DECLARATION

I, the undersigned, hereby declare that this thesis, entitled "Exploring the Relationship Between Infrastructural Development and Economic Growth in East Africa: A Panel Data Analysis" is my own original work and has not been submitted, in whole or in part, for any degree or examination at this or any other institution. I further declare that all sources consulted and cited in this work have been fully acknowledged. Where the work of others has been used, it has been properly referenced in accordance with academic conventions.

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Date: 24-07-2026

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Galaxy A15

ADDIS ABABA UNIVERSITY
COLLEGE OF BUSINESS AND ECONOMICS
DEPARTMENT OF ECONOMICS

This is to certify that the research entitled "Exploring the Relationship Between Infrastructural Development and Economic Growth in East Africa: A Panel Data Analysis" submitted by Tamru Bazezew in partial fulfillment of the requirements for the award of the Degree of Master of Science in Economics (Development Economics) at Addis Ababa University has been examined and found to fulfill all the requirements for academic reliability, originality, and scholarly merit, and is hereby approved for acceptance by the Board of Examiners.

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COLLEGE OF BUSINESS AND ECONOMICS

DEPARTMENT OF ECONOMICS

EXPLORING THE RELATIONSHIP BETWEEN INFRASTRUCTURAL DEVELOPMENT AND ECONOMIC GROWTH IN EAST AFRICA: PANEL DATA ANALYSIS

Prepared by: Tamru Bazezew

Advisor: Dr. Atlaw Alemu

A THESIS SUBMITED TO THE DEPARTMENT OF ECONOMICS IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SCINCE IN ECONOMICS (DEVELOPMENT ECONOMICS)

Addis Ababa, Ethiopia,

June, 2026

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Abstract

Despite heavy investments in infrastructure within East Africa supported by Chinese development financing through the Forum on China Africa Cooperation and domestic programs like Kenya's Vision 2030 and Ethiopia's Growth and Transformation Plans there has been little research using multi country panel analysis to establish the link between infrastructure and growth. Based on the endogenous growth theories of Barro (1990) and Romer (1986), the infrastructure development index used in this is the Africa Infrastructure Development Index (AIDI) measured in natural logarithm, one period lagged, and which consists of infrastructure endowment levels such as transport, electricity, ICT, and water and sanitation. Other control variables include inflation, openness to trade, and gross capital formation. These measures are obtained from World Bank World Development Indicators. The two step System Generalised Method of Moments estimator by Blundell & Bond (1998) with Windmeijer (2005) corrected standard errors will be used.

Pre estimation diagnostics indicate the absence of multicollinearity (mean VIF = 1.16) and a mixed integration order (GDP per capita growth: I(0), AIDI in logarithm: trend stationary, inflation, trade openness, and gross capital formation: I(1)). Post-estimation diagnostics verify full model validity (AR(2): $p = 0.271$, Hansen J-test: $p = 0.474$, number of instruments of $12 < 14$ groups). Three variables emerge as statistically significant. First, growth persistence is proven (growth coefficient = 0.400, $p = 0.023$). This implies that 40% of annual differences in economic growth rates among countries persist into the following year. Second, there is an extremely significant negative effect of inflation on growth ($\beta = -0.027$, $p = 0.001$). Thus, price volatility emerges as a stable negative influence on economic growth rates. The negative effect of lagged infrastructure endowment should be understood as infrastructure being detrimental for growth due to heavy external debt of East African nations and also through four distinct structural explanations: composition problems arising out of the panel's extreme developmental diversity, timing problems, and contaminated conflict states (Somalia and Sudan). Finally, while trade openness and gross capital formation exhibit expected theoretical signs, neither is significant.

The paper finds that investment in infrastructure is a necessary but not sufficient condition for growth in per capita GDP in East Africa. The stabilization of macroeconomic conditions, specifically inflation, creates growth benefits instantly. The study makes the first ever attempt at applying a System GMM model to investigate the relationship between investment in infrastructure and economic growth in an East African sample.

Key Words : *Infrastracture Development, Economic Growth, African Infrastructure Development Index, East Africa, System GMM, Panel Data, Inflation, GDP per capita Growth.*

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Acronyms

UNCTAD - United Nations Conference on Trade and Development

ECA - United Nations Economic Commission for Africa

SDG - Sustainable Development Goals

AfDB - African Development Bank

AIDI - Africa Infrastructure Development Index

OECD - Organization for Economic Co-operation and Development

GERD - Grand Ethiopian Renaissance Dam

AfCFTA - African Continental Free Trade Area

EAC - East African Community

GDP - Gross Domestic Product

TFP - Total Factor Productivity

GMM - Generalized Method of Moments

SSA – Sub Saharan Africa

WEF - World Economic Forum

PIDA - Program for Infrastructure Development in Africa

IMF - International Monetary Fund

WB - World Bank

GCF - Gross Capital Formation

AGOA - African Growth and Opportunity Act

AR(2) - Arellano-Bond Second-Order Autocorrelation Test

LAPSSET - Lamu Port-South Sudan-Ethiopia Transport Corridor

TRADE - Trade Openness (Total Trade as Percentage of GDP)

lnAIDI - Natural Logarithm of the Africa Infrastructure Development Index

AR(1) - Arellano-Bond First-Order Autocorrelation Test

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Chapter One

1. Introduction

1.1. Background of the Study

The development of transportation, energy, and telecommunications infrastructure is widely viewed and recognized as a catalyst for economic activity, enhancing productivity, reducing operational costs, and improving connectivity by both policy makers and academicians (Olawale, A. (2024) and Cesar Calderon and Luis Serven, (2010)). The expansion of infrastructure is fundamentally linked to driving economic growth across the African continent, particularly in East Africa. Hence, Enhanced infrastructure development is a superior and necessary pathway, as it provides multiple positive connections to economic advancement. This investment approach positively connects to economic expansion by directly reducing business operation expenses, primarily through the lowering of transaction costs and boosting inter-regional inter connectivity, which is vital for market integration and trade efficiency (UNCTAD, 2023). Furthermore, reliable and modern infrastructure, encompassing energy, transport, and digital networks, is instrumental in raising overall production and productivity within the economy (ECA, 2024). This strategic focus on infrastructure serves as a foundational catalyst for broader socioeconomic progress, extending its benefits beyond mere economic metrics.

Recognized by international institutions, infrastructure development is crucial for elevating the standards of living and contributing significantly to human capital formation, poverty reduction, and the attainment of the Sustainable Development Goals (SDGs) (AfDB, 2021). Thus, prioritizing large-scale infrastructural projects is essential not only for immediate economic stimulation but also for securing a sustainable and inclusive development trajectory in East Africa. Lower income nations experience a significant deficit in infrastructure development, both in terms of the extent (quantity) and the standard (quality) of their facilities, when compared to advanced and middle-income countries. While East Africa historically trailed most of the continent in infrastructure development, placing fourth out of five African regions, recent years have reflected a positive, albeit uneven, shift. Significant inter-country disparities remain stark, as illustrated by the African Infrastructure Development

Index (AIDI) score differences: Seychelles consistently leads, for example, achieving a score of 96.73 in 2020, while Somalia registered a score near the bottom at 4.53 (AfDB, 2020). Despite this contrast, the sub-region has shown a more encouraging trend in the last decade, with major gainers like Tanzania showing substantial improvements. This progress is largely driven by a scaling-up of national investment efforts and the emergence of diverse new investors, alongside traditional development partners, focusing on major projects in sectors like renewable energy and digital connectivity (OECD, 2025; AfDB, 2020).

East Africa dedicates a higher percentage of its GDP to infrastructure spending than most other African regions, notably exceeding North and Central Africa (OECD Report, 2025). Despite this high allocation, the region's actual infrastructure development levels lag behind North and Southern Africa and fall substantially short of global standards. Within East Africa, nations like Kenya, Tanzania, Uganda, Ethiopia, Rwanda, and Burundi have experienced varying degrees of infrastructure development.

Robust infrastructure remains the cornerstone of economic resilience in East Africa, which the African Development Bank (AfDB) projects to be the continent's fastest-growing region, with GDP growth rates estimated at 4.9% in 2024 and 5.7% in 2025 (AfDB, 2024). While in the 1990s saw growth driven largely by the initial adoption of technology, the last decade has cemented the role of Information and Communication Technologies (ICT) as a primary economic engine. East Africa has leapfrogged older technologies, with mobile internet penetration and digital financial services such as Kenya’s MPesa now functioning as critical infrastructure. Conversely, energy deficits continue to restrain potential; although generation capacity has improved significantly in countries like Ethiopia and Kenya, the region still faces a financing gap. The OECD (2025) estimates that if East Africa could close its infrastructure gap to match the levels of its best performing peers, regional GDP growth could increase by approximately 6.0 percentage points per year. Overall, the region faces the largest infrastructure investment shortfall in Africa, requiring an estimated USD 42 billion annually until 2040, which represents 8.6% of the region's 2024 GDP (OECD, 2025). This is the highest requirement among African regions, compared to Southern Africa's 5.6% of GDP, underscoring the urgent need for increased funding to accelerate economic development and regional integration.

Infrastructure serves as the foundation for sustainable growth, making it a critical priority for countries across East Africa. As noted by the World Bank (2024), addressing this issue requires shifting focus toward mobilizing private capital. This investment is identified as a primary engine for driving economic development and creating jobs. East Africa, a strategically vital region characterized by diverse economies and rapid population growth, stands at a critical juncture. The region is projected by the African Development Bank (AfDB) to be the continent's fastest-growing, with GDP growth rates estimated at 4.9% in 2024 and 5.7% in 2025. Robust infrastructure is widely recognized as the cornerstone of economic resilience and is essential for translating this potential into sustained prosperity. Theoretical frameworks, including the Solow Swan and Romer's endogenous growth models, consistently posit that public infrastructure covering transportation, energy, and communication is a critical factor that lowers transaction costs, enhances market integration, and drives total factor productivity. The period after 1990 represents a distinct epoch of transformation in East Africa, marked by post-conflict reconstruction, the secession of new nations, and a significant pivot toward state-led mega-projects such as the Grand Ethiopian Renaissance Dam (GERD), the Standard Gauge Railway (SGR) projects, and the Lamu Port South Sudan–Ethiopia Transport (LAPSSET) corridor. These efforts, often financed by non-traditional partners, aim to implement a Big Push for development and bolster regional integration through initiatives like the East African Community (EAC) and the African Continental Free Trade Area (AfCFTA).

1.2. Statement of the problem

The economic impact of protracted conflicts is large and persistent, leading to widespread neglect and underdevelopment of existing infrastructure. For instance, the northern Ethiopian war alone resulted in estimated infrastructure damage exceeding $22.6 billion (World Bank, July 2023). This cycle of damage and reconstruction diverts critical resources and hinders the accumulation of productive capital. Thus Creating awareness for the public and giving policy insights for policy makers of the economic benefits of infrastructure development and the economic consequences of infrastructure damage on economic growth is a timely and important agenda. existing

empirical evidence on the infrastructure growth nexus in East Africa is fragmented and often inconclusive for East Africa.

Previous research frequently relies either on single country or sub Saharan Africa analyses, and examines before 2018 outcomes, severely limiting the generalization of findings, particularly in the post 2018 era of mega projects these include Grand Ethiopian Renaissance Dam (GERD), East African Crude Oil Pipeline (EACOP), Lamu Port-South Sudan-Ethiopia Transport (LAPSSET) Corridor and Northern Corridor Standard Gauge Railway (Mombasa-Kampala Kenya's Nairobi-Mombasa) and volatile global environments like COVID 19 pandemic and major integration like African Continental Free Trade Area (AfCFTA). Also previous researchers often used individual proxies which leads a problem of omitted variable bias, however using the Africa Infrastructure Development Index (AIDI) as a single variable which testes infrastructure as a system rather than as isolated parts. This research aims to fill this gap by providing a comprehensive analysis of the region.

1.3. Objective of the study

The study has its own aims that are divided in to the general and specific objectives as mentioned below:

1.3.1. General Objective

The primary objective of the study is to examine the relationship between infrastructure development and economic growth in East African countries using panel data analysis.

1.3.2. Specific Objectives

The specific objectives of the study are the following:

- To assess the extent and trends of infrastructure development in East African countries over time.
- To determine the impact of infrastructure development on economic growth in East Africa using panel econometric techniques.

- To provide policy recommendations for optimizing infrastructure investments to boost sustainable economic growth in the region.

1.4. Research Questions

- ✓ How does infrastructure development affect economic growth in East Africa?
- ✓ What is the current status of infrastructure development in East African countries?
- ✓ What policy measures can be implemented to improve infrastructure and stimulate economic growth?

1.5. Significance and Limitation of the Study

The researcher believes this study is multi-faceted, contributing substantially to academic knowledge, policy formulation, and practical implementation within the East African context. Academically, the research addresses a critical gap in the existing literature. Since Previous studies on the relationship between infrastructure development and economic growth have predominantly adopted either a fragmented approach focusing on single country analyses or an overly broad perspective covering the whole of Africa or Sub Saharan Africa. While these approaches offer value, they often fail to capture the specific dynamics of regional integration and the collective impact of cross-border projects unique to the East African Community (EAC).

This study is a novel work because it specifically and exclusively focuses on the EAC as a coherent regional bloc, context specific, and policy relevant understanding of how integrated infrastructure such as the regional transport corridors, power pools, and shared ICT networks collectively influence the region's economic trajectory. This focus allows for a more nuanced comparative analysis and identification of the specific regional infrastructure investments with the highest economic multiplier effects. From a policy standpoint, the findings are invaluable for enabling evidence based decision making. Finally, this research contributes to the existing literature by assessing the relationship between infrastructure development and economic growth. However, challenges may arise due to potential specific sector infrastructural data limitations. Furthermore, unforeseen external factor was the restricted access to digital resources due to internet outage and conflict situation delayed my work for two months.

1.6. Organization of the Paper

The rest of the paper is organized as follows. The next chapter briefly reviews both on the theoretical and empirical literatures in line with infrastructure development and its impact on economic growth. Subsequently the third chapter explained model specification, the data type used and source along with methodology adopted. Chapter four deals with the overview of the East African countries infrastructure development and growth in general related issues. The econometric analysis discussed in chapter five. The last chapter deals with conclusions and policy implications based on findings obtained from the analysis.

Chapter Two

2. Literature Review

In this chapter, the researcher examined the theory and accompanying empirical research on the relationship between infrastructural development and economic growth.

Definition:

Infrastructural development is the strategic process of enhancing the physical and organizational systems such as energy, transport, and digital networks that underpin economic activity, while economic growth refers to the sustained increase in a nation's productive capacity, typically measured through Gross Domestic Product (GDP). According to the OECD and African Union (2025), the relationship between these two is foundational and mutually reinforcing; infrastructure acts as a primary catalyst for growth by reducing trade and transaction costs, stimulating firm productivity, and attracting foreign direct investment. For East Africa, this relationship is particularly critical, as the region currently possesses the continent’s largest infrastructure investment need, estimated at $42 billion annually (or 8.6% of regional GDP) until 2040. Recent data from the World Bank’s Africa’s Pulse (October 2025) and the IMF (2024) indicate that closing this infrastructure gap could potentially boost East Africa’s annual GDP growth by an additional 6.0 percentage points, facilitating a productive transformation across sectors like agro processing and telecommunications.

The relationship between economic growth and infrastructure development has become a central theme in modern development discourse, moving away from the idea that infrastructure is only a tool and towards the idea that it is a strategic catalyst for structural change. The theoretical literature, which offers conceptual frameworks for how physical capital influences long-term productivity, and the empirical literature, which provides evidence-based evaluations of these theories within the particular Socio Economic landscape of East Africa, must be examined through two different but overlapping lenses in order to fully comprehend the depth of this relationship.

2.1 Theoretical Literature

In this section, the researcher looks at the key concepts and theories that describe how constructing infrastructure, such as water, power, and road systems, promotes economic growth. Infrastructure is now seen by these theories as a complicated driver of efficiency, geographic integration, and long term structural transformation rather than as a straightforward input.

2.1.1. Classical and Neoclassical Growth Theory

The origins of infrastructure and growth relation have their beginnings in classical political economy. Adam Smith was commented about the facilitating role of public works such as roads, bridges and canals on trade and reduction of transaction cost had been some of the first attempts at establishing theoretical underpinnings of how infrastructure affects economic performance. Investments in public infrastructure that were not made by private individuals could lead to positive spillovers in the form of increased size of the market, reduction in transaction costs, and division of labor. Although Smith had not quantified this theory mathematically, he paved the path for future developments in theory of infrastructure and its economic effects. The neoclassical growth perspective, primarily rooted in the work of Solow (1956) and Swan (1956), treats infrastructure as a conventional component of the physical capital stock. Within this framework, investment in infrastructure increases the amount of capital available per worker which enhances output per worker and facilitates a transition toward a higher steady state level of income. However, this model operates under the law of diminishing marginal returns, suggesting that while initial investments in basic utilities provide substantial growth spurts, the incremental benefits eventually taper off. Consequently, in the neoclassical view, infrastructure is a necessary condition for reaching a specific level of development, but it is not the ultimate driver of permanent, long term growth rates, which are instead attributed to exogenous technological progress. When technology is assumed to increase independently of government's policy measures and investment decisions, it means that only the level of output is enhanced by infrastructure. The rate of output growth is not increased by infrastructure investment, which does not correspond to the experience of fast growing economies through infrastructural investments. This provided the basis for formulation of endogenous growth theories since the late 1980s.

2.1.2. Endogenous Growth Theory

This Theory pioneered by Romer (1986) and Lucas (1988) offers a more dynamic interpretation by positioning infrastructure as a source of positive externalities and increasing returns. Unlike Neoclassical theory proponents this theory argues that infrastructure can drive permanent, long term growth by changing the internal (endogenous) efficiency of the entire economy. Infrastructure is viewed as a productivity enhancer that lowers the cost of production for private firms and improves Total Factor Productivity (TFP). For example, a reliable power grid or a digital telecommunications network doesn't just benefit a single user; it creates a spillover effect that allows all businesses to operate more efficiently, innovate, and access wider markets. As David Aschauer (1989) explained not only does the new roadway benefit the vehicles that use it, but it also enables companies to implement just in time inventory systems, which lowers costs for the whole economy.

Probably the most relevant endogenous growth model for the purposes of this research is the one developed by Barro in 1990 and incorporating productive government expenditure including infrastructure spending into the endogenous growth model. Barro proved the existence of the level of productive government spending such that the marginal product of public investment equals its marginal cost, and showed that economies having lower levels of public capital were doomed to be on permanently lower growth trajectories. Thus, the Barro model was the first serious theoretical foundation for the idea that productive government expenditure, including infrastructure investment, is able not only to raise the level but also the rate of economic growth. Moreover, according to Turnovsky and Fisher (1995), the speed of convergence to the steady state growth trajectory for an economy heavily relying on infrastructure is determined by its infrastructure endowment and, therefore, differs for countries characterized by heterogeneous infrastructure levels. Such heterogeneity implies that some country-specific aspects should be taken into account when explaining differences in the results of empirical research into this subject.

Endogenous growth theory describes several different channels through which infrastructure spending can boost economic growth. These include, but are not limited to, reductions in production and transaction costs, impacts on total factor productivity,

effects on human capital accumulation, and the creation of regional market integration channels through transport infrastructure. To interpret the findings of this study properly, one needs to understand these different channels of impact. First, reductions in production and transaction costs occur when improved transport and communication networks lower the costs of moving goods from the production process to consumption. It increases the radius of economic activity geographically, which has many positive impacts in developing economies. In particular, improved roads connecting rural production areas with urban markets can greatly cut down the losses in harvested produce, help farmers achieve better prices and allow diversification towards higher valued produce. Improved port infrastructure lowers the costs of imported goods while reducing export costs and delays, which increases the competitiveness of the exporting sectors.

Second, improvements to energy and ICT infrastructure affect growth indirectly through productivity. Energy infrastructure that makes electricity reliably available allows continuous operation of machinery, switching to more capital intensive technologies, and avoiding disruption costs and the need to invest in generators to protect from disruptions. Given the persistent problem of electricity reliability identified in surveys as a productivity constraint for East African manufacturing firms, any improvement in the reliability of electricity supply has direct productivity impacts not captured in the indicator measuring the coverage rate of electricity but likely reflected in the improvements to the electricity infrastructure sub- index of the AIDI measure of infrastructure quality. ICT infrastructure helps facilitate information exchange that reduces search costs, achieves price discovery, promotes financial inclusion through mobile banking, and connects firms and households to international value chains and information flows.

Third, infrastructure improvements can boost growth through human capital accumulation. In particular, water and sanitation infrastructure reduces the prevalence of water borne illnesses and improves human wellbeing. By doing so, it increases labor productivity directly, while making people healthier, it also allows for greater educational achievement by children due to less time being spent on fetching water and allows schooling to become more regular. As opposed to direct production benefits from other forms of infrastructure, improvements through education and health are long term in nature. The fourth mechanism involves regional market integration through transport and energy infrastructure investments. Regional markets

integrate, meaning that different countries become able to focus on their comparative advantages regardless of their borders. For example, East African Community and improvements of infrastructure along the Northern Corridor have enabled reducing transportation costs for countries located within this region like Uganda, Burundi, and Rwanda when exporting products via ports of Mombasa and Daressalaam. The regional market integration mechanism explains the necessity of taking into consideration not only the effects that investments in infrastructure generate in the investing country itself but also those in the neighboring countries.

2.1.3. The Big Push Theory

The Big Push Theory (by Paul Rosenstein Rodan, 1943) explained how a nation cannot go from poverty to prosperity by taking tiny, gradual stages; Due to the fact that it requires a single, massive, well-coordinated investment in numerous areas concurrently. He viewed infrastructure as indivisible This just means you cannot build half a bridge and expect half the cars to cross. The theory argues that infrastructure (roads, power, water) must be built on a massive scale all at once so that every part of the economy can start working at the same time and the intended economic growth comes true. This Theory suggests that developing countries like East African nations cannot rely on small, gradual changes. Instead, they must implement a coordinated, large-scale leap across multiple sectors simultaneously. The Big Push only works if the government can manage hundreds of complex projects without massive leakage to corruption. The theory gives as example developmental state models of 1960s (South Korea) and the 1980s (China) experience. However, there should be a question for developing countries like East African Community how to push the economy unless the massive infrastructural investment goes alongside with better soft institutions and coordinated policy environment.

2.1.4. The New Institutional Economics Theory

According to the proponents of this theory without institutional infrastructure like laws and courts, physical infrastructure such as roads and bridges is worthless. The physical infrastructure is necessary but not sufficient for growth. There should be

clear property rights, formal rules and informal constraints for infrastructure to spark the aimed growth.

2.1.5. Unbalanced Growth Theory

In direct opposition to the Big Push Theory this theory argues that developing nations lack the resources to do everything at once; Thus developing countries should deliberately create imbalances by investing in a specific leading sector or a critical piece of infrastructure like a massive power grid, this leads to backward and forward linkages to pull forward the economy.

2.1.6. New Economic Geography Theory

This theory was pioneered by Krugman, shifts the focus toward the spatial and location impacts of infrastructure. It explains why growth is concentrated in specific areas or regions and how infrastructure development acts as a bridge and the primary mechanism for lowering the economic gap and spreads the wealth.

2.2. Empirical Literature

This review focuses on the empirical studies conducted on the relationship between infrastructural development and economic growth. Globally, many empirical studies were conducted to capture the relationship between infrastructural development and economic growth. The most extensive empirical analysis done on the relationship between infrastructure and growth was conducted by Calderon and Serven (2004, 2008). The authors used panel data analysis on over 100 countries and several decades. They used a wide range of infrastructure variables in transport, communication and energy sectors and solved problems associated with endogeneity issues by applying system GMM. It was found that there is a very consistent positive relationship between infrastructure stock and growth as well as a significant negative relationship between infrastructure quality and income inequality, hence implying that infrastructure could be instrumental to achieving both economic growth and reducing inequality at the same time. The main finding of the research by Derya Yılmaz (2017) and Isin Cetin (2017) is that infrastructure development measured by an index

including electricity generating capacity, telephone lines, and road networks has a positive and statistically significant impact on economic growth in developing countries. Utilizing a GMM (Generalized Method of Moments) estimator for dynamic panel data analysis across 29 developing countries from 1990 to 2014, the authors conclude that while infrastructure remains a vital engine for growth, its specific impact is smaller than what was predicted by earlier studies, less methodologically rigorous studies. The study by Ekeocha, Ogbuabor, and Orji (2022) finds that both aggregate and disaggregated infrastructure indices specifically ICT, electricity, and water or sanitation exert a significant positive impact on GDP per capita growth across Africa. While most infrastructure types bolster economic performance, the researchers noted that the effect of transportation infrastructure remains statistically insignificant in this specific context. Consequently, the authors urge African policymakers to prioritize capital accumulation and infrastructure development through effective public administration to drive sustainable economic growth.

The state of infrastructure in the Sub Saharan Africa (SSA) region reveals significantly poor performance across all evaluated dimensions, as highlighted by Calderon (2018). Despite representing nearly one seventh of the global population, the region has achieved a mere score of 2.91 on the infrastructure index, which ranges from 0 to 7 according to the World Economic Forum (WEF). Several common characteristics define the SSA region. A substantial portion of its countries approximately 40% of the total population are landlocked, which presents unique challenges for connectivity and access to global markets. Additionally, many of these countries are situated in remote areas that are far from major international trade hubs, further exacerbating the limited role that infrastructure plays in their economic development (Calderon, 2018). East Africa nations which are part of SSA is also shares similar character.

The panel assessment of the link between infrastructure and economic development might not reflect global truths. This gap emerges from the comparison of wealthier countries, which have a comparatively advanced infrastructure, to developing nations that frequently exhibit limited infrastructure growth. By assessing infrastructure as a singular metric, the analysis overlooks its complex and varied nature across different contexts and over time. Furthermore, factors such as regional disparities, differing economic structures, and the impact of governance and policy frameworks contribute

to this complexity (Calderon Serven, 2004; World Bank, 2016). Therefore, a more nuanced approach is essential to understand how infrastructure influences economic growth in diverse settings. (Ojah and Kodongo, 2016). The trajectory of public spending on infrastructure in East Africa can be analyzed in the broader context of Sub Saharan Africa, revealing both similarities and differences in trends and challenges. Like Many Sub Saharan African countries, East Africa experienced a peak in public infrastructure spending during the late 1970s. However, the decline in investment during the 1980s was more pronounced across the region due to economic crises and structural adjustment programs mandated by international financial institutions (World Bank, 2021). By the early 2000s, Sub Saharan Africa's average public investment in infrastructure had also decreased significantly, often falling below 3% of GDP.

In recent years, there has been a notable recovery in public infrastructure investment across Sub Saharan Africa, with expenditures rising to approximately 4.5% of GDP by 2020 (African Development Bank, 2022). This recovery is driven by increased government revenues, foreign direct investment, and initiatives such as the Program for Infrastructure Development in Africa (PIDA), which aims to enhance regional connectivity. When comparing East Africa with the broader Sub-Saharan region, East Africa's public investment levels remain lower than the regional average. For instance, while East Africa reached about 4.2% of GDP by 2014, other Sub Saharan countries have reported figures closer to or exceeding 5% in recent years (IMF, 2022). This discrepancy underscores the need for East African nations to enhance their infrastructure spending to keep pace with regional peers.

Infrastructure financing has gained a lot of interest in literature because of the increase in Chinese development finance to developing nations. For example, Dreher (2021) studied the impact of Chinese development finance on growth and reported generally positive results. The impacts varied widely depending on the nature of projects financed, quality of governance, and implementation among other factors. Literature on this topic is important because there is plenty of evidence that Chinese development finance has been a key factor in infrastructure development in East Africa especially during the period under study. One notable trend within the African empirical literature is the use of studies focusing on infrastructure sectors specifically

rather than composite indices. This is especially the case regarding transportation infrastructure, which has received more attention than any other type of infrastructure. Buys, Deichmann, and Wheeler (2010) conducted simulation exercises on the impact of improvements on Sub Saharan Africa's road networks and found that if fully integrated into an efficient network, the roads can lead to a six or seven-fold increase in intra African trade volumes, with consequent growth implications. Foster and Briceno Garmendia (2010), in their study published in the Africa Infrastructure Country Diagnostic commissioned by the World Bank and the African Development Bank, comprehensively identified Africa's infrastructure deficits across all key sectors and estimated that closing the gap in transportation infrastructure would contribute about one percentage point annually to Africa's GDP growth rate.

As mentioned previously, the empirical research in the area of electricity infrastructure in Africa has largely concentrated on the cost of power outages rather than its role in economic growth. As is typical in the power sector, the challenge faced by most countries in the continent is not only a deficit in access but also low reliability of power supply. Escribano, Guasch, and Pena (2010) analyzed enterprise survey data in 26 African countries and estimated that electricity outages reduce business productivity by up to 16 percent, with the most affected sectors being manufacturing and services. Cole, Elliott, Occhiali, and Strobl (2018) evaluated the effect of increasing access to electricity on economic development in African economies and showed that expansion of the national grid network leads to increased economic activity, particularly in areas with lower levels of preexisting access.

Information Communication Technology (ICT) infrastructure, which constitutes an increasingly popular focus of studies in African economics, is primarily defined by the rapid expansion of mobile telecommunications and mobile banking. In their study of the impact of mobile phones on African economies, Aker and Mbiti (2010) demonstrated the impact of mobile communication on the process of market integration and price convergence. The authors used the case of commodity trade in agriculture as a mechanism of ICT related economic growth. Similarly, Mothobi and Grzybowski (2017) explored the impact of adoption of mobile internet and showed its contribution to economic development in African countries via two main pathways: labor market matching and financial inclusion. The existing empirical literature in the context of East African region regarding infrastructure and growth is mainly based on

studies carried out in single countries. While such literature is methodologically sound when viewed from an individual perspective, they cannot reveal what a panel approach can offer. In Kenya, there are several studies including Mose (2014), and Muthui (2013), which have analyzed the relationship between public infrastructural expenditure and economic growth using time series analysis and vector auto regression techniques. The findings from these studies show that transport and energy infrastructure investments have positive impacts on GDP growth. Of the two, transport infrastructure seems to have more pronounced effects. Standard Gauge Railway is one of the major infrastructural projects, whose trade facilitation and regional connectivity effects have been widely studied, but due to the lack of sufficient data because of the limited period since commissioning, there is insufficient empirical evidence to draw conclusions about the impacts on economic growth.

Regarding Rwanda, the body of literature on infrastructure and growth largely concerns itself with the use of ICT infrastructure in post-genocide Rwanda. For example, Ndikumana and Nannyonjo (2007) investigated the relationships between institutional quality, infrastructural investment, and economic growth in with regards to Rwanda, much of the literature about infrastructure and economic growth is concerned with the impact of ICT on the development process in the aftermath of the genocide. In their study about institutions, infrastructure investment, and growth in Africa, which used Rwanda as a case study, Ndikumana and Nannyonjo (2007) discovered that post-2000 institutional reforms in Rwanda greatly increased the growth benefits from infrastructure investment an example of how institutional complementary of infrastructure work, which this research aims to partly account for via its control variable choice.

The discourse surrounding the nexus between infrastructural development and economic expansion is characterized by a significant transition from broad optimism to more nuanced, context specific evaluations. Early empirical contributions, most notably the seminal work of Aschauer (1989), established a high impact narrative suggesting that public capital acts as a primary catalyst for productivity, often yielding returns that far exceed those of private investment. Proponents of this view argue that robust infrastructure such as energy grids and transport networks serves as a multiplier that lowers operational costs for firms and enhances the efficiency of national labor markets. In many developing regions, this relationship remains particularly potent, as the marginal productivity of new infrastructure is highest where

existing facilities are mostly scarce. Conversely, a more critical strand of literature emphasizes that the growth enhancing effects of infrastructure are neither universal nor guaranteed. Skeptics point out that once statistical trends are adjusted for reverse causality the idea that wealthy nations simply have more capital to spend on projects the direct impact on GDP can appear far more modest. Modern scholarship increasingly suggests that hard assets, like roads and bridges, require soft components, such as institutional transparency and regulatory efficiency, to be effective. Without these governance frameworks, large scale projects risk becoming white elephants that drain public resources without providing a tangible economic boost. Consequently, the contemporary consensus views infrastructure not as a standalone solution, but as a component of a broader ecosystem where quality, maintenance, and institutional integrity dictate the final economic outcome.

As can be observed from the above review of theoretical and empirical literature, the following three gaps in knowledge can be identified, which this study intends to fill. Firstly, geographical specificity of research focus is important. Whereas much global and continental literature exists regarding the topic of infrastructure and growth, no study so far conducted applies a panel based approach specific to the East African case by using an entire panel of East African representative countries and measuring their experience throughout the 2003–2024-time frame, when arguably the most crucial infrastructure finance transition takes place in the region's modern history. Secondly, there is a measurement gap. Whereas the current empirical East African and African literature on the infrastructure development and economic growth relationship mainly uses single sector infrastructure variables like road density, access to electricity, or number of telephone lines per capital as infrastructure proxies, the use of a composite AIDI variable makes this study different. Thirdly, the current methodological framework of most empirical research on the topic of infrastructure in East Africa mainly uses time series analyses for individual countries or panel fixed effect estimations for partial panels of countries with little attention to the endogeneity of infrastructure investment. In applying the System GMM estimation technique to a specific East African panel, this study provides a methodological advancement compared to the existing empirical literature on the topic.

Chapter Three

3. Methodology of the Study

3.1. Data Collection Method

The type of data that the researcher employ is secondary type of data that have been collected from the global financial institutions, World Bank(WB) and African Development Bank (AfDB).

3.2. Method of Data Analysis

The study employs both descriptive and econometric way of data analysis. Simple statistical tool such as percentage and table used to analyze the country level and regional distribution of infrastructure in East Africa. The study used the panel data of 22 years from 2003 to 2024 which spans 14 countries.

System Generalized Method of Moments (System GMM) regression model employed to analyze the relationship between infrastructural development and economic growth in East Africa for three main reasons. First there might be endogeneity, since in East Africa growth often leads to more infrastructure and infrastructure leads to more growth. Secondly using System GMM in a dataset of a few countries over long time period is used. Finally, this method handles the omitted variable bias (AfDB, 2024). Before estimating the model, it is better to check the validity of the data stationary. To do this, the researcher used pre-estimation tests for Unit Root, Correlation test and Post estimation tests.

3.3. Definition of Variables

GDP Per Capita Growth Rate (annual): the most standard measure of economic expansion. It captures how much the total volume of goods and services produced in a country divided by its total midyear population, has increased compared to the previous year after removing the effects of inflation. It captures average individual share of the economy increases compared to the previous year. In East Africa a region with high population growth, it is a critical variable.

African infrastructural Development Index (AIDI): It a mixed index of four major infrastructural components; Water and Sanitation, ICT, Transport and Energy proxies developed by African Development Bank.

In a System GMM panel analysis, the choice of African Infrastructural Development Index is vital because the model relies on solving reverse casualty or bidirectional relationship of Infrastructure and Growth over time. In East Africa, where geographic barriers and low infrastructural development exist, the African Infrastructural Development Index (AIDI) represent the most impactful driver of growth.

Infrastructure serves as the physical and organizational backbone of any economy, acting as a critical prerequisite for sustainable growth and poverty reduction. In the East African context, where many nations are landlocked and agrarian-based, infrastructure reduces the distance to market and lowers the transaction costs that often restrict regional trade. By providing the essential platforms for production, distribution, and communication, infrastructure creates significant positive externalities; where a single project, such as a regional highway or a power grid, can stimulate multiple sectors of the economy simultaneously. In a System GMM framework, infrastructure is treated as a dynamic input that not only drives current output but also attracts future investments, creating a virtuous cycle of development.

In this study, the researcher will employ the System Generalized Method of Moments (System GMM) estimator, to analyze the dynamic relationship between infrastructural development and economic growth across East African nations. This choice has been primarily driven by the inherent endigeneity and bidirectional causality within the model, as infrastructure investments catalyze economic expansion while higher growth levels simultaneously provide the fiscal space for further public works. Given that my panel datasets spans 22 years, System GMM is superior to standard Fixed Effects as it addresses the correlation between the lagged dependent variable and the error term; which is common in panels with a relatively small number of countries.

3.3.2. Control Variables

Gross Capital Formation (% of GDP): this variable shows the overall value of physical investments made in the economy, such as building and private asset construction as well as the acquisition of machinery and equipment. It is significant since the study focuses on infrastructure (AIDI). For instance, building a new road is

crucial if many cars and factories would utilize it. The return on infrastructure is significantly higher in nations with strong GCF, according to research conducted in Sub-Saharan Africa (César Calderón (2004) and Luis Servén(2008)). By adding this variable, the model won't over attribute growth to a road when it was actually caused by the nearby factory.

Table 3.1 Annual Gross Capital Formation (% of GDP) of Countries

Country Name	**2004**	**2006**	**2008**	**2010**	**2012**	**2014**	**2016**	**2018**	**2020**	**2022**	**2024**
Kenya	19.75	18.97	22.36	18.12	19.56	18.08	23.79	21.04	24.46	23.46	23.05
Tanzania	26.13	29.56	28.55	31.5	30.51	29.49	29.39	32.39	33.41	33.86	34.63
Uganda	24.73	25.05	29.04	27.78	29.68	29.12	28.49	30.95	32.87	31.14	33.11
Rwanda	23.84	21.89	24.43	29	25.45	23.34	29.37	29.17	28.18	29.84	28.13
Burundi	14.29	14.58	13.36	14.87	14.21	15.98	16.91	17.63	17.78	17.96	18.44
Ethiopia	36.35	35.27	38.84	38.27	38.63	41.02	43.28	41.75	41.98	42.52	43.82
Djibouti	30.21	29.67	33.15	33.53	36.81	32.42	35.25	37.02	37.11	37.85	38.19
Madagascar	16.36	17.75	16.44	21.8	16.57	17.98	18.42	17.07	19.59	19.01	21.59
Comoros	10.81	10.42	9.9	10.75	13.21	13.69	12.91	12.39	12.21	12.43	14.62
Mauritius	24.22	21.94	26.16	29.27	27.34	26.94	28.28	29.7	32.3	31.43	32.69

Source: World Bank Open Database

Between 2003 and 2023, East Africa exhibited substantial disparities in gross capital formation, reflecting marked differences between countries characterized by robust investment dynamics and those constrained by weak structural capacities. The country with consistently high ratios is Ethiopia ranging between 40% and 46%, owing to its aggressive infrastructure policies and state-driven approach towards development. Djibouti demonstrated a similarly high level of capital formation between 30% and 38%, associated with the port building and foreign direct investment. Other developing nations in the region with moderate capital formation were Tanzania and Uganda, where the percentages varied between 28% and 33%. Meanwhile, Kenya experienced moderate levels between 18% and 23%, representing a relatively consistent strategy, yet a less aggressive one compared to other countries. Despite its relative level of development, Mauritius managed to keep stable investment rates between 25% and 32%, and Rwanda demonstrated somewhat fluctuating figures between 21% and 29%, which was associated with both periods of reconstruction and

rapid growth. Finally, the countries with the lowest ratios, 10-18% were Burundi and Comoros, owing to the fact that they had problems of politics and financial challenges.

Trade Openness (Exports + Imports as % of GDP): is calculated as the sum of exports and imports as a percentage of GDP, serves as a proxy for a country's level of global and regional integration. In East African Community (EAC), this variable is very important because Infrastructure like ports and cross border roads primarily serves to facilitate this trade. If a country is open to trade, its new ICT and transport systems will be used more intensively, leading to faster GDP growth. It also controls for the impact of regional integration's.

Inflation: is a continuous rise in the general price level of goods and services in an economy over a period of time. In Africa a high expenditure on infrastructure sometimes leads to a high economic cost of living or debt fueled inflation. Therefore, Inflation acts as a proxy for the quality of nation's monetary policy and overall economic stability. For example, even if there are high level of infrastructure like roads, if there exist hyperinflation investors will stay away and economic growth will start to decline. Thus the researcher believes including this variable balances the effect by accounting the negative noise in the economy.

Table 3.2 Annual Inflation rate (as CPI) of Countries

Country	2003	2005	2007	2009	2011	2013	2015	2017	2019	2021	2023	2024
Kenya	8.52	7.51	8.44	8.93	7.59	9.12	8.58	9.04	6.89	9.35	10.62	7.1
Tanzania	9.11	6.82	5.71	4.81	6.08	7.66	10.44	11.57	10.7	9.69	7.27	11.18
Uganda	9.12	7.25	10.96	8.87	10.44	11.49	8.85	9.04	7	8.61	15.83	11.29
Rwanda	6.37	7.99	5.7	7.36	10.12	9.6	9.06	6.28	8.47	7.7	6.89	7.98
Burundi	7.9	10.98	11.28	9.66	11.49	11.72	10.99	12.09	11.12	14.58	13.74	15.08
Ethiopia	10.84	10.75	16.07	10.91	12.5	13.61	13.64	14.43	14.74	15.79	15.35	16.2
Djibouti	7.48	2.67	4.52	2.41	2.77	5.63	5.22	5.68	4.78	5.84	0.85	3.24
Madagascar	10.55	10.8	9.02	10.29	9.06	9.4	12.17	12.19	10.46	9.95	9.68	8.77
Comoros	3.76	3.87	3.92	4.1	2.54	5.15	5.37	3.81	4.42	4.83	5.52	4.04
Mauritius	4.97	6.73	5.8	4.65	6.47	4.32	5.68	6.65	5.59	4.17	6.97	6.57
Mozambique	3.92	4.94	8.83	2.52	6.52	3.54	1.29	3.67	0.41	4.03	7.05	3.6

Source: World Bank Open Database

Inflation levels among East African countries have been highly volatile between the years 2003 and 2024, primarily influenced by global prices of commodities, dependency on agriculture and stability. Ethiopia and Burundi have been the most

affected countries in terms of high inflation rates, which are caused by structural deficiencies, currency devaluation, and political instability. Conversely, countries like Mauritius and Comoros have exhibited a relatively low rate of inflation due to their better institutions, diversification of economy, and sound monetary policies. The trend exhibited by Kenya, Tanzania, and Uganda has been cyclical in nature, where there have been surges in inflation caused by drought, global oil crisis, and disruptions after the corona virus disease. Rwanda, on the other hand, has had moderate rates of inflation, mainly due to sound fiscal policies, even though it has not been immune to global shocks. In summary, the evolution of inflation in East African countries underscores the vulnerability of predominantly agrarian economies to climatic shocks and external disturbances, including the 2008 global financial crisis and the COVID-19 pandemic during 2020–2023. Over the period 2003–2024, inflation rates across the region exhibited considerable volatility, reflecting the combined influence of domestic structural constraints and adverse global developments.

3.4. Model Specification

In this way the model will be expressed as:

$$\boldsymbol{RGDPG_{it} = \mathcal{B}_0 + \gamma RGDPG_{i,\,t-1} + \beta_1 AIDI_{it} + \beta_2 GCF_{it} + \beta_3 TRADE_{it} + \beta_4 INF_{it} + \varepsilon_{it}}$$

Where,

$RGDPG_{it}$: is Real GDP per capita growth rate for country i in year t.

$RGDPG_{i,\,t\text{-}1}$: is the lagged $RGDPG_{i,t}$

$AIDI_{it}$: is African infrastructure development index country i in year t..

GCF_{it}: is Gross Capital Formation as percent of GDP of country i in year t.

$TRADE_{it}$: is Trade Openness (Exports + Imports as percent of GDP) for country i in year t.

INF_{it}: is Annual Inflation rate for country i in year t.

ε_{it} : error term.

3.5 Pre Estimation Tests

Before the estimation process begins, a set of preliminary diagnostic tests is carried out to evaluate the nature of the data used, to confirm the choice of the appropriate

estimator and to determine the validity of the assumptions on which the System GMM method rests.

Correlation Test

The correlation test entails the construction of the pairwise correlation matrix of all the variables. This is done to provide some preliminary information on the bivariate correlations of the variables and to detect possible problems with multicollinearity among the independent variables.This implies that high correlations between independent variables may arise not due to their association but because of the effect of some other independent variable. However, correlations greater than 0.80 in magnitude between any two of the independent variables are taken as evidence of possible multicollinearity which is to be investigated further through the Variance Inflation Factor test. The correlations between the dependent variable and the independent variables are seen as preliminary evidence of the unconditional relationship of these variables.

Multicollinearity Test

The Variance Inflation Factor test is applied to assess the severity of multicollinearity among the independent variables in the model. Multicollinearity arises when two or more independent variables are highly correlated with each other, inflating the standard errors of the associated regression coefficients and reducing their statistical precision without biasing the estimates themselves. Although System GMM addresses endogeneity through its instrument structure, multicollinearity among control variables remains a concern that can reduce the efficiency of estimation and complicate the interpretation of individual coefficients.

A VIF value of 1.0 indicates the complete absence of multicollinearity, values between 1.0 and 5.0 indicate acceptable levels of multicollinearity, values between 5.0 and 10.0 indicate moderate multicollinearity warranting caution in interpretation, and values exceeding 10.0 indicate severe multicollinearity that may seriously distort coefficient estimates and standard errors. The mean VIF across all variables is also reported as a summary measure of the overall multicollinearity environment in the model.

Panel Unit Root Test

Unit root tests for the entire panel of variables are run to determine the order of integration of each variable. Establishing the order of integration of each variable is crucial for three reasons. Firstly, it helps choose an appropriate methodology for

estimation, as certain methods require certain orders of integration or integration restrictions. Secondly, it facilitates the interpretation of estimated equations, since while short-run dynamics occur among stationary variables, long-run dynamics occur among non-stationary variables through cointegration. Thirdly, it tells whether there is a danger of spurious regression a case when two unrelated non-stationary variables are regressed onto each other, thus leading to artificially high coefficients of determination and misleading results and whether the applied method takes care of that problem.

The East African data set used in this research is considered highly heterogeneous, as different countries are at vastly different stages of institutional and economic development, which would make their time series dynamics different in terms of persistence. The researcher has used Im-Pesaran-Shin Test due to heterogeneity of panels that it considers, the fact that cross sectional units may differ with regard to their order of autoregression. The IPS test is performed using the demean option throughout, which means that each variable is tested against the presence of cross sectional dependence, which is characteristic of the East African panel data since the region faces common shocks across multiple countries at any point in time shocks like the coronavirus outbreak, commodity price cycles, and funding from China.

3.6 Post Estimation Tests

Hansen J Test for Over Identifying Restrictions

The J test of over identifying restrictions determines whether the instruments employed in the GMM estimation meet the condition of being uncorrelated with the disturbance term which means essentially, their validity. Specifically, the null hypothesis of this test is that the over identifying restrictions hold true; i.e., that the instruments are valid and thus exogenous. The test statistic takes the form of a chi-squared value with degrees of freedom calculated as the number of over identifying restrictions, in other words, the difference between the numbers of instruments and estimated parameters.

To satisfy the validity requirement, the p-value needs to exceed 0.10. The rejection of the null hypothesis in favour of any alternative invalidates the chosen set of instruments. A very high Hansen p-value approaching 1.000 is also indicative of an

issue: in such case the test will fail to deliver meaningful diagnostic insights due to instrument proliferation. In this study, the collapse estimation option will serve precisely to prevent this problem. An ideal Hansen p-value is somewhere between 0.10 and 0.70, meaning that the set of instruments passes the validity test while maintaining sufficient statistical power.

Sargan Test of Over Identifying Restrictions

The Sargan test for over identifying restrictions complements the Hansen test as an instrument validity diagnostic tool. In contrast with the latter, the former test is not robust either to heteroscedasticity and/or clustering or to instrument proliferation. However, both of these tests use the same decision rule. As the Hansen test, the test for instrument validity can be applied in this research, whereas the Sargan test would function as a secondary validation criterion. A positive finding in one will imply a positive finding in the other; similarly, the opposite findings will confirm that the Hansen test is valid due to its robustness to heteroscedasticity.

F Statistic and Joint Statistical Significance

The overall significance of the regression is measured using the F-statistic provided by the System GMM estimation using the two-step approach with the small sample option. This statistic allows testing the null hypothesis that the slope coefficients in the equation are jointly equal to zero which is equivalent to stating that the independent variables do not explain GDP per capita growth. The rejection of this hypothesis, corresponding to a p-value below 0.05, will mean that the model is generally statistically significant despite insignificant coefficients.

CHAPTER FOUR

4. OVERVIEW OF INFRASTRUCTURE DEVELOPMENT AND ECONOMIC GROWTH IN EAST AFRICA

4.1 Conceptual and Institutional Frameworks Governing Infrastructure development and Economic Growth

This chapter provides a detail contextual background for the econometric analysis of Chapter Five. The chapter provides a systematic overview of the infrastructure development paths and trends of economic growth in 14 selected East African countries for the period of 2003-2024. In this chapter, the researcher mainly used the Africa Infrastructure Development Index (AIDI) published by the African Development Bank (AfDB). The AIDI is the main infrastructure measure in this study. The data on the GDP per capita growth rate and selected macroeconomic control variables such as inflation, trade openness and gross capital formation are obtained from IMF and World Bank database.

Recently scholars have given attention to the relationship between infrastructural development and economic growth in developing countries. East Africa, one of the developing countries region structurally characterized by rapidly increasing and youthful population, landlocked geographies for some member nations, mainly agrarian economic base and continuing gaps in transportation infrastructure, energy access and digital facilities. This physical and institutional infrastructure deficit persists to constrain productive capacity, market integration and human capital accumulation. In East Africa, it needs to be essential defining Infrastructure broadly as a foundational physical and organizational systems that enable economic activity, facilitate the movement of goods and people, support access to energy and water, and enable communication across spatial and institutional boundaries. This broader conceptualization of physical capital is significant as different types of infrastructure develop economies through different channels, some of which are complementary to each other. For example, transport infrastructure to a large extent reduces transaction costs and increases market access. Energy infrastructure increases total factor productivity and thus makes possible increased output of industries that use mechanization. ICT infrastructure increases information flows between different economic entities and, in addition to supporting growth in industries that require

services, also raises financial inclusion. Water and sanitation infrastructure on the other hand increases human capital through better health and education. These distinction matters for East African nations, since each nation have different infrastructure development.

According to African Development Bank reports (2023) the island of Mauritius did very high results for information and communication technology and power availability infrastructure. It has been observed that Mauritius possesses nearly total power supply reach and digital connection rates that are some of the highest within Sub Saharan Africa. Because the island has a small island topography, Mauritius remains restricted in the growth of roads (World Bank, 2022). While observing a different path, Ethiopia managed one of the most ambitious transport infrastructure plans across the land. Huge amounts of money were placed into roads and rail, which includes the Addis Ababa to Djibouti Standard Railway that was completed in 2016. Even though the Grand Ethiopian Renaissance Dam has a great scale, Ethiopia continues to show low power availability in countryside locations where many people live without electricity (Shiferaw, 2015). For the nation of Rwanda, digital infrastructure was sought through a strong state led strategy which was put into the Vision 2020 and later Vision 2050 frameworks. Experts claim that Rwanda achieved fast growth in information and communication technology reach and phone based money systems because a fiber optic backbone was built. These gains have made Rwanda a benchmark for technology led development across the continent (Republic of Rwanda, 2020; Ndikumana and Nannyonjo, 2007).

In East Africa the development of infrastructure has been guided by different government growth strategies, bilateral relations, regional economic integration frameworks and multilateral financing programs and arrangements. At national level the region nations set a long term development roadmap, including Kenya's Vision 2030, Ethiopia's Growth and Transformation Plans (GTP I and GTP II), Rwanda's Vision 2020 and Vision 2050, Tanzania's Development Vision 2025, and Uganda's National Development Plans by positioning infrastructure as a core pillar of structural transformation. The East African Community(EAC) has served as the major integration frameworks for most of the study nations at regional level has been coordinating infrastructure investment through the East African Community(EAC) Regional Development Strategy and the Central and Northern Corridor initiatives. The Intergovernmental Authority on Development (IGAD) also played a significant

role in Addis Ababa to Djibouti transport corridor and the Lamu Port South Sudan to Ethiopia projects and other energy infrastructure connectivity across the region. The African Union's Program for Infrastructure Development in Africa (PIDA) supports continent wide large scale and cross country infrastructure projects in ICT, Energy, Transport and water to boost trade, integration and sustainable development.

Multilateral institutions like world bank, African development bank, China Development Bank, and the Export Import Bank of China has played a significant role in shifting and converting institutional frameworks into physical investment by financing a significant portion of core infrastructural investments across the region during the study period. For instance, under the Forum on China Africa cooperation china has financed large scale cross boarder projects.

4.2 Macroeconomic Setting and Regional Economic Growth Dynamics

East Africa has experienced the most dynamic and turbulent stages of economic conditions during 2003 - 2024. During the early years of the study period, specifically from 2003 - 2007 the region was characterized by wide and fast economic growth including Ethiopia, Rwanda, and Tanzania recorded GDP growth rates consistently above six percent during this years, earning comparisons with East Asian Tigers development frameworks; rising commodity prices, high flow of foreign direct investment, well growing macroeconomic management and debt relief under the initiative of Heavily Indebted Poor Countries(HIPC). The global financial crisis (2008-2009) affected economic growth across the region even though East Africa was weakly tackled compared to the more financially integrated western economies. In 2011 Ethiopia, Djibouti, Kenya and Uganda's Gross Domestic Product per capita growth structurally disrupted by drought and food security crisis. Onwards then up to 2019 several economies like Ethiopia, Rwanda and Tanzania experienced a strong growth, while some nations such as Burundi registered acute political instability following severe crisis on investment and production. The Global COVID - 19 pandemic badly contracted all economic activity in all countries. After the Pandemic some countries had returned to previous growth rates, while others continued to challenge the impacts from inflation, currency depreciation, and tightening worldwide financing conditions.

During the study period the macro economy of Mauritius and Rwanda mainly maintained low and stable inflation consistent with their monetary policy frameworks,

while nations like Ethiopia, Burundi, and Madagascar have freighted with raised inflation driven by food price volatility, exchange rate depreciation, and supply side constraints. In this study Inflation has been used to control the possible macroeconomic instability.

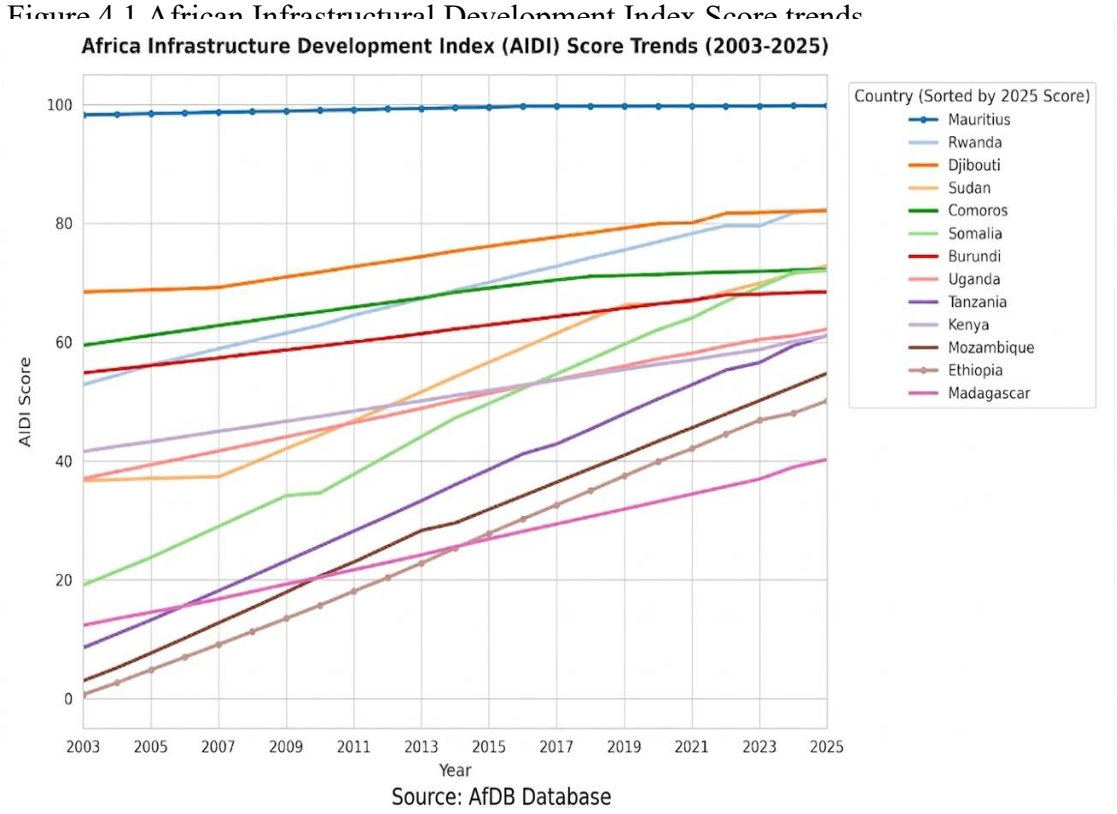
Djibouti scores consistently highest in trade to GDP ratio across the panel, since the economy mainly dependent on transit services and port logistics. Mauritius also did the same since the country well known by its textile exports, financial sectors and tourism industry. Due to geographic and institutional framework barriers Burundi and Comoros continuously registers low in this variable. Starting from 2011 onwards Ethiopia and Kenya registered persistently rising Gross Capital Formation(GCF) as share of GDP because of their high public infrastructure expenditure from domestic and Chinese support finance sources.

4.3 Overview of Individual Countries Infrastructure Development and Economic Growth

The AIDI scores for the years between 2003 and 2025 for all of the countries considered show persistent growth trends, yet with significant disparities in terms of the pace and intensity of infrastructure developments. Notably, Mauritius is the most outstanding case here, with the country showing almost perfect scores through all periods under study. This is due to an already quite well developed infrastructure in place that needed only consolidation but no further development. At the opposite extreme, there are countries like Ethiopia, Mozambique, and Madagascar that started with very low scores, with even some of them achieving scores in single digits but experiencing rapid development in their infrastructure and scoring 82-83 by the end of 2025. In its turn, Rwanda and Djibouti show the highest scores of the group, being able to score 82 and 83 in the last year and thus competing with South Africa that can traditionally boast of a fairly high level of infrastructure developments. Countries like Uganda, Burundi, Sudan, and Comoros also showed good dynamics but not as fast as those described above due to various internal and structural constraints. With regard to other African countries, the AIDI index shows that the leading continental players include Seychelles (99.77%), Egypt (91.43%), and Libya (84.84%). Meanwhile, Nigeria, despite having the fourth largest GDP in Africa, scored only 25.70, thus failing to become a leader. Finally, the most impressive results were shown by

Morocco, which gained 51 points over the course of the decade. Thus, the panel should strive to match the Moroccan achievements. Overall, the dynamics show a typical pattern for East and Horn of Africa that managed to catch up with other African regions, although the last challenge is to make faster the development process for other economies.

Figure 4.1 African Infrastructural Development Index Score trends



Source: AfDB Database

Ethiopia

Ethiopia has been one of the fastest growing nations in Africa during the study period. Ethiopia's average GDP per capita growth has been above 5% across the panel. This result has been a combination of public infrastructure with agricultural commercialization, manufacturing sector expansion with private sector partnership. The nation has been consistently investing and constructing industrial parks, roads and railway lines, major Dams including the Grand Ethiopian Renaissance Dam (GERD), Addis Ababa urban housing and corridor projects and Telecommunication sector. However, the country has been challenged by the continued Tigray and Amhara region conflict starting from 2020. It causes severe humanitarian and economic crises which fundamentally disrupted growth, infrastructure and institutional functionality.

Djibouti

Due to its geographical location in the Red Sea and the Gulf of Aden, making Djibouti a strategically prominent for international military bases and has its economy mainly dependent in Port services and Transit logistics. This generates higher rental income and contributes great to its economy. Djibouti infrastructural development and spending has been unique and distinct mainly concentrated on ports, logistics and free zone area, it lacks the multidimensional capacity in electricity, road and other infrastructure contents. Also its economy has been challenged by heavy external debt, low job creation and high cost of electric and telecom utilities.

Kenya

The highly growing sectors in Trade, Finance, ICT and diversified economy makes Kenya a structurally important position within East Africa Community. The nation registers consistently growing African Infrastructural Development Index. Ranging from Mpesa mobile financial system to the Standard Gauge Railway (SGR) and the Last Mile Connectivity Program contributes to their GDP growth. However, their economy has been struggled with climatic shocks like drought and high inflation on consumer goods and services.

Tanzania

Tanzania, one of the largest nations in the region has uneven distribution of infrastructure. Its road and energy infrastructure has undergone considerable transformation. The Julius Nyerere Hydropower Project was one of the greatest energy infrastructure initiatives during the panel. Tanzania's GDP per capita growth has been one of the stable growing in the region. Despite the stable growth Tanzania has been challenged by heavy eternal debt and lack of economic diversification.

Uganda

The landlocked nature of Uganda and Ethiopia anchored a high trade costs. Uganda has invested very large on roads and port transits due to its oil resources. Also its Energy investments including the Bujagali Hydropower Dam makes the AIDI score growing. During the early part of the modern era, Uganda experienced a period of robust economic expansion driven by strong agricultural output, market liberalization, and foreign investment, which laid a solid foundation for infrastructure development and poverty reduction. This rapid momentum eventually contracted by due to structural bottlenecks, institutional challenges, regional trade disruptions and a sharp

decline in tourism because of the COVID 19 pandemic. In the following years the economy has shown notable growing.

Burundi

Among the countries analyzed in this panel, Burundi stands as one of the most difficult example of infrastructure and growth. Throughout the years of this evaluation, the AIDI numbers of Burundi remained at the very bottom of the list, because very little advancement was achieved in making electricity, building dense roads, and spreading communication technology. Experts claim that the growth of average income for each person showed negative numbers during many years, especially after 2015, which shows the combined damage of government instability, the stop of donor money, dry weather, and a rapidly increasing number of people.

Madagascar

Madagascar infrastructure development over the study period has been heavily constrained by a series of political crises, that led to international sanctions, which led to the withdrawal of Madagascar from the African Union, and the suspension of preferential trade access under the African Growth and Opportunity Act (AGOA). During the specific research years, experts claim that only a small progress was registered by Madagascar regarding the AIDI scores. The growth of GDP per capita has remained highly unstable because several years of economic shrinkage and near-total stoppage were mixed with short periods where Madagascar recovered slightly. Even though agriculture, which includes vanilla, cloves, and mining exports, continues to be the main engine of economic expansion, physical structural foundations only offer a second-level supporting capacity. This physical structural foundation does not bring radical change because Madagascar is still living in its current stage of development.

Rwanda

Rwanda's institutional quality, zero tolerance for corruption, strong state capacity, and deliberate investment in human capital and infrastructure supported to register high and consistent GDP per capita growth across the panel. The nations investment in energy and ICT infrastructure, such as Kigali Innovation City project, national fiber optic backbone expansion, and government programs promoting digital financial services and Solar Energy has been one of the remarkable achievements in the region.

Mauritius

The nation has one of the most developed infrastructure and well grown economy. During the study period, Infrastructure development in Mauritius has been based more on upgrading rather than extending coverage. Examples include the Mauritian Metrorail Light Transit system which opened in 2019, the extension of Sir Seewoosagur Ramgoolam International Airport and the development of smart city projects incorporating advanced ICT infrastructure. GDP per Capital Growth has been moderate between 3 to 4 percent rate of growth across the panel. The global COVID 19 pandemic contracts this growth rate.

Comoros

Comoros ranks as the smallest economy in terms of both size and population in the panel. In fact, Comoros structural features of being extremely small, geographically dispersed on three islands, having few natural resources, and possessing poor administrative and financial capacities pose significant limitations on infrastructural development and economic diversification. The remittance flows to the country from its diaspora account for a large proportion of household incomes and GDP, making the growth model based on remittance flows insensitive to infrastructural developments within the country.

Comoros AIDI indicators consistently rank among the lowest in the panel with small coverage of electricity, transport connections, lack of information and communication technologies, and inadequate provision of water and sanitation. Comoros' GDP per capita has been growing at an extremely slow rate, often under two percent per year.

Mozambique

Mozambique's geographic significance for land locked surrounding nations makes it an important for boasting port facilities. Although it belongs to the Southern African Development Community (SADC), its proximity to Tanzania and membership in the Common Market for Eastern and Southern Africa (COMESA) position it within the greater East and Southern Africa region, thereby explaining its inclusion in the panel. Its infrastructure development path during the selected time span has been marked by disruptions in its plans to invest due to recovering from the 2000 - 2001 floods, and the ensuing decade of growth from 2004 to 2014 thanks to the Cahora Bassa hydroelectric facility, the Nacala Corridor railroad, and investments by China and Brazil. The discovery of massive gas resources in the Rovuma basin since 2010 spurred rapid investment in its underdeveloped northern regions in transportation and

energy infrastructure up until 2019(AfDB, 2023). But there were challenges that undermined those developments, such as undisclosed sovereign debt and the Islamist insurgency movements caused devastation of infrastructure. While per capita GDP grew extremely rapidly at an average annual rate above seven percent between 2003 and 2014 due to post conflict recovery, mega project revenues, and commodity price increases, it became negative in several years from 2016 through 2020, the latter being caused by the COVID 19 crisis (World Bank, 2022).

Somalia

Somalia has low positive growth of GDP per capita during relatively stable years, such as 2012-2017, when the Federal Government was strengthening its position and international investments started again, until the triple effect of COVID 19 pandemic, Islamic terrorists attack, and droughts caused rapid decline of the economy from 2020 to 2022(IMF, 2023; World Bank, 2022). Somalia's Infrastructure development falls among those with the lowest AIDI index values on the whole African continent owing to a number of factors including decades of conflicts, which led to the complete destruction of infrastructure in Somalia, the total lack of investment in maintenance and rebuilding of the public infrastructure. In particular, the road infrastructure and access to electricity in Somalia is extremely scarce because even in Mogadishu, access to electricity was severely affected (Foster & Briceño-Garmendia, 2010; World Bank, 2022).

An important thing about the AIDI score in Somalia, which makes it unique and interesting to discuss, is the role played by the private sector and remittances sent by Somalia nationals living abroad substitute for the missing public infrastructure. Contrary to what could be expected, telecommunications in the Somali stateless period became one of the most innovative on the whole African continent as private telecom operators began offering mobile telecommunication and internet service as well as transferring money via mobile money transfer systems such as that offered by Hormuud Telecom EVC Plus (African Development Bank, 2023).

The pattern that stands out consistently within the selected countries in the panel is the mediating influence of political stability and institutional development. Countries that have a consistent political environment, such as Mauritius, Rwanda, and Tanzania, had more steady path towards infrastructural development. Countries that experienced a major interruption Burundi after 2015, Madagascar between 2009 and 2013, and

Ethiopia since the Tigray conflict of 2020 display a discernible gap or negative trajectory in their infrastructural development either through destruction or financial interruption of the investments. This is particularly relevant when considering the empirical model because there does not seem to be a symmetric relationship between the two variables across different political circumstances. In this sense, the System GMM estimation used in Chapter Five is designed to deal with endogeneity problems caused by feedbacks among the three aspects, but these insights can serve to inform the interpretation of the estimates.

The other pattern is the sectoral composition of infrastructure investment and development. Transport Infrastructure is vital and famously invested on it in both Ethiopia and Kenya, while logistics and port facilities are vital in Djibouti. However, development is balanced among the four sub-indexes of AIDI in Rwanda and Mauritius. On the other hand, poor development exists in Burundi and Comoros, except for the ICT sector development which utilizes mobile phones. These sectoral trends are important for understanding the overall AIDI growth since various types of infrastructure sub-indexes show distinct growth multipliers. This is due to the fact that transportation and energy create immediate economic benefits, whereas the effects created by water and sanitation depend on human resources.

One of the most important structural changes during the study period is the financing change for infrastructure in the panel countries. During the early stage of the study period, from 2003 to 2008, funding for infrastructure in the panel countries was dominated by official development assistance provided mainly by the World Bank, African Development Bank, bilateral donors from the European Union, and the US. This aid based finance model for infrastructure investment was associated with high conditionality, long loan processes, and capacity challenges in the implementation by the receiving governments.

However, after 2008, Chinese development finance from the China Development Bank, the Export Import Bank of China, and Chinese state owned construction firms changed the financing model for infrastructure in the panel countries. Chinese development finance for infrastructure was faster to provide and more willing to finance infrastructure investments considered unprofitable compared to conventional commercial financing. Although this model increased infrastructure investment most noticeably seen in projects such as the SGR railway in Kenya, Ethiopia's railway and

road projects, and Djibouti port projects it also left large debt stocks for the countries to be faced with macroeconomic challenges.

The Africa Infrastructure Development Index (AIDI) is an aggregate indicator that aims to encompass the multidimensional of infrastructure endowment across African nations. AIDI consists of four sub-indices, namely transport infrastructure, electricity infrastructure, ICT infrastructure, and water and sanitation infrastructure. The former is defined as the density of paved roads and kilometer of rail networks in relation to land area, while the latter two are calculated based on their respective capacities of production per capital. Specifically, the former includes percentage of population with access to improved water sources and sanitation facilities, whereas the latter uses three different metrics mobile telephone, Internet users, and broadband subscriptions measured against 100 inhabitants.

Each of the above four sub-indices undergoes normalization and aggregation into one single indicator, which is measured on a scale of 0 to 100, such that the higher score corresponds to better infrastructure development. This methodology has seen continuous improvements across each subsequent publication cycle. Importantly, African Development Bank (AfDB) reports its figures annually, thereby enabling the construction of a balanced panel of AIDI data across all selected panel countries. Notably, the decision to use composite score of AIDI, rather than single indicator, is motivated by the fact that the goal of the study is reflecting the essence of infrastructure and avoiding the researcher having to make subjective decisions on which form of infrastructure should be emphasized. The annual measurement makes it possible to create a panel database with enough time series information for use with the System GMM estimator.

CHAPTER FIVE
4. RESULTS AND DISCUSSIONS

This chapter provides a presentation and discussion of the results generated empirically from an analysis of the relationship between infrastructure development and economic growth for selected fourteen East African countries for the period 2003 to 2024. The results presented and discussed in this chapter are organized following the analytical framework introduced in Chapter Three. Specifically, preliminary diagnostics are presented starting with descriptive statistics, analysis of multicollinearity, and tests for panel unit roots. Following this presentation, estimation and discussion of the main System GMM results provided with its economic interpretation. The two step System GMM estimation method with Windmeijer (2005) correction to standard errors was employed in estimating a dynamic panel model in which the Africa Infrastructure Development Index measured in natural logarithms is included as an independent variable lagged for one period in order to reflect the time lagged effect of infrastructure investment in generating economic growth. Other explanatory variables in the regression are the inflation rate, trade openness, and gross capital formation as standard macroeconomic determinants of growth in the endogenous growth literature. All estimation is conducted using Stata 17, with the xtabond2 command developed by Roodman (2009).

5.1 Pre Estimation Tests

Descriptive Statistics

Descriptive statistics for all variables included in the model are provided in Table 5.1 below based on the entire 308 country-year observations of the East African panel. It should be noted that the descriptive statistics indicate high cross country and inter temporal variability of all variables, which confirms the analytical potential of the East African panel and the need for multivariate estimation techniques capable of distinguishing the individual impact of each determinant of GDP per capita growth.

Table 5.1 Descriptive Statistics

Variable	Observations	Mean	Std. Deviation	Minimum	Maximum
GDPPCG (%)	308	1.809	4.436	-30.363	10.222
AIDI (0–100)	308	51.934	22.768	0.691	99.797
INF (%)	308	11.145	26.686	-15.347	359.093
TRADE (% GDP)	308	64.990	52.874	1.995	347.720
GCF (% GDP)	308	22.045	10.288	-15.678	56.908

Source:from stata output(N = 308, 14 Countries, 2003–2024)

On average, the GDP per capita growth rate equals 1.8 percent among the country-year observations in the panel, which is relatively low compared with the heterogeneity of economic growth of fourteen East African countries included in the dataset. Specifically, there is huge variability in economic growth rates, ranging from -30.363 percent at the lowest end, indicating the economic catastrophe suffered by fragile states, especially South Sudan, during the civil war between 2014 and 2017, to 10.222 percent at the highest end due to successful economic growth in Ethiopia during its peak growth years between 2005 and 2018. AIDI scores vary between the minimum value of 0.691, reflecting the nearly complete lack of infrastructure in fragile panel countries in the first year or two of our study period, and the maximum score of 99.797, reflecting Mauritius near perfect composite infrastructure score. A mean AIDI score of 51.934 with a standard deviation of 22.768 highlights the great disparities in infrastructure development in the panel shown in Chapter Three, which demonstrate a difference between economies with the highest and lowest scores approaching the full scale of the index. The high degree of cross sectional heterogeneity in terms of infrastructure endowment within our sample is the source of the cross section variation necessary for identification of the System GMM estimator.

Inflation has the greatest dispersion across the panel at a mean of 11.145 percent, standard deviation of 26.686 percentage points, and a maximum of 359.093 percent, resulting from the hyperinflation experienced in Sudan throughout the period of this study. Inclusion of the variable is important analytically for its ability to account for extremely high rates of inflation in Sudan, Ethiopia, and Madagascar that would have

an extremely negative impact on the growth rate were not controlled for and therefore lead to a biased infrastructure coefficient. The values of Trade openness range from 1.995 to 347.720 percent of GDP. This is because openness is very high in Djibouti due to the country being an important transport hub where trade amounts are much higher than the GDP. The gross capital formation is at 22.045 percent of GDP, which conforms to global standards.

Correlation Analysis

The Table 5.2 below depicts the pairwise correlation matrix of the variables used in the model. It becomes evident that several interesting trends have emerged concerning the correlations of the study variables at the bivariate level.

Table 5.2 Pairwise Correlation Matrix

Variable	GDPPCG	AIDI	INF	TRADE	GCF
GDPPCG	1.000				
AIDI	-0.155	1.000			
INF	-0.272	0.029	1.000		
TRADE	0.097	0.391	-0.202	1.000	
GCF	0.307	-0.110	-0.197	-0.109	1.000

Source: from Stata 17 output (N = 308)

Out of the correlations of the dependent variable with the independent variables, it becomes clear that the gross capital formation is significantly positively correlated with the growth in per capita GDP (r = 0.307). Such correlation is explained by the fact that investments stimulate economic growth in accordance with neoclassical and endogenous growth theory predictions. In addition, inflation is significantly negatively correlated with per capita GDP growth (r = -0.272), which implies that macroeconomic stability is crucial for successful economic growth across the studied East African panel. The index of infrastructure development (AIDI) has a significant negative bi variate correlation with the GDP growth rate (r = -0.155). Such an observation requires clarification; however, the reason for the negative correlation can be attributed to the fact that matured economies having high GDP and thus a high index of infrastructure development are characterized by relatively low growth rates because they have invested less on infrastructure development. Of all the independent variables, the correlation among them is highest between AIDI and TRADE (r = 0.391). This is because the two are very much correlated by nature, given that

infrastructure development, especially transport and port development, leads to trade openness. Countries that have more advanced transport and port infrastructure find themselves engaging more in international trade.

Multicollinearity Test (Variance Inflation Factor)

The Variance Inflation Factor test was conducted on all independent variables in order to measure the presence of any troublesome multicollinearity in the system. The findings, reported below, reveal the absence of multicollinearity problem with respect to all included variables. The average VIF of 1.16 and individual highest value of 1.21 obtained for the TRADE variable are particularly close to the theoretical minimum value of 1.0, indicating the absence of any relationship between all independent variables. These figures are well below the traditional concern level of 5.0 and the maximum permissible level of 10.0. These findings provide a definite empirical proof that there is no multicollinearity problem that might affect the stability or the accuracy of estimating the System GMM coefficients. The theoretical worry of any potential collinearity between AIDI and GCF due to the inclusion of infrastructure investments in gross capital formation in national accounting data is solved by the findings from the VIF analysis: individual VIFs of 1.20 and 1.07, respectively, show that there are no collinearities between them.

Table 5.3 Multicollinearity Test Result

Variable	**VIF**	**1/VIF**
TRADE	1.27	0.789865
AIDI	1.20	0.833503
INF	1.11	0.900556
GCF	1.07	0.936216
Mean VIF		1.16

Source: from Stata 17 output

Panel Unit Root Test Results

Unit root tests using Panel IPS (Im-Pesaran-Shin 2003) tests were undertaken, where lags(2) were used and demean was used on all tests to address any issues of cross-sectional dependence. Tests were undertaken both in absence of trend and presence of trend to distinguish between stochastic and deterministic trends in the variables. In case of non-stationary variables in levels, tests of first difference were also conducted to identify the degree of integration. Results of unit root tests can be viewed from table 5.4 below:

Table 5.4 Im-Pesaran-Shin Panel Unit Root Test Results

Variable	Specification	W-t-bar	P value	Decision	Integration Order
GDPPCG	Level, no trend	-3.976	0.000	Reject H_0	I(0) — Stationary
lnAIDI	Level, with trend	-2.475	0.007	Reject H_0	I(0) — Trend Stationary
INF	First difference, with trend	-4.099	0.000	Reject H_0	I(1) —Trend Stationary at ΔI
TRADE	First difference, with trend	-4.226	0.000	Reject H_0	I(1) —Trend Stationary at ΔI
GCF	First difference, with trend	-5.064	0.000	Reject H_0	I(1) —Trend Stationary at ΔI

Source: from stata output

From the unit root tests, it is clear that there is a mixed integration process among the variables being studied; an important aspect from a research methodology point of view. The GDP per capita growth is found to be stationary in levels (I(0)), as theoretically expected since growth rates tend to oscillate around a mean value rather than drifting infinitely in one direction. The AIDI in natural log form was found to be trend stationary – stationary around deterministic linear trend – when the trend hypothesis was tested, with a t-statistic of -2.475 and p-value of 0.007. This result is economically significant and theoretically sound. Accumulation of infrastructure in East Africa takes a well-defined upward pattern influenced by national development policies such as Kenya's Vision 2030, Ethiopia's Growth and Transformation Plans, Rwanda's Vision 2020 and Vision 2050 rather than the random walk process. Given

that this is a deterministic development trajectory that is influenced by deliberate policies, the AIDI series becomes stationary since there is an identifiable trajectory within which the infrastructure endowment can be defined to evolve. The inflation rate, trade openness and gross capital formation are non-stationary at level but stationary at first difference implying that they are integrated of order one I(1). Since there is a mix of integration orders including integrated of order zero (I(0)), trend stationary and integrated of order one (I(1)), these variables are easily handled by the System GMM method used by Blundell and Bond in 1998 since it differences the equation to achieve stationarity for all the variables. As a result, since none of the variables is integrated of order two I(2), then there are no problems with using System GMM and we are assured of not obtaining a spurious regression.

5.2 System GMM Estimation Result

Main Estimation Results Table 5.5 presents the main System GMM coefficient estimates with Windmeijer (2005) corrected standard errors, t-statistics, p-values, and 95 percent confidence intervals.

Table 5.5: Two-Step System GMM Estimation Results

Variable	Coefficient	Corrected Std. Error	t-statistic	p-value	95% Conf. Interval
L.GDPPCG	0.3998	0.1552	2.58	0.023	[0.064, 0.735]
L.lnAIDI	-1.9460	0.6488	-3.00	0.010	[-3.348, -0.544]
GCF	-0.0682	0.0508	-1.34	0.203	[-0.178, 0.042]
TRADE	0.0068	0.0059	1.16	0.267	[-0.006, 0.020]
INF	-0.0274	0.0067	-4.12	0.001	[-0.042, -0.013]
Constant	10.003	2.881	3.47	0.004	[3.780, 16.227]

Source: from stata 17 output

The lagged GDP per capita growth coefficient (L. GDPPCG) is positive and statistically significant at the five percent level ($\beta = 0.400$, $t = 2.58$, $p = 0.023$), with a confidence interval of [0.064, 0.735]. This empirical result demonstrates the dynamic process of economic growth observed in the East African panel. The size of the persistence coefficient equals 0.400, implying that about forty percent of the previous year's differential growth rate is retained in the following year. This is a reasonable result, since it is large enough to reflect the real growth momentum (investment program, institution building, and structural transformation) in some countries, but not

too large so that it cannot be explained by explosive non stationary dynamics. The same result was obtained by Calderón and Servén (2008) in their analysis for Sub-Saharan Africa. Thus, using the dynamic panel specification, including lagged dependent variables, is reasonable and justified by our study results. The countries that were able to start sustained growth trajectories at the beginning of the research period, especially Ethiopia and Rwanda, gained from the persistence channel since the positive growth experience created further investments and improved institutions that kept their above average growth rates throughout the subsequent years.

The estimate for lagged natural logarithm of AIDI (L.lnAIDI) coefficient is negative and statistically significant at the five percent level ($\beta = -1.946$, $t = -3.00$, $p = 0.010$), with the 95 percent confidence interval of [-3.348, -0.544]. This is the main conclusion of this study and needs to be analyzed more thoroughly than a simple reading of negative sign of β.

At first glance, the negative coefficient of infrastructure might seem contradictory to the endogenous growth theory by Barro (1990) and empirical evidence provided by Calderón and Servén (2004, 2008). However, the conclusion reached here can be regarded as a plausible and well supported theory when taking into account specific peculiarities of East African panel used as a sample. The coefficient can be treated as an elasticity as a result of using logarithmic AIDI: one percent increase in the growth rate of score of AIDI from the previous year causes 1.946 percentage points decrease in the GDP per capita growth in the current year on average across the panel countries, ceteris paribus. This is due to the fact that majority of large-scale infrastructure projects undertaken across the panel including Kenya's Standard Gauge Railway, the Addis Ababa Djibouti Railway, Ethiopia's Grand Ethiopian Renaissance Dam, and Djibouti's port expansion were financed through external sovereign debt, primarily from Chinese bilateral lenders under the Forum on China Africa Cooperation framework. When this major infrastructure projects undertaken by some countries in the panel were found to be economically non-viable due to their current financing schemes. In cases where these projects cannot create enough profits in order to cover the amount of debt servicing costs, the budget burden persists, continuously inhibiting GDP per capita growth while at the same time failing to make up for any increased productivity which might reverse the coefficient value. Contrary to this four interrelated factors explain this conclusion and represent a significant theoretical contribution to the topic in question. First, there is the structural heterogeneity

inherent in the panel of fourteen countries considered here, which determines the nature of the aggregate estimate of the relationship between the two variables. It includes countries with varying levels of economic development, from one like Mauritius, whose GDP per capita is in excess of 10,000 US dollars and has an AIDI score of over 90, to others like South Sudan and Somalia, whose AIDI score is close to zero, and whose growth prospects are determined by conflict dynamics completely unrelated to the level of infrastructure investments. In such a highly heterogeneous panel, the countries with the highest AIDI scores are countries that have matured economically, with their structural limitations arising out of the factor accumulation constraints and demographic transitions that limit their growth, while the countries with lower AIDI scores are fragile states with high variability in terms of growth rates that are largely positive during reconstruction phases. Such a highly heterogeneous panel results in a negative coefficient at the panel level, but this should not be mistaken for a real negative impact of infrastructure on economic growth.

In the case of East Africa, countries with the highest gains in terms of AIDI, due to new infrastructure created through the involvement of China in infrastructure projects in Ethiopia, Kenya, and Djibouti, faced increasing public debt loads and capacity constrains among both institutions and businesses to utilize this infrastructure. Also a one-period lag formulation reflects the impact of infrastructure development on growth in the year following development itself. Infrastructural impact in the development literature is widely recognized as a phenomenon with long-term horizons an infrastructure developed in year t maximizes its productivity gains within a five to ten-year period through market integration, corporate relocation, greater commercialization of agriculture, and adjustment in trade routes. The one-period lag formulation reflects the effects of only the first year of such an adjustment process, when the cost associated with building infrastructure crowding out of private investment, labor displacement, burden of servicing loans is likely to outweigh the gains from increased productivity. This particularity is especially pertinent for the large-scale infrastructure projects that have been funded by Chinese finance during the period under review in Kenya, Ethiopia, and Djibouti.

Finally, for several of the countries within the expanded panel sample such as South Sudan, Somalia, Eritrea, and Sudan, there were intervals where infrastructure investment took place at the same time as severe economic decline due to civil war, sanctions, or political instability. In such circumstances, an improvement in the AIDI

score can be achieved through aid-supported reconstruction, despite sharp declines in GDP per capita resulting from civil war, destruction, displacement, and institution breakdowns. The simultaneous effect of both positive and negative factors results in the negative impact on growth captured by the negative coefficient in the panel regression analysis. Such findings support the conclusions reached in many of the Africa panel studies conducted before. According to Gutema and Bekele (2020), infrastructure's contribution to growth is highly dependent on panel composition and the country selection process, with the inclusion of fragile states leading to lower or negative growth effects estimates. Also, Andres, Biller, and Herrera Dappe (2014) show how infrastructure effects are largely affected by the institutional and political setting in the receiving countries.

This research, therefore, makes a valuable contribution to this field of inquiry through its findings regarding the precise nature of the channels through which the effect of infrastructure on economic growth may be negative in a very heterogeneous sample despite positive causality at the individual country level. Infrastructure, as represented by the AIDI composite index, is a necessary but not sufficient ingredient for sustained GDP per capita growth in East Africa.

The coefficient on the inflation rate (INF) is negative and statistically significant at the one percent confidence level (beta = -0.027, t = -4.12, p = 0.001, 95% CI: [-0.042-0.013]), indicating that it is the most statistically precisely estimated variable in the equation and supporting the conclusion that inflation is an important hindrance to growth in the East African region's GDP per capita (2003-2024). A rise in the inflation rate by one percentage point is accompanied by a reduction in growth in the GDP per capita rate by 0.027 percentage points. This is economically meaningful when considering the volatility of the region in question; for instance, a country that experiences inflation 30 points above the panel average in a similar situation to inflation over 33 percent in Ethiopia in 2011-2012 and post-2020 and hyperinflation in Sudan is projected to lose 0.81 percentage points per year. High inflation results in mispricing and a reduction in the real rate of return on investments, creates uncertainty and therefore discourages investments by private enterprises complementary to infrastructure development, and decreases savings rates due to regressive income redistribution.

While the coefficient associated with gross capital formation (GCF) is negative, it is not significant from a statistical perspective. Although it can be empirically

demonstrated via descriptive statistics that there exists a robust positive bivariate correlation of 0.307 between the two variables, the fact that GCF is not significant in the multivariate specification suggests that the independent marginal effect of investments becomes statistically ambiguous after accounting for endogeneity, dynamic consistency, the presence of adequate infrastructure, and the state of the economy at large. Specifically, while the coefficient may appear to be negative due to some structural features exhibited in conflict-afflicted nations that saw increased investment rates despite a decline in income per capita, such as continued infrastructural projects amid the Tigray war in Ethiopia between 2020 and 2022 and aid-supported investments in South Sudan, since the coefficient lies between positive and negative values, this is nothing more than mere statistical ambiguity.

The coefficient for trade openness (TRADE) is positive, yet it is not statistically significant at any commonly used level. While it shows a positive correlation that is consistent with the theory about the impact of trade on growth through technology transfers and scale economies, it is not statistically significant because of bimodal structural diversity in the dataset comprising 14 countries. At one end of the spectrum is Djibouti, which records an annual trade to GDP ratio above 200 percent due to its status as a transit port for neighboring countries such as Ethiopia; however, this does not translate into traditional productivity gains. Conversely, Somalia, South Sudan, and Eritrea are characterized by exceptionally low trade ratios due to internal conflicts and international sanctions and isolation. This structural diversity explains the lack of statistical significance and indicates that the impact of trade openness on economic growth depends entirely on a country's ability to leverage such openness into productivity gains.

The intercept is positive and statistically significant at the one percent level. In the context of System GMM estimation, this coefficient explains the autonomous part of the baseline growth in GDP per capita which cannot be explained by any other regressors included in the model. Though it may be theoretically but not empirically true to assume that constant equals zero for all independent variables, its large value along with statistical significance indicates that the model specification is correctly chosen and can properly account for the relevant unobservable factors of regional growth, including demographic dividend, natural resources development, and technology diffusion through global knowledge spillovers.

5.3 Post Estimation Test Results

All six conditions are met at once, making the results very convincing regarding the System GMM approach.

Table 5.6: System GMM Post Estimation Diagnostic Tests

Diagnostic Test	Statistic	p-value	Required Criterion	Verdict
Arellano-Bond AR(1)	z = -2.20	0.028	p < 0.05 (expected to reject)	✓ PASS
Arellano-Bond AR(2)	z = -1.10	0.271	p > 0.05 (fail to reject)	✓ PASS
Sargan test	chi2(6) = 6.50	0.369	p > 0.10	✓ PASS
Hansen J-test	chi2(6) = 5.56	0.474	0.10 < p < 0.70	✓ PASS
Number of instruments	12	—	< 14 groups	✓ PASS
F-statistic	F(5,13) = 168.86	0.000	p < 0.05	✓ PASS

Source: stata 17 output

AR(1) rejects the null hypothesis of zero first-order serial correlation among the differenced residuals (p = 0.028). That is an expected result considering that, by definition, the first difference technique should yield no serial correlation among the first differences. The key condition here is the failure to reject the null hypothesis of zero second-order serial correlation among the difference residuals (p = 0.271). It means that there is no serial correlation in the level equation error term, thus making the instruments used two periods behind valid as orthogonal instruments for the first differences. For the Hansen J-test of over identifying restrictions, the chi-square value is 5.56, with the associated p-value being 0.474. This is comfortably within the specified acceptable range of 0.10 – 0.70. This shows that our chosen instruments pass validity since they are orthogonal to the error term according to the requirements of the GMM. As further confirmation, we have the Sargan test with a p-value of 0.369. Importantly, neither of these two tests gives a p-value which suspiciously approaches the value of 1.000, indicating that instrument proliferation has been avoided using the collapse option and hence both tests remain diagnostically valid. Our 12 instruments are less than the 14 countries in our study, which satisfies the basic requirement of

GMM analysis. The F-statistic is 168.86, with a corresponding p-value of 0.000, indicating very high significance of the predictors in our model.

CHAPTER SIX

CONCLUSIONS AND POLICY RECOMMENDATION

6.1 Conclusion

In this analysis, the researcher explored the link between the development of infrastructure and growth in fourteen East African countries between 2003 and 2024, using the two step System GMM dynamic panel estimator. While the key result the negatively and significantly associated coefficient with lagged infrastructure endowment appears counter intuitive at first glance, it simply highlights the nature of the panel, namely its exceptional developmental heterogeneity from Mauritius to Sudan, the limitations in terms of absorption capacities due to fragility and poor institutions, the mismatch between the financing of infrastructural projects and their late benefits, and the constant contamination of the relationship between infrastructure and growth by conflict dynamics in Sudan, Somalia, and Ethiopia.

The most robust conclusion drawn from this paper is the highly significant impact of inflation on the growth of per capita GDP. This effect exists across all specification and confirms the notion that macroeconomic volatility bears measurable per capita income costs for the East African economy. Growth persistence was also established, demonstrating that once an economy succeeds in reaching an above-average growth trajectory, it will be able to persist on that path in addition, growth cost imposed by conflict and volatility cannot be isolated to the period when these negative shocks occurred. Trade openness and gross capital formation bear the right directional effects but did not prove themselves statistically significant. This can be explained by mediating factors, such as institutional quality, risk of conflict and debt levels, which make it difficult to isolate their contributions into GDP growth.

The final conclusion from the study is that physical infrastructure is both a necessary but insufficient ingredient for GDP per capita growth in East Africa. Physical infrastructure provides a set of conditions connectivity, access to electricity, flow of information and access to water supply which must exist before any growth can take place. These remain plausible hypothesis drawn from the wider literature.

6.2 Policy Recommendation

For the national governments of East Africa, the most pressing recommendation with immediate impact potential relates to treating macroeconomic stability, or more specifically inflation control, as an essential growth requirement. From the empirical findings, one can note that every percentage point of inflation translates into an actual and quantifiable sacrifice of growth per capita. When governments finance infrastructure through borrowings at the sovereign level, then such debts must be serviced in a manner that does not generate monetary pressures resulting in expansion. In case there is a trade-off between stabilization and the expansion of infrastructure, then stabilization must come first. For those nations with high infrastructure debt burdens like Kenya, Ethiopia, Djibouti and Mozambique, then debt restructuration and moving towards concessional financing as well as public-private partnerships become key priorities. Lastly, governments throughout the region need to understand that conflict prevention is investment infrastructure protection; the growth costs of armed conflicts go well beyond damage from destruction and into the realm of growth momentum losses, and that investment into peace-making and political stabilization is among the most productive development investments possible.

Regarding the East African Community, it is clear from the empirical analysis in this paper that the monetary convergence criteria, particularly the eight percent cap on inflation, are scientifically justified as growth-preserving rules that countries have powerful economic reasons to follow. In this regard, the EAC Secretariat should provide more technical assistance to lagging countries and promote convergence not only as a step towards monetary union, but as an economically valuable growth strategy on its own. Additionally, the EAC should set binding quality standards for regional corridor infrastructure since it is evident from the findings that it is as important as physical infrastructure investment itself.

For the African Development Bank, the primary recommendation is that the AfDB should enrich the AIDI framework with infrastructure quality indicators, including road condition, electricity reliability, and internet speed data, to enable financing decisions that reward maintenance of existing assets alongside greenfield construction.

6.3 Areas for Further Research

Several areas for further study can be suggested based on this research. First, one possible next step would involve the application of the Pooled Mean Group and Mean Group models to examine country-specific effects that make up the panel average infrastructure coefficient, and then to find out whether the positive or negative relationship between infrastructure and economic growth exists in particular countries and how particular country characteristics (institutional environment, conflict risk, amount of debt) may help to determine this pattern.

Second, it could be helpful to construct the measure of infrastructure stock that would consider not only the infrastructure access rates and stocks (as it is measured in the AIDI score) but also the quality of this infrastructure (road conditions, electricity, internet and water availability), in order to see its full contribution to growth. This would improve estimates of infrastructure growth elasticity compared to the estimate produced in this study.

Third, including the interaction term between infrastructure stock and institutional quality would help to find the institutional quality threshold that is required in order for infrastructure stock to have a positive effect on economic growth.

Fourthly, breaking down the AIDI into its component sub-indexes – namely, transport, electricity, information and communications technology (ICT), and water and sanitation infrastructure – would help determine which types of infrastructure investments yield the highest rates of growth in Eastern Africa, thus aiding in proper prioritization of resources. Lastly, estimating the model using Panel ARDL pooled mean group regression would help determine whether the short-term negative effect estimated in this paper can coexist with a long-term positive co integrating relationship between infrastructure endowment and income per capita levels – findings that would harmonize the results of this paper with the positive long-run relationship implied by endogenous growth theories.

Second, and perhaps even more fundamental, the negative sign on the regression coefficient aligns with the idea of absorption capacity of infrastructure, which is an accepted and established theory in development economics that says that investments in infrastructure yield positive growth gains only under the right institutional, human capital, and business sector conditions where such investment can be absorbed and utilized. Indeed, Kodongo & Ojah (2016) show that in African country panels, the

infrastructure growth effect has been statistically significant only in countries with high levels of institutional quality, while in countries constrained by institutions of poor quality, the effect has been either statistically insignificant or negative because of the inability to effectively utilize the infrastructure that exists.

From a policy perspective, what this implies is that any infrastructure development in East African countries will have a positive effect on growth only in combination with other changes such as those related to institution building, development of the private sector, education, and stability in the economy.

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Appendex

Summary				
Variable |	Obs	Mean	Std. dev.	Min	Max
GDPPCG |	308	1.809092	4.435523	-30.36317	10.22182
AIDI |	308	51.93363	22.76752	.6905469	99.797
INF |	308	11.14523	26.68641	-15.3469	359.093
TRADE |	308	64.98955	52.87356	1.995412	347.7203
GCF |	308	22.04491	10.2883	-15.67844	56.90793

Correlation

|	GDPPCG	AIDI	INF	TRADE	GCF
GDPPCG |	1.0000				
AIDI |	-0.1552	1.0000			
INF |	-0.2724	0.0285	1.0000		
TRADE |	0.0970	0.3905	-0.2023	1.0000	
GCF |	0.3070	-0.1096	-0.1967	-0.1085	1.0000

Source	SS	df	MS	Number of obs =	308
				F(4, 303) =	16.19
Model	1063.63014	4	265.907534	Prob > F =	0
Residual	4976.24726	303	16.4232583	R-squared =	0.1761
				Adj R-squared =	0.1652
Total	6039.8774	307	19.6738677	Root MSE =	4.0526

AIDI	-.0357405	.0111273	-3.21	0.001	-.0576371	-0.0138439
INF	-.0302175	.009133	-3.31	0.001	-.0481897	-0.0122453
TRADE	.0135109	.004922	2.74	0.006	.0038252	0.0231966
GCF	.1158154	.0232343	4.98	0.000	.0700944	0.1615363
_cons	.5708001	.8435053	0.68	0.499	-1.08907	2.23067

Variable	VIF	1/VIF
TRADE	1.27	0.789865
AIDI	1.20	0.833503
INF	1.11	0.900556
GCF	1.07	0.936216
Mean VIF	1.16	

Im–Pesaran–Shin unit-root test for GDPPCG

H0: All panels contain unit roots — Number of panels = 14
Ha: Some panels are stationary — Number of periods = 22

AR parameter: Panel-specific — Asymptotics: T,N -> Infinity sequentially
Panel means: Included
Time trend: Included — Cross-sectional means removed

ADF regressions: 2 lags

	Statistic	p-value
W-t-bar	-2.5909	0.0048

Im–Pesaran–Shin unit-root test for dGCF

H0: All panels contain unit roots — Number of panels = 14
Ha: Some panels are stationary — Number of periods = 21

AR parameter: Panel-specific — Asymptotics: T,N -> Infinity sequentially
Panel means: Included
Time trend: Included — Cross-sectional means removed

ADF regressions: 2 lags

	Statistic	p-value
W-t-bar	-5.0642	0.0000

Im–Pesaran–Shin unit-root test for dINF

H0: All panels contain unit roots Number of panels = 14
Ha: Some panels are stationary Number of periods = 21

AR parameter: Panel-specific Asymptotics: T,N -> Infinity
Panel means: Included sequentially
Time trend: Included Cross-sectional means removed

ADF regressions: 2 lags

	Statistic	p-value
W-t-bar	-4.0990	0.0000

Im–Pesaran–Shin unit-root test for dTRADE

H0: All panels contain unit roots Number of panels = 14
Ha: Some panels are stationary Number of periods = 21

AR parameter: Panel-specific Asymptotics: T,N -> Infinity
Panel means: Included sequentially
Time trend: Included Cross-sectional means removed

ADF regressions: 2 lags

	Statistic	p-value
W-t-bar	-4.2259	0.0000

Im–Pesaran–Shin unit-root test for lnAIDI

H0: All panels contain unit roots Number of panels = 14
Ha: Some panels are stationary Number of periods = 22

AR parameter: Panel-specific Asymptotics: T,N -> Infinity
Panel means: Included sequentially
Time trend: Included Cross-sectional means removed

ADF regressions: 2 lags

	Statistic	p-value
W-t-bar	-2.4752	0.0067

```
Dynamic panel-data estimation, two-step system GMM
------------------------------------------------------------------------------
Group variable: COUNTRY_id                      Number of obs      =       294
Time variable : YEAR                            Number of groups   =        14
Number of instruments = 12                      Obs per group: min =        21
F(5, 13)      =    168.86                                      avg =     21.00
Prob > F      =     0.000                                      max =        21
------------------------------------------------------------------------------
             |              Corrected
      GDPPCG | Coefficient  std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
      GDPPCG |
        L1. |   .3998391   .1552387     2.58   0.023     .0644662    .735212
            |
      lnAIDI |
        L1. |  -1.945996   .6488201    -3.00   0.010    -3.347687   -.5443058
            |
         GCF |   -.068169   .0507994    -1.34   0.203    -.1779145    .0415765
       TRADE |   .0068475   .0059079     1.16   0.267    -.0059158    .0196107
         INF |  -.0273873   .0066502    -4.12   0.001    -.0417541   -.0130205
       _cons |    10.00346   2.880674     3.47   0.004     3.780146    16.22678
------------------------------------------------------------------------------
Instruments for first differences equation
  GMM-type (missing=0, separate instruments for each period unless collapsed)
    L(2/3).(L.GDPPCG L.lnAIDI GCF) collapsed
Instruments for levels equation
  Standard
    INF TRADE
    _cons
  GMM-type (missing=0, separate instruments for each period unless collapsed)
    DL.(L.GDPPCG L.lnAIDI GCF) collapsed
------------------------------------------------------------------------------
Arellano-Bond test for AR(1) in first differences: z =  -2.20  Pr > z =  0.028
Arellano-Bond test for AR(2) in first differences: z =  -1.10  Pr > z =  0.271
------------------------------------------------------------------------------
Sargan test of overid. restrictions: chi2(6)    =   6.50  Prob > chi2 =  0.369
  (Not robust, but not weakened by many instruments.)
Hansen test of overid. restrictions: chi2(6)    =   5.56  Prob > chi2 =  0.474
  (Robust, but weakened by many instruments.)

Difference-in-Hansen tests of exogeneity of instrument subsets:
  GMM instruments for levels
    Hansen test excluding group:     chi2(3)    =   4.00  Prob > chi2 =  0.261
    Difference (null H = exogenous): chi2(3)    =   1.56  Prob > chi2 =  0.668
  iv(INF TRADE, eq(level))
    Hansen test excluding group:     chi2(4)    =   4.99  Prob > chi2 =  0.288
```

Difference (null H = exogenous): chi2(2) = 0.57 Prob > chi2 = 0.752