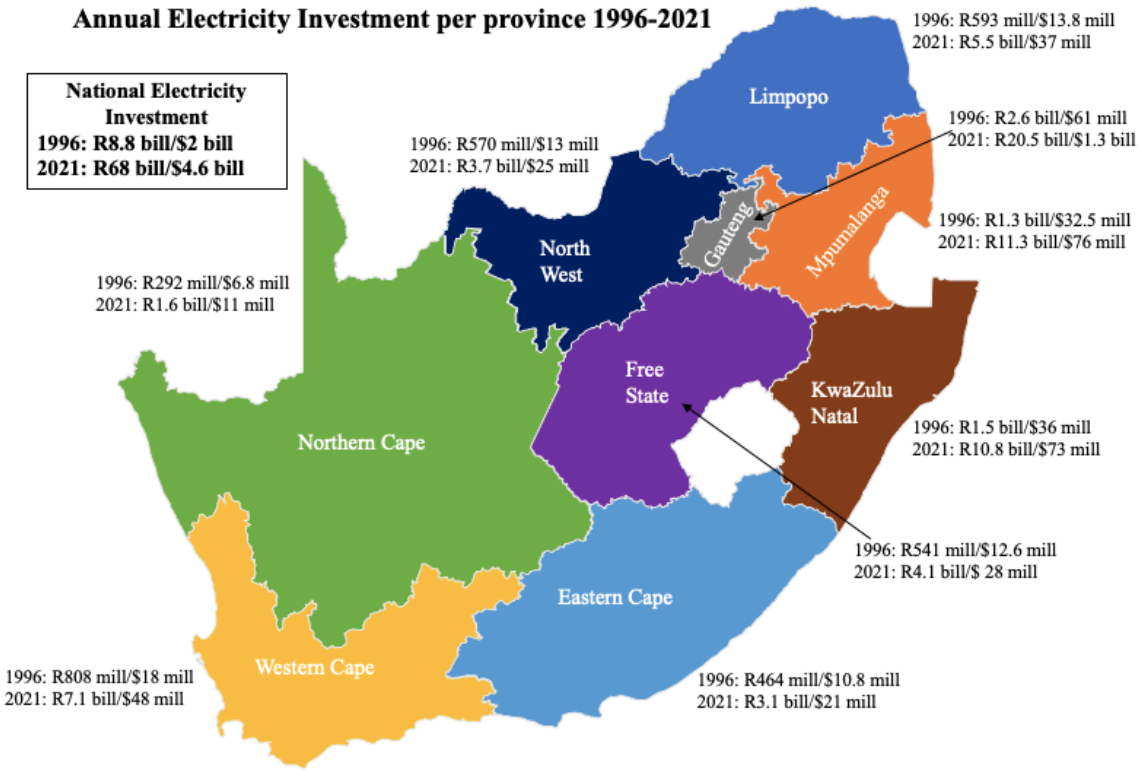
Transportation (TRANS) investments, which are concentrated in regions with the most substantial contributions to the national Gross Domestic Product (GDP).

Figure 22: Provincial Electricity Investment 1996-2021.



Source: Author's construction from SARB data (2024).

Figure 23: National, Provincial Electricity Investment 1996 and 2021.

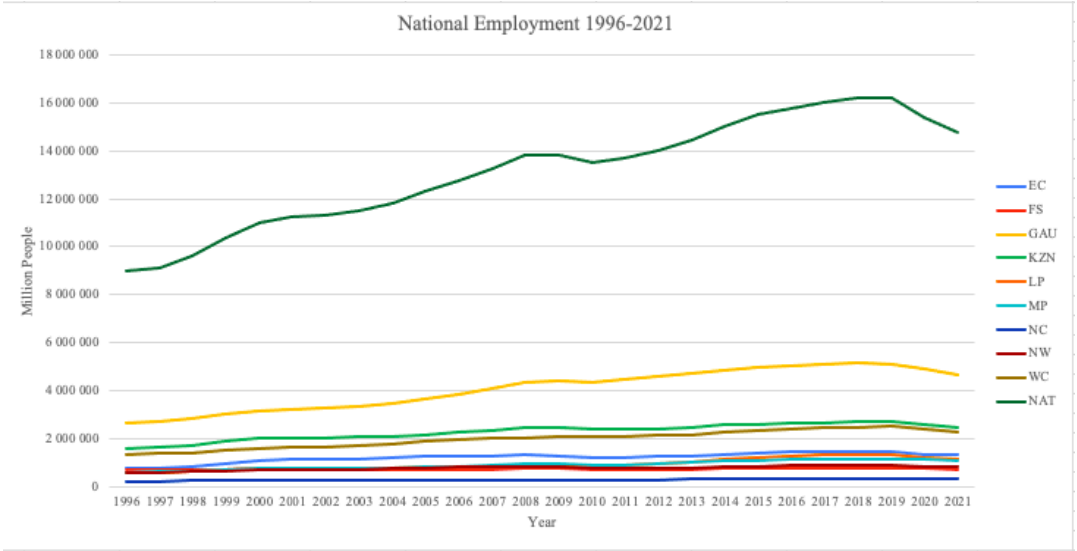


Source: Author's construction from SARB data (2024).

4.3.5c National versus Provincial Employment

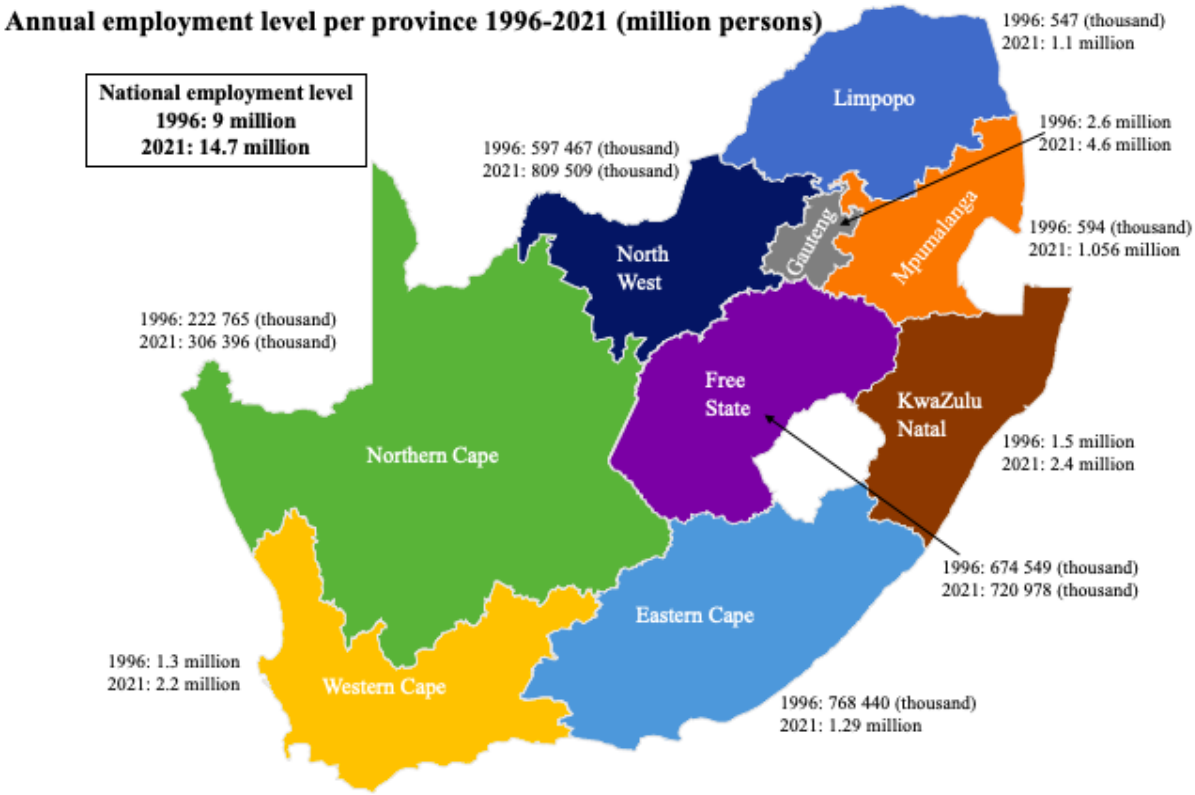
The latest census conducted in South Africa in 2022 indicates that the nation's total population is approximately 62 million individuals. The provinces of Gauteng, KwaZulu-Natal, and the Western Cape register the highest population figures, with 15 million, 12.4 million, and 7.4 million residents, respectively (Statistics South Africa, 2023). Figures 24 and 25 illustrate the national and provincial employment levels in South Africa from 1996 to 2021. The national employment level in 1996 stood at 9 million, which progressively increased over a decade, reaching 13.8 million in 2008. The peak of employed individuals, post-apartheid, was observed in 2019, numbering 16.22 million; however, this figure declined to 14.7 million in 2021. This reduction can be ascribed to the COVID-19 pandemic, which emerged globally in early 2019, prompting governments worldwide to heed the World Health Organization's guidance, enacting national lockdowns that curtailed citizens from departing their residences and engaging in work. The highest proportion of the employed populace is situated in Gauteng province, the province with the smallest geographic area, with figures rising from 2.6 million in 1996 to 4.6 million in 2021. KwaZulu-Natal holds the position as the province with the second-largest number of employed individuals, with employment figures increasing from 1.6 million in 1996 to 2.4 million in 2021. The Western Cape houses the third-largest number of employed individuals, rising from 1.3 million in 1996 to 2.3 million in 2021. The distribution of the employed population is aligned with the levels of economic activity and capital investments, which are predominantly concentrated in these three provinces.

Figure 24: Annual SA National vs Provincial Employment Level 1996-2021.



Source: Author's construction from SARB data (2024).

Figure 25: National, Provincial Employment Level 1996 and 2021.



Source: Author's construction from SARB data (2024).

This chapter offers an in-depth primary analysis of the study examining the economic performance of the nine provinces within South Africa and evaluating the impacts of infrastructure investment, either positive or negative, over the period from 1996 to 2021. The research investigates the relationship between real GDP per capita, serving as the dependent variable, and various independent variables including employment, domestic investment, ICT investment, construction investment, electricity investment, and transport investment. This analysis incorporates both short-term and long-term perspectives. Three estimation methods were employed to evaluate a range of econometric approaches, as previously discussed in earlier chapters. These methods comprise Pooled OLS, OLS with Fixed Effects, and the one-step system GMM approach. Additionally, the chapter provides a graphical illustration of economic development distribution across the country, as indicated by the empirical data analysis. Chapter 5 subsequently focuses on the second segment of this research, which entails a comparative analysis between South Africa and the OECD.

5. International Comparative Analysis: South Africa-OECD

Discusses the secondary research which explored the convergence phenomenon by comparing South Africa's growth trajectory to the OECD across a 39-year period, from 1980 to 2019. This was accomplished by analysing the long-term steady-state relationship in GDP per capita across time, using the OECD average GDP per capita as the benchmark.

5.1 Data: South Africa and the OECD

According to the World Bank (2018), South Africa has the most structurally advanced economy on the African continent with strong institutions and is classified as an upper-middle-income country. The OECD has four members in the same category (Columbia, Costa Rica, Mexico and Turkey); therefore, it is justifiable to comparatively analyse South Africa's economic performance with these four countries. Furthermore, the members of the group represent the continents of Asia, Australasia, Central Eastern Europe, Western Europe, North America and South America, as summarised in Table 13 and Table 14. This diversity enables an analysis of South Africa's economic performance at the global scale. Among the current OECD members are 6 post-socialist countries (PSCs) namely, Czechia, Estonia, Latvia, Lithuania, Slovenia and Slovakia, all of which have a 10-year gap in their available data from 1980 to 1990, amounting to a loss of 360 observations for the 6 variables. This posed difficulties for the stability and reliability of the analysis of the unbalanced panel dataset as it could produce spurious results. Hungary and Poland, both PSC's, remained in the panel as they did not have any data gaps for the entire period of investigation. The unbalanced panel problem was solved by removing the six PSCs and introducing six control Latin American countries (Argentina, Bahamas, Barbados, Panama, Trinidad and Tobago and Uruguay) that have similar World Bank classifications, thereby restoring balance in the panel dataset.

Table 13: OECD Member Countries.

OECD Member countries as at December 2023					
Australia	Czechia	Hungary	Lithuania	Portugal	Turkey
Austria	Denmark	Iceland	Luxembourg	Slovakia	United Kingdom
Belgium	Estonia	Ireland	Mexico	Slovenia	United States
Canada	Finland	Israel	Netherlands	South Korea	

Chile	France	Italy	New Zealand	Spain	
Columbia	Germany	Japan	Norway	Sweden	
Costa Rica	Greece	Latvia	Poland	Switzerland	

Source: Author's construction.

Table 14: International Comparative Analysis Population.

32 OECD member countries				
Australia	Denmark	Ireland	New Zealand	Switzerland
Austria	Finland	Israel	Norway	Turkey
Belgium	France	Italy	Poland	United Kingdom
Canada	Germany	Japan	Portugal	United States
Chile	Greece	Luxembourg	South Korea	
Columbia	Hungary	Mexico	Spain	
Costa Rica	Iceland	Netherlands	Sweden	
6 Control countries				
Argentina	Bahamas	Barbados	Panama	Trinidad and Tobago
Uruguay				
1 Comparative analysis country				
South Africa				

Source: Author's construction.

This study sheds new light on this area from an African perspective as it comparatively analyses 39 countries—South Africa, 6 Latin American countries and the 32 OECD members. It investigates their respective average steady-state equilibriums and tests convergence patterns from 1980 to 2019. This allows South Africa's developmental performance to be plotted against an international benchmark. The sources of the secondary data for this analysis are the Penn World Tables 10.0. Annual data for 5 variables of the 39 countries from 1980 to 2019 were extracted and converted into a balanced panel dataset that comprises 1,560 observations. This macroeconomic phenomenon was investigated by analysing real GDP per capita PPP as the dependent variable along with domestic investment, capital stock, employment, labour share of compensation as the independent variables. The real GDP per capita purchasing power parity (PPP) value used in these calculations were adjusted for inflation and cost of living differences between countries.

The OECD (2022) defines in real terms domestic investment or Gross Fixed Capital Formation (GFCF) as an attainment of newly produced, purchased, and second-hand assets, inclusive of the production of such assets by producers (industries, producers of government services and producers of private non-profit services to households) for their own use, minus those assets that have been sold or written off. These assets are inputs into the production process of other goods and services which have an economic life of longer than one year (OECD, 2022). Employment or number of persons engaged is described as "working for at least one hour a week for some payment, either for a wage or for profit, or commission, or without pay in a family business" (Junankar, 2004:42). This wage or compensation is the reward for the individual for services rendered of which the aggregate is expressed as a percentage of GDP. Table 15 summarises the macroeconomic variables investigated in this study.

Table 15: Macroeconomic Variables – SA-OECD Comparative Study.

Macroeconomic variable	Abbreviation	Measurement	Source
Capital stock at current PPP	Cap stock	Millions in USD	Penn World Table 10.0
Number of persons engaged	Emp	Millions of persons	Penn World Table 10.0
Output-side real GDP at chained PPP	Real GDP	Millions in USD	Penn World Table 10.0
Share of gross capital formation at current PPP	GFCF	Millions in USD	Penn World Table 10.0
Share of labour compensation in GDP at current national prices	Labs	Millions in USD	Penn World Table 10.0

Source: Author's construction.

The choice of variables was guided by the literature and is deemed the most appropriate to test the Solow–Swan model (1956) and calculate convergence (Monfort and Nicolini, 2000; Blonigen, 2005; Head and Rise, 2008; Grigoras, 2015; Egri and Tánczos, 2018; Lengyel, and Kotosz, 2018; Kanó and Lengyel, 2021; Szanyi, 2021; Bolganbayev, *et al*., 2022 and Gbadamosi, *et al*., 2022). Sala-i-Martin (1996) illustrated that to enumerate economic convergence, it is necessary to include the GDP per capita for a cross-section of economies.

Table 16 presents the descriptive statistics on the 39 countries from 1980 to 2019. The table summarises the descriptive data for central tendency and variability. The mean values represent the average value of the variables in the overall model. The standard deviation represents the dispersion of data around the mean value. It also indicates the

data's proximity to the average value throughout the specified period. The range of data can be assessed by the highest and minimum values in each model. The range indicates the amount of variance in variables. Variables with broader range values exhibit more variance and vice versa.

Table 16: Descriptive Statistics SA-OECD.

Variable	N	Mean	Median	Maximum	Minimum	Std. Dev
real GDP per capita	1560	5,435431	5,476747	7,31378	3,480623	0,771461
Capital stock	1560	6,014458	6,116556	7,839221	3,681969	0,836371
Labour share	1560	0,560347	0,5755	0,7506	0,2677	0,091415
Employment	1560	14,14289	4,5837	158,2996	0,0716	23,6868
Domestic investment	1560	0,247069	0,24845	0,5699	0,042	0,067986

Source: Authors construction from EViews 12 output (2024).

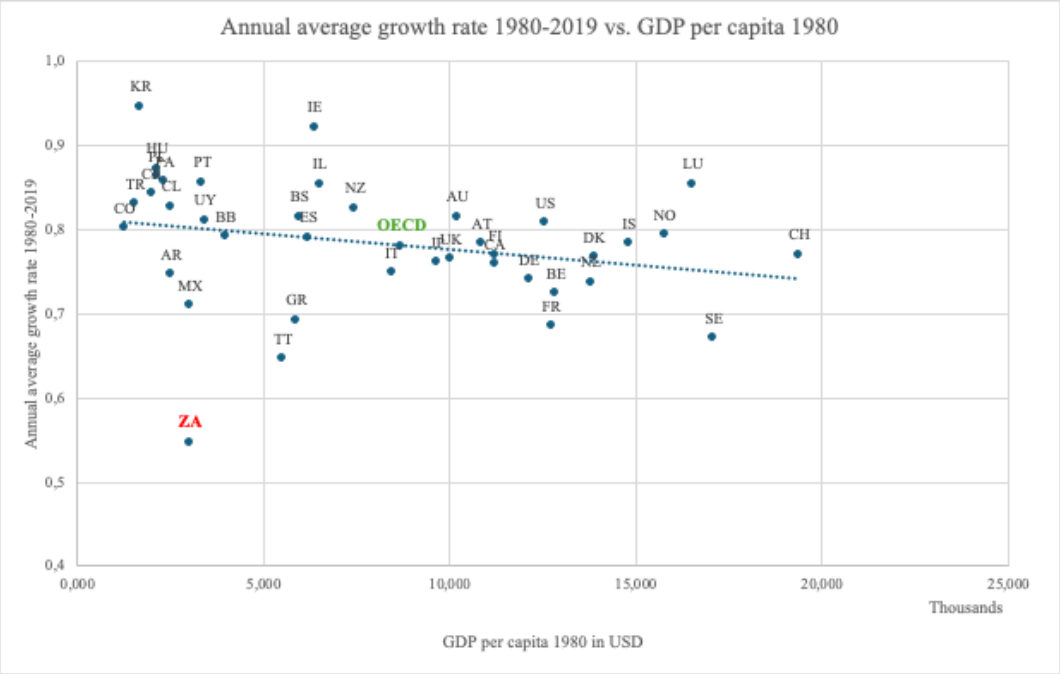
5.2 Empirical Estimation Findings

The secondary analysis investigated the convergence phenomenon by examining the growth trajectory of South Africa in comparison to the OECD over a 39-year period, from 1980-2019. The enumeration of the β-convergence, α-convergence and the steady state equilibrium was conducted, and the results are presented in the paragraphs that follow (Marais, 2024a, 2024b).

Figures 26 and 27 illustrate the GDP per capita 1980 and 2019 versus the annual average growth rate 1980-2019 respectively, for the population of 39 countries including the OECD average (in green). In 1980 the average GDP per capita for the OECD was $8708 with an annual growth rate for the thirty-nine-year period of 0.78. This is considered as the benchmark for the convergence analysis and is positioned on the downward sloping trendline showing a negative relationship between the initial income in 1980 and the growth rate of member states. The data reveals that several member states are positioned in close proximity to the benchmark, either above with higher a GDP per capita and growth rate (AU, AT, CA, FI, US, LU, NO) or below with a lower GDP per capita and growth rate (IT, GR, TT, MX, AR, ZA) than the OECD average. South Africa (in red) finds itself in the latter group with its GDP per capita at $3035 and a growth rate of 0.55. No members are in an overlap position with the benchmark. Another observation of the data reveals that a number of members have a lower GDP per capita but a higher growth rate than the benchmark (TR, NZ, BS, IL, IE, PT, UY, CL, HU, KR). Moreover, there are

members that have lower growth rate but a higher GDP per capita than the benchmark (CH, JP, UK, DE, BE, FR, NL, SE).

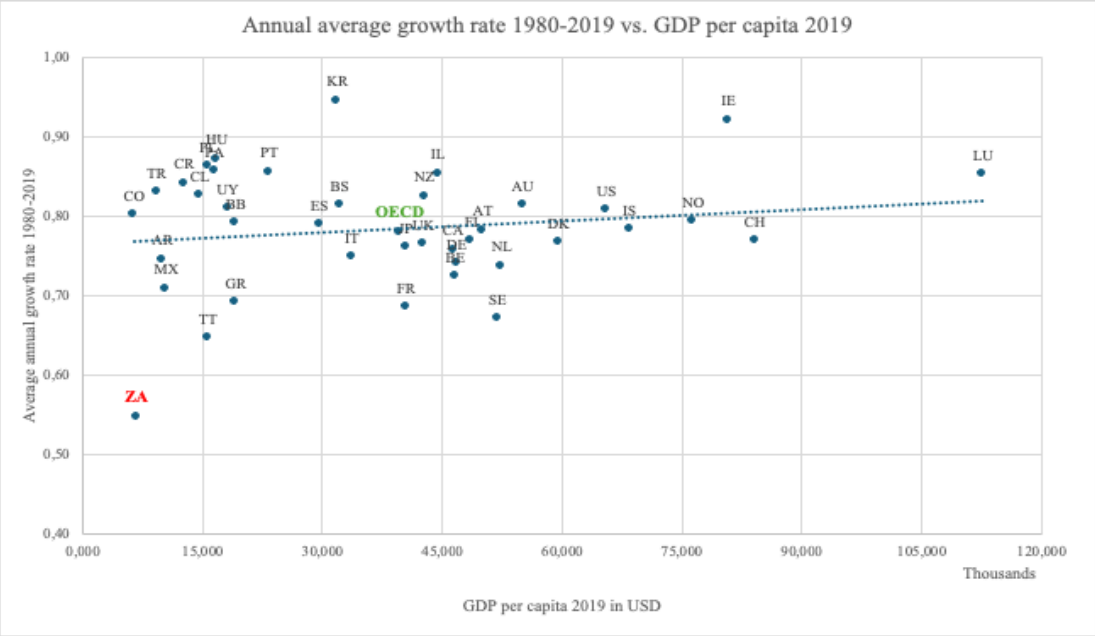
Figure 26: Growth Rate 1980-2019 vs. GDP per capita 1980.



Source: Author's construction.

Pointing to the data in 2019 in Figure 27, it is observable that each of the 39 countries have experienced considerable increases in their GDP per capita. The upward sloping regression trend line indicates that now a positive relationship can be observed between the income in 2019 and the average annual growth rate. The average GDP per capita for the OECD jumps to $39,685, which becomes the new benchmark of comparison. The data reveals that several member states are positioned in close proximity to the benchmark, either above with higher a GDP per capita and growth rate (NZ, IL, AU, AT, IE, LU) or below with a lower GDP per capita and growth rate (IT, GR, TT, MX, AR, ZA the same countries as in 1980) than the OECD average. South Africa still finds itself in the latter group with its GDP per capita now reaching $6073, which is more than double that of 1980. This illustrates conditional β-convergence where the country's GDP has dramatically increased, slightly narrowing the per capita income gap with developed nations of the OECD. Repeatedly, no members are in an overlap position with the benchmark. Observation of the data reveals that a number of members have a lower GDP per capita but a higher growth rate than the benchmark (BS, ES, PT, UY, CL, HU, KR, TR etc.). Moreover, there are members that have lower growth rate but a higher GDP per capita than the benchmark (CA, JP, UK, DE, BE, FR, NL, NO, SE).

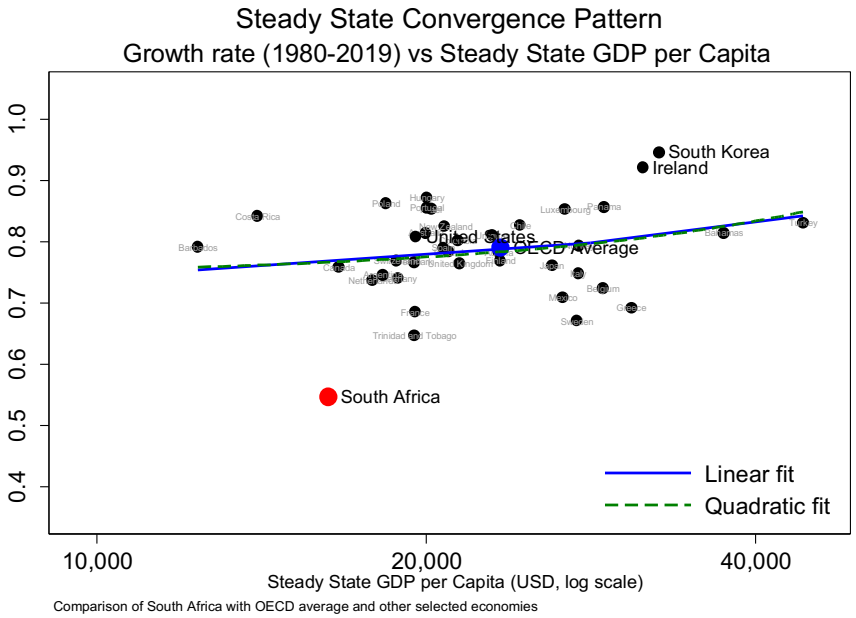
Figure 27: Growth Rate 1980-2019 vs. GDP per capita 2019.



Source: Author's construction.

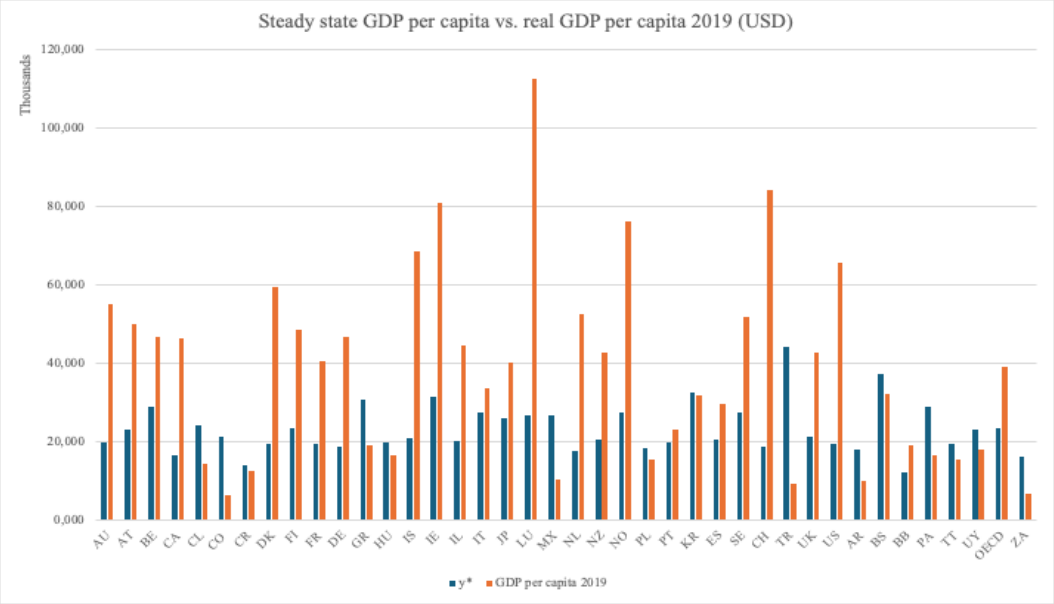
The steady-state GDP per capita in Figures 28 and 29, represents the per capita income level that an economy is able to maintain in the long run when its equilibrium is attained. At this stage, capital investment equals capital depreciation, with population increase and technical development factored in. Steady-state GDP per capita is the constant amount of production achieved per person by an economy when capital investment equals capital depreciation, population increase, and technological advancement are all taken into consideration. In the steady state, the capital stock in the economy does not shift, implying that the quantity of new capital added via investment matches the amount lost through depreciation. The model predicts that poorer countries would expand faster than affluent ones because they have more space to amass capital. This process is referred to as convergence. As these economies invest and thrive, GDP per capita approaches its steady-state level.

Figure 28: Growth Rate 1980-2019 vs. Steady State GDP per Capita



Source: Author's construction.

Figure 29: Steady state GDP per capita vs. GDP per capita 2019.



Source: Author's construction.

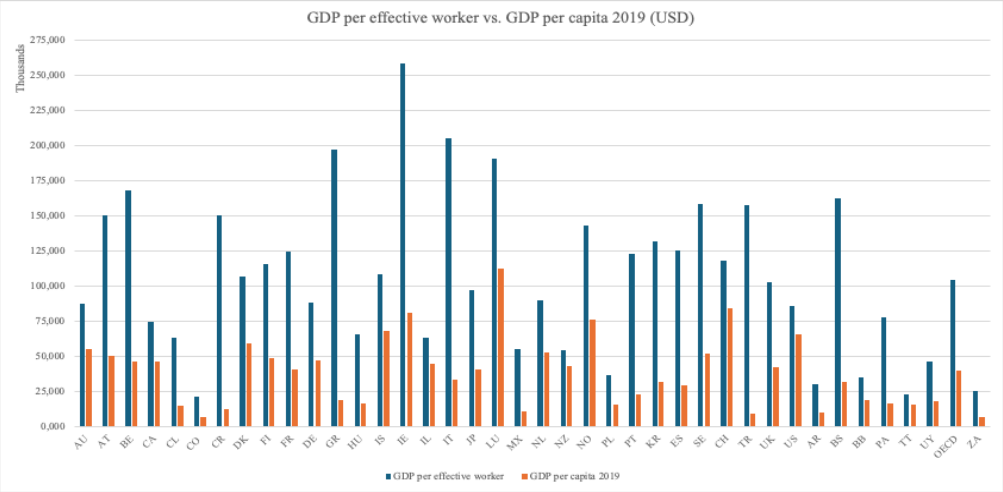
Figure 28 illustrates the quadratic and linear regression analysis of the growth rate throughout the period of study in relation to the modelled steady-state GDP per capita across each of the 39 countries. The OECD's average per capita income steady-state equilibrium level ($23,417) and growth rate (0.78) are highlighted in blue on both regression lines with an upward trajectory. Conversely, South Africa, highlighted in red, exhibits its own steady-state level ($16,282) and growth rate (0.55), both of which fall

significantly below the trend line. A more distinct visualisation of the modelled and real GDP per capita in 2019 is shown in Figure 29.

Figure 29 demonstrates the modelled steady state equilibrium level (y* in blue) and the real GDP per capita in 2019 of the 39 countries including the OECD average (in orange). This is an approximate income per capita level that can be sustained in the long term by each of these economies when equilibrium has been achieved. It is evident that the vast majority of the OECD members have attained a GDP per capita in 2019 that exceeds their steady state equilibrium levels including the blocks average. These are developed nations with mature capital markets enabling efficient capital accumulation. This approximation is a static view, and it is important to note that new steady state equilibrium levels are continually identified as economies are dynamic. The data reveals that the Latin American countries (TT, PA, AR, MX, CO) and South Africa ($16,282) are largely the countries with a GDP per capita in 2019 that is below the steady state equilibrium level but gravitate towards their individual levels. Based on the parameters of the model, potentially the South African economy has the capacity to enhance its economic performance by technological amelioration in labour or gains in capital accumulation, and eventually reducing dispersion and attaining the OECD average steady state equilibrium level ($23,417). Moreover, conditional β-convergence is inferred whereby South Africa is diverging from its low initial GDP toward a higher GDP level potentially at a faster rate therefore closing the per capita income gap between itself and the OECD average.

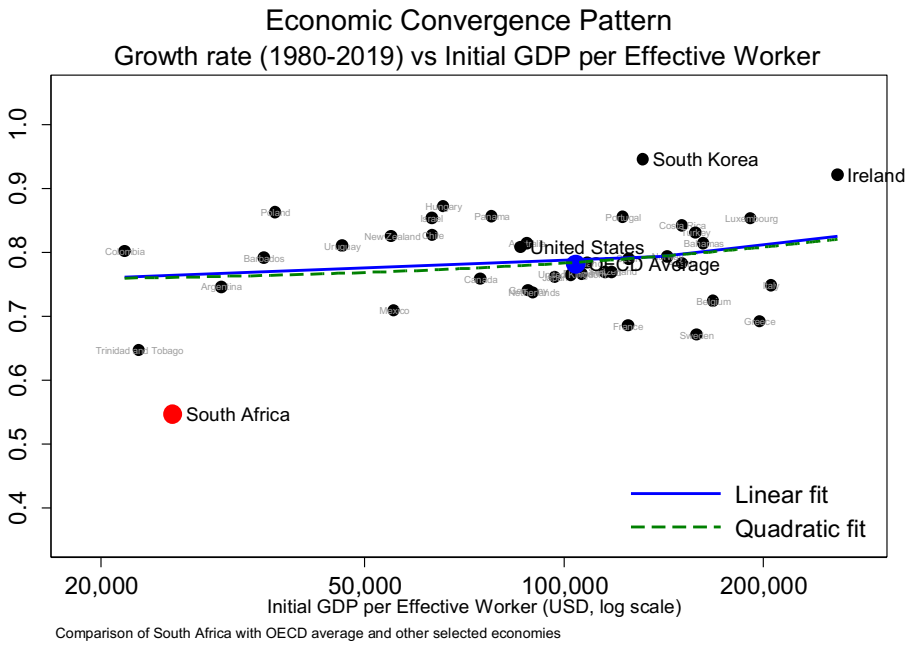
Figure 30 illustrates the modelled GDP per effective worker (blue) versus the GDP per capita in 2019 (orange). An effective worker is described as one whose productivity is enhanced by technology. This indicates that a worker's production is determined by not just the amount of labour but also the level of technology accessible in the economy. This is determined as the total production (GDP) divided by the number of productive workers. It reflects labour productivity while considering technology advancements. The modelled GDP per effective worker value is greater than the actual GDP per capita in 2019 for each of the 39 countries. Highlighting that advances in technology could catapult these economies in attaining greater levels of GDP per capita. The Solow-Swan model states that economies will gravitate to a steady state in which GDP per effective worker remains fixed over time, unless technology adjustments occur.

Figure 30: GDP per Effective Worker vs. real GDP per capita 2019.



Source: Author's construction.

Figure 31: Growth Rate 1980-2019 vs. GDP per Effective Worker.



Source: Author's construction.

Figure 31 presents the modelled GDP per effective worker in conjunction with the average growth rate throughout the period under examination. The average GDP per effective worker level of the OECD, amounting to $104,215, alongside its growth rate of 0.78, is represented in blue on both regression lines, each displaying an ascending path. In stark contrast, South Africa, depicted in red, demonstrates a GDP per effective worker level of $25,679 and a growth rate of 0.55, both of which are markedly below the trend line. The theoretical model emphasises that increasing capital per effective worker results in increased production per effective worker. However, due to decreasing returns to

capital, the growth rate of production per effective worker will ultimately stabilise unless technological advancement is made. The model predicts that poorer nations would expand faster than wealthy ones as they catch up on capital accumulation and productivity. Poorer nations frequently enjoy better returns on investment due to lower initial levels of capital per effective worker, which facilitates the convergence process. Continuous technological advancements are required for long-term GDP growth per effective worker. In the long term, technological breakthroughs raise the steady-state level of GDP per effective worker, allowing for continuous improvements in the standards of living. The speed of convergence approximates that ceteris paribus, it will take South Africa 34.11 years to reach the OECD average GDP per capita of 2019 ($39,686).

This subchapter presented the secondary analysis that investigated the convergence phenomenon by examining the growth trajectory of South Africa in comparison to the OECD over a 39-year period, from 1980-2019. This was done through the analysis of the long-term steady state relationship in GDP per capita over the period and adopted the OECD average GDP per capita as a benchmark for this analysis. The enumeration of the β-convergence, α-convergence and the steady state equilibrium was conducted, and the results were presented. Next, chapter 6 discusses the key findings of part one and part two of this research study and draws conclusions.

6. Discussion of Key Findings and Conclusions

This analysis scrutinized the empirical findings from the provincial study (Chapter 4) and the international study (chapter 5), contextualizing them within the theoretical foundations articulated in the literature review (Chapter 2) and the methodological framework (Chapter 3). It evaluates the extent to which the findings corroborate or refute the stated hypotheses and furnishes reasoned elucidations for the outcomes.

6.1 Domestic Analysis: South Africa’s 9 Provinces

Chapter 4 conducted an extensive econometric inquiry 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; Kumo, 2012; Marais, 2025). 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 Chapter 2. 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. The graphical and spatial analysis (Figures 19-30) offers incontrovertible visual evidence of this disparity.

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 & 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 (Chapter 5): how might a nation achieve convergence with advanced economies if its growth is both inefficient and internally divergent?

6.2 International Comparative Analysis: South Africa-OECD

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 (Chapter 5) to evaluate whether South Africa is aligning with advanced economies, in accordance with the neoclassical growth and convergence theory delineated in the literature review (Chapter 2). 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. Figure 31 (1980) illustrates the classic neoclassical inverse relationship between initial income levels and subsequent growth rates (characterized by a downward-sloping trendline). 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 in Figure 33, 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 (Marais, 2024a, 2024b).

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 Chapter 2. 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. Figure 34 illustrates that 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.

6.3 Linkages between South Africa’s Domestic Provincial Analysis and the International OECD Comparative Analysis

6.3 (a) Infrastructure Investment and Economic Growth

Chapter 4 investigated the effect of infrastructure investment (transport, ICT, construction, etc.) on economic development at the province level in South Africa. Panel data econometric models were used to investigate the causal connections between infrastructure investment and real GDP per capita in South Africa's nine provinces over the period 1996-2021. Thereafter, Chapter 5 expanded this research by comparing South Africa's economic performance to that of the OECD nations, with a focus on convergence theory. The chapter explores whether South Africa is catching up with the OECD average in terms of real GDP per capita, as driven by infrastructure investment. The findings in Chapter 4, demonstrate that infrastructure investment, particularly transport investment and ICT investment have a significant positive influence on real GDP per capita in South Africa. This lays the groundwork for understanding why the country may or may not be catching up with OECD nations average per capita income. As infrastructure investment is a fundamental engine of economic growth and development in South Africa, the monetary value the country invests in infrastructure will contribute to its capacity to catch up with OECD nations. Increased infrastructure investment might assist South Africa narrow the gap with other OECD nations. However, investment must be equally allocated throughout provinces to prevent aggravating internal inequities.

6.3 (b) Spatial Distribution of Economic Growth

Chapter 4 emphasised the geographical inequalities in economic development and infrastructure investment throughout South Africa's provinces. Gauteng, the Western Cape, and KwaZulu-Natal receive the largest share of infrastructure investments and contribute the most to national GDP, while the remaining provinces fall behind. Chapter 5 compared South Africa's overall economic performance to the OECD, using its 2019 average GDP per capita as a baseline. South Africa's geographical inequities, as demonstrated in Chapter 4 may explain why the country as a whole struggle to catch up with OECD countries. The unequal distribution of infrastructure investment and economic activity in South Africa may impede its overall economic convergence with more developed nations. The geographical differences in infrastructure investment and economic development in South Africa (Chapter 4) have a direct influence on the country's potential to converge with OECD nations. If specific provinces are undeveloped owing to a lack of infrastructure investment, this lowers the national average, making it more challenging for South Africa to catch up with the OECD’s level of performance.

6.3 (c) Convergence Theory

By examining whether provinces with lower baseline GDP per capita are catching up to more developed provinces in South Africa, Chapter 4 indirectly addresses convergence theory. The findings indicate that although some provinces (such as Gauteng and the Western Cape) are more developed, others (such as Limpopo and the Eastern Cape) are falling behind. The convergence patterns identified inside South Africa (Chapter 4) shed light on the country's capacity to converge with OECD nations (Chapter 5). If particular provinces stay underdeveloped and do not edge closer to convergence, the national average income will continue to fall, making it insurmountable for South Africa to catch up with the OECD. The convergence study in Chapter 5 demonstrated that South Africa needs structural economic reforms to catch up with OECD nations. These changes should include not just more infrastructure investment, but also steps to reduce economic inequality, promote education and skill development, and strengthen governance. This conclusion is supported by the findings in Chapter 4, which underscore the relevance of infrastructure investment. Furthermore, Chapter 5 also examined global issues (such as trade agreements, financial flows, and technical innovation) that affect South Africa's capacity to catch up with OECD nations. Moreover, Chapter 4, which demonstrated that ICT investment has a major influence on economic growth, implies that South Africa may profit from global technical breakthroughs. However, in order to effectively exploit these global prospects, the country must overcome domestic difficulties (for example, uneven investment distribution).

The linkages between Chapters 4 and 5 are evident and crucial. Chapter 4 presents a thorough examination of the influence of infrastructure investment on economic development in South Africa, revealing regional inequalities between provinces. These conclusions are directly pertinent to Chapter 5, which looks at South Africa's capacity to catch up with OECD countries. Internal differences in infrastructure investment and economic growth in South Africa (Chapter 4) impede the country's capacity to converge with OECD nations (Chapter 5). To attain convergence, South Africa must address internal imbalances, enhance infrastructure investment, and carry out structural economic changes. Both chapters' findings indicated that infrastructure investment, particularly in transport and ICT, is an important driver of economic development and convergence, but it must be equitably dispersed and complemented by larger reforms to be successful.

Based on the key findings and conclusions derived from the empirical analysis of both parts of this study, specific policy recommendations for each have been developed and discussed in Chapter 7.

7. Policy Recommendations, Study Limitations and Future Research

7.1 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.

7.1 (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) 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.

7.1 (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.

7.1 (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. The South African government must undertake tough negotiations with trading partners to create a position for itself in the first and second value addition activities to its mineral markets before exportation. 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.

This research on 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 as discussed in chapter 2.4.1 (most recently by the National Development Plan). Despite their existence, implementation thereof has been unsuccessful as shown by their meagre impact.

7.2 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.

7.2 (a) Enhance Capital Accumulation Capabilities

According to the convergence hypothesis (Solow and Swan, 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 domestic 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 without disenfranchising the wellbeing of its citizens and labour market. Moreover, it should focus on decreasing the practices of corruption and increase efficiencies across sectors. Policies that encourage long-term investment in critical industries (such as manufacturing, mining, and technology) should be prioritised.

7.2 (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.

7.3. 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 report looks at aggregate infrastructure investment (for example, transportation, ICT, and building), but it doesn't go into depth about specific industries or projects. Moreover, did not take exogenous shocks such as the covid-19 pandemic into account.

7.4. 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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Appendix

Table A1: VAR lag order selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	165.0836	NA	0.010109	-1.756484	-1.632313	-1.706138

1	548.0414	731.8751	0.000145	-6.000460	-5.858551	-5.942922
2	550.7140	5.077861	0.000142*	-6.019044*	-5.859397*	-5.954314*
3	550.7736	0.112662	0.000144	-6.008596	-5.583210	-5.936673
4	550.7769	0.006131	0.000146	-5.997521	-5.802396	-5.918406
5	550.8384	0.114869	0.000147	-5.986094	-5.774230	-5.900787
6	550.8533	0.027503	0.000149	-5.976147	-5.745545	-5.882648
7	553.9009	5.621199*	0.000145	-5.998899	-5.750558	-5.898207
8	553.9012	0.000566	0.000147	-5.987791	-5.721711	-5.879907

Source: Author's construction (2025). *Indicates the lag order selection by the criterion. LR: sequential modified LR test statistic (each test at 5% level), FPE: final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion.

The results demonstrate that the VAR(2) model is the optimal choice as it has the greatest number of asterisk symbols (*) shown in Table A1 and confirms the GMM procedure has selected the optimum lag for modelling.

Table A2: Static Panel Estimation

Dependent variable: lnrGDPpc		
Variable	Pooled OLS	FE OLS
LnCon	-0.248 (0.000)	0.031 (0.739)
LnElec_con	0.142 (0.001)	0.057 (0.240)
LnTrans	0.102 (0.068)	0.062 (0.393)
LnICT	0.533 (0.000)	1.475 (0.000)
LnEmp	-0.122 (0.035)	-1.397 (0.000)
LnGFCF	-0.217 (0.058)	-0.122 (0.366)
F-statistic	27.79 (0.000)	14.21 (0.000)
Constant	5.075 (0.058)	9.151 (0.000)
R-squared	0.384	0.589
Root MSE	0.107	0.092
Observations	234	234
Cross sections	9	9

Source: Author's construction (2025).