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Relationship between Infrastructure Development and economic Growth in Ethiopia: A Time series

By

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DECLARATION

I hereby declare that this thesis is my own work and has never been presented in any other university. All sources of materials used for this thesis has been appropriately acknowledged.

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ENDORSEMENT

This thesis has been submitted to St. Mary's University, School of Graduate Studies for examination with my approval as a university advisor.

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ST. MERY'S UNIVERSITY

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ACRONYMS

ADF	**AUGMENTED DICKEY-FULLER**
ARDL	**AUTOREGRESSIVE DISTRIBUTED**
Asroad	**ASPHALT ROAD**
CSA	**CENTRAL STATISTICAL AGENCY**
ECM	**ERROR CORRECTION MODEL**
ERA	**ETHIOPIAN ROAD AUTHORITY**
Groad	**GRAVEL ROAD**
Ht	**HUMAN CAPITAL**
MoFEC	**MINISTRY OF FINANCE AND ECONOMIC COOPERATION**
NBE	**NATIONAL BANK OF ETHIOPIA**
OLS	**ORDINARY LEAST SQUARE**
REER	**REAL EFFECTIVE EXCHANGE RATE**
Rruler	**RULER ROAD**
RGDP	**REAL GROSS DOMESTIC PRODUCT**
RSDP	**ROAD SECTOR DEVELOPMENT**
SE	**SECONDARY SCHOOL ENROLLMENT**
VAR	**VECTOR AUTO REGRESSION**
VECM	**VECTOR ERROR CORRETION MODE**

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ABSTRACT

Researches has shown direct and indirect contribution of road infrastructure for sustainable economic growth at national level. The main objective of the study to examine the link between road infrastructure development and economic growth and identify the long- and short-term impact of infrastructure development in Ethiopia using time serious data from 1975-2019.To achieve this objective co-integrated VAR approach was employed. The estimated models enable to understand the long run and short run nexus of the variables. The long run test show that gross domestic exerts positive and significant impact on Asphalt road and gravel road; Asphalt road and Gravel road exert positive and significant impact on economic growth; Ruler road exert negative and significant impact on economic growth. The short run test results reveals that the impact of Asphalt on economic growth is significant where as others have insignificant values so that short run causality isn't occurred. The granger causality test shows real gross domestic product granger-causes Asphalt road, gravel road, ruler road. The Asphalt road granger-causes economic growth and gravel road; it doesn't cause, ruler road. The gravel road granger-cause real domestic product while it doesn't cause Asphalt road and ruler road enrollment. Whereas the Ruler road case the granger-case gross domestic product; it doesn't cause Asphalt road and gravel road. By way of recommendation, donors need to strengthen their support on road financing in order to maintain the road infrastructure and the government has to give a sufficient attention both in terms of regional or federal road authorities.

Keywords: Gross domestic product, Asphalt road, gravel road, ruler road Vector Autoregressive Model, Granger Causality.

Chapter one

Introduction

1.Background of the study

Economic growth is the process by which the country's wealth increases over time. There are number of independent, interweaved, micro and macroeconomic variables that enhance and shake the process of the growth at different capacity. In order to achieve economic growth factors such as policy, strategies, legal frame works and technological advancement is needed among this infrastructure development is one of the factors that affect the economic growth as well as the economic development. Infrastructure is classified, analyzed in four categories: Transportation, Telecommunication, power, water and sanitation. (World Bank 1994)

This study will deal with only one category: Transportation, specifically on road constructions with respect to the economic growth. Infrastructure's linkages to the economy are multiple and complex, because growth it affects production and consumption directly, creates much positive and negative spillover effects (externalities), and involves large flows of expenditure According to some author the direction of causality is from GDP to infrastructure rather than the other way around (Gramlich 1994; Munnell 1992). Therefore, it is not adequate to establish an empirical relationship between GDP and infrastructure investment; the problem of the causal direction between economic growth and infrastructure investment has to be clearly addressed. It might well be the case that high GDP and high infrastructure investment are correlated, which has important inferences for public policy.

Economic growth on other side is increase in a country's total output or real Gross Domestic Product (GDP) or Gross National Product (GNP). The Gross Domestic Product (GDP) of

a country is the total value of all final goods and services produced within a country over a period of time while real (GDP) is (GDP) adjusted for inflation. Therefore, an increase in GDP is the increase in a country's production. Economic growth is a qualitative measure of the economic activity irrespective of all societal change. Economic growth is also important to change the living standard of the society. Economic growth as a crucial means for expanding the substantive freedoms that people value. These freedoms are strongly associated with improvements in general living standards, such as greater opportunities for people to become healthier, eat better and live longer (Sen, 1999). Infrastructure development on the other hand is the process of differentiating strengthens, including all economic means and providing modern and consistent infrastructures.

Infrastructure's linkages to the economy are multiple and complex, because it affects production and consumption directly, creates much positive and negative spillover effects (externalities), and involves large flows of expenditure World Bank Report (1993). However, there is a defined link between infrastructure and economic development. Infrastructure investment directly affects the economic development. Consequently, that the only way to build up a country's productivity and raise per capita income is to magnify the capacity for producing goods, this need not refer simply to the establishment of industrial plant and machinery, but also to dam, highways, telecommunication, railways, power lines, water pipes and even "incentive" consumer goods such as consumer durables, all of which can contribute to increased productivity and higher living standards.

Economic growth led to economic development while economic development is measured by improvements in the living standard of the society; the impact of infrastructure's is also considered 'amenity' value, mainly in connection with the discussion of linkages with personal welfare and the environment. The impact of infrastructure on the economy is the main focus, but the influence of macroeconomic developments on infrastructure is also examined, since causality runs in both directions.

Infrastructure development and GDP is closely associated. One percent growth in infrastructure stock is associated with one percent growth per capita GDP(Mondel2016). Therefore,

infrastructure is vital element for the country to rise per capital income through providing roads, railway, power lines, water pipe and house for agricultural and industrial zones. In addition to this region with inadequate infrastructure usually have lower per capita income bigger proportion of primary sector, a smaller population density region with high infrastructure usually has smaller primary sector and bigger proportion of population. (Srinivasu& Srinivasa Rao jan 2013). Beside this infrastructure development is important for inclusive growth by providing employment opportunity for the poor, provide facilities and stimulate economic activity which reduce transaction due to this effective infrastructure is inclusive. Investment in physical and social infrastructure positively affects the poor directly and indirectly in multiple ways (Estache 2004, Jones 2004).

1.2. Statement of the Problem

The provision of infrastructure helps people to exercise the freedom by accessing clean water, energy, communication system, health, education and basic transportation in order to alleviate poverty and providing a setting to wealth through increasing productivity and competitiveness. Among this road infrastructure plays the crucial role by providing mobility for efficient movement of people, good and services by providing accessibility to land and wide Varity of commercial (Meyer and Miller,2001).

The Ethiopian government expenditure pattern have been changed through time for the past four decades, capital expenditure for the road construction has changed from 17.2% to 25.9% on the Derg regime and EPRDE regime respectively (NBE). Within the twenty-one year (1997 to 2018) of road sector development program (RSDP) physical work has been undertaken on the total of ETB 335.8 billion. While the physical and finical performance of RSDP over the last 21 year against the plan is 73% and 94% respectively (ERA, 2019). Due to large amount of investment is carried out it is important to analyze the road infrastructure for the overall growth aspiration of the nation.

In recent studies, the development of road infrastructure has positive relationship with economic growth infrastructure development with economic growth and he study demonstrate the growth in road length per thousand population, per capita export contributes positive for economic growth (Ng et al.2018).

Furthermore, Lokesha and Mahesha (2016) analyze the impact of road infrastructure on agricultural development and rural road infrastructure development in India. The finding revealed the road transportation plays an important role in agricultural development and overall economic development t also improves the quality of life. Tripathi et al. (2015) outline the unidirectional long run causality relationship between growth and road infrastructure.

In Ethiopian context, research is scared despite the huge investment. According to Worku (2011) the total road network has significant growth spurring impact. The study also revels when the network is disaggregated, asphalt road has a positive sectorial impact but gravel road fail to significantly affect both the overall and sectorial GDP growth including agricultural. Shiferaw et al, (2013) analyze the road infrastructure and enterprise development in Ethiopia. The finding revels road infrastructure and enterprise development dynamics showed that the better road access increase the attractiveness of manufacturing firms. Zelalem (2013) analyze the impact of government road spending in Ethiopia. The finding reveals the government spending on road has significant and positive effect on economic growth (GDP) in the short and long run. Recently Nigatu (2017) analyze the socio-economic impact of road sector development in Benshangul Gumuz, Ethiopia the study shows that the contribution of road on the quantity of agricultural production was high. It also indicated that there is variation in the prices of agricultural products and inputs between places accessible to road and not.

However, the existing studies doesn't follow a detailed econometrics analysis. The studies fail to show the two directional causalities between the two factors. Most of the studies emphasize the long term only, not the short-term benefit. Another drawback of the studies is compressing countries that have different development policy, strategy and different development level. Most of researches that has done in Ethiopia is before 2013 and the studies are done on specific region, doesn't cover the entire nation. Therefore, this research fills those gaps that has listed, beside the gap the empirical studies that show the effect of road transportation and economic growth is not sufficient compared to the level of investment. This research used as an input for policy maker and development partners on the area of infrastructure investment.

1.3. Research objective

1.3.1. General

The general objective of this study is to examine the link between road infrastructure development and economic growth and identify the long- and short-term impact of infrastructure development in Ethiopia using time serious data from 1975-2019.

1.3.2. Specific objectives

- To examine the trend and magnitude of road infrastructure development in Ethiopia in the stated time period.
- To assess the direction of causality between road infrastructure development and economic growth.
- To assess if there is any long- and short-term economic growth contribution coming from road infrastructure development.

1.3.3. Research Question

- Is there causality between road infrastructure development economic growth in Ethiopia?
- To what magnitude dose road infrastructure sector affect the economic growth?
- What is short run and long run impact of road infrastructure and on economic growth rate of the country?
- What is the short run and long run impact of economic growth rate on economic growth of the country?

1.4. Scope and Limitations of the study

The study pursues the nexus between road infrastructure development and economic growth in Ethiopia. In order to capture its effect on the economy a thorough empirical inquiry will be conducted with data covering a period of 44 years i.e., from 1975-2019. In this research has faced the following limitations: one of the limitations is data inconsistency, seasonal effect is not considered most of the data are considered only the annual value.

1.5. Significance of the study

This study conveys relevant message for the policy maker by shading light on the contributions of investment on road infrastructure for the economic growth. In addition to this the research work further serves as a guide and provides insight for future research on the topic and related field for academia's and policy makers who are interested on the topic.

1.6. Organization of the thesis

This research organized in to five chapters. Following the introduction part, chapter two present the review of related theoretical and empirical literature is about the infrastructure development and economic growth nexus. Chapter three gives discuss on the model specification and general methodology employed. Chapter four emphasize about the result and finding and the last chapter provides conclusion and recommendation based on the finding

Chapter two

2.Review of Related Literature

2.1. The Concept of infrastructure

There is no standard definition of infrastructure across economic studies; this is due to the formulation of the term infrastructure, the incorporation of theoretical approach and the description of the reality of infrastructure provision (Torrisi, 2004). World Bank (2004) used the word infrastructure as an umbrella for many activities it plays many important roles for industrial and other economic activity.

According to Jocimsen (1966) define infrastructure as the sum of material, institutional and personal facilities and data which are available to the economic agents and which contribute to realizing the equalization of the remuneration of comparable inputs in the case of a suitable allocation of resources, that is complete integration and maximum level of economic activities. The author also mentioned material infrastructure as totality of all earning asset equipment and circulating capital in an economy that serve energy provision, transport service and telecommunications; we must add structures etc. for the conservation of natural resources and transport routes in the broadest sense and buildings and installations of public administration, education, research, health care and social welfare".

However, Bouhr (2003) has put limitation on Jochimen definition, the first has disadvantage of not making factor price equalization concrete, the second problematic aspect of this definition is that it understands the material infrastructure to be enumeration of essentially public facilities characterized by specific attributes. Bohur rejects the mainstream approach of infrastructure attribution and define infrastructure on the favor of functional approach as the sum of all relevant economic data such as rule and measure with function of mobilization the economic potentiality of economic agent.

Infrastructure is classified differently by different author. Hansen (1965) classify it into economic and social according to the fact that they act on the level of economic development of a territory in direct or indirect way. Hansen (1965) divide the public head capital in to social over capital (SOC) and economic over capital (EOC). The economic over capital primarily oriented toward the support of directly productive activities or toward the movement of economic goods. SOC items may also increase productivity; the way in which they do so is much less direct than in the case.

The economic infrastructure directly supports the productivity activity such as: road infrastructure, railway, hydropower, air transport, telecommunication network, sewerage lines, water supply lines and irrigation line. While social infrastructure is those that increase the social comfort and increase the economic activity such as school, hospitals, green areas and sport structure.

While Torrisi (2008) categorize infrastructure into personal, institutional, material and immaterial, core, not core, basic and complementary, network, nucleus and territory infrastructure and subcategorize immaterial infrastructure to economic and social infrastructure by using Bohur and Jocimen definition.

2.2. Theories of Economic Growth

The goal of growth theory is to give explanation about the determinants of the economic growth in a given country and the reason for difference in economic growth rates and per-capita income across countries (Dornbush &Fisher,1992,pp.269).Interest in the study of economic growth has experienced remarkable ups and downs in the history of economics .It was central in classical political economy from Adam Smith to David AcemRicardo, and then in its critique by Karl Marx ,but moved to periphery during the so called marginal revolution .John von Neumann's growth model and Roy Harrod's attempt to generalize Keynes's principle of effective demand to the long run re-ignited interest in growth theory. Following the publication of a paper by Robert Solow and Nicholas kaldor in themid-

1950, growth theory become one of the central topics of the economics profession until the early1970s.After the decades of dormancy, since themid-1980s, economic growth has once again become a central topic in economic theorizing.

2.3 Solow-swan Growth model

Robert Solow and Trevor swan growth model is 1956 that help to think about approximate case and mechanics of the process of economic growth and country income difference. The model is simply called the Solow-swan model. this model has shaped the way to approach not only economic growth but the entire field of macroeconomics (Acemagin,2008).

The Solow model focuses on four variables: output(Y), capital(K), labor(L) and knowledge or the effectiveness of labor (A). At some time, the economy has some amounts of capital, labor and knowledge and these are combined to produce output. The production function takes the form: $Y(t)=F[K(t),A(t)L(t)]$,where t denote time .The output will change if the inputs to production change .In particular the amount of output obtained from quantities of capital and labor rises overtime-there is technological progress-only if the amount of knowledge increase .AL implies that effective labor (Romer,2006).

Higher saving /investment rate leads to accumulation of more capital per worker and hence more output per worker. On the other hand ,high population growth has a negative effect on economic growth simply because a higher fraction of saving in economies with high population growth has to go to keep the capital labor ratio constant .In the absence of technological change and innovation ,an increase in capital per worker would not be matched by a proportional increase in output per worker because of diminishing returns .Hence capital deepening would lower the rate of return on capital (Nkiru and daniel, 2013).

2.4. The nexus between Infrastructure and Economic growth.

A vast array of literature is available on the nexus of infrastructure development for economic growth. Nurkse(1955), Hirschman(1958), Rostow (1960) and Rodan (1943) had mentioned infrastructure is the main vehicle for economic development. The modern economic literature writer Hirschman differentiated between the direct productive activity and the social overhead capita.

According to Hirschman (1958) an activity can be included in the category of social overhead capital (Infrastructure) provided if it satisfies the services provided by the activity facilitate or are in some sense basic to the carrying on of a great variety of economic activities and if these services are usually provided in practically all countries by public agencies because of externalities, or by private agencies subject to some public control. And the service must be provided free of charges or at rates regulated by public agencies and these services cannot be imported. In addition to this the investments needed to provide the services are characterized by lumpiness (technical indivisibilities) as well as by a high degree of capital- output ratio (provided the output is at all measurable).

Nurkse(1955)elaborated the concept of overhead capital. According to him “overhead investment aims at providing the services – transport, power, and water supply, which are basic for any productive activity, cannot be imported from abroad, required large and costly installations and in the history of western economics outside England, have usually called for public assistance or public enterprise. Typically, overhead investments take a considerable time to reach maturity in growing.

Rostow (1960) in his 'Theory of Stages of Growth' social overhead capital is a pre-condition for take-off into self-sustained growth. Investment in social overhand development of those services inspires potential capitalists to participate in risk-bearing business. Those Social overhead cost prepare the base for development of economic activities by decreasing the cost and increasing the profitability of productive activities.

Jocimsen (1966) divides the relevant time path of economic development for the modern market economy theory in to three stages 1. quasi-stagnation 2. economic- dualism 3. self- development. The first stage is characterized by relatively constant level of economic activists. The dualism stage is characterized by the disintegration of decomposed economy in to segments. The last stage is the stage where the level of activities is start to increase. Jochimen denotes “infrastructure” as the important preconditions of economic development concerning the time-path mentioned above.

According to Rodan (1943) the services of overhead capital are indirectly productive and become available only after a long gestation period. They include all those basic industries like power, transport or communication. Their investments precede directly productive investments.

They constitute the framework and overhead costs of the economy as a whole. Its installations are characterized by a sizeable initial lump and low variable cost.

Todaro (1981) emphasized capital accumulation including all new investments in land, physical equipment and human resources, results when some proportion of present income is saved and invested in order to augment future output and income. New factories, machinery equipment and materials increase the physical “capital stock” of a Nation and make it possible for expanded output levels to be achieved. These directly productive investments are supplemented by investments in what is often known as social and economic **“Infrastructure”** roads, electricity, and water, and sanitation, communications etc. which facilitate and integrate economic activities. In general, all the above economists’ views on infrastructure in the form of overhead capital or overhead costs. This was the theoretical base of socio-economic infrastructure of the economy.

According to Rao and Srinivasu (2013) the relationship between infrastructure and economic growth is multiple and complex, because not only does it affect production and consumption directly, but it also creates many direct and indirect externalities, and involves huge flows of expenses thereby generating additional employment. Also, the link between infrastructure and development is not a once for all affair, it is a continuous process and progress in development has to be preceded, accompanied and followed by progress in infrastructure, if are to fulfill our declared objectives of self-accelerating process of economic development. (Rao ,2013). However, Studies linking infrastructure investment and economic performance fail to capture the complexity of this relationship, which is that "the economic impact of additional investment depends on the size and configuration of the existing network and on the degree of congestion at each point in the network.

Infrastructure has strong forward and backward linkages within the economy. It affects economic development process both at production and consumption levels. In the case of production, it contributes to economic growth in various ways such as by reducing input costs, by increasing the productivity of other factors like capital and labor, by providing more job opportunities and by attracting foreign and local investment. At the consumption level, it contributes to the quality of life of households through providing clean water, sanitation, electricity, transport and communication facilities which increase the real income level of households on the one hand and to help to reduce environmental pollution on the other (World bank,2004).

Infrastructure investment generally has two types of effects. First, it has demanded creation effect in other economic activities which is flow impact. Second, it has stock impact which makes better availability of services and improves productivity of the private sector and the economy as a whole. Therefore, infrastructure development contributes to investment and growth through increase in productivity and efficiency as it links between resources to factories, people to jobs and products to markets. But many of the benefits of infrastructure services accrue to firms – in France, for example, that input-output tables reveal that firms consume two-thirds of all infrastructure services (Prud'homme 2004). Thus, it is through this channel that costs are lowered and, most importantly, market opportunities are expanded (especially through telecommunications and transport). The resulting gains in competitiveness and production are what drive the gains in economic growth and ultimately welfare.

2.5. Transport infrastructure

Transport infrastructure is one of the economic (physical) infrastructures which integrate the transport system of the any city or states. Road infrastructure is one of the predominate type of the transport system other than the fixed installation such as railways, water ways, cannel pipelines and terminals.

Transport infrastructure has a specific role in regional development. It was assumed that transport infrastructure has only a positive impact on regional development for the long time. However, the its effect is evaluated both through the direct and indirect effect, to identify whether it has positive and negative effect (Padjen, 1996).

Transport infrastructures directly affect transport cost by decreasing fuel consumption, capital consumption as well as decrease of related compensation for employees. Changes of cost are followed by changes in transport mode, transport route, time horizon and accessibility of movements within the region (Ladavac, 1999).

Cost reductions of the transportation change pattern of the economic activity directly facilitate the productivity of the household and business firms. It decreases the travel time to achieve the same level of productivity but consumption in short time. The indirect impact of building of transport infrastructure can be analyzed through changes of attractiveness of the monitored region, size of movement of goods and services and changes in the size of transport costs, i.e., changes in relative competitiveness of the regions (Skufic, 2006)

Skufic (2006) sub categorize the effect of the indirect effect in to impact on the income and impact on capacity, for the less develop countries. Impact on income derived from the time travel savings and reductions in vehicle operating costs, which directly influences the size of transportation costs. Were as impact capacity refers as to the increase of regional production capacities. For example, increased transport capacity can increase the export potential of the monitored regions.

Likewise, road infrastructure has always played the crucial effect for the economic growth both through direct and indirect effect for the mobility of the citizens or via the indirect benefit derives from the presses of building infrastructure (Vantanen, 2007).

The other direct benefit of road infrastructure is poverty alleviation as to provide poor with a better physical access to employment (Papi and Attane,2001) and indirectly it reduces the differences across the region within the countries (Estache-Fay,2010).

2.6. Road sector policies in Ethiopia

Ethiopia has implemented the millennium development goal (MDGs) which span from 2000 to 2015 and registered remarkable achievement integrating with national development frame work. Ethiopia was one of the nations that evaluated the conduct that has been performed the MDGs in the national level with which Ethiopia has made a significant contribution for the preparation of 2030's Global agenda for sustainable development. Ethiopia has accepted with strong government commitment and endorsed the 2030's Agenda for sustainable government by House of people of Representative with full sense of national to implement the 2030's Agenda and its sustainable development goals as a part of national of integral part of its national development frame work, the second five-year growth and transformation plan GTP 2 (National Plan Commission, 2017).

The 2030's SGD Agenda comprise 17 goals and 169 targets. among the 17 goals building resilient infrastructure promote inclusive and sustainable industrialization and foster innovation. Road infrastructure is one the infrastructure that has proposed in the document. (National Plan Commission, 2017).

Ethiopia's economy is highly depending on road sector Road transport is the dominant mode that carries about 95 percent of the country's passenger and freight traffic and is the only form of access to most rural communities. Ethiopian government has launched a large scale of public investment program known as Road Sector Development Program (RSDP) since 1997 to meet the objectives. (ERA, 2019)

The objectives are

1. Improve the efficiency of transportation system and reduce road transport costs for freight and passengers so as to encourage production, distribution and export.
2. Provide access to previously neglected food deficit rural areas to support efficient production, exchange and distribution throughout the country, and
3. Develop adequate institutional capacity of the road sub-sector both at central as well as regional level

Over the twenty-one year's Road Sector Development Program (RSDP) have five stages since 1997

RSDP I -From July 1997

- RSDP I -From July 1997 to June 2002 (5 years plan)
- RSDP II -From July 2002 to June 2007 (5 years plan)
- RSDP III -From July 2007 to June 2010 (3 years plan)

- RSDP IV -From July 2010 to June 2015 (5 years plan)
- RSDP V -From July 2015 to June 2020 (Ongoing) also known as the GTPII.
-

The Physical and financial performance of RSDP over the past 21yearsagainst plan is 73%and94%respectively and the total length in km that has been performed for the past twenty-one years is summarized in Table 1 below.

Table 1 Physical and financial performance of RSDP over the past 21yearsagainst plan.

Program	**Physical Plan Vs. Accomplishment, km**			**Financial Plan Vs. Disbursement, in million ETB**		
	Plan	Actual	Age%	Budget	DISB	Age%
RSDP I	8908	8709	98	9812.9	7284.6	74
RSDP I I	8252	11589	140	15985.9	18112.8	113
RSDP I I I	14686	12395	84	34643.9	34957.9	101
RSDP IV	97517	85860	88	125409.1	158333.3	126
RSDP V	69302	27210	39	170751.6	117086.8	69
Total of RSDP 21 years	198665.5	145763.5	73	356603.4	335775.4	94

Source: ERA, 2019

2.7. Review of Empirical Literature

2.7.1. The Overall relationship of infrastructure and economic growth.

In both developed and developing countries much of empirical research has been done on the significance of infrastructure development for economic growth since Aschauer(1989).

The first generation Aschauer (1989), Munell (1990) and Port (1991) found that the output elasticity of public capital is very high, ranging from 0.38 to 0.56. Aschaure further recommends that lack of infrastructure spending leads to slowdown of productivity growth in the US. By using annual macroeconomic time series data for the US spanning from 1949–1985 periods and assess the public sector capital to be at least twice as productive as the private sector capital in the aggregate.

Later Gramlich(1994) citizen those studies on various grounds, estimation of marginal product of a unit of public capital from elasticity are bound to be approximate, the result are very sensitive to measure error in the ratio Y/G, but the rough implication is marginal product are around 100%. Which imply infrastructure would pay its self in one year. Underlining this point Gramlich pointed if the infrastructure payees with this short time, the rate of return from the infrastructure investment should outperform the type of investment.

Fernald, (1999) found an output elasticity of road investment around 0.35 which is similar to Aschaure However, Fernald argues the massive interstate highway network built in1950s generated a onetime boost in productivity rather than a permanent one. he also categorizes the period, the pre- and post-1973 were Aschauer result were the pre-1973 which boost in productivity while the post-1973 shows the slowdown in productivity.

Jan et al (2012) finds a long run relation between the GDP and physical infrastructure by using Cobb-Douglas production function. It uses transportation, energy and telecommunication infrastructure and constructs an index of physical infrastructure using principal component analysis.

Nadeem et al. (2011) use Cobb-Douglas production function to examine the effect of social and physical infrastructure on agricultural productivity in Punjab and finds as the investment in infrastructure increase the total factor of production increase on agriculture and livestock sub sector Therefore, more resources should be diverted towards the development of social and physical infrastructure in rural area.

Straub and Hagiwara (2011) examine the state of existing infrastructure in developing Asian economies and the link between infrastructure, productivity and growth by using cross -country growth regression and growth accounting framework. The study concludes that not only the overall infrastructure in these countries remains below the average world's level but its quality is also poor as compared to the industrialized countries. Cross-country regression shows a positive and significant impact on per capita GDP growth rate because of the accumulation of infrastructure capital. Growth accounting technique reveals that positive impact of infrastructure on TFP is in few countries only.

Straub (2011) evaluates the existing macro-level literature about infrastructure and economic growth and development linkages through a sample of 80 different specifications from 30 studies. The results reveal 56 per cent found a significant positive effect of infrastructure, 38 per cent found no effect and 6 per cent found significant negative effect. Due to regional disparities and various data specification disparity in results occurred, which make the studies difficult to be comparable.

Faridi et al. (2011) studies the effect of transportation and telecommunication infrastructure on the economic development of Pakistan by using time series data from 1972 to2010. The study finds out transport infrastructure plays significant role in increasing the GDP whereas telecommunication decrease the GDP growth in Pakistan through Solow growth model.

Agénor (2010) proposes a theory of long-run development based on public infrastructure as main engine of growth. It argues that if public governance is adequate then diverting public funds from non-productive activities to the infrastructure capital will help the economy to shift from low growth equilibrium to high growth steady state characterized by high productivity and high savings. The model also has implications regarding choice of technology and the role of the state in fostering private sector growth.

Agenor and Dodson (2006) examine various networks through which public infrastructure can affect economic growth. It highlights the impact of developing infrastructure on investment adjustment cost like durability of private capital and production of health and education services. The endogenous growth model is used to develop a link between health infrastructure and growth. The study draws out the implications for the design of strategies which aim at promoting growth and reducing poverty. But it does not consider the fact that different regions show different behavior regarding infrastructure investment and economic growth.

Calderon and Serven (2004) analyze the impact of quantity and quality of infrastructure stock on long-run economic growth and income inequality. By using panel data set for 121 countries over the period of 1960-2000 for power infrastructure, telecommunication and safe water availability. The study finds out infrastructure stock has positive impact on long-run economic growth and negative impact on income inequality through simple GDP equation and formal inequality measures long-run economic growth and negative effect on income inequality.

Looney (1997) studies the role of infrastructure in the economic expansion of Pakistan. The outcomes of the study the complicated role of infrastructure for economic development. On one hand it does not seem to significantly accelerate the development but on the other hand it responds to private investment thus alleviating real bottlenecks.

Hashim et al. (2009) empirically analyze the impact of telecommunication infrastructure on the economic growth in Pakistan by using data for the period of 1968-2007 and empirically analyzes the impact of telecommunication infrastructure on economic development in Pakistan. The study shows the investment in telecommunication results in higher economic growth rates.

Yilmaz and Certain (2018) use Dynamic panel data analysis to study the effect of infrastructure growth on economic growth on developing countries by using data from 1990 to 2015 comparing 29 countries and find positive and significant effect of infrastructure on economic growth.

2.5.2. The Relationship of Road infrastructure with Economic growth

Kwon, (2005) found direct and indirect contribution of road infrastructure for poverty reduction. By using panel data from 1979 to 1996 in Indonesia Kwon found the following results: The first result is the positive impact of road infrastructure on poverty reduction, the second one is the investment of road infrastructure increase the GDP growth, with 1% of provincial growth led to 0.33%decline on poverty with province of good road and 0.09% for bad road.

The third one is road infrastructure can contribute directly to reducing poverty, independent of its effect on GDP growth in each of two provinces. Compared with other types of government investments, such as those in education and health, Kwon's (2005) study

reveals that the poverty rate is to public investment in roads, such that a 1 % increase in road investment is associated with a 0.3 % drop in poverty incidence over 5 years.

Ng et al.(2018) has studied the development of road infrastructure has positive relationship with economic growth infrastructure development with economic growth and he study demonstrate the growth in road length per thousand population, per capita export contribute positive for economic growth(Ng et al.2018).

Furthermore, Lokesha and Mahesha (2016) analyze the impact of road infrastructure on agricultural development and rural road infrastructure development in India. The finding revealed the road transportation plays an important role in agricultural development and overall economic development also improves the quality of life. Tripathi et al. (2015) outline the unidirectional long run causality relationship between growth and road infrastructure.

According to Worku (2011) the total road network has significant growth spurring impact. The study also revels when the network is disaggregated, asphalt road has a positive sectorial impact but gravel road fails to significantly affect both the overall and sect GDP growth including agricultural.

Shiferaw et al, (2013) analyze the road infrastructure and enterprise development in Ethiopia. The finding revels road infrastructure and enterprise development dynamics showed that the better road access increase the attractiveness of manufacturing firms. Zelalem (2013) analyze the impact of government road spending in Ethiopia. The finding reveals the government spending on road has significant and positive effect on economic growth (GDP) in the short and long run.

Recently Nigatu (2017) analyze the socio-economic impact of road sector development in Benshangul Gumuz, Ethiopia the study shows that the contribution of road on the quantity of agricultural production was high. It also indicated that there is variation in the prices of agricultural products and inputs between places accessible to road and not.

2.6. Conceptual framework of the study

Based on reviewed theoretical and empirical literature the study has developed the following schematic representation of the conceptual framework. The diagram below shows bidirectional causality among gross domestic product and road infrastructure.

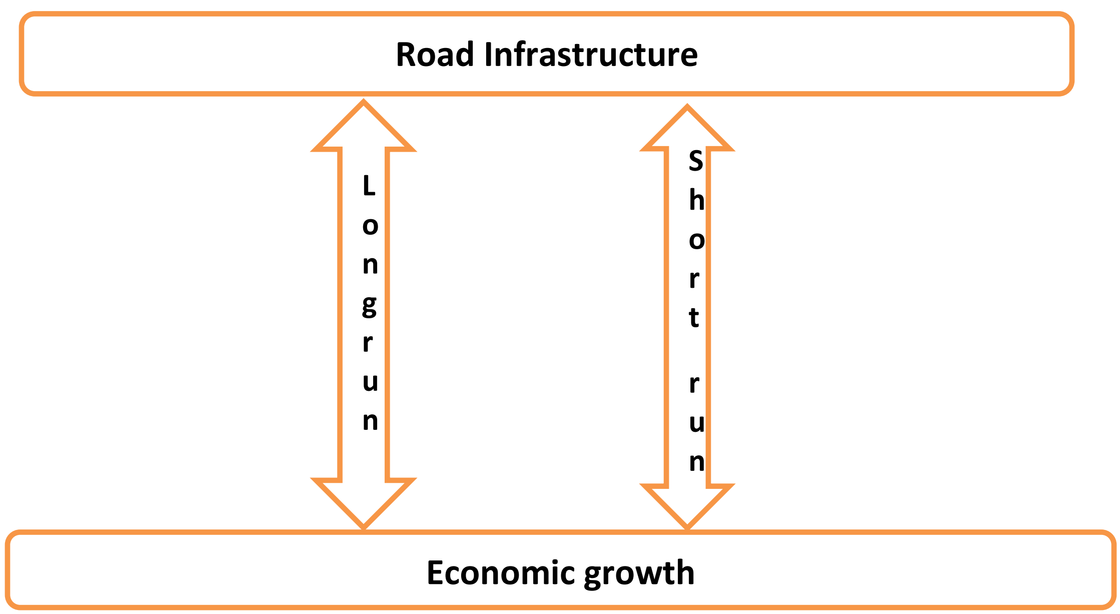

Figure 1 Flow chart for transmission channel of infrastructure for economic growth

Chapter Three

3.RESEARCH METHODOLOGY

3.1. Research Approach and design

The study will adopt quantitative research approach. Because quantitative approach indicates the investigators primarily uses postpositive claims for developing knowledge that is the cause-and-effect relationship between known variables of interest or it employs strategies of inquiry which is collect data on predetermined instruments that yield statistics data and the purpose of this study is to investigate the relationship between road infrastructure and economic growth in Ethiopia.

In this study both descriptive and casual research design, to study the trend and magnitude of road infrastructure descriptive analysis will be used and in order to examine the unidirectional causality research deign will be used.

3.2 Data source and data collection method

The data that will be used in this analysis is a time serious data from1975 up to 2019 and directly used from the following organization; real gross domestic capital from National bank of Ethiopia (NBE), length of the road infrastructure for the paved and unpaved(gravel) road type in kilometer from Ethiopian Road Authority (ERA) and secondary school enrollment from world bank.

For the model specification that will be explained below physical and human capital is needed so that the capital variable could be derived from Kohler's (1988) capital accumulation function, which is refereed as perpetual method. In order to drive the capital stock is set as follow:

$K_t = I_t + (1- σ)\, k_{t-1}$-- (1)

Were

K_t is capital stock.

t is period.

I_t is gross capital formation in year t. the data is collected from National Bank of Ethiopia

k_t is computed as follow $k_t = I_t/(\sigma+r)$.--------------------------------- --------------------------(2).

σ is a rate of deprecation. Kohler (1988) and Worku (2010) suggests 8%.

r is real interest rate. In order to have the real interest value the nominal interest and inflation is collected from the national bank of Ethiopia and calculated using the Fisher equation.

$$r = (1+R/l+i)-1 \text{-----} (3)$$

Where, R is the Nominal interest rate and I is the inflation rate

3.2.Research Hypothesis

Regarding the long run and short run relationship between variables;

H0: There is no cointegration between series.

HA: There is cointegration between series.

3.3. Model specification.

In order to analyze the impact of infrastructure on economic growth arrays of studies adapted the Augmented Solow growth model. Worku(2010), Ayelew(2016), Birhanu(2017) and other used Cobb-Douglas production function. Cobb-Douglas production function is particular functional production widely used t represent the technological relationship between Physical, Capital and labor.

$$Q = AL^{a} K^{\beta} \text{-----} (4)$$

Where Q is output and L and K are inputs of labor and capital respectively.

A, a and β are positive parameters where = $a > 0$, $\beta > 0$

The above general Cobb-Douglas type functional specification will be augmented with road so as to identify its impact on economic growth. Accordingly, the above functional specification will be reformulated as:

$$GDP = f(L, K, T) \text{ --- } (5)$$

This equation assumes that at any point in time, the economy has some amount of K, L and T so that in particular the amount Y is amount Y is obtained from K and L rise overtime. The model also assumes that there is a technological progress only in amount A increases.

Following the previous studies that have been lo listed on the literature review this study follow the log transformation of the Cobb-Douglas production function, the Augmented Solow growth model. This includes the dummy variable which captures the impact of any policy intervention in the analysis period.

Starting from the general Cobb-Douglas production function type the model specification will be as follow:

$$GDP=F(L,K,R_t) \text{ --- } (6)$$

$$GDP=F(L,K,R_p,R_g,Rr) \text{ --- } (7)$$

$$Rp=F(GDP,L,K,Rg,Rr) \text{ --- } (8)$$

$$Rg=F(GDP,L,K,Rp,Rr) \text{ --- } (9)$$

$$Rr=F(GDP,L,K,Rg,Rp) \text{ --- } (10)$$

$$GDP=\sigma_t H_t^{a} k_t^{\beta}(R_{pt} R_{gt} Rr) \text{ --- } (11)$$

$$\ln GDP_t = \alpha_0 + a_1 \ln H_t + \alpha_2 \ln k_t + \alpha_3 \ln R_{pt} + \alpha_4 \ln R_{gt} + \alpha_5 \ln R_r + e \text{ -------------- } (12)$$

$$\ln R_{pt} = \beta_0 + \beta_1 \ln H_t + \beta_2 \ln k_t + \beta_3 \ln GDP + \beta_4 \ln R_{gt} + \beta_5 \ln R_r + e \text{ -------------- } (13)$$

$$\ln R_{gt} = \Theta_0 + \Theta_1 \ln H_t + \Theta_2 \ln k_t + \Theta_3 \ln GDP + \Theta_4 \ln R_{pt} + \Theta_5 \ln R_r + e \text{ ------- } (14)$$

$$\ln R_{rt} = £_0 + £_1 \ln H_t + £_2 \ln k_t + £_3 \ln GDP + £_4 \ln R_{gt} + £_5 \ln R_{pt} + e \text{ --------- } (15)$$

Where H_t is human capital

K_t is physical capital at time t

Rpt Rg ,Rr is road network for paved , gravel roads and ruler road respectively at time t

a and β are parameter of interest.

The model is then transformed to the logarithmic form whereby the resulting equation is set as follows.

3.4. Econometric analysis

3.4.1. Vector Autoregressive (VAR) Model

Vector autoregressive model are used for multivariable time series in order investigate the direction of causality and to assess the linkages between Road infrastructure and economic growth. VAR model is a statistical model used to capture the relationship between multiple quantities as they change over time. VAR was introduced by Sims (1980) as a technique that could be used by macroeconomists to illustrate the joint dynamic activities of variables without setting strong limitations of the kind needed to identify under structural parameters approach. VAR model is appropriate to investigate the relationship among the variables that are mutually dependent in the model. Unlike other model VAR model analyzes relationship between two or more endogenous variables.

3.4.4. The Vector Error Correction Model (VECM)

The vector autoregressive (VAR) model was first introduced by (Sims, 1980). According to him VAR model provide a theory-free method for the estimation of economic relationship, and it describes the simultaneous relationship between proposed variables. VAR model is utilized to find out the relationship between proposed variables; however, the variables which are used in VAR must be stationary. If including variables are non-stationary may create problem, this problem is called spurious relationship. Vector error correction model distinguish clearly between long and short run impact through a equilibrium correction model and facilitate dynamic simulation of variables using “impulse response analysis” (Harris and Soilles,2003).

3.4.2. Test for Stationarity

In this study unit root test and Augmented Dickey Fuller test (ADF)is used to find out the degree of differencing required to induce stationarity. To find out long run co-integration between the variables, VAR and Vector Error Correction Model (VECM) approach has been used. Granger causality test was employed to test the direction of causality between variables. Diagnostic check, such as Multicollinearity test, normality, serial correlation and heteroscedasticity test are performed.

Unit root test

Various time series techniques can be used in order to model the dynamic relationship between time series variables (Gujarati, 2004). However, it is important to determine the characteristics of the individual series before conducting further analysis. Therefore, Unit root tests are tests for stationarity in a time series. A time series has stationarity if a shift in time doesn't cause a change in the shape of the distribution; unit roots are one cause for non-stationarity. When dealing with time series data it is important to test the stationary or non-stationary nature of the data set for the reason that non-stationary variables might lead to spurious regression. In this regard Harris (1995) stated that: models containing non-stationary variables will often lead to a problem of spurious regression, whereby the results obtained suggest that there is statistically significant relationship between the variables in the regression model when in fact all that obtained is evidence of contemporaneous correlation rather than meaningful causal relation. According to Cheung and Lai, (1999)and Pedroni,(1998a) there are considerable evidence for presence of unit roots in PCGDP time series data as such there was need to make the data stationary.

Stationarity tests allow verifying whether a series is stationary or not. There are two different approaches: stationarity tests such as the KPSS test that consider as null hypothesis H0 that the series is stationary, and unit root tests, such as the Dickey-Fuller test and its augmented version, the augmented Dickey-Fuller test (ADF), or the Phillips-Perron test (PP), for which the null hypothesis is that the variable contains a unit root, and the alternative is that the variable is generated by a stationary process. Pperron uses Newey-West standard errors to account for serial correlation, whereas the augmented Dickey-Fuller test implemented in duller uses additional lags of the first-difference variable. Stata automatically select the appropriate lag length when we use pperron. So, this study uses both the pperron and ADF tests to check the stationary nature of the variables

3.4.3. Co-integration

Co-integration deals with the common behavior of a multivariate time series. It often happens in practice that each individual component of a multivariate time series may be non-stationary, but certain linear combinations of these components are stationary. Co-integration studies the effects of these combinations and the relationships among the components. If two variables are co-integrated only and only if the two have long run relationships between them. Many macroeconomic time series are not stationary at levels and are most adequately represented by first difference. Even though, the individual time series are not stationary, a linear combination of these variables could be stationary. If these variables are co -integrated, then they have stable relationship and cannot move too far away from each other. Testing co-integration implies testing for the existence of such long run relationship among economic variables.

3.5. Granger Causality Test

Granger Causality test is developed by Granger (1969) and advanced by Sims (1980). In the Granger Causality test, we observed the direction of cause-effect relationship among the variables. The use of causality test is to identify which variable causes another variable in time series analysis or it provides the basis for determining which variable provide the lead for responses by other variables. Sims (1980) points out that a necessary condition for x to be exogenous of y is that x fails to Granger-cause y. Similarly, variables x and y are only independent if both fail to Granger-cause the other. Causality can be only one direction or both directions. If both x and y variables are granger cause each other, there is a bi-directional causality between x and y.

Real GDP (RGDP):- is a macroeconomic measure of the value of economic output adjusted for price changes (Birhanu 2017)

Gravel Road (Groad):- A gravel road is a type of un paved road surfaced with gravel that has been brought to the site from a quarry and measured in kilometer(ERA,2008)

Asphalt Road (Asroad):- A road with a hard smooths surface or bitumen or tar and measured in kilometer. (ERA,2008)

Ruler road (Rroad):- are defined as low traffic volume roads located in forested and rangeland settings that serve residential, recreational and resource management uses which is measured in kilometer.((ERA,2008)

Human capital (Ht):- is the stock of habits, knowledge, social and personality attributes embodied in the ability to perform labor so as to produce economic value. Kang (2005) suggests secondary school enrollment as the best proxy for the human capital for infrastructure and measured in percent.

Physical capital (Kt):- refers to assets, such as building, machinery and vehicles, which are owned and employed by an organization. In this research we use Kohler's (1988) capital accumulation function, which is referred as perpetual inventory method.

3.6 Diagnostic Checks

3.6.1 Heteroscedasticity Test

One of the basic assumptions of the classical linear regression model is the variance of each disturbance term ui, is some constant number equal to δ2. This assumption is known as homoscedasticity. If this condition is not fulfilled or if the variance of the error terms varies as sample size changes or as the value of explanatory variables changes, then this leads to heteroscedasticity problem. The study employs the White's heteroscedasticity test.

3.6.2 Residual Vector Normality Test

The disturbance term Uiis assumed to have a normal distribution with zero mean and a constant variance. The test of residual normality is very important after estimation in empirical studies. Jarque-Bera(JB) test will be an important residual normality test in this study. It is a joint asymptotic test and the test statistics is calculated from the skewness and kurtosis of the residuals.

$JB = N/6[S^2 + (\beta_3 - 3)^2/4]$

Where N is the number of observations; S is the coefficient of skewness, $\beta_3$is a measure of kurtosis; and the test statistic is χ^2 distributed. The joint test is based on the null hypothesis that the residuals are normally distributed (i.e., S=0 and $\beta_3=3$). Non rejection of the null hypothesis at the standard critical values indicates normality of the residuals.

3.6.3 Auto Correlation Tests

Serial correlation arises when the error terms from different time periods are correlated. In time series studies it occurs when the error associated with observations in a given time period carry over into future time periods. Serial correlation also called autocorrelation. Breusch Godfrey Langrange Multiplier (LM) test is used in this study to test the presence of serial correlation in the residuals.

Chapter four

4. Result and Discussion

In this chapter contain both descriptive and econometrics analysis. Under the descriptive analysis the trend and the overall performance of the variables that are listed in the model by using statistical tools such as graph and tables. While the econometrics analysis conducted by using the STATA13 software from 1975 up to 2019.

The analysis begins by necessary testes such as stationarity and diagnostic test then after Granger causality and Cointegration test is conducted for short run and long-term model respectively. following the results interpretation and discussion are conducted.

4.1 Descriptive analysis

4.1.1. Trend of real GDP and its growth in E`thiopia (1975-2019)

Figure 4.1: Trends of real GDP and its growth in Ethiopia (1980-2018)

Source: own computation

The performance of Ethiopian economy is weak and remained weak throughout the 1970's and1980's. The socialist economy system during the 1974-1991 military regime was grossly inefficient marked by the out discouragement of private sector participation and poor performance of the state-owned enterprise beside this the violent civil war that culminated in the overthrow of the derge in the mid 1991was financial burden of the economy.

At the end of 1991 following the overthrow of derge, the political and economic reform occurred. among the economic reform; currency devaluation, trade liberation, deregulation of market and removal of restriction on private sector participation.

The economy starts recovering and intensified since 1991 and 2005 respectively. In order to achieve this outcome, the government demonstrated unprecedented commitment to public investment in economic infrastructure and physical infrastructure beside the investment the government has established the developmental planes and strategies under the macro policy development (Shiferaw,2017).

The government has established Economic Recovery Reconstruction Program in 1992, Agricultural Development Led Industrialization in1995, Poverty Reduction Strategy Paper (PRSP) in 1999, Sustainable Development for Poverty Reduction Program (2001), Plan for Accelerated and Sustained Development to End Poverty (PASDEP) in 2005 (Kedede,2015).

GTP1 was launched in 2010, before that the government developmental strategy dubbed agricultural development industrialization (ADCI) that emphasize the agricultural productivity a well as poverty reduction however, it did not lead to agriculturally based industrialization as it is anticipated.

As shown in the figure 4.1 the GDP has been growing since 2010 till the projected time as the government launched the GTPI and GTPII. One of the pillar strategies of GTPI and GTPII is to accelerate sustainable and equitable economic growth. Since then, the GDP has risen in order to meet the government's lower and upper growth goal during the GTP period: achieving 11-15% gross domestic product each year over the period; that enable Ethiopia to achieve its millennium development Goals (MDGs) by 2015 rise middle income state by 2025.

4.1.2. Trend of Asphalt road and its growth in Ethiopia (1975-2019)

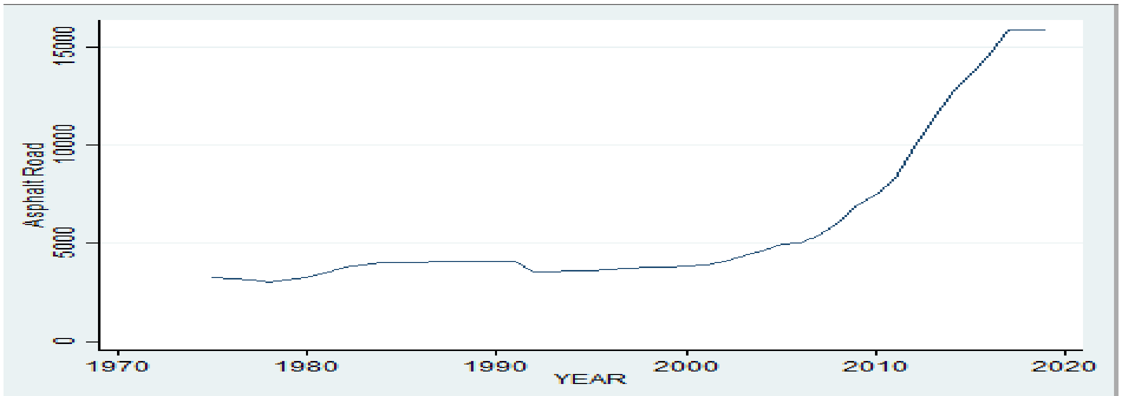

Figure 4.2: Trends of Asphalt road and its growth in Ethiopia.

Source: own computation ERA data

As the graphical representation shows the trend of asphalt road in Ethiopia have been nearly steady from 1975-1978 whereas, from 2000 onward the graph is sharply upward indicating the government program called Road sector development have been significantly increase the size of road infrastructure in the country. The program was formulated in 1997 and has been implemented over the period of twenty-one years with four successive phases.

4.1.3. Trend of Gravel road and its growth in Ethiopia (1975-2019)

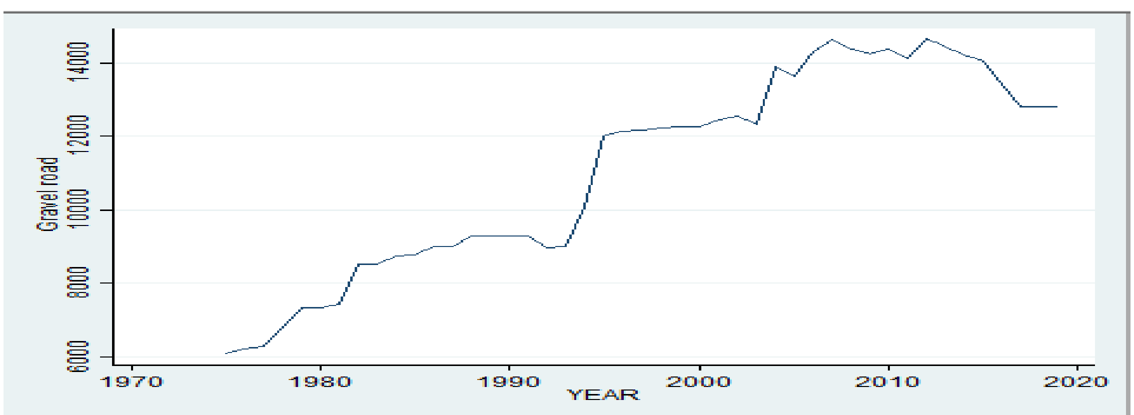

Figure4.3: Trends of Gravel road and its growth in Ethiopia (1980-2018).

Source: own computation ERA data

Trends of gravel roads in the above figure shows moderate ups and downs from 1975 to 1993 whereas from1994 to 2000 the graph is sharply upward then after the graph steadily rises up till 2013 whereas the graph starts to fall down from 2014 to 2019 this is due to if RSDP V fails to comprise a construction of new link roads with gravel standards because of the financial shortage (ERA,2015).

4.1.3. Trend of Ruler road and its growth in Ethiopia (1975-2019)

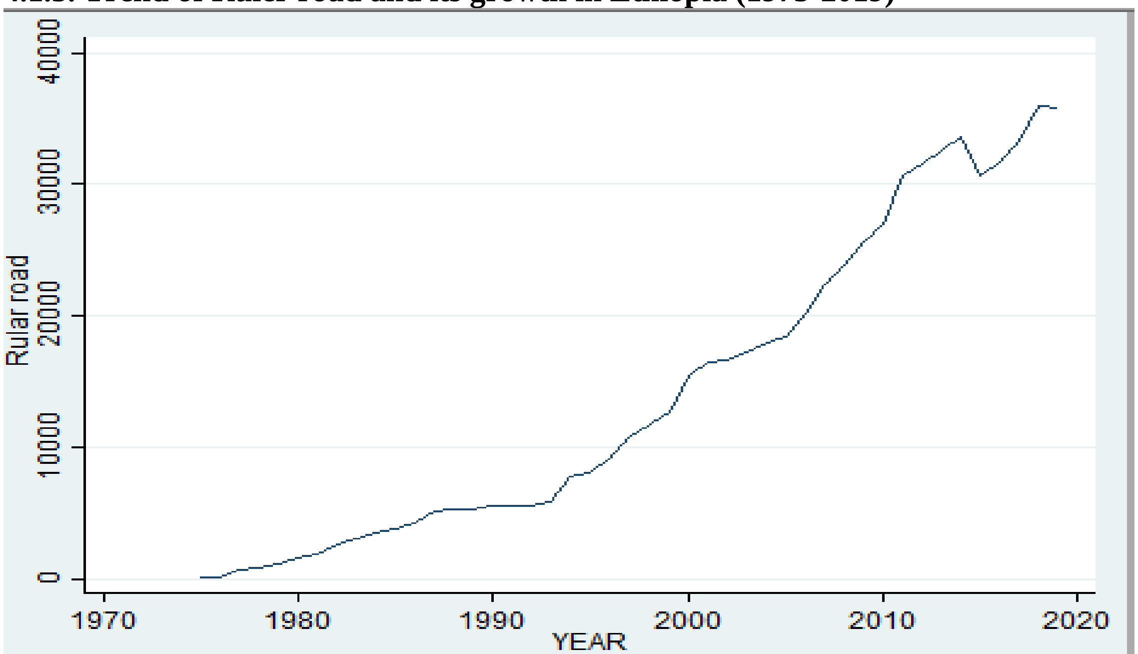

Figure4.4: Trends of Ruler road and its growth in Ethiopia (1980-2018).

Source: own computation `

Trends of ruler road as shown in figure 4.3, shows the graph is sharply upward indicating higher growth of ruler road. RSDP has been adopted and implemented policies and strategies, among the strategies the regional/ruler road authority (RRAS) carried out heavy maintenance on ruler roads which are in poor condition and routine maintenance on ruler road which are in poor condition. (ERA2015).

4.2. The unit root analysis.

Unit root test is prerequisite task to estimate the econometric model and obtain consistence and reliable result. The test checks whether the time serious is stationary or not. If the model contains non stationary variables it will led to a problem of spurious regression, whereby the result suggests there is statically significant relationship between variables in regression model, when in fact all it obtained is contemporaneous correlation rather than meaningful causal relationship (Harris 1995).

There are two main methods to test the stationarity: the graphical and Augmented Dicky Fuller method, the formal and the informal test respectively. Prior to the formal method graphical method is used in this study in order to visualize the plot. Augmented fuller test assumes, the null hypotheses is that the variables that contain a unit root ad this test is performed with different trend assumption with intercept and (trend and intercept) as shown below on the table.

Table 4.1: Augmented Dickey-Fuller (ADF) Stationarity Test Result

Augmented Dicky fuller method.						
Variables	With intercept			Trend and intercept		
	At level	At first difference	Order of integration	At level	At first difference	Order of integration
lnRGDP	2.317	-3.964	I(1)	-0.23	-5.199	I(1)
lnAsphalt	-4.286	-3.184	I(1)	-3.46	-4.883	I(1)
lnGroad	-2.39	-4.09	I(1)	-1.096	-4.915	I(1)
lnRroad	-5.319	-12.309	I(1)	-11.3	-12.43	I(1)
lnKt	-2.219	-7.07	I(1)	-3.398	-7.07	I(1)
lnSEE	0.03	-3.899	I(1)	-1.287	-3.969	I(1)
MacKinnon (1996) with constant Test critical values 1% -3.621 Test critical values 5% -2.943 Test critical values 10% -2.610				With constant and trend Test critical values 1% -4.227 5% -3.537 10% -3.200		

Source: STATA 14 result

Null hypothesis H0= data has unit root (non-stationary)

Alternate hypothesis H1= data doesn't have unit root (stationary)

Guideline (Criteria): if absolute value of the test statistic is greater than /5% critical value/, the criteria is to reject the null hypothesis and to accept the data as stationary and vice versa otherwise. As can be seen from the ADF test results, all the time series are stationary at I (1) while they are not at I (0). When all variables are integrated of the same order and in this case with integrated at order one; it is advised that Johansen cointegration estimation method should be used.

According to the result from the above Table 4.1, all the variables are not stationary in their levels at 5% level of significance. Hence, we take the first difference of the variables and they become stationary. The ADF result reveals that Gross domestic product, Asphalt road, gravel road, Ruler road, Capital and Secondary school enrollment are stationary at first difference with lag two.

4.3. Determination of Optimal Lag Length for Endogenous Variables

Prior to conducting co-integration test and vector error correction method determining the optimal lag order is necessary since the Johansen co-integration test is very sensitive to the number of lags. The optimal lag order is determined with the sequential modified Likelihood Ratio test statistics [LR], the Final Prediction Error [FPE], the Akaiki Information Criterion [AIC], the Hannan Quinn Information Criterion [HQ]) and the Schwarz Information Criterion [SC].

Guideline: The lower the AIC value, the better will be the model all the time

Table 4.2: Optimal lag order selection criteria

```
varsoc lnRGDP  lnAsroad  lnGroad lnRroad lnKt lnSE

 Selection-order criteria
 Sample:  5 - 45                          Number of obs      =        41
```

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	14.0891				2.7e-08	-.394588	-.303273	-.143822
1	271.066	513.95	36	0.000	5.8e-13	-11.1739	-10.5347*	-9.41858*
2	299.771	57.411	36	0.013	9.2e-13	-10.8181	-9.63101	-7.55814
3	360.414	121.28	36	0.000	3.8e-13*	-12.0202*	-10.2852	-7.25561
4	393.514	66.201*	36	0.002	9.1e-13	-11.8787	-9.59585	-5.60957

```
 Endogenous:  lnRGDP lnAsroad lnGroad lnRroad lnKt lnSE
  Exogenous:  _cons
```

Note: * indicates lag order selected by the criterion

Source: STATA 14 result

4.4. The Johansen Co-Integration Test Result

The main purpose of conducting co-integration is to long-run relationship between the variables. Two variables will be co-integrated if they have long run relationship between them. In VAR models the test for co-integration is essential because if there is no co- integration relationship between the variables under consideration then there is no point in estimating VEC model.

H0: Null hypothesis =there is no cointegration

H1: Alt hypothesis= there is cointegration

Guideline: if the trace statistic is greater than the critical value (5%), reject the null hypothesis and accept the alternative hypothesis.

Table 4.3: Johansen Tests for Co-Integration

```
. vecrank lnRGDP lnAsroad lnRroad lnGroad  lnKt  lnSE, trend(constant) lags(3)

                       Johansen tests for cointegration
Trend: constant                                         Number of obs =      42
Sample:  4 - 45                                                  Lags =       3
```

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	78	290.81839	.	153.1622	94.15
1	89	323.49593	0.78904	87.8071	68.52
2	98	341.20699	0.56975	52.3850	47.21
3	105	354.87451	0.47839	25.0499*	29.68
4	110	361.86158	0.28303	11.0758	15.41
5	113	366.95159	0.21524	0.8958	3.76
6	114	367.39947	0.02110		

Note: * denotes rejection of null hypothesis at 5 percent level

Source: STATA 14 result

From the given table above, three co-integration equation exist. The null hypothesis of no-integration among the variables is rejected because the trace statistics of 153.162,87.807 and 52.383 is greater than 94.15,68.52 and 47.21 respectively. from the above result shown the existence of three co-integration relationship between real GDP, Asphalt road, Gravel road, Ruler road, capital stock and secondary school enrollment, the long run relationship between the variables exists and in order to correct the long run model itself VECM is used

4.5. Granger Causality Test

Granger Causality test is used to identify the presence of causality between variables. This test is helpful to understand the bidirectional causality between the variables.

H0: Null hypothesis =there is no causality

H1: Alt hypothesis= there is causality

Guideline: The guideline is if the probability is more than five percent, the null hypothesis is rejected.

Table 4.4: Granger causality Wald test

vargranger

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
lnRGDP	lnAsroad	.35346	2	0.838
lnRGDP	lnGroad	.59055	2	0.744
lnRGDP	lnRroad	.5256	2	0.769
lnRGDP	lnKt	2.5614	2	0.278
lnRGDP	lnSE	2.8156	2	0.245
lnRGDP	ALL	6.8678	10	0.738
lnAsroad	lnRGDP	10.526	2	0.005
lnAsroad	lnGroad	2.261	2	0.323
lnAsroad	lnRroad	15.856	2	0.000
lnAsroad	lnKt	8.4732	2	0.014
lnAsroad	lnSE	.33474	2	0.846
lnAsroad	ALL	42.52	10	0.000
lnGroad	lnRGDP	2.1476	2	0.342
lnGroad	lnAsroad	6.9089	2	0.032
lnGroad	lnRroad	4.874	2	0.087
lnGroad	lnKt	.86744	2	0.648
lnGroad	lnSE	9.0868	2	0.011
lnGroad	ALL	24.118	10	0.007
lnRroad	lnRGDP	1.2249	2	0.542
lnRroad	lnAsroad	39.63	2	0.000
lnRroad	lnGroad	16.97	2	0.000
lnRroad	lnKt	.89121	2	0.640
lnRroad	lnSE	1.4441	2	0.486
lnRroad	ALL	298.1	10	0.000
lnKt	lnRGDP	7.9263	2	0.019

—more—

Source: own computation

As table 4.8 shows the real gross domestic product granger-causes Asphalt road, gravel road, ruler road capital stock and secondary enrollment. The Asphalt road granger-causes economic growth, gravel road and secondary school enrollment; it doesn't cause, ruler road and capital stock. The gravel road granger-cause real domestic product, capital sock while it doesn't cause Asphalt road, ruler road and secondary school enrollment. Whereas the Ruler road case the granger-case gross domestic product, capital stock and secondary enrollment; it doesn't cause Asphalt road and gravel road. The capital stock cause granger-causes Asphalt road, Gravel road and school enrollment; it doesn't cause domestic product and ruler road. finally secondary enrollment granger-causes ruler road and capital stock.

4.6. Vector Error Correction Model (VECM)

VECM model is performed by choosing the optimal lag length and the co-integration relationship by optimal lag that is chosen based on the information criterion and Johansen co-integration test respectively. The VECM consists of two parts: the matrix of long-run co-integrating coefficients that is used to derive the long-run co-integrating relationship, and the short-run coefficients which is for the short-run analysis.

Guideline: when the error correction term is significant (0.05) and the sign is negative there is long run equilibrium or loosely speaking causality running from the explanatory variables to the dependent variable.

Table 4.5: The Estimated Long- Run Model for lnRGDP (Real Gross Domestic Product)

lnRGDP	**Ce1**	**Ce2**	**Ce3**
Coff	**-0.27**	**0.01**	**1.2**
p>[z]	**0.001**	**4.21**	**0.09**
Result	**Significant**	**Not significant**	**Not significant**

Source: own computation

The VECM result of this thesis reviles among the three equations Ce1 is significant , a long run equilibrium (causality) running from the dependent variable Real GDP to all the explanatory variables since the error correction term is negative and P value is significant. This means that Ce1 explain the model is adjusting itself at the rate of 27 % towards the long run equilibrium respectively. This is certainly a significant and stable correction. What this means in other terms is, the coefficient of the speed of adjustments implies that 27% disturbance in the short run will be corrected each year.

Table 4.6: The Estimated Long- Run Model for lnAsroad (Real Gross Domestic Product)

lnAsroad	**Ce1**	**Ce2**	**Ce3**
Coff	**0.875**	**-0.14**	**0.147**
p>[z]	**0.0**	**0.001**	**0.122**
Result	**Not Significant**	**significant**	**Not significant**

Source: own computation

The VECM shows a long run equilibrium (causality) running from the dependent variable Asphalt road to all the explanatory variables since the error correction term is negative and P value is significant. This means that Ce2 explain the model is adjusting itself at the rate of 14 % towards the long run equilibrium respectively. This is certainly a significant and stable correction. What this means in other terms is, the coefficient of the speed of adjustments implies that 14% disturbance in the short run will be corrected each year.

Table 4.7: The Estimated Long- Run Model for lnGroad (Gravel road)

lnGroad	**Ce1**	**Ce2**	**Ce3**
Coff	**-0.11216**	**0.106**	**-0.62**
p>[z]	**0.8**	**0.302**	**0.009**
Result	**Not Significant**	**Not significant**	**significant**

Source: own computation

The VECM shows a long run equilibrium (causality) running from the dependent variable Gravel road to all the explanatory variables since the error correction term is negative and P value is significant. This means that Ce2 explain the model is adjusting itself at the rate of 62 % towards the long run equilibrium respectively. This is certainly a significant and stable correction. What this means in other terms is, the coefficient of the speed of adjustments implies that 62% disturbance in the short run will be corrected each year.

Table 4.8: The Estimated Long- Run Model for lnRroad (Ruler road)

lnRroad	**Ce1**	**Ce2**	**Ce3**
Coff	**0.32**	**-0.58**	**-0.59**
p>[z]	**0.001**	**0.001**	**0.009**
Result	**Not Significant**	**significant**	**Not significant**

Source: own computation

The VECM shows a long run equilibrium (causality) running from the dependent variable Ruler road to all the explanatory variables since the error correction term is negative and P value is significant. This means that Ce3 explain the model is adjusting itself at the rate of 58%towards the long run equilibrium respectively. This is certainly a significant and stable correction. What this means in other terms is, the coefficient of the speed of adjustments implies that 58% disturbance in the short run will be corrected each year.

4.7. Long-run Relationship

The aim of this study to investigate the impact of road infrastructure on the economic growth and the economic growth on road infrastructure, Johansen co-integration test indicates the presence of these Three co-integrating equations

Table 4.9: The Estimated Long- Run Model for lnRGDP (Real Gross Domestic Product)

Variable	**lnAsroad**	**lnGroad**	**lnRroad**	**lnKt**	**lnSE**	**Constant**
coefficient	**1.4**	**0.8**	**-0.54**	**-0.232**	**0.018**	**-7.8**
t-statistics	**8**	**2**	**-0.69**	**-0.11**	**0.63**	**-3.07**

R-squared== 0.95, Adj-R-squared=0.951

Source: own computation

$lnRGDP=1.4lnAsroad+0.8lnGroad-0.54lnRroad -0.23lnKt+0.018lnSE -7.8+\varepsilon$

The long run regression result in the above table indicated that Asphalt road, Gravel road and Ruler road is found statistically significant determinants of Real Gross Domestic product. The result shows that 1 percent increase in Asphalt road increases gross n national product t rate by 1.40 percent in the long run, 1% increase in Gavel road increase gross product rate by 0.8 percent and 1% increase in Ruler road decrease by 0.54%.

Table 5: The Estimated Long- Run Model for lnAsroad (Asphalt road)

Variable	lnRGDP	lnGroad	lnRroad	lnKt	lnSE	Constant
coefficient	0.14	0.69	0.1	0.07	0.5	-0.19
t-statistics	4.7	5.86	4.1	0.09	0.9	-0.24

R-squared== 0.98, Adj-R-squared=0.9819

Source: own computation

$lnAsroad= -0.19+0.14lnRGDP+0.69lnGroad+0.1lnRroad+0.07lnKt+0.5lnSE+\varepsilon$ t

The long run regression result in the above table indicated that Real Gross domestic product is found statistically significant determinants of Asphalt road. The result shows that 1 percent increase in gross domestic increases the asphalt rate by 0.14 percent in the long run.

Table 5.1: The Estimated Long- Run Model for lnGroad (Gravel road)

Variable	lnAsroad	lnRGDP	lnRroad	lnKt	lnSE	Constant
coefficient	-0.07	0.15	0.18	-0.0112	0.187	-7.03
t-statistics	2	0.69	10.66	-0.91	2.29	15.69

R-squared== 0.91, Adj-R-squared=0.905

$lnGroad=0.15lnRGDP-0.07lnAsroad +0.18lnRroad-0.187lnKt+0.189lnSE-7.03+\varepsilon$ t

The long run regression result in the above table indicated that Real Gross domestic product is found statistically significant determinants of Gravel road. The result shows that 1 percent increase in gross domestic increases the Gravel road rate by 0.15 percent in the long run.

Table 5.3: The Estimated Long- Run Model for lnRroad (Ruler road)

Variable	lnAsroad	lnGroad	lnRGDP	lnKt	lnSE	Constant
coefficient	-0.614	4.045	-0.218	0.053	1.55	-25.3
t-statistics	-1.05	10.66	-0.69	0.92	4.8	-6.38

R-squared== 0.95, Adj-R-squared=0.94

Source: own computation

lnRroad=-0.614lnAsroad+4.0045lnGroad-0.218lnRGDP+0.053ln Kt+1.55nSE+ε t

The long run regression result in the above table indicated that Real Gross domestic product is found statistically significant determinants of Ruler road. The result shows that 1 percent increase in RGDP decrease Ruler road the rate by 0.15 percent in the long run.

This result is in line with the Kwon,(2005) investment of road infrastructure increase the GDP growth, with 1% of provincial growth lead to 0.33%decline on poverty with province of good road and 0.09% for bad road. He also reveals Compared with other types of government investments, such as those in education and health, that the poverty rate is to public investment in roads, such that a 1 % increase in road investment is associated with a 0.3 % drop in poverty incidence over 5 years. Worku(2011) findings of the econometric results according the link between road length and economic growth, the results indicate that road network per worker is positively related with economic growth and that expansion of asphalt road has a positive influence on overall economic growth. Similarly, though statistically insignificant, gravel road has a positive impact on economic growth. Ng et al. (2018) also proved road infrastructure has positive relationship with economic growth infrastructure development with economic growth and he study demonstrate the growth in road length per thousand population, per capita export contributes positive for economic growth (Ng et al.2018).

4.8.SHORT RUN

Hereunder, we discuss the short run causality of the differenced individual lag of explanatory variables and that of their sum at a maximum lag order running from the explanatory variables to the dependent (target variable) .

H0: Null hypothesis =there is no short run

H1: Alt hypothesis= there is causality is short run

Short run causality test for Real GDP

Table 5.4: short run from RGDP to As road

```
 test ([D_lnRGDP]:LD.lnAsroad L2D.lnAsroad)

( 1)   [D_lnRGDP]LD.lnAsroad = 0
( 2)   [D_lnRGDP]L2D.lnAsroad = 0

           chi2(  2) =     5.39
         Prob > chi2 =     0.0675
```

.

Source: own computation

Table 5.5: short run from RGDP Groad.

```
. test ([D_lnRGDP]: LD.lnGroad L2D.lnGroad)

 ( 1)   [D_lnRGDP]LD.lnGroad = 0
 ( 2)   [D_lnRGDP]L2D.lnGroad = 0

           chi2(  2) =     4.57
         Prob > chi2 =     0.1018
```

Source: own computation

Table 5.6: short run from RGDP to Rroad.

```
 test ([D_lnRGDP]:LD.lnRroad L2D.lnRroad)

( 1)  [D_lnRGDP]LD.lnRroad = 0
( 2)  [D_lnRGDP]L2D.lnRroad = 0

          chi2(  2) =    1.30
        Prob > chi2 =    0.5217
```

Source: own computation

Table 5.7: short run from Asroad to RGDP

```
 test ([D_lnAsroad]: LD.lnRGDP L2D.lnRGDP)

( 1)  [D_lnAsroad]LD.lnRGDP = 0
( 2)  [D_lnAsroad]L2D.lnRGDP = 0

          chi2(  2) =    6.89
        Prob > chi2 =    0.0320
```

Source: own computation

As can be seen from the test statistics result above, there is short run causality running from lags of Asroad to GDP which is consistent to theories and our predictions. Hence, the test result shows that the expanding paved road infrastructure investments in various part of the country can be explained by a short run impact that it has in the country's economic growth

Short run causality test for Gravel Road

Table 5.8: Short run causality test for Gravel and RGDP road

```
. test ([D_lnRroad]: LD.lnRGDP L2D.lnRGDP)

 ( 1)  [D_lnRroad]LD.lnRGDP = 0
 ( 2)  [D_lnRroad]L2D.lnRGDP = 0

           chi2(  2) =    1.69
         Prob > chi2 =    0.4300
```

Source: own computation

Short run causality test for Rular Road

Table5.9: Short run causality test for Gravel and RGDP road

```
. test ([D_lnGroad]: LD.lnRGDP L2D.lnRGDP)

 ( 1)  [D_lnGroad]LD.lnRGDP = 0
 ( 2)  [D_lnGroad]L2D.lnRGDP = 0

           chi2(  2) =    0.41
         Prob > chi2 =    0.8134
```

Source: own computation

As can be seen from the test statistics, there is no short run causality running from lags of Gravel, and ruler road which creates paradox and inconsistent to most of the theories however, its impact on Asphalt in the long term may have contributed to the existence of long run equilibrium**.**

4.9. Diagnostic Tests

Diagnostics test are usually undertaken to detect whether the model is consistent or not and as a guide for model improvement. Multicollinearity, serial correlation, normality and heteroscedasticity are among the diagnostic tests.

Multicollinearity test is one of the pre-requisites tests of the empirical analysis. If two explanatory variables are perfectly correlated, it would be difficult to identify the independent impact of each explanatory variable on the dependent variable. In this case a formal test of multicollinearity has to be conducted to determine which variable to retain and which one to exclude from the final analysis.

In order to identify the multicollinearity test formally, variance inflation factor [VIF] is used. If VIF is greater than 10 and the reciprocal is less than 0.1 the test indicates the existence of multicollinearity among predictor variables. The result shows that the variance inflation factor is less than 10 and the tolerance (1/VIF) is greater than 0.1 for all independent variables, which confirm the absence of the multicollinearity among the independent variables.

Table 6: Multicollinearity Test

```
. estat vif
```

Variable	VIF	1/VIF
lnRroad	15.37	0.065061
lnSE	12.65	0.079033
lnGroad	10.27	0.097331
lnAsroad	9.36	0.106854
lnKt	2.06	0.485273
Mean VIF	9.94	

Source: STATA 14 result

The study conducted different post-estimation diagnostic tests to guarantee that the residuals from the model are Gaussian that the assumptions are not violated and the estimation results and inferences are trustworthy. The serial correlation test can be done using the Lagrange multiplier

(LM) test. It helps to identify the relationship that may exist between the current value of the regression residual.

4.9.1 Residual Vector Serial Correlation LM Tests

The Breusch- Godfrey Lagrange Multiplier (LM) serial correlation test is shows from the above table there is a of the presence of serial correlation since the p- value is less than five percent at lag 1 and 2 so the null hypothesis is rejected and accept the alternative hypothesis and proceed At lag 3 the p value is greater than 5% so there is no serial correlation, fortunately the lag selection criteria reviles the data is significant at lag three.

Table 6.1: Breusch- Godfrey Serial Correlation LM Test

```
varlmar, mlag(4)
```

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	69.5573	36	0.00066
2	51.2859	36	0.04729
3	38.4143	36	0.36068
4	31.2276	36	0.69492

H0: no autocorrelation at lag order

Source: STATA 14 result

4.9.2 Residual Vector Normality (Jarque-Bera) Test

In order to check the normality of the residuals Jarque-Bera statistics test is undertaken. The J.B. test result reveals the presence of normality for the models such as asphalt road, gravel road, ruler road and capital stock exchange rate.But the normality test result for real gross domestic and secondary school enrollment. indicates the rejections of the null hypothesis of residuals are normally distributed for the reason that the p-value associated with the Jaque-Berra normality test is less than the standard significance level of five percent. This is due to the lack of large sample of property of the variable and can be solved by increasing the size of variables.

Table 6.2: Jarque-Bera Normality Test

```
varnorm,jbera

Jarque-Bera test
```

Equation	chi2	df	Prob > chi2
lnRGDP	391.344	2	0.00000
lnAsroad	0.112	2	0.94534
lnGroad	1.537	2	0.46376
lnRroad	1.073	2	0.58492
lnKt	0.350	2	0.83944
lnSE	5.993	2	0.04996
ALL	400.408	12	0.00000

Source: STATA 14 result

4.9.3. Residual Vector Heteroscedasticity Test

The last diagnostic test is for heteroscedasticity test. As we have seen from table4.4, we can reject at 5% significant level due to its p-value associated with the test statistics are greater than the standard significance level that is 0.05.

Table 6.3: Jarque-Bera Normality Test

```
White's test for Ho: homoskedasticity
         against Ha: unrestricted heteroskedasticity

         chi2(20)      =     32.47
         Prob > chi2   =    0.0385

Cameron & Trivedi's decomposition of IM-test
```

Source	chi2	df	p
Heteroskedasticity	32.47	20	0.0385
Skewness	5.10	5	0.4036
Kurtosis	0.92	1	0.3376
Total	38.49	26	0.0545

Source: STATA 14 result

CHAPTER FIVE

Conclusion and Recommendation

5.1 CONCLUSIONS

The main purpose of this analysis was to investigate the causal relationship between Road infrastructure of on economic growth in Ethiopia using a time series data running from 1975 to 2019 and vise-versa. The research employed a method of co-integrated VECM approach or vector error correction to define the short- and long-term relationship between variables and Some econometric empirical inferences such as stationarity, cointegration and the long run diagnostic tests were employed to grasp the nature of time series data

Prior of conducting VECM, the Augmented Dickey Fuller test is conducted as a result, RGDP, Asroad, Groad , Rroad Kt and SE is stationary at first difference Following stationarity test, model stability test was carried out in the study and the result shows the absence of multi-collinearity, serial correlation, heteroscedasticity problem and abnormal distribution of the residuals, than after the co-integration test indicates the existence of long run relationships between the variables included in the model.

The major finding of the study is the long run model of t Asphalt road and Gravel road have a positive and significant effect on economic growth in the long-term effect while Ruler road have negative effect on the economic growth on the long run. In other case real gross domestic product has positive and significant effect on the Asphalt road gravel road while negative effect on the ruler road in the long run. However, the asphalt road is the only variable that have short-run effect on economic growth. and the VCEM matrix revealed that there is a long run equilibrium to which short run dynamics adjustment for Real gross domestic, Asphalt road, Gravel road and ruler road is 27%,14%62% and 59% percent respectively

The result of this research is inline with most of the research such as, Kwon’s (2005) study reveals that the poverty rate is to public investment in roads, such that a 1 % increase in road investment is associated with a 0.3 % drop in poverty incidence over 5 years, Ng et al. (2018) has also found infrastructure has positive relationship with economic growth infrastructure development with economic growth. Zelalem (2013) reveals the government spending on road has significant and positive effect on economic growth (GDP) in the long run. Zelalem also find a positive short-run relationship between road infrastructure and economic growth which contradicts to the finding of this thesis. Worku (2011) has also found the that road network per worker is positively related with economic growth and that expansion of asphalt road has a positive influence on overall economic growth. However the finding about gravel and ruler contradict with this study, gravel road has insignificant and a positive impact on economic growth while rural road has positive impact on economic growth.

5.2. Recommendation

Based on the findings of the study the following policy recommendations are suggested:

- The that emerges from this study is that the Ethiopian policymakers should be aware of causality running from Asphalt road and Gravel road to real economic growth and from economic growth to Asphalt road and Gravel road infrastructure. Policy makers should put in place measures to boost gross domestic product so that investment in road infrastructure should be appropriately mobilized and directed towards productive investments specifically on paved road and gravel road and hence growth would be accelerated.
- Road infrastructure and economic has positive relationship so that the policy makers should consider to put a direction about the maintenance of road infrastructure in order to achieve sustainable economic growth.
- Community roads should be given sufficient attention both in terms of expansion, management, and accountancy by either regional or federal road authorities. At this point, Ethiopian Road Authority should design an easy way to get detailed information regarding community road networks from regional road authorities. Future community road expansion needs to be an integral part of the road networks as these might be an easy way to ascertain access to the destitute rural poor. Community roads are supposed to better reflect the community demand of which roads should be constructed or upgraded.

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APPENDICES

APPENDIX: **A ADF Unit Root Test Result**

Dependent Variable (lnRGDP)

Intercept only at level

`

```
. dfuller lnRGDP, regress lags(1)

Augmented Dickey-Fuller test for unit root          Number of obs   =        43

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)              2.317            -3.628            -2.950            -2.608
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.9990

------------------------------------------------------------------------------
    D.lnRGDP |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lnRGDP |
         L1. |   .0560467   .0241937     2.32   0.026     .0071495    .1049439
         LD. |  -.0549107   .1718872    -0.32   0.751    -.4023076    .2924862
             |
       _cons |  -.6188988   .2931886    -2.11   0.041    -1.211455   -.0263426
------------------------------------------------------------------------------
```

Intercept only at first difference

Trend and intercept at level

```
. dfuller lnRGDP, trend regress lags(1)

Augmented Dickey-Fuller test for unit root          Number of obs   =        43
```

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-0.253	-4.214	-3.528	-3.197

MacKinnon approximate p-value for Z(t) = 0.9905

D.lnRGDP	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnRGDP						
L1.	-.013313	.0526398	-0.25	0.802	-.119787	.0931609
LD.	-.0321116	.1700987	-0.19	0.851	-.3761687	.3119455
_trend	.0049666	.0033605	1.48	0.147	-.0018306	.0117638
_cons	.121546	.5783502	0.21	0.835	-1.048278	1.29137

Trend at first difference

```
. dfuller lnRGDP_d1, regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        42
```

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-3.964	-3.634	-2.952	-2.610

MacKinnon approximate p-value for Z(t) = 0.0016

D.lnRGDP_d1	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnRGDP_d1						
L1.	-.8203151	.2069531	-3.96	0.000	-1.238917	-.4017131
LD.	-.0378479	.1589343	-0.24	0.813	-.3593229	.2836271
_cons	.0585588	.0234211	2.50	0.017	.0111851	.1059325

Trend and intercept at first difference

```
. dfuller lnRGDP_d1, trend regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        42
```

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(t)	-5.199	-4.224	-3.532	-3.199

```
MacKinnon approximate p-value for Z(t) = 0.0001
```

D.lnRGDP_d1	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnRGDP_d1						
L1.	-1.231389	.2368649	-5.20	0.000	-1.710897	-.7518809
LD.	.1734777	.1629242	1.06	0.294	-.1563452	.5033006
_trend	.0050944	.0017574	2.90	0.006	.0015368	.008652
_cons	-.0278271	.0367296	-0.76	0.453	-.1021823	.0465281

Dependent Variable: D (lnAsroad)

Intercept only at level

```
. dfuller lnAsroad, regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        43

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -4.286            -3.628            -2.950            -2.608
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0005
```

D.lnAsroad	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnAsroad						
L1.	-.0364481	.0085038	-4.29	0.000	-.0536348	-.0192613
LD.	-.2433576	.1480554	-1.64	0.108	-.5425887	.0558736
_cons	.3759009	.0797502	4.71	0.000	.2147197	.5370821

Intercept only at first difference

```
. dfuller lnAsroad_d1, regress lags(1)

Augmented Dickey-Fuller test for unit root          Number of obs   =        42

                              ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.184            -3.634            -2.952            -2.610
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0209

------------------------------------------------------------------------------
D.           |
 lnAsroad_d1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 lnAsroad_d1 |
         L1. |  -.6801162   .2136247    -3.18   0.003    -1.112213   -.2480193
         LD. |  -.2856863   .1547976    -1.85   0.073     -.598794    .0274213
             |
       _cons |   .0249909   .0088591     2.82   0.007     .0070716    .0429101
------------------------------------------------------------------------------
```

Trend and intercept at level

```
. dfuller lnAsroad, trend regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        43

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.460            -4.214            -3.528            -3.197
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0439

------------------------------------------------------------------------------
D.lnAsroad |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lnAsroad |
         L1. |  -.1638806   .0473675    -3.46   0.001    -.2596904   -.0680708
         LD. |  -.2479861   .1374108    -1.80   0.079    -.5259257    .0299536
      _trend |   .0044716   .0016389     2.73   0.009     .0011566    .0077865
       _cons |   1.427412   .3924326     3.64   0.001      .633642    2.221182
------------------------------------------------------------------------------
```

Trend and intercept at first difference

```
. dfuller lnAsroad_d1, trend regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        42
```

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-4.883	-4.224	-3.532	-3.199

MacKinnon approximate p-value for Z(t) = 0.0003

D.lnAsroad~1	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnAsroad_d1						
L1.	-1.199479	.245664	-4.88	0.000	-1.696799	-.702158
LD.	-.0180253	.1594423	-0.11	0.911	-.3407993	.3047487
_trend	-.0012273	.0003673	-3.34	0.002	-.0019708	-.0004838
_cons	.0719803	.0161233	4.46	0.000	.0393403	.1046203

Dependent Variable: D (lnGroad)

Intercept only at level

```
. dfuller lnGroad, regress lags(1)
```

Augmented Dickey-Fuller test for unit root   Number of obs   =   43

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-2.390	-3.628	-2.950	-2.608

MacKinnon approximate p-value for Z(t) = 0.1447

D.lnGroad	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnGroad						
L1.	-.0630531	.0263872	-2.39	0.022	-.1163837	-.0097226
LD.	.107502	.148683	0.72	0.474	-.1929976	.4080015
_cons	.6006445	.2456876	2.44	0.019	.1040913	1.097198

Intercept only at first difference

```
. dfuller lnGroad_d1, trend regress lags(1)
```

Augmented Dickey-Fuller test for unit root   Number of obs   =   42

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-4.915	-4.224	-3.532	-3.199

MacKinnon approximate p-value for Z(t) = 0.0003

D.lnGroad_d1	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnGroad_d1						
L1.	-1.073995	.2185006	-4.92	0.000	-1.516327	-.631664
LD.	.1368643	.1593136	0.86	0.396	-.1856491	.4593778
_trend	-.0015015	.0006393	-2.35	0.024	-.0027957	-.0002072
_cons	.052066	.0178594	2.92	0.006	.0159115	.0882205

Trend and intercept at level

```
. dfuller lnGroad, trend regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        43

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.096            -4.214            -3.528            -3.197
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.9297

------------------------------------------------------------------------------
D.lnGroad    |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     lnGroad |
         L1. |   -.086448   .0788831    -1.10   0.280    -.2460042    .0731081
         LD. |   .1315404    .168622     0.78   0.440    -.2095299    .4726107
      _trend |   .0005392   .0017107     0.32   0.754    -.0029211    .0039994
       _cons |   .8051154   .6947386     1.16   0.254    -.6001261    2.210357
------------------------------------------------------------------------------
```

Trend and intercept at first difference

```
. dfuller lnGroad_d1, trend regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        42
```

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(t)	-4.915	-4.224	-3.532	-3.199

```
MacKinnon approximate p-value for Z(t) = 0.0003
```

D.lnGroad_d1	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnGroad_d1						
L1.	-1.073995	.2185006	-4.92	0.000	-1.516327	-.631664
LD.	.1368643	.1593136	0.86	0.396	-.1856491	.4593778
_trend	-.0015015	.0006393	-2.35	0.024	-.0027957	-.0002072
_cons	.052066	.0178594	2.92	0.006	.0159115	.0882205

Dependent Variable: D (lnRroad)

Intercept only at level

```
. dfuller lnRroad, regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        43

                              ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -5.319            -3.628            -2.950            -2.608
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
   D.lnRroad |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     lnRroad |
         L1. |  -.1538655   .0289288    -5.32   0.000    -.2123329   -.0953982
         LD. |  -.0984519   .1364599    -0.72   0.475    -.3742476    .1773438
             |
       _cons |   1.534297   .2745079     5.59   0.000     .9794959    2.089098
------------------------------------------------------------------------------
```

Intercept only at first difference

```
.
. dfuller lnRroad_d1, regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        42

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)            -12.302            -3.634            -2.952            -2.610
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
D.lnRroad_d1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  lnRroad_d1 |
         L1. |  -.7807449   .0634624   -12.30   0.000    -.9091098     -.65238
         LD. |  -.1648307   .0540016    -3.05   0.004    -.2740592   -.0556022
             |
       _cons |   .0636706   .0164545     3.87   0.000     .0303883    .0969529
------------------------------------------------------------------------------
```

Trend and intercept at level

```
. dfuller lnRroad, trend regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        43

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)           -11.378            -4.214            -3.528            -3.197
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000
```

D.lnRroad	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnRroad						
L1.	-.4998822	.0439351	-11.38	0.000	-.5887494	-.411015
LD.	-.2586926	.0835463	-3.10	0.004	-.4276808	-.0897043
_trend	.0354645	.004141	8.56	0.000	.0270886	.0438404
_cons	3.862043	.3173363	12.17	0.000	3.220169	4.503916

Trend and intercept at first difference

Dependent Variable: D (lnKt)

Intercept only at level

```
. dfuller lnKt, regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        43
```

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(t)	-2.219	-3.628	-2.950	-2.608

MacKinnon approximate p-value for Z(t) = 0.1995

D.lnKt	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnKt						
L1.	-.3572675	.1610182	-2.22	0.032	-.6826975	-.0318375
LD.	-.2699184	.1524101	-1.77	0.084	-.5779506	.0381138
_cons	4.041041	1.768754	2.28	0.028	.4662551	7.615827

Intercept only at first difference

```
. dfuller lnRroad_d1, trend regress lags(1)
```

Augmented Dickey-Fuller test for unit root   Number of obs = 42

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-12.434	-4.224	-3.532	-3.199

MacKinnon approximate p-value for Z(t) = 0.0000

D.lnRroad_d1	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnRroad_d1						
L1.	-.8907792	.0716379	-12.43	0.000	-1.035803	-.7457559
LD.	-.1056919	.0547002	-1.93	0.061	-.2164268	.0050429
_trend	-.0034673	.001285	-2.70	0.010	-.0060687	-.0008658
_cons	.1573196	.0379192	4.15	0.000	.0805562	.2340831

intercept at level

```
. dfuller lnKt, regress lags(1)

Augmented Dickey-Fuller test for unit root          Number of ob

                               ———————————— Interpolated Dickey-F
                  Test         1% Critical       5% Critical
               Statistic           Value             Value
------------------------------------------------------------------
 Z(t)            -2.219            -3.628            -2.950
------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.1995

------------------------------------------------------------------
      D.lnKt |      Coef.   Std. Err.       t    P>|t|      [95% 
-------------+----------------------------------------------------
        lnKt |
         L1. |  -.3572675   .1610182    -2.22   0.032     -.6826
         LD. |  -.2699184   .1524101    -1.77   0.084     -.5779
             |
       _cons |   4.041041   1.768754     2.28   0.028      .4662
------------------------------------------------------------------
```

Trend and intercept at level

```
. dfuller lnKt, trend regress lags(1)
```

Augmented Dickey-Fuller test for unit root   Number of obs   =   43

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(t)	-3.398	-4.214	-3.528	-3.197

MacKinnon approximate p-value for Z(t) = 0.0517

D.lnKt	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnKt						
L1.	-.6900962	.203116	-3.40	0.002	-1.100937	-.2792553
LD.	-.1210574	.1557733	-0.78	0.442	-.4361386	.1940238
_trend	.0474063	.0192399	2.46	0.018	.0084899	.0863228
_cons	6.58729	1.960717	3.36	0.002	2.621366	10.55321

D_lnAsroad						
_ce1						
L1.	.0875158	.0233478	3.75	0.000	.0417549	.1332767
_ce2						
L1.	-.1410811	.0414665	-3.40	0.001	-.2223539	-.0598083
_ce3						
L1.	.1479994	.0968614	1.53	0.127	-.0418455	.3378444
lnRGDP						
LD.	-.0714655	.0350145	-2.04	0.041	-.1400927	-.0028383
L2D.	-.0668524	.0300898	-2.22	0.026	-.1258273	-.0078775
lnAsroad						
LD.	-.5305511	.1885102	-2.81	0.005	-.9000242	-.161078
L2D.	-.3549363	.1841385	-1.93	0.054	-.7158411	.0059686
lnGroad						
LD.	.0099896	.0783357	0.13	0.899	-.1435456	.1635247
L2D.	-.0514131	.0799154	-0.64	0.520	-.2080444	.1052181
lnRroad						
LD.	-.0163184	.0205461	-0.79	0.427	-.0565881	.0239512
L2D.	-.0321803	.0207328	-1.55	0.121	-.0728159	.0084553
lnKt						
LD.	.0135225	.0049288	2.74	0.006	.0038622	.0231829
L2D.	.0057314	.0033012	1.74	0.083	-.0007388	.0122016
lnSE						

—more—

intercept at first difference

```
. dfuller lnKt_d1,  regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        42

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -7.072            -3.634            -2.952            -2.610
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
   D.lnKt_d1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     lnKt_d1 |
         L1. |  -1.845341    .260953    -7.07   0.000    -2.373169   -1.317514
         LD. |   .2603798    .149104     1.75   0.089    -.0412115     .561971
             |
       _cons |   .1691561   .1989705     0.85   0.400    -.2332997    .5716118
------------------------------------------------------------------------------
```

Trend and intercept at first difference

```
. dfuller lnKt_d1, trend regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        42

                               ---------- Interpolated Dickey-Fuller ----------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -7.014            -4.224            -3.532            -3.199
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
D.lnKt_d1    |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     lnKt_d1 |
         L1. |   -1.85701   .2647486    -7.01   0.000    -2.392966   -1.321054
         LD. |   .2681886   .1515176     1.77   0.085    -.0385428    .5749199
      _trend |   .0078146   .0165525     0.47   0.640    -.0256943    .0413235
       _cons |  -.0056704   .4213368    -0.01   0.989    -.8586222    .8472815
------------------------------------------------------------------------------
```

Dependent Variable: D (lnSE)

Intercept only at level

```
. dfuller lnSE,  regress lags(1)
```

Augmented Dickey-Fuller test for unit root   Number of obs   =   43

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	0.003	-3.628	-2.950	-2.608

MacKinnon approximate p-value for Z(t) = 0.9588

D.lnSE	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnSE						
L1.	.0001193	.0364117	0.00	0.997	-.0734715	.0737101
LD.	.2912432	.1579588	1.84	0.073	-.0280034	.6104899
_cons	.0354597	.095546	0.37	0.713	-.1576459	.2285653

Intercept only at first difference

```
. dfuller lnSE_d1,  regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        42
```

		Interpolated Dickey-Fuller		
	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-3.899	-3.634	-2.952	-2.610

MacKinnon approximate p-value for Z(t) = 0.0020

D.lnSE_d1	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnSE_d1						
L1.	-.7419799	.1903048	-3.90	0.000	-1.126908	-.3570522
LD.	.0456346	.1601381	0.28	0.777	-.2782753	.3695445
_cons	.0370993	.0190143	1.95	0.058	-.0013608	.0755595

Trend and intercept at level

```
. dfuller lnSE,  trend regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        43

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.287            -4.214            -3.528            -3.197
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.8911

------------------------------------------------------------------------------
D.lnSE       |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        lnSE |
         L1. |  -.0930668   .0723045    -1.29   0.206    -.2393164    .0531828
         LD. |   .3514333   .1608301     2.19   0.035     .0261236    .6767429
      _trend |   .0038283    .002579     1.48   0.146    -.0013882    .0090449
       _cons |   .1905896   .1406549     1.36   0.183    -.0939117    .4750908
------------------------------------------------------------------------------
```

Trend and intercept at first difference

```
. dfuller lnSE_d1,  trend regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        42

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)            -3.969            -4.224            -3.532            -3.199
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0097

------------------------------------------------------------------------------
D.lnSE_d1    |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     lnSE_d1 |
         L1. |  -.7710079    .194273    -3.97   0.000    -1.164293   -.3777229
         LD. |    .060363   .1617719     0.37   0.711    -.2671271    .3878532
      _trend |     .00114   .0013778     0.83   0.413    -.0016492    .0039291
       _cons |   .0129284   .0348982     0.37   0.713    -.0577192     .083576
------------------------------------------------------------------------------
```

APPENDIX B: TheRegressed Variables

```
reg lnRGDP lnAsroad lnGroad lnRroad lnSE lnKt

      Source |       SS           df       MS      Number of obs   =        45
-------------+----------------------------------   F(5, 39)        =    174.74
       Model |  33.5404709         5  6.70809418   Prob > F        =    0.0000
    Residual |  1.49717713        39  .038389157   R-squared       =    0.9573
-------------+----------------------------------   Adj R-squared   =    0.9518
       Total |   35.037648        44  .796310182   Root MSE        =    .19593

------------------------------------------------------------------------------
      lnRGDP |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lnAsroad |   1.493127   .1765531     8.46   0.000     1.136014    1.850239
     lnGroad |   .8403668   .3500924     2.40   0.021      .132238    1.548496
     lnRroad |  -.0545653    .079499    -0.69   0.497    -.2153672    .1062366
        lnSE |   -.023035   .2041289    -0.11   0.911    -.4359247    .3898547
        lnKt |   .0182986   .0292479     0.63   0.535    -.0408609    .0774581
       _cons |  -7.820267   2.547162    -3.07   0.004    -12.97239   -2.668147
------------------------------------------------------------------------------
```

```
reg  lnAs1road lnRGDP lnGroad lnRroad lnSE lnKt

      Source |       SS           df       MS      Number of obs   =        45
-------------+----------------------------------   F(5, 39)        =    478.33
       Model |  9.19859241         5  1.83971848   Prob > F        =    0.0000
    Residual |  .149999101        39  .003846131   R-squared       =    0.9840
-------------+----------------------------------   Adj R-squared   =    0.9819
       Total |  9.34859151        44  .212467989   Root MSE        =    .06202

------------------------------------------------------------------------------
   lnAs1road |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lnRGDP |   .1430384    .030108     4.75   0.000     .0821392    .2039377
     lnGroad |   .6920308   .1181307     5.86   0.000     .4530888    .9309728
     lnRroad |   .1023024   .0249666     4.10   0.000     .0518028    .1528021
        lnSE |   .0500506   .0556212     0.90   0.374    -.0624539     .162555
        lnKt |   .0007774   .0091403     0.09   0.933    -.0177105    .0192653
       _cons |  -.1966871   .8320466    -0.24   0.814     -1.87966    1.486286
------------------------------------------------------------------------------
```

```
. reg  lnRroad lnRGDP lnAsroad lnGroad lnKt  lnSE

      Source |       SS           df       MS      Number of obs   =        45
-------------+----------------------------------   F(5, 39)        =    113.54
       Model |  87.3592908         5  17.4718582   Prob > F        =    0.0000
    Residual |  6.00165157        39  .153888502   R-squared       =    0.9357
-------------+----------------------------------   Adj R-squared   =    0.9275
       Total |  93.3609424        44   2.1218396   Root MSE        =    .39229

------------------------------------------------------------------------------
     lnRroad |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lnRGDP |  -.2187328   .3186832    -0.69   0.497    -.8633305    .4258649
    lnAsroad |   -.614391     .58688    -1.05   0.302    -1.801468    .5726857
     lnGroad |   4.045902   .3797119    10.66   0.000     3.277862    4.813942
        lnKt |   .0537096   .0582203     0.92   0.362    -.0640521    .1714714
        lnSE |   1.555094    .324162     4.80   0.000     .8994148    2.210774
       _cons |  -25.36068   3.975281    -6.38   0.000    -33.40144   -17.31991
------------------------------------------------------------------------------
```

```
. reg lnGroad lnRGDP lnAsroad lnRroad lnSE lnKt

      Source |       SS           df       MS      Number of obs   =        45
-------------+----------------------------------   F(5, 39)        =     84.18
       Model |  2.94515708         5  .589031417   Prob > F        =    0.0000
    Residual |  .272896762        39  .006997353   R-squared       =    0.9152
-------------+----------------------------------   Adj R-squared   =    0.9043
       Total |  3.21805385        44  .073137587   Root MSE        =    .08365

------------------------------------------------------------------------------
     lnGroad |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lnRGDP |   .1531772   .0638128     2.40   0.021     .0241036    .2822508
    lnAsroad |  -.0786542   .1262645    -0.62   0.537    -.3340481    .1767398
     lnRroad |   .1839683   .0172656    10.66   0.000     .1490453    .2188913
        lnSE |  -.1876022    .081824    -2.29   0.027    -.3531069   -.0220976
        lnKt |   -.011282   .0124188    -0.91   0.369    -.0364014    .0138373
       _cons |   7.030968   .4481926    15.69   0.000     6.124413    7.937524
------------------------------------------------------------------------------
```

APPENDIX. C. Vector error-correction model.

Vector error-correction model

Sample: 4 - 45		Number of obs	= 42
		AIC	= -11.89879
Log likelihood =	354.8745	HQIC	= -10.30647
Det(Sigma_ml) =	1.85e-15	SBIC	= -7.554612

Equation	Parms	RMSE	R-sq	chi2	P>chi2
D_lnRGDP	16	.115006	0.5660	32.60823	0.0083
D_lnAsroad	16	.016821	0.9125	260.6057	0.0000
D_lnGroad	16	.041698	0.5589	31.6704	0.0110
D_lnRroad	16	.070596	0.8386	129.8945	0.0000
D_lnSE	16	.073698	0.7584	78.48048	0.0000
D_lnKt	16	.982148	0.7139	62.38954	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
D_lnRGDP						
_ce1						
L1.	-.2733355	.084041	-3.25	0.001	-.4380529	-.1086182
_ce2						
L1.	1.008326	.2394232	4.21	0.000	.5390654	1.477587
_ce3						
L1.	1.2087	.4605111	2.62	0.009	.3061144	2.111285
lnRGDP						
LD.	-.237456	.157458	-1.51	0.132	-.5460681	.0711561
L2D.	-.203643	.1440829	-1.41	0.158	-.4860403	.0787544
lnAsroad						
LD.	-1.170187	.560039	-2.09	0.037	-2.267843	-.0725305
L2D.	-.4031909	.5624428	-0.72	0.473	-1.505559	.6991767
lnGroad						
LD.	-.2136166	.414753	-0.52	0.607	-1.026518	.5992845
L2D.	-.8910329	.4204126	-2.12	0.034	-1.715027	-.0670393
lnRroad						
LD.	-.0002395	.0818466	-0.00	0.998	-.1606558	.1601768
L2D.	-.101695	.0938443	-1.08	0.279	-.2856264	.0822364
lnKt						
LD.	.033205	.025344	1.31	0.190	-.0164683	.0828783
L2D.	.0434241	.0175787	2.47	0.014	.0089706	.0778777
lnSE						
LD.	-.0222214	.1923522	-0.12	0.908	-.3992247	.354782

—more—

D_lnAsroad						
_ce1						
L1.	.0875158	.0233478	3.75	0.000	.0417549	.1332767
_ce2						
L1.	-.1410811	.0414665	-3.40	0.001	-.2223539	-.0598083
_ce3						
L1.	.1479994	.0968614	1.53	0.127	-.0418455	.3378444
lnRGDP						
LD.	-.0714655	.0350145	-2.04	0.041	-.1400927	-.0028383
L2D.	-.0668524	.0300898	-2.22	0.026	-.1258273	-.0078775
lnAsroad						
LD.	-.5305511	.1885102	-2.81	0.005	-.9000242	-.161078
L2D.	-.3549363	.1841385	-1.93	0.054	-.7158411	.0059686
lnGroad						
LD.	.0099896	.0783357	0.13	0.899	-.1435456	.1635247
L2D.	-.0514131	.0799154	-0.64	0.520	-.2080444	.1052181
lnRroad						
LD.	-.0163184	.0205461	-0.79	0.427	-.0565881	.0239512
L2D.	-.0321803	.0207328	-1.55	0.121	-.0728159	.0084553
lnKt						
LD.	.0135225	.0049288	2.74	0.006	.0038622	.0231829
L2D.	.0057314	.0033012	1.74	0.083	-.0007388	.0122016
lnSE						

—more—

D_lnGroad						
_ce1						
L1.	-.0112116	.0578786	-0.19	0.846	-.1246515	.1022282
_ce2						
L1.	.1061164	.1027942	1.03	0.302	-.0953564	.3075893
_ce3						
L1.	-.6247148	.2401167	-2.60	0.009	-1.095335	-.1540948
lnRGDP						
LD.	.0460598	.0868	0.53	0.596	-.1240649	.2161846
L2D.	-.012765	.0745917	-0.17	0.864	-.158962	.133432
lnAsroad						
LD.	-.5258129	.4673111	-1.13	0.261	-1.441726	.3901
L2D.	-.091654	.456474	-0.20	0.841	-.9863265	.8030186
lnGroad						
LD.	.2920627	.1941919	1.50	0.133	-.0885463	.6726718
L2D.	.1893037	.1981078	0.96	0.339	-.1989805	.5775879
lnRroad						
LD.	.0480318	.0509332	0.94	0.346	-.0517954	.147859
L2D.	.0559762	.0513961	1.09	0.276	-.0447583	.1567106
lnKt						
LD.	.0189548	.0122184	1.55	0.121	-.0049929	.0429024
L2D.	.0157944	.0081835	1.93	0.054	-.000245	.0318339

—more—

D_lnGroad						
_ce1						
L1.	-.0112116	.0578786	-0.19	0.846	-.1246515	.1022282
_ce2						
L1.	.1061164	.1027942	1.03	0.302	-.0953564	.3075893
_ce3						
L1.	-.6247148	.2401167	-2.60	0.009	-1.095335	-.1540948
lnRGDP						
LD.	.0460598	.0868	0.53	0.596	-.1240649	.2161846
L2D.	-.012765	.0745917	-0.17	0.864	-.158962	.133432
lnAsroad						
LD.	-.5258129	.4673111	-1.13	0.261	-1.441726	.3901
L2D.	-.091654	.456474	-0.20	0.841	-.9863265	.8030186
lnGroad						
LD.	.2920627	.1941919	1.50	0.133	-.0885463	.6726718
L2D.	.1893037	.1981078	0.96	0.339	-.1989805	.5775879
lnRroad						
LD.	.0480318	.0509332	0.94	0.346	-.0517954	.147859
L2D.	.0559762	.0513961	1.09	0.276	-.0447583	.1567106
lnKt						
LD.	.0189548	.0122184	1.55	0.121	-.0049929	.0429024
L2D.	.0157944	.0081835	1.93	0.054	-.000245	.0318339

—more—

D_lnRroad						
_ce1						
L1.	.3243828	.0979908	3.31	0.001	.1323245	.5164412
_ce2						
L1.	-.5878358	.1740347	-3.38	0.001	-.9289376	-.2467341
_ce3						
L1.	.5957155	.4065273	1.47	0.143	-.2010633	1.392494
lnRGDP						
LD.	-.189566	.1469559	-1.29	0.197	-.4775942	.0984622
L2D.	-.0713292	.1262868	-0.56	0.572	-.3188467	.1761883
lnAsroad						
LD.	-1.602572	.7911768	-2.03	0.043	-3.15325	-.0518938
L2D.	-.4811557	.7728291	-0.62	0.534	-1.995873	1.033562
lnGroad						
LD.	-.1244854	.3287748	-0.38	0.705	-.7688721	.5199013
L2D.	-.1873764	.3354046	-0.56	0.576	-.8447574	.4700046
lnRroad						
LD.	-.2301093	.086232	-2.67	0.008	-.3991209	-.0610977
L2D.	-.0814511	.0870157	-0.94	0.349	-.2519987	.0890964
lnKt						
LD.	.0408814	.0206863	1.98	0.048	.000337	.0814258
L2D.	.0371773	.0138551	2.68	0.007	.0100219	.0643327

—more—

APPENDIX D . The Time Series Data Used for the Study

year	Real GDP	Asphalt	Gravel	Rular	al Inflation	interst rat	SE
1975	97651	3280	6080	52	4.8	6.0	5.424
1976	98835	3200	6200	120	29.6	6.0	5.884
1977	99589	3126	6290	652	11.6	6.0	6.354
1978	99233	3051	6801	790	18.5	6.0	6.824
1979	102859	3115	7328	1091	18.5	6.0	7.304
1980	108023	3285	7328	1595	3.9	6.0	7.794
1981	108920	3515	7430	1830	5.4	6.0	8.284
1982	109170	3769	8532	2630	5.2	6.0	9.784
1983	120202	3916	8532	3053	-0.2	6.0	11.33
1984	111616	4000	8738	3420	9.0	6.0	12.5
1985	101803	4042	8788	3808	20.5	6.0	12.8
1986	111910	4050	8989	4198	-11.8	6.0	13.01
1987	126611	4062	8994	5158	-4.7	4.0	14.08
1988	125936	4109	9270	5232	6.9	4.0	15.33
1989	126868	4109	9270	5232	11.1	4.0	15.27
1990	132336	4109	9287	5550	5.0	4.0	13.94
1991	128347	4109	9298	5610	45.0	4.0	13.93
1992	125406	3542	8966	5573	2.1	4.0	12.18
1993	139412	3555	9011	5800	4.7	10.0	10.83
1994	139480	3622	10100	7812	6.3	10.0	10.46
1995	147455	3630	12000	8043	14.8	10.0	10.49
1996	162373	3656	12133	9100	-9.0	10.0	10.86
1997	169247	3708	12162	10680	-2.7	7.0	11.32
1998	167917	3760	12240	11737	0.1	6.0	11.88
1999	178513	3812	12250	12600	10.4	6.0	12.45
2000	184881	3824	12250	15480	1.9	6.0	12.53
2001	198595	3924	12467	16480	-10.8	6.0	12.4
2002	201840	4053	12564	16680	-1.2	3.0	11.2
2003	197604	4362	12340	17154	17.8	3.0	11.6
2004	220782	4635	13905	17956	2.4	3.0	13
2005	248698	4972	13640	18406	10.7	3.0	14.8
2006	277396	5002	14311	20164	10.8	3.0	17.1
2007	310115	5452	14628	22349	15.1	3.0	20.2
2008	344775	6066	14363	23930	55.2	4.0	19.6
2009	379362	6938	14234	25640	2.7	4.0	19.1
2010	419218	7476	14373	26944	7.3	4.0	21.8
2011	475648	8295	14136	30712	38.0	5.0	21.5
2012	517027	9875	14675	31550	20.8	5.0	22.7
2013	568432	11301	14455	32582	7.4	5.0	24.7
2014	626977	12640	14217	33609	8.5	5.0	23.9
2015	692222	13551	14055	30641	10.4	5.0	23.78
2016	1449397	14632	13400	31620	7.5	5.0	27.6
2017	1595316	15886	12813	33367	8.4	5.0	47.6
2018	1717795	15886	12813	35985	16.8	7.0	48.3
2019	1840274	15886	12813	35806	15.3	7.0	51.8
source	NBE	ERA	ERA	ERA	NBE	NBE	ME