ADDIS ABABA UNIVERSITY SCHOOL OF GRADUATE STUDIES

Economy Wide Impact of Investment in Road Infrastructure in Ethiopia: A Recursive Dynamic Computable General Equilibrium Approach

By

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A Thesis Submitted to the Department of Economics in Partial Fulfillment of the Requirements for the Degree of Master of Science in Economics (Economic Policy Analysis)

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DECLARATION

I, the undersigned, declare that this thesis is my original work, has not been presented for degrees in any other University and all sources of materials used for the thesis have been duly acknowledged.

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This thesis has been submitted for examination with my approval as a university advisor.

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This is to certify that the thesis prepared by Semen Bekele Gunjo, entitled: *Economy -Wide Impact of Investment in Road Infrastructure in Ethiopia*: *A Recursive Dynamic Computable General Equilibrium Approach* and submitted in partial fulfillment of the requirements for the Degree of Masters of Science in Economics (Economic Policy Analysis) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

Economy-wide impact of investment in road infrastructure in Ethiopia:
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Semen Bekele Gunjo
Addis Ababa University, 2015

In current periods Ethiopia has been implementing huge investment in road infrastructure across the country. Despite the significant improvements in road length, accessibility and quality of roads, few researches were conducted on the impacts of investments in road infrastructure on economic growth, household income and consumption growth. These researches were conducted following the partial equilibrium or econometric techniques that lacks to address the interrelated effect in addition to the limitation that some of these studies were done for a specific road sector development programs and or specific areas

In this study an attempt has been made to examine economy wide impact of investment in road infrastructure using a recursive dynamic CGE model. The study used an updated version of the 2005/06 EDRI Social Accounting Matrix. Six simulations were considered. While the first three simulations were based on the existing and past Ethiopia policy which considered the average road density growth in the PASDEP period, the average density growth required to reach the middle income level and the average road density growth in the GTP period, the last three simulation were considered as robustness test.

Simulations with the CGE model confirm that with increasing availability of road infrastructure, there is a positive growth in the macroeconomic and sectorial indicators (Real GDP, absorption, investment, private consumption, real export, and real import) though the magnitude of the effects is relatively small compared with the high investment costs and the changes varies among the different indicators. Similarly the demand for labor, capital, land and livestock increases with increasing availability of road infrastructure. Income from livestock and land responds better compared to labor and capital as road investment increases. Welfare, measured as real consumption, increases on average and at the disaggregate level for all households. In this case the rural poor benefited more from road investment in terms of earning better income and consumption. Road infrastructure affects the production sectors differently. Manufacturing and capital-intensive activities benefit, while agricultural sectors are less favored, given the relative increase in wages.

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Acronyms

ADB -African Development Bank

AICD- Africa Infrastructure Country Diagnostic

BADEA- Bank of Arab for Economic Development in Africa

CES -Constant Elasticity of Substitution

CET -Constant Elasticity of Transformation

CGE- Computable General Equilibrium

DCGE-Dynamic Computable General Equilibrium

EDRI- Ethiopian Development Research Institute

ERA- Ethiopia Road Authority

EPRDF- Ethiopian People Revolutionary Democratic Front

EU- European Union

GDP-Gross Domestic Product

GMM- Generalized method of moments

GOE –Government of Ethiopia

GTP-Growth and Transformation Plan

HICES- Household Income and Consumption Expenditure Surveys

IFPRI - International Food Policy Research Institute

IMF-International Monitory Fund

MOFED – Ministry of Finance and Economic Development

NDF - Nordic Development Fund

OECD - Organization for Economic Cooperation and Development

OFID- OPEC Fund for International Development

OLS-Ordinary least Square

OPEC- Organization of the Petroleum Exporting Countries

PASDEP- Plan for Accelerated and Sustained Development to End Poverty

RAI - The Rural Access Index

RSDP- Road Sector Development Program

SSC- Sub-Saharan Countries

WB-World Bank

1. Introduction

1.1Back ground

Investment in infrastructure in general, and in transport infrastructure in particular, is seen as a crucial prerequisite for sustainable economic development. This common belief is reflected in a strong emphasis on the part of all donors, especially those of multilateral aid. World Bank lending to Africa for these sectors amounted to US$3.3 billion in 2009, which is a doubling of infrastructure aid since 2006 (Hannah,2014).

The developing world, and especially the African continent, has a very poorly developed infrastructure, compared to middle- and high-income countries. On average, Sub-Saharan Africa has a road density of only approximately 200 meters of paved roads per km^2 compared to 1400 meters in high-income OECD countries (Fay and Yepes, 2008 as cited in Hannah, 2014)

Recently, enhancing transport infrastructures has been a vital strategy for sustainable development and poverty reduction in developing regions. Reducing poverty by half is one of the Millennium Development Goals in 2015. There is wide recognition that the poor not only have low level consumption but they are also less connected with inadequate access to basic services. The international community has thus been providing considerable support to build roads, rail ways, bridges, power plants, and some basic infrastructures with the objective of promoting economic growth (Lulit, 2012).

As the government of Ethiopia cognized the role played by road infrastructure in economic development and poverty reduction, the country has undergone rapid expansion in road infrastructure since 1997 as the result of the Road Sector Development Program. Massive amount of capital has been invested by the government with the support of international donors for the provision of all-weather roads that improve regional connectivity ERA (2014). It is therefore important to examine empirically the impact of investment in road infrastructure on overall economy.

1.2. Statement of the problem

Ethiopia is a land locked country where the major share of passenger and freight movement is by means of road transport and where the transport network is recognized as a major bottleneck. In the 1990's, due to civil war, financial constraints and limited capacity for planning and maintenance, much of the road infrastructure deteriorated. Recognizing the seriousness of the problem, since 1997 the government launched a road sector development program (RSDP) with the aim of expanding the road network to 67, 300 km as well as increasing the share of good quality roads from its level of less than 50% at the start of the program to 65% by the end of 2002 (Lulit, 2012).

In addition Ethiopia on its growth and transformation plan in the year between 2010/11 to 2014/15 planned to reach its Federal and regional total road length from 51,636 to 64,522KM,length of all-weather woreda road from 9568 km to 71522 km, kebele connected to all weather road from 48% to 100%, area farther than 5 km from all-weather road from 53.7% to 29%,area further than 2 km from all-weather roads from 80% to 61%,road density (km/1000 km2) from 55.6 to 123.7, road density (km/1000 population) from 0.78 to 1.54 and roads in acceptable (fair+ good) condition (%) from 81.3% to 86.7%.

Over the Seventeen years of the RSDP, physical works have been undertaken on a total of 110,163 km of roads excluding routine maintenance work. The total budget for the planned works during this period amounted to ETB 160.3 billion (USD 11.1 billion). The total amount disbursed in the same period, is ETB 180.9 billion (USD 12.2billion).The Fourth Phase of RSDP which is part of GTP has been implemented since 2010/11. During the past four years of RSDP IV, a total of 69,421 km physical work has been carried out, of which 10,970 km by Federal roads, 19,355km by regional roads and 39,096 km woreda roads (ERA, 2014).

As a result of this, accessibility measured in terms of average distance from the road network and proportion of area farther than 5 km from an all-weather road, shows substantial progress in expanding the road network. Specifically, due to the construction of new roads, the average distance from a road has been reduced from 21 km in 1997 to 5.5 km in 2014. The proportion of area farther than 5 km from an all-weather road, which was 79% in 1997, has been reduced to 40.5% in 2014(ibid)

In addition the average Rural Access Index, RAI1 for the whole country is currently around 50%, a significant improvement when compared to the situation at the outset of the RSDP (13%)(ibid).

Despite of significant improvements on road length, accessibility and quality of roads, few researches were conducted on the impacts of investments in road infrastructure on economic growth, household income and consumption.

The general gaps in those researches were the inability to address the long term effect and the spillover effect of investing on road infrastructure. That is to mean that the researches were conducted following the partial equilibrium or econometric techniques that lacks to address the interrelated effect (see Wondimu (2010) ,Lulit (2012) ,Worku (2011) and Dercon (2008)). In addition some of these studies were done for a specific road sector development programs and or specific areas (Wondimu (2010) ,Lulit (2012), Dercon (2008 and ERA(2014)).

Generally the research conducted so far did not consider the issue of policy simulation which gives the option for policy makers how much and where to invest on the road infrastructure. In general partial equilibrium model do not provide good understanding of multiple linkages through which investment on infrastructure for road affects the economy and do not provide an adequate framework to outline the transmission mechanisms of the economy wide impact that we need to understand.

Therefore, this study aims to fill this gap by trying to address the limitations described above by using a recursive dynamic CGE Model which is believed to be best suited to assess the impact of investment on road infrastructure on different macroeconomic indicators and welfare effects.

[1] The Rural Access Index, RAI, measures the number of rural people who live within two kilometers (typically equivalent to a walk of 20-25 minutes) of an all-season road as a proportion of the total rural population. An "all-season road" is a road that is motorable all year round by the prevailing means of rural transport. Occasional interruptions of short duration during inclement weather (e.g. heavy rainfall) are accepted, particularly on lightly trafficked roads.

1.3 Objective of the study

1.3.1 General objective

The general objective of this study is to assess the economy wide impact of investment in road infrastructure in Ethiopia. The study also examines how household consumption responds to improvements in road accessibility and identifies the channel through which the benefits of roads are realized.

1.3.2 Specific objective

The specific objectives are to analyze the impact of investment in road on:

- Macroeconomic indicators (real GDP, absorption, investment, private consumption, real export, real import),
- Sectorial growth effect (agricultural, industrial, service),
- Factor income (rural poor, rural non poor, urban poor, urban non-poor),
- Household income (rural poor, rural non poor, urban poor, urban non-poor),
- Household consumption expenditure (rural poor, rural non poor, urban poor, urban non-poor),
- In addition the study has an objective of identifying whether road investment is a pro-poor growth or not.

1.4 Significance of the Study

The study will help the government of Ethiopia in general and Ethiopian Road Authority (ERA) in particular in providing feedback on the economy wide impact of investing in road infrastructure. From the policy point of view it will also help ERA to promote more evidence-based policy making and decision making towards the identified impacts. The study will also have a contribution to the regional road Authorities and promote appropriate intervention mechanism. Finally, it will also be used as a reference for further study and motivate other researchers to conduct further study on the area.

1.5. Scope of the Study

This study focuses on the impact of investment in road infrastructure in Ethiopia considering years between 2009-2019 where 2009 is base year and 2019 is the maximum simulation year.

1.6. Limitation of the Study

Dynamic Computable General Equilibrium (DCGE) has a number of advantages that makes it suitable for evaluating the economy wide impact of investing in road infrastructure. However, these model is very data-intensive, which is perhaps the most common criticism lodged against CGE models. Therefore there might be a problem of data to analyze as intended. One way of addressing the impact of road infrastructure investment to the overall economy is through the in direct channel (transportation and trade cost) which requires translating transportation and trading cost to road networks.

1.7 Organization of the study

The paper is organized as follows: chapter one discusses introduction and chapter two treats the theoretical and empirical literature reviews. Chapter three describe Overview of road infrastructure and economic development in Ethiopia while chapter four provides data and methodology of the study Chapter five presents results and findings of the study and policy simulations. Finally, chapter six concludes and forward policy implications.

2. Literature Review

2.1 Theoretical literature

The theoretical foundations of the effect of infrastructure on growth in general and road infrastructure in particular on development outcomes are mostly to be found in growth theory.

Infrastructure has always been seen as a prerequisite for growth. Different authors define infrastructure at different time from different perspective. According to Emmanuel (1995), it is defined as "The foundation on which the factors of production interact to produce output and services". Hirschman (1958) considered infrastructure as services without which primary, secondary and tertiary production activities cannot function.

Most infrastructure including road share common features in which they are mostly non-tradable, and are characterized by economies of scale (Emmanuel, 1995). They also influence consumption and production, though their influence on production is usually indirect through increasing total factor productivity, reducing costs, facilitating market transactions and promoting economies of scale.

The role played by the infrastructure to enhance growth has also been recognized long ago. According to Adam Smith, infrastructure is considered as a major conditioning factor for growth to occur through limiting the size of the market and hence the extent of division of labor. Although less visible, the role of road infrastructure has also been highlighted in subsequent growth theories. According to the Keynesian theory, the growth impact of infrastructure mainly comes through its effect on raising aggregate demand; and the productivity enhancing role of infrastructure is not much emphasized (Nourzad, 2000). Under neoclassical growth framework, transport infrastructure contributes to growth through facilitating the accumulation of factors of production, increasing the supply of productive inputs and raising resource allocation efficiency (Guild, 1998). In the context of endogenous growth theory, while growth is claimed to come through the accumulation of capital and knowledge, transport infrastructure contributes to growth indirectly by enabling firms to make an optimal choice of firm location, technology, scale of production, through expanding market size and increasing the incentive for innovation (Guild 1998, Barro 1990).

Dissou et al, 2011 noted that investment on productive infrastructure is important in maintaining good economic performance. They also mentioned that Low level of investment on infrastructure is considered as partly responsible for poor growth performance in developing countries.

2.2. Empirical literature

Several studies have investigated the impact of infrastructure investment in general and road infrastructure in particular on economic growth and or poverty reduction. These studies confirm that road infrastructure can have a direct and an indirect effect on reducing poverty.

Direct contribution is evidenced by studies undertaken by Barro (1990) in which he considers production function where aggregate output is produced by utilizing capital, labor and infrastructure as production inputs. Likewise Morrison and Schwartz (1996) argue that infrastructure provision improves the productivity of private firms and does contribute to output. The indirect channels reveal that beyond the direct inclusion of infrastructure in production function, there are also transmissions channels through which infrastructure can affect growth. Hanna (2014), considered road infrastructure as enhancing indirectly the productivity of workers through reduction in adjustment costs. In similar vein, infrastructure investments impacts through human development, as investment are made on improving health (Brenneman and Kerf (2002). Different empirical studies in the past have produced diverse results based on the methodologies used and data employed.

CGE modeling approach

So far different scenarios were considered and different results were obtained while analyzing the over all impact of infrastructure in general and road infrastructure in particular to the economy. Some of these literatures are described below.

Abhijit et al (2012) assess the impact of transportation infrastructure on economic growth in China by using a dynamic CGE model by considering different financing scenarios. Their results reveal that public infrastructure investments have the same direction of impact whether funded by taxation or international borrowing, particularly when looking at macroeconomic gains and poverty reduction in the long run. However, in the very short run, tax financing puts a strain on output in the industrial sector and thus reduces economic growth in the short run.

Likewise, Vaqar et al (2013) study public infrastructure and economic growth in Pakistan by using a dynamic CGE model. The same scenarios were considered and the same result were obtained like that of Abhijit et al (2012).

In the same modeling approaches but using different linking mechanism and focusing on road infrastructure, Jayant et al (2006) study the effect of rural road improvement in Lao PDR on poverty incidence using a general equilibrium modeling approaches. The author differentiates between three categories of rural villages according to the quality of road access available to them: (i) no vehicular access; (ii) dry season only access; and (iii) all weather access. The approach taken in the study is to use information on transport costs in these three types of roads to estimate the transport cost margins facing rural people in villages serviced by these three categories of roads. They then simulate the effect of upgrading category (ii) roads to category (i) roads, on the one hand and category (iii) roads to category (ii) on the other. The results indicate that both forms of road improvement reduce poverty incidence. They do this by improving the income earning opportunities of rural people and through reducing the costs of the goods they consume.

In similar way but after estimating the elasticity of trade and transport margin to road investment using econometric technique, Hannah (2014) also develops a modeling framework for analyzing the effects of improved road infrastructure on the economy of African countries using CGE modeling approach. Simulations with the CGE model confirm that with increasing availability of roads, the demand for labour and capital for transport declines. These factors move to the other sectors to produce a higher aggregate output. Welfare, measured as real consumption, increases on average and at the disaggregate level for all households. The empirical and simulation results show that infrastructure investment programmes are an instrument to support the development of a country, as increased infrastructure has positive effects on production and welfare.

Generally from the above few literatures, one can understand that there are different mechanisms to see the impact of infrastructure in general and road infrastructure in particular on the overall economy and poverty. Some of them linked it directly in the production function (Abhijit et al (2012, Vaqar et al (2013)) and some of them linked it indirectly through transport cost (Jayant et al (2006) and Hannah (2014)).All studies reviewed above indicated the positive impact of road infrastructure on production and welfare.

Econometric modeling approach

The impact of infrastructure in general and road infrastructure in particular can also be modeled using different econometric techniques. Some of them are reviewed below.

Shenggen and Connie (2005) assess the impact of public infrastructure on growth and poverty reduction in China, paying particular attention to the contribution of roads and using econometric model. The most significant finding of this study is that low-quality (mostly rural) roads have benefit–cost ratios for national GDP that are about four times greater than the benefit–cost ratios for high-quality roads. In terms of poverty reduction, low-quality roads raise far more rural and urban poor above the poverty line per yuan invested than do high-quality roads.

Similarly, but using household level panel data, Khandker et al. (2009) assess the impacts of two road projects in Bangladesh (RDP and RRMIMP) on a range of household outcomes. They apply a fixed effect estimation approach to control for heterogeneity among households and among communities. The results reveal that rural road infrastructure can promote poverty reduction through higher prices of agricultural products, lower input prices and transportation costs, higher men's agricultural wages and increased agricultural production.

Khandker and Koolwal (2010) also examines the impact of rural roads using household level panel data from Bangladesh between 1997and 2005. They estimate the benefit of road projects on consumption expenditure before and after the project in control and treatment villages. Results from GMM estimation show positive and significant outcomes of roads on per capita expenditure in the short-run especially for extremely poor households. However, in the long-run large benefit will be accrued to higher-income groups due to the increasing rate of return to rural investments and expansion of non-farm employments.

Similarly, Mu and van de Walle (2007) also investigate the impact of a rural road rehabilitation project funded by the World Bank and implemented in Vietnam between 1997 and 2001. The study suggests that road improvements can exert an almost immediate impact on poverty reduction through the human capital channel.

Balisacan and Pernia (2002) also show the importance of complementarities between public investments in infrastructure and human capital. Using provincial level data for the Philippines from the 1980s and 1990s, their estimates show that road infrastructure, as measured by concrete-equivalent roads per square kilometer, can in fact significantly reduce the welfare of the poor, unless complemented by investments in human capital. They also state that providing access to markets and information alone may exert an adverse impact on the poor through such channels as factor-market and political economy processes. Only when road infrastructure is coupled with human capital (measured as the mean years of schooling of household heads), do the authors find that the welfare of the poorest improves, such that a 1 % improvement in roads and schooling results in a 0.11 % increase in the mean consumption expenditures of the bottom 20 % percent of the population.

Renkow et al (2004) by using maximum likelihood technic to estimate how transaction costs and market participation is responsive to rural infrastructure. They showed that physical remoteness brings economic isolation and this increases fixed transaction cost incurred by farm households in Kenya. Therefore, they underline public infrastructure facilitate market integration and minimize the transaction cost.

Fan and Zhang (2008) provides evidence on the importance of the market access channel in alleviating poverty in poor countries. Using a full information maximum likelihood technique applied to a simultaneous equations model, the authors examine the poverty impacts of road infrastructure by analyzing the marginal returns to public investment of different types of roads. Their calculations indicate that, among the different types of roads, feeder (dirt) roads have the largest impact on poverty reduction across Uganda, such that an additional million shillings invested in building feeder roads would allow 33 persons to escape poverty in Uganda. For murram (gravel) and tarmac (tarred) roads, the authors' estimate that nine persons would be able to rise above the poverty line for each additional million shillings spent on these roads.

Fan et al. (2002) carry out a similar study using Tanzanian household level data. Their calculations of marginal returns to public investment in road infrastructure indicate that for every shilling invested, household income rises by 9.13 shillings. The authors also estimate that for every one million shillings invested in roads, on average, 27 persons are lifted out of poverty. Road investments are also found to have the largest poverty impacts in the Central and Western regions of Tanzania and in the South Highlands, where each million shillings spent on roads leads to 60–75 persons exiting poverty.

At the local level in Ethiopia, some of the studies carried out including that of Worku (2011), Lulit (2012), Wondimu (2010) and Dercon et al. (2009) show in general that road infrastructure investment has a significant impact on output growth.

Worku (2011) analyze the impact of roads sector development on economic growth in Ethiopia. The study use time series data on the country's road network and GDP growth over the period 1971-2009. Results from a two-step GMM estimator show that paved roads have positive and significant impact on economic growth while gravel roads do not. He adopt an extended Cobb-Douglas production function and an OLS estimation technique to investigate the Ethiopian economy in the specified period.

Lulit (2012) on her study to identify the impact of road on rural poverty by taking fifteen rural villages in Ethiopia show that the poverty head count ratio declines with improvement in road accessibility of rural villages. She use econometric techniques using GMM to assess the robustness of the association between road infrastructure and rural wellbeing. The study shows that better road connectivity not only increases the likelihood of crossing over the poverty line but also enhances the rate of consumption growth significantly. In addition she found that rural households with better road network are not only more likely to use modern fertilizers but they also make intensive use of fertilizers. Moreover, the study finds evidence that the overall productivity of farm households increases significantly with the degree of road access.

Wondimu (2010) studies the link between road infrastructure and rural poverty in Ethiopia. He empirically substantiate if there is a robust link between farm income and the quality of road infrastructure farm households have access to as well as the pathways through which the effects of road on rural income are felt. The mechanisms by which road boosts rural income and reduce poverty are also found to work through narrowing down spatial price gaps, promoting technology adoption, boosting resource allocation efficiency and raising the market return to land and labour. The result also shows that the rural poor benefits from road induced income growth.

Dercon et al. (2009) use panel data from fifteen rural villages in Ethiopia and examine the impact of agricultural extension program and roads access on poverty and consumption growth. The study finds based on GMM estimation that access to all-weather roads reduces poverty by 6.9%

and it increases average consumption growth by 16.3% after controlling for regional fixed-effects and seasonal shocks.

In general both the econometric and the CGE modelling approach of the literature indicates that road infrastructure investment has positive effects in economic growth, welfare effect and poverty reduction. Few of them also indicated that investment in road infrastructure alone does not give the targeted growth of economy, reduce poverty and positive welfare effect. To bring such growth, it has to be coupled with human capital (Balisacan and Pernia (2002)).

In Ethiopian case all the researches conducted on the impact of road infrastructure on different macro and micro issues were done following different econometric techniques at country level, regional level or specific road projects. In all cases, under their scope the response of road investment is positive to all macro and micro indicators (Work (2011), Lulit (2012), Wondimu (2010) and Dercon et al. (2009)).

Generally this study tries to fill the existing gaps in terms of identifying the macro impact, sectoral impact and welfare impact brought by road infrastructure investment at national level using CGE modeling approach. The study also utilizes the trade and transportation margin as a channel to realize the impact of road infrastructure investment.

3. Overview of road infrastructure and economic performance in Ethiopia

3.1 Road Sector Development in Ethiopia

3.1.1 Road sector policies in Ethiopia

In the context of Ethiopia's geography, pattern of settlement and economic activity, transport plays a vital role in facilitating economic development as 95% of the movement of people, and goods is still carried out by road transport. In particular, it is road transport that provides the means for the movement of peoples and agricultural products from rural areas to urban areas and movement of industrial goods, modern agricultural inputs and peoples from urban areas to rural areas. Road transport also provides a means for the utilization of land and natural resources, improved agricultural production and marketing, access to social services, and opportunities for sustainable growth (ERA, 2014).

Since its commencement the Ethiopian Roads Authority (ERA) has been administering the road sector. ERA was established in 1967 by proclamation No 256/67 to provide for the control and regulation of travel and transport on the road. The ERA is responsible for the use of all roads within Ethiopia, vehicles using these roads, and to all matters relating to road transport activities of the country. After the downfall of the military government, ERA restructured its obligations with a vision to ensure the provision of a modern, integrated, and safe road transport service to meet the needs of all the communities of a strong and unitary economic and political system in Ethiopia (Worku, 2011).

The Government of Ethiopia has also placed increased emphasis on improvement of the quality and size of road infrastructure in the country. To address constraints in the road sector, mainly low road coverage and poor condition of the road network, the Government formulated the Road Sector Development Program (RSDP) in 1997(ibid). The RSDP has already been implemented over a period of seventeen years and in four successive phases.

3.1.2 Trend of road network

In 1951 the total stock of road network was only 6400 km of which 3400 km was asphalt and the remaining 3000 km was gravel road. When the Imperial regime lost power, the network has reached to 9160 km in 1973. On average, the network has been growing at a rate of 2.05 percent per annum over the period 1951-1973. During the Derg regime, 1974-1991, the stock of road increased to 19017 km with a growth rate of 6.2 percent per annum ((Worku (2011), ERA (2014)). With the current EPRDF regime, the road network has reached 99,522 km in 2014 with an average annual growth rate of 8.61 percent. Over the period 1991 to 2014, 80505 km of new road network was constructed. The main reason for a dynamic increase in road network is the commitment of the governments in formulating the Road Sector Development Program (RSDP) in 1997.

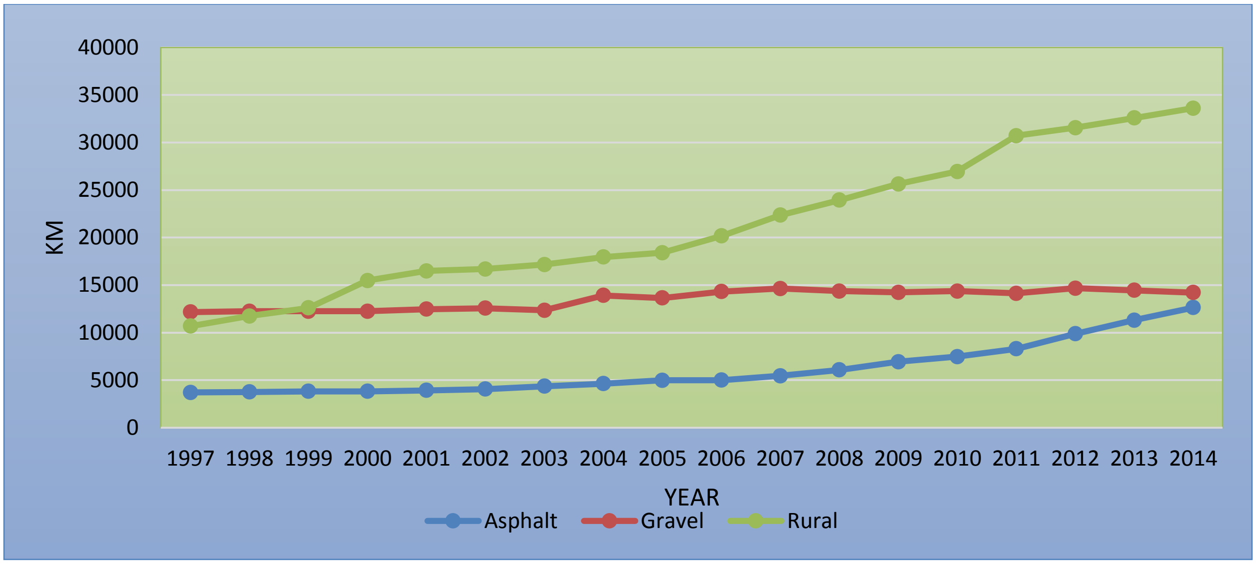
As can be seen in table 1, asphalt, gravel, rural and total road network on the average grows by 7.6%, 0.98%, 7.1% and 8.3%, respectively, for the period between 1997 and 2014.

Table1: Road network of the Country (1997-2014)

	Road network					Growth rate (%)
	Asphalt	Gravel	Rural	Woreda	Total	
1997	3708	12162	10680		26550	
1998	3760	12240	11737		27737	4
1999	3812	12250	12600		28662	3.3
2000	3824	12250	15480		31554	10.1
2001	3924	12467	16480		32871	4.2
2002	4053	12564	16680		33297	1.3
2003	4362	12340	17154		33856	1.7
2004	4635	13905	17956		36496	7.8
2005	4972	13640	18406		37018	1.4
2006	5002	14311	20164		39477	6.6
2007	5452	14628	22349		42429	7.5
2008	6066	14363	23930		44359	4.5
2009	6938	14234	25,640		46812	5.5
2010	7476	14373	26944		48793	4.2
2011	8295	14136	30712	854	53997	10.7
2012	9875	14675	31550	6983	63083	16.8
2013	11301	14455	32582	27628	85966	36.3
2014	12640	14217	33609	39056	99522	15.8
Growth rate	7.6	0.98	7.1	351	8.3	8.3

Source: ERA

Figure 1. Road network improvement in Ethiopia (1997-2014)



Source: ERA

Table2 Road network in Ethiopia by region

Name	Federal	% age	Rural	% age	Woreda	% age	Total	% age
Tigray	2192	9	1336	4	1010	3.7	4538	5
Afar	1552	6	1110	3			2662	3
Amhara	6099	24	4583	14	5084	18.4	15766	18
Oromia	8907	35	9158	28	15275	55.3	33340	39
Somali	2411	9	2749	8			5160	6
SNNP	3858	15	10433	32	5939	21.5	20230	24
Benishangul-Gumz	336	1	1590	5	110	0.4	2036	2
Gambella	401	2	1202	4	12	0.04	1615	2
Dire Dawa			335	1	88	0.3	423	0.5
Harari			86	0.3	110	0.4	196	0.2
Total	25756	100	32582	100	27628	100	85966	100

Source: ERA

Regarding regional road network coverage Oromiya, SNNP, Amhara, Somali ,Tigray, Afar, Benishangul-Gumz, Gambella, Dire Dawa, Harari has a share of 39%, 24%, 18%, 6%, 5%, 3%, 2%, 2%, 0.5% and 0.2%,respectively, from the total road network.

3.1.3 Road density

The proper level of road network is assessed by road density, which is measured by road length per 1000 persons or by road length per 1000 km^2.

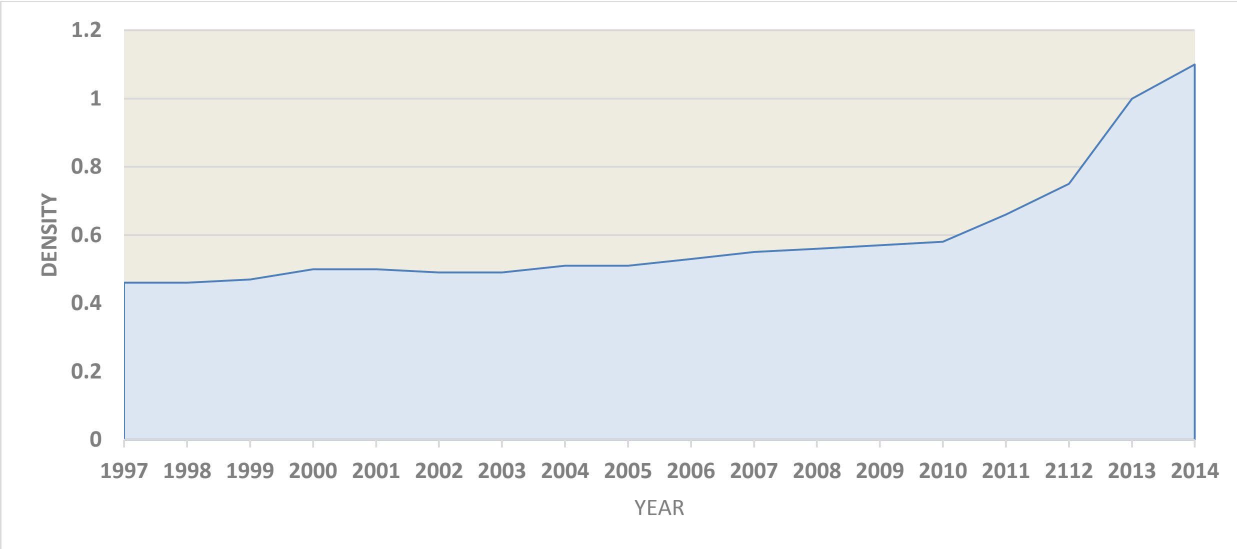
Since 1997, the RSDP has focused on rehabilitation and expansion of the main paved and unpaved roads and important regional roads. The total road network has expanded from about 26,550 km at the beginning of the RSDP to its current 99,522 km including woreda roads, increasing the road density from 24.1 to 90.5 km per 1000 sq. km and from 0.46 to 1.1 km per 1000 population. The growth of the road network over the RSDP period is summarized in Table below.

Table3: Change in road density (1997 – 2014)

Year	Road Density /1000 popn.	Road density /1000sq. km
1997	0.46	24.14
1998	0.46	25.22
1999	0.47	26.06
2000	0.50	28.69
2001	0.50	29.88
2002	0.49	30.27
2003	0.49	30.78
2004	0.51	33.18
2005	0.51	33.60
2006	0.53	35.89
2007	0.55	38.60
2008	0.56	40.30
2009	0.57	42.60
2010	0.58	44.39
2011	0.66	49.09
2112	0.75	57.30
2013	1.0	78.20
2014	1.1	90.5

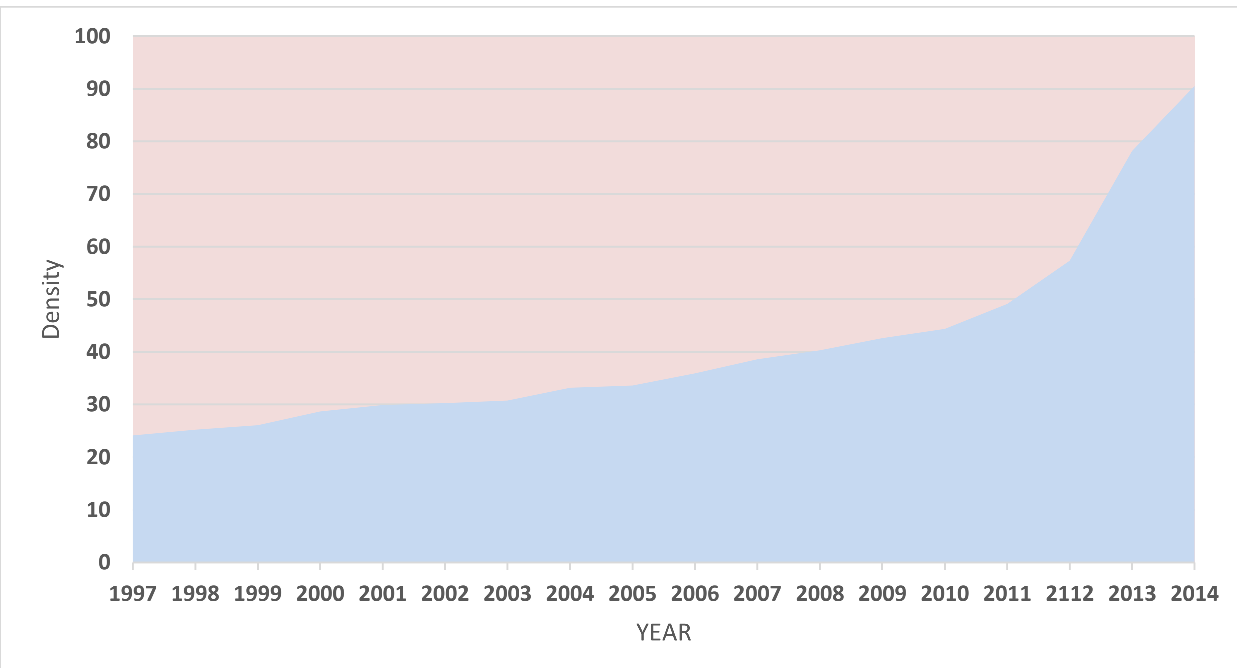
Source: ERA

Figure 2. Road density per 1000 population in KM



Source: ERA

Figure 3. Road density per 1000 Sq KM

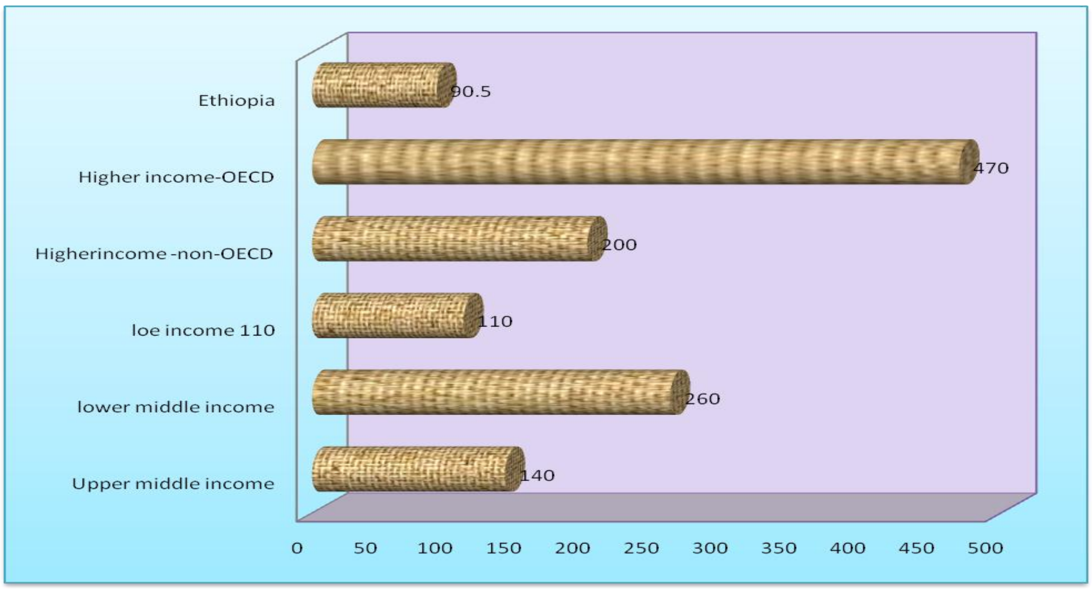


Source: ERA

Though there is huge increase in road length which lets the road density to increase, it still lags even to sub-Saharan standard. According to Ken, et al (2008), Sub-Saharan Africa has a density of 204 kilometers of road per thousand square kilometers of land area, where one quarter are paved. The world average density is 944 kilometers per thousand square kilometers, with over half paved. Sub- Saharan Africa has a total road network of 3.6 kilometers per thousand persons, while the world average is 7.07 kilometers

The road density in terms of kilometers of road per thousand square kilometers of land area for different income groups of countries are given below.

Figure 4. Road density per 1000 Sq KM by income group



Source: *AICD Database, 2008*

3.1.4 Accessibility

Isolation is a key characteristic of poverty. Improved road access offers for the rural poor the ability to reach, visit or use services effectively and also contributes to the country's economy and development. Improving rural road access can provide an effective poverty alleviation catalyst by reducing constraints and providing access to new opportunities.

Improving access to transport for rural men and women is considered essential to promote rural development, to increase uptake of human development services (educational and health), to facilitate inclusion of different ethnic and other groups, to improve employment opportunities, and to stimulate growth for poverty reduction.

Accessibility, measured in terms of average distance from the road network and proportion of area farther than 5 km from an all-weather road, shows that substantial progress has been made in expanding the road network. Specifically, due to the construction of new roads, the average distance from a road has been reduced from 21km in 1997 to 5.5 km in 2014. The proportion of area farther than 5 km from an all-weather road, which was 79% in 1997, has been reduced to 40.5% in 2014.

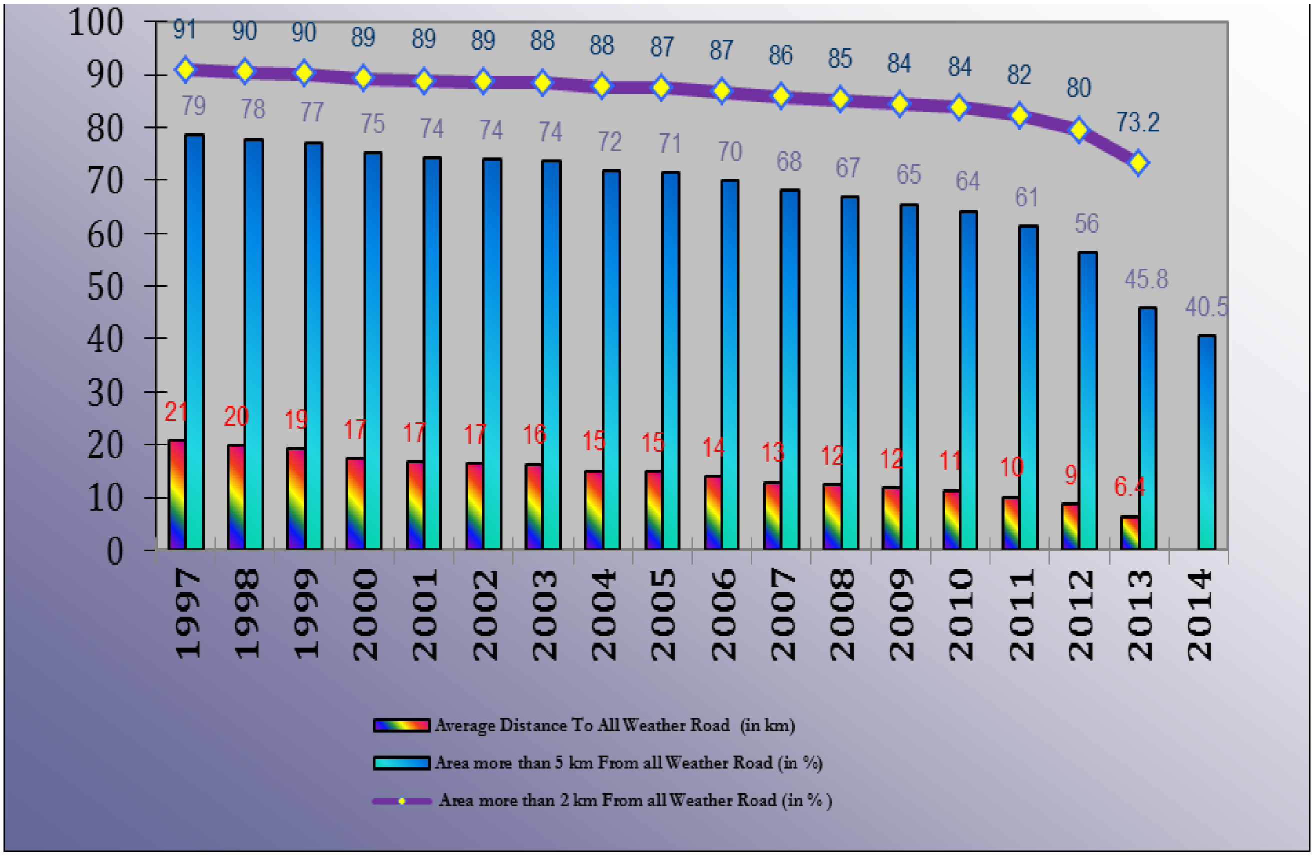
The Rural Access Index, RAI is one of the indicators of access that is recommended by the World Bank in 2003 and RAI is accepted by the African Ministers of Transport as a comparative measure of rural access in Africa. Table 4 shows the current level of accessibility of the rural population to an all-weather road as measured by the RAI and the progress made to improve accessibility through successive RSDP implementation years. The average RAI for the whole country is currently around 50%, a significant improvement when compared to the situation at the outset of the RSDP. Table 4 shows rural access index for the country.

Table 4. Rural Access Index Values

Year	Total Population	Rural Population	Rural Pop'n. Density	Road Network	Rural Pop'n Within 2km Access	Rural Access Index (%)
1997	58,117,000	46,493,600	58	26,550	6,203,041	13
2002	67,220,000	53,776,000	68	33,297	8,997,887	17
2007	74,186,830	61,259,132	77	42,429	13,061,124	21
2010	79,777,690	65,680,187	83	48,793	16,104,158	25
2011	82,100,000	68,143,000	86	53,997	18,483,797	27
2012	84,500,000	70,135,000	88	63,083	22,232,795	32
2013	86,000,000	71,380,000	90	85,966	30,835,443	43
2014	87,000,000	72075,185	91	99,522	36,045,561	50

Source: *ERA*

Figure 5. Average distance to all weather road in (%) 1997 to 2014



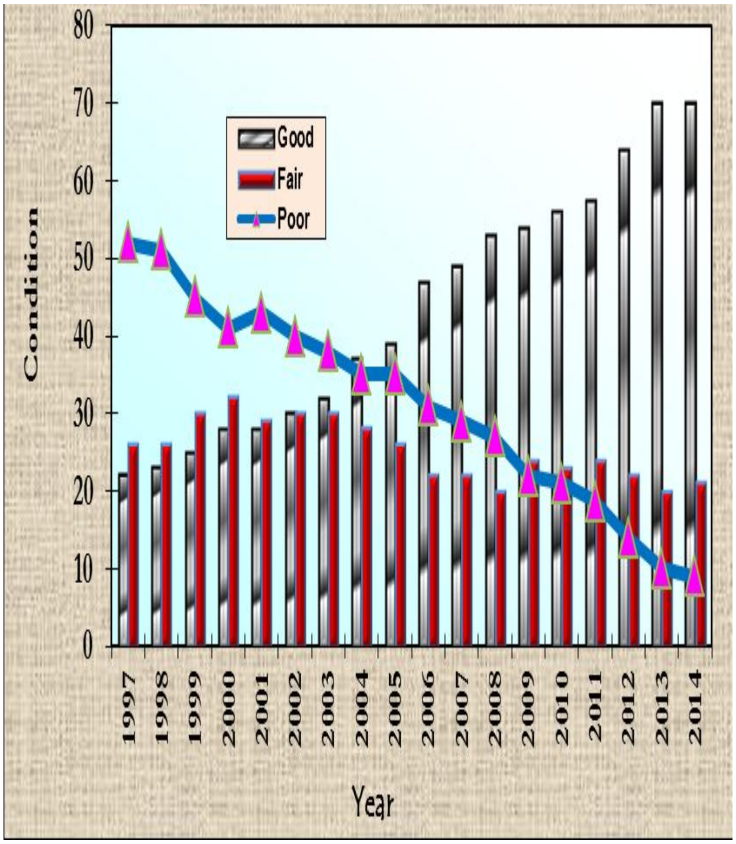
Source: ERA

3.1.5 Road condition in Ethiopia

Road quality is the primary indicator of the performance of the road management system in any country. A three-way quality classification is used: good, fair, and poor. The classification of poor is used to designate roads that are in need of rehabilitation.

Improving the condition of the road network was a challenge. In the first year of the RSDP 52% of the road network was in poor condition and only 22% was in good condition. The rehabilitation, upgrading and maintenance intervention effort under the RSDP improved the proportion of the road network in good condition to 70 percent, with only 9% remaining in a poor condition. Roads in fair and poor condition are consistently declining. The trend in the condition of the classified road network during RSDP from 1997 to 2014 is presented in figure 6 and Table 5 below.

Figure 6(Table 5): Road condition improvement in Ethiopia % (1997-2014)



Year	Good	Fair	Poor
1997	22	26	52
1998	23	26	51
1999	25	30	45
2000	28	32	41
2001	28	29	43
2002	30	30	40
2003	32	30	38
2004	37	28	35
2005	39	26	35
2006	47	22	31
2007	49	22	29
2008	53	20	27
2009	54	24	22
2010	56	23	21
2011	57	24	19
2012	64	22	14
2013	70	20	10
2014	**70**	**21**	**9**

Source: ERA

3.1.6 Road sector financing

RSDP has been financed from domestic sources including GOE and the Road Fund Office, and foreign sources including Governments and International Financial institution. The Government of Ethiopia has been major financer of RSDP followed by the Road Fund Office. Development partners such as the World Bank (WB), European Union (EU), African Development Bank (ADB), Nordic Development Fund (NDF), Bank of Arab for Economic Development in Africa (BADEA), OPEC Fund for International Development (OFID) and the Governments of Japan, Germany, U.K, Ireland, the Saudi Fund for Development, the Kuwait Fund and the Government of China have been involving in financing the Program. The recent donor which joined this effort is Abu Dhabi Fund. Seventeen years have passed since the launch of the RSDP (ERA, 2014)

An assessment of contribution of finance to the implementation of the RSDP shows that 78.8% came from internal sources (the Government, the Road Fund and the Community). The remaining 21.2% has been pooled from the international community.

Specifically, the share of the Government of Ethiopia is the highest (69.4%), followed by Road Fund (7.7%), the IDA (7.3%) and EU (4.5%). The overall disbursement over 17 years of RSDP is about Birr 180.9 billion (USD 12.2 billion). Table 6 gives a breakdown of the RSDP disbursements by financier. Annual disbursement by donors and the Government for execution of projects under the RSDP is given in Table 6.

Table 6: Source of finance by the pursued RSDP programs

Financier	Overall Disbursement during 17 years	percent age contrib ution
GOE	125438.3	69.4
Road Fund	13838.7	7.7
Community	3209.1	1.8
World Bank	13292.3	7.3
European Union *	8201.9	4.5
China	7755.2	4.3
AfDB	4080.8	2.3
Japan	2169.7	1.2
OFID	605.0	0.3
Saudi Fund for Development	442.5	0.2
Germany	470.1	0.3
BADEA	406.1	0.2
United Kingdom	193.6	0.1
Kuwait Fund	361.7	0.2
NDF	343.6	0.2
Ireland	42.8	0.02
Sweden	5.0	0.003
TOTAL	180856.5	100.0

Source: *ERA*

Over the past 17 years, **41.2%** of the total RSDP expenditure was on rehabilitation and upgrading roads, **28.8%** was on construction of link roads, **5.7%** on maintenance of federal roads, **8%** on regional road and **11.7%** on Woreda roads and **2.8%** was on institutional support projects and other activities at the federal level. Table 7 shows the RSDP expenditure by category and implementers.

Table 7: Share of Expenditure on road by Category (1997-2014)

Expenditure Category	Share of Expenditures (%)	Cost	Dis
Federal Roads			
Rehabilitation	8.3	11,908.3	15,043.2
Upgrading of Trunk Roads	12.8	18,490.2	23,195.8
Upgrading of Link Roads	20.1	29,598.0	36,407.2
Construction	28.8	39,595.2	52,049.8
Periodic Maintenance	3.0	7,236.7	5,455.2
Performance based Maintenance	0.04	650.0	73.4
Routine Maintenance	2.7	4,133.5	4,830.9
Others (including Institutional Support)	2.8	3,981.9	5,039.5
Regional Roads			
Construction	6.6	18,222.4	11,900.1
Emergency and Routine Maintenance	1.3	2,270.4	2,378.8
Others	0.1	203.0	115.4
Woreda Roads			
URRAP	11.7	20,374.8	21,242.0
Community Roads	1.3	2,642.9	2,295.9
Urban Roads	0.5	1,006.6	829.3
Total	100	160,313.9	180,856.4

Source: *ERA*

3.2 Overview of overall economic performance

Economic growth of the country has shown various changes in different political regimes. These change in government structure created a problem of inconsistency in implementing the policies by previous regimes as well as natural disaster like famine and drought had a depressing effect on the history of economic growth of the country.

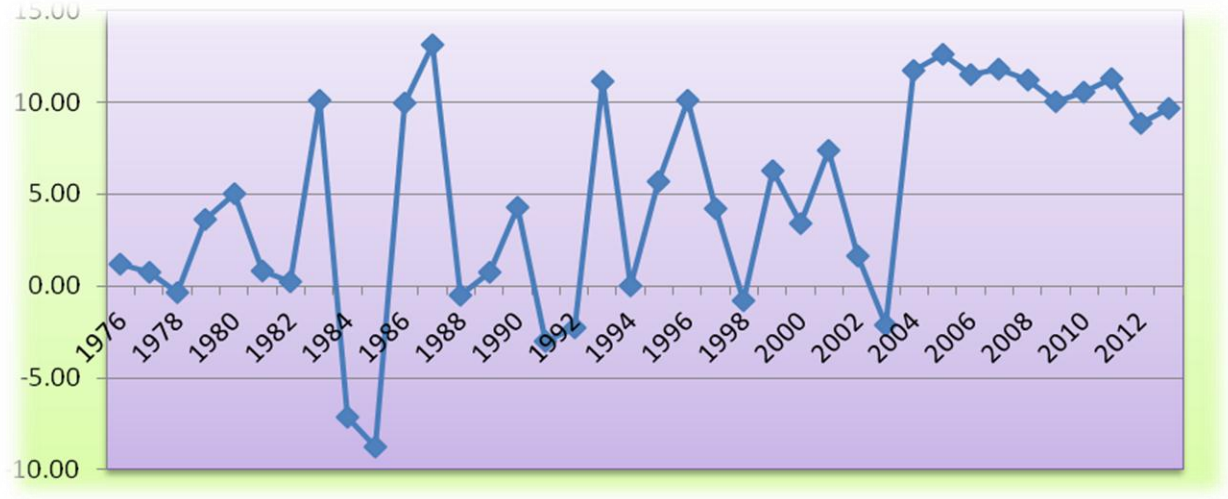
During the Imperial Regime (1930- 1974), the county had an experience for modern technology , developments in infrastructure and industries that showed an increase in the rate of GDP in the late 1960 and beginning of 1970' s compared to the previous periods. But during the last years of the Imperial regime, the GDP growth rate started to fall mainly due to famine in some parts of the country. In addition the rise of opposition parties and political disorder in the country had enormous role for the decrease in GDP (Geda & Befekadu, 2003).

Under the Derg regime (1975- 1991), known for its socialist policy, Ethiopia's GDP growth became lower. These was related to the takeover of the private sector by the government, high pressure from different opposition parties within the country as well as war with Somalia within the first three years were some of the major effects behind the fall in output growth in the country during the Derg Regime. The severe drought that took place in 1984/85 was also additional factor for the decrease in total GDP.(Ibid) In 1984 and 1985 the severe drought declined the growth rate by 3% and 10% in per capita respectively.

During the EPRDF regime, the GDP growth decelerated by 3% and 2% in 1998 and 2003 respectively. On the other hand GDP grew by 14% in 2004 which is the highest growth rate up to present time. The average growth rate in the recent 10 year (2003-2014) is 11%.While the GDP per capita is 5.9%. According to NBE(2013/14) report, during the F.Y 2013/14, the real GDP revealed a remarkable growth of 10.3 percent compared to the 5.6 percent forecast for sub-Saharan Africa countries for 2014. The growth was mainly contributed by the service sector (51.7 percent), agricultural sector (21.7 percent) and industrial sector (26.4 percent). Nominal GDP per capita went up to USD 631.5 from USD 557.6 in the preceding year, registering a 13.2 percent increase. Real per capita GDP increased by 3 percent to USD 371 against the preceding year. All in all, Ethiopian economy registered average annual growth rate of 10.1 percent during the GTP period of 2010/11-2013/14.

In line with the single digit inflation policy target and the Growth and Transformation Plan of the country, the Ethiopian economy is projected to grow by 11.4 percent in 2014/15 in contrast to 4.0 and 5.8 percent growth projected by IMF for the world and SSA respectively (WEO ,July 2014 as cited in NBE 2014)..

Figure7. Real GDP growth rate (1976-2013)



Source: *MOFED*

In terms of sectoral contribution to GDP, the agricultural sector contributes 60.4%, 55.8% and 49.6 %, respectively, in 1970/71-1973/74, 1974/75- 1990/91, and 1991/92-2013/14. And the contribution of the service sector in the specified period is 28.9%, 33.2% and 38% respectively. Similarly the industrial sector contributed 10.7%, 11% and 11.9% respectively (see table 8)

Table 8. Contribution of the agricultural, industrial and service sector (%)

	1970/71-1973/74	1974/75-1990/91	1991/92-2013/14
Agriculture	60.4	55.8	49.6
Service	28.9	33.2	38.7
Industry	10.7	11.0	11.9

Source: *MOFED*

In terms of growth in the period between 1970/71-1973/74 , 1974/75- 1990/91 and 1991/92-2013/14, agriculture grew just by 1.15%,1.45% and 5.9 %, respectively, while the industrial sector grew by 1.4% ,1.1% and 8.9%.Similarly,the service sector grew by 5%,2.5% and 9.8% respectively(see table 9).

The share of agriculture to Ethiopian economy during 2013/14 was 39.9 percent. The sector contributed 2.2 percent to GDP growth rate and grew by 5.4 percent in comparison with the 7.1 percent growth recorded in the preceding year. Similarly, the industrial sector had achieved 21.2 percent growth showing an improvement of 2.6 percentage points against the preceding year. The sector had contributed 3 percent to the overall economic growth. On the other hand, the service sector was relatively the dominant economy in Ethiopia. The share of service sector was about 51.7 percent of the overall economy representing a principal contribution of about 5.4 percent to the GDP growth in 2013/14 with 11.9 percent of its sectoral growth.

Table 9: Absolute growth rate of the agricultural, industrial and service sectors (%)

Variable	1970/71-1973/74	1974/75-1990/91	1991/92-2013/14
Agriculture	1.1	1.4	5.2
Industry	1.4	1.1	8.9
Service	5	2.5	9.8

Source: *MOFED*

4. Data and methodology

4.1 Source of data

To capture the economic wide impact of investment in road, the study have employed a dynamic CGE (which is developed by IFPRI). This study utilized an updated version of 2005/06 SAM which represents the Ethiopia economy by activities, factors (capital, land and different types of labor) and commodities and institutions (households, government and the Rest of World), including an aggregate savings-investment account (EDRI, 2009).The source of this data is EDRI. In addition to this data from Ethiopia road authority is also employed in the study.

4.2 The Social Accounting Matrix

A social accounting matrix (SAM) is a comprehensive, economy wide data framework, typically representing the economy of a nation. More technically, a SAM is a square matrix in which each account is represented by a row and a column. Each cell shows the payment from the account of its column to the account of its row. Thus, the incomes of an account appear along its row and its expenditures along its column. The underlying principle of double-entry accounting requires that, for each account in the SAM, total revenue (row total) equals total expenditure (column total) (Lofgren et.al, 2002).

The 2005/2006 Ethiopia SAM is the first comprehensive economy wide dataset. A SAM can be seen as an extension of input-output (I-O) matrices, filling in the links in the circular flow from factor payments to household income and back to demand for products .The SAM delineates flows across product and factor markets, and provides the statistical underpinnings for multi-sector, multi-factor, computable general equilibrium (CGE) models, as the national accounts provide the data framework for macro-econometric models (EDRI, 2009).

With regard to the structure of SAM, the standard SAM basically has four major accounts. These are activities, commodities, institutions, factors of production and saving-investment accounts. In addition to these accounts, SAM may have extra accounts like taxes, total margins (Lofgren et.al, 2002).

The activity accounts show the value of commodities (goods and services) produced by each activity and the cost of inputs into each production activity consisting of intermediate input purchases along with payments to primary factors of production.

Commodity accounts show the components of total supply in value terms (domestic production, imports, indirect taxes and marketing margins) and total demand (intermediate input use, final consumption, investment demand, government consumption and exports). Factor accounts describe the sources of factor income and how these factor payments are further distributed to the various institutions in the economy (EDRI, 2009).In the commodity columns, payments are made to domestic activities, the rest of the world, and various tax accounts (for domestic and import taxes).

The matrix explicitly associates trade flows with transactions (trade and transportation) costs, also referred to as marketing margins. For each commodity, the SAM accounts for the costs associated with domestic, import, and export marketing. For domestic marketing of domestic output, the marketing margin represents the cost of moving the commodity from the producer to the domestic demander. For imports, it represents the cost of moving the commodity from the border (adding to the c.i.f. price) to the domestic demander, while for exports, it shows the cost of moving the commodity from the producer to the border (reducing the price received by producers relative to the f.o.b. price) (Lofgren et.al, 2002).

The institution account summarizes payments among government, households, enterprises, and rest of the world. In the SAM, payments between the government and other domestic institutions are reserved for transfers. In the matrix for government – household sub account the row represents the income to government from taxes (direct and indirect taxes), direct transfer from households and the rest of the world (ibid).

The enterprises earn factor incomes (reflecting their ownership of capital and/or land). They may also receive transfers from other institutions (the rest of the world and government).The rest of the world makes payments for exports, factors, transfers to households and government, and foreign saving. Technically, the standard CGE model requires that the SAM have at least one household account; however, enterprise accounts are not necessary (ibid).

The factors of production account reports payments to factors from activities in the domestic economy and the rest of the world and distribution of their income to different institutions on the row and column. The factors of production in the SAM consist of four types of labor: Skilled, Semi-skilled, unskilled workers and agricultural labor. In addition, it consists of land, livestock and capital

The savings-investment (S-I) account should be seen as representing the “loanable funds” market. The account collects savings from various sources (government, private, and foreign) and spends the accumulated savings on capital goods (I).

This study utilized the updated version of 2005/06 SAM that is disaggregated into 113 activities (with 77 agricultural activities by agro ecological zones, AEZs), 64 commodities, 16 factors (by AEZs except capital), and 13 institutions including 12 households. The SAM also has different taxes, saving-investment, inventory, and rest of the world accounts to show the interaction of different economic agents. It integrates regionally disaggregated agricultural production and income generation for the four main agro-ecological zones of Ethiopia (Humid, high land cereals, drought prone and pastoralist zones).

4.3 Overview of Standard Computable General Equilibrium Model

A CGE model is generally appropriate in the study where an economy wide impact of a given policy is analyzed. The model explains all of the payments recorded in the SAM of Ethiopian economy. It follows the SAM disaggregation of factors, activities, commodities, and institutions. It is written as a set of simultaneous equations, many of which are nonlinear. The equations define the behavior of the different actors. There is no objective function (Lofgren et.al, 2002). In part, this behavior follows simple rules captured by fixed coefficients.

For production and consumption decisions, behavior are captured by nonlinear, first order optimality conditions that are driven by the maximization of profits and utility respectively. The equations also include a set of constraints that have to be satisfied by the system as a whole but are not necessarily considered by any individual actor.

These constraints cover markets (for factors and commodities) and macroeconomic aggregates (balances for Savings-Investment, the government, and the current account of the rest of the world) (Lofgren et.al, 2002). The CGE models also include equations for closures. Solving the CGE model entails the specification of closure conditions that refer to the balancing of major accounts in the economy demand, supply, government and external sectors.

CGE models typically do not explicitly represent money as a commodity. However, in order to account for such trades the quantities of different commodities still need to be made comparable by denominating their values in some common unit of account. The flows are thus expressed in terms of the value of one commodity the so called numeraire good whose price is taken as fixed. For this reason, CGE models only solve for relative prices (wing, 2004).

CGE models are broadly divided into two: static and dynamic. Static CGE models show one time effects of policy changes while dynamic CGE considers the second round effect. Even though static CGE are simple for application, they are unable to account for growth or second effects (Annabi et al, 2004). Most CGE models are static in nature because consumers' demands are derived from a one-period utility function. Household savings is not endogenously determined using an inter-temporal utility function, and so it does not smooth consumption over time. Dynamic CGE is developed to solve these problems.

Dynamic CGE model is divided into two: truly dynamic (intertemporal) and recursive dynamic (sequential).Truly dynamic model is based on optimal growth theory where the behavior of economic agents is characterized by perfect foresight. They know all about the future and react to price change in the future. Recursive dynamic model is basically a series of static CGE models that are linked between periods by an exogenous and endogenous variables updating procedure.
The equations presented below fully specify the within-period component, in which consumers and producer maximize their utility and profits based on prevailing factor and product prices (i.e. without forward-looking expectations). Then, in between-periods, certain exogenous variables are updated based on previous period results (Diao et al, 2011).

4.3.1. One Period Static CGE Blocks

Price Block

The price block consists of several equations which endogenous model prices are linked to other prices (endogenous or exogenous) and to non-price. Most of the linear and nonlinear equations in this block are annexed as appendix B .Only those that are directly included in the objective are described below.

Absorption

Absorption is total domestic spending on a commodity at domestic demander prices. Equation below defines it exclusive of the sales tax. Absorption is expressed as the sum of spending on domestic output and imports at the demand prices, PDD and PM. The prices PDD and PM include the cost of trade inputs but exclude the commodity sales tax

$$PQ_C(1 - tq_C).QQ_C = PDD_C.QD_C + PM_C.QM_C \quad \text{..........................equation (4.1)}$$

$$\begin{bmatrix} absorption \\ (at\ demand \\ prices\ \ net\ of \\ sales\ tax \end{bmatrix} = \begin{bmatrix} domestic\ demand\ price \\ times \\ domestic\ sales\ quantity \end{bmatrix} + \begin{bmatrix} import\ price \\ times \\ import\ quantity \end{bmatrix}$$

Where

QQc = quantity of goods supplied to domestic market (composite supply),

QDc = quantity sold domestically of domestic output,

QMc = quantity of imports of commodity, and

tq_c = rate of sales tax (as share of composite price inclusive of sales tax).

Marketed Output Value

For each domestically produced commodity, the marketed output value at producer prices is stated as the sum of the values of domestic sales and exports. Domestic sales and exports are valued at the prices received by the suppliers, PDS and PE, both of which have been adjusted downwards to account for the cost of trade inputs.

$$PX_C.QX_C = PDS_C.QD_C + PE_C.QE_C \quad \text{.................equation (4.2)}$$

$$\begin{bmatrix} Producer\ price \\ times\ marketed \\ output\ quantity \end{bmatrix} = \begin{bmatrix} domestic\ supply\ price \\ times \\ domestic\ sales\ quantity \end{bmatrix} + \begin{bmatrix} export\ price \\ times \\ export\ quantity \end{bmatrix}$$

Where

$PX_C = aggregate\ producer\ for\ commodity,$

$QX_C = aggregate\ marketed\ quantity\ of\ dometic\ output\ of\ commodity$

$QE_C = quantity\ of\ exports, and$

$c\epsilon CX(\subset C) = a\ set\ of\ commodities\ with\ domestic\ output$

Production and Trade block

The production and trade block covers four categories: domestic production and input use; the allocation of domestic output to home consumption, the domestic market, and exports; the aggregation of supply to the domestic market (from imports and domestic output sold domestically); and the definition of the demand for trade inputs that is generated by the distribution process. Several linear and nonlinear equation are annexed as appendex B, only those directly linked to the objective are described below.

Output Aggregation Function

Producers may produce output to sell in domestic market or foreign market. Decision of producers to produce for the domestic and foreign markets is governed by Constant Elasticity of Transformation (CET) function which distinguishes between exported and domestic goods leading to captures any time, distance and quality differences between the two products.

In commodity market flow, domestically produced marketable output from each activity contributes to aggregate domestic output by using CES function. Accordingly, the domestic output (QXc) is allocated to domestic sales (QDc) and export (QEc) using constant elasticity of transformation function as follows:

$$QX_{ca}=\alpha_a^{ac}.\left(\sum_{\alpha\epsilon A}\delta_{ac}^{ac}.QXAC_{ac}^{-\rho_c^{ac}}\right)^{-\frac{1}{\rho_a^{ac}-1}} \text{.........................equation (4.3)}$$

$$\begin{bmatrix} aggregate \\ marketed \\ production\ of \\ commodity\ C \end{bmatrix} = CES\begin{bmatrix} activity-specific \\ marketed \\ production\ of\ commodity\ C \end{bmatrix}$$

Where

α_a^{ac} = shift parametre for domestic commodity aggregation function,

δ_{ac}^{ac}=share parametre for domestic commodity aggregation function,and

ρ_c^{ac}=domestic commodity aggregation function exponent.

The destination of domestic products based on the profitability of the destination. On the other hand, the share parameter denotes the proportion of exports or domestic sale from domestically produced output, while the exponent shows the elasticity of transformation between the two destinations (Lofgren et al., 2002).

Export-Domestic Supply Ratio

Based on the assumption of imperfect transformability between the two destinations, the export-domestic supply ratio is formulated. Then the optimal mix between exports and domestic sales is explained by export-domestic supply ratio.

$$\frac{QE_C}{QD_c} = \left(\frac{PE_c}{PDS_c} \cdot \frac{1-\delta_c^t}{\delta_c^t}\right)^{\frac{1}{\rho_c^{t-1}}}$$ ……………………………………………… equation (4.4)

$$\begin{bmatrix} export - domestic \\ supply\ ratio \end{bmatrix} = f \begin{bmatrix} export - domestic \\ price\ ratio \end{bmatrix}$$

Composite Supply (Armington) Function

Domestically produced commodities that are not exported are supplied to the domestic market. Substitution possibilities exist between imported and domestic goods under a CES Armington specification (Armington, 1969). So, composite supply function or Armington function (QQc) is function of import quantity (QM_c) and domestic use of domestic output (*QDc*). It is specified to absorb imperfect substitutability of imports and domestic output sold domestically. The CES aggregation function in which the composite commodity supplied domestically is produced by domestic and imported commodities entering this function as inputs capture the imperfect substitutability of imports and domestic output sold domestically.

When the domain of the CES function is restricted to commodities that are both imported and produced domestically, then, this function is often known as‘’ Armington” function, which is named after Paul Armington in honour of his work in 1969 (Lofgren et al., 2002).

$$QQ_c = \alpha_c^q \left(\delta_c^q QM_c^{-\rho^q} + (1-\delta_c^q). QD_c^{\rho^q}\right)^{\frac{1}{\rho^q}}$$ …………………………………… Equation (4.5)

$$\begin{bmatrix} composite \\ supply \end{bmatrix} = f \begin{bmatrix} import\ quantity, domestic \\ use\ of\ domestic\ output \end{bmatrix}$$

Where

α_a^q = an Armington function shift parametre,

δ_c^q= an Armington function share parametre,and

ρ_c^q= an Armington function exponent

Demand for Transactions Services

Total demand for trade inputs is the sum of the demands for these inputs that are generated by imports (from moving commodities from the border to domestic demanders), exports (from moving commodities from domestic producers to the border), and domestic market sales (from moving commodities from domestic producers to domestic demanders). In all three cases, fixed quantities of one or more transactions service inputs are required per unit of the traded commodity.

$QT_c = \sum_{c'\varepsilon C'}(icm_{cc'}.QM_{c'} + ice_{cc'}.QE_{c'} + icd_{cc'}.QD_{c'})$ ………………………… equation (4.6)

$$\begin{bmatrix} demand\ for \\ transactions \\ service \end{bmatrix} = \begin{bmatrix} sum\ of\ demands \\ for\ imports, exports, \\ and\ domestic\ sales \end{bmatrix}$$

Where,

$QT_c = quantity\ of\ commodity\ demands$

Institution Block

In the CGE model, institutions are represented by households, enterprises, the government, and the rest of the world.

The households receive income from the factors of production (directly or indirectly via the enterprises) and transfers from other institutions. Transfers from the rest of the world to households are fixed in foreign currency. In fact, all transfers between the rest of the world and domestic institutions and factors are fixed in foreign currency. The households use their income to pay direct taxes, save, consume, and make transfers to other institutions. In the basic model version, direct taxes and transfers to other domestic institutions are defined as fixed shares of household income whereas the savings share is flexible for selected households. The treatment of direct tax and savings shares is related to the choice of closure rule for the government and savings-investment balances.

The income that remains after taxes, savings, and transfers to other institutions is spent on consumption. Household consumption covers marketed commodities, purchased at market prices that include commodity taxes and transaction costs, and home commodities, which are valued at activity-specific producer prices.

Household consumption is allocated across different commodities (both market and home commodities) according to linear expenditure system (LES) demand functions.

Instead of being paid directly to the households, factor incomes may be paid to one or more enterprises. Enterprises may also receive transfers from other institutions. Enterprise incomes are allocated to direct taxes, savings, and transfers to other institutions. Enterprises do not consume. Apart from this, the payments to and from enterprises are modeled in the same way as the payments to and from households.

The government collects taxes and receives transfers from other institutions. In the basic model version, all taxes are at fixed *ad valorem* rates. The government uses this income to purchase commodities for its consumption and for transfers to other institutions. Government consumption is fixed in real (quantity) terms whereas government transfers to domestic institutions (households and enterprises) are CPI-indexed. Government savings (the difference between government income and spending) is a flexible residual.

The final institution is the rest of the world. As noted, transfer payments between the rest of the world and domestic institutions and factors are all fixed in foreign currency. Foreign savings (or the current account deficit) is the difference between foreign currency spending and receipts.

The factor income (YF_f) is the sum of activity payment (QF_{fa}) and activity specific wage multiplied by employment level (Lofgren et al, 2002). It defines the total income of each factor.

Factor Income

$YF_f = \sum_{\alpha \epsilon A} WF_f \,. \overline{WFDIST}_{fa} . QF_{fa}$ ………………………………………………….. Equation (4.7)

$$\begin{bmatrix} income\ of \\ factor\ f \end{bmatrix} = \begin{bmatrix} sum\ of\ activity\ payments \\ (activity - specific\ wages \\ times\ employment\ levels) \end{bmatrix}$$

$YF_f = income\ of\ factor\ f$

Institutional Factor Incomes

This income then split among domestic institutions after direct factor tax and transfers to rest of the world are paid. So, income of each institution from factor payment is the product of share of income of factor to institution and income of factor after transfer to the rest of the world are paid.

$YIF_{if} = shif_{if}\left[\left(1 - tf_f\right). YF_f - trnsfr_{rowf}. EXR\right]$ ………………………….. Equation (4.8)

$$\begin{bmatrix} income\ of \\ institution\ i \\ from\ factor\ f \end{bmatrix} = \begin{bmatrix} share\ of\ income \\ of\ factor\ f\ to \\ institution\ i \end{bmatrix} \begin{bmatrix} income\ of\ factor\ f \\ (net\ of\ tax\ and \\ transfer\ to\ Row) \end{bmatrix}$$

Where

$i\epsilon INS = a\ set\ of\ institutions(domestic\ and\ rest\ of\ the\ world),$

$i\epsilon INSD(\subset INS) = a\ set\ of\ domestic\ institutions,$

$YIF_{if} = income\ of\ domestic\ institution\ i\ from\ factor\ f,$

$shif_{if} = share\ of\ domestic\ institution\ i\ in\ income\ of\ factor\ f,,$

$tf_f = direct\ tax\ rate\ for\ factor\ f, and$

$trnsfr_{if} = transfer\ from\ factor\ f\ to\ institution\ i.$

Income of domestic, non-government Institutions

The above equation gives reference to the set of domestic institutions in general (households, enterprises, and the government), including the rest of world. Income to domestic nongovernment institutions is then the sum of factor incomes, transfers from other domestic nongovernment institutions, transfers from the government, and transfers from the rest of the world

$YI_i = \sum_{f\epsilon F} YIF_{if} + \sum_{f\epsilon INSDNG'} TRII_{ii'} + trnsfr_{igov}.\overline{CPI} + trnsfr_{irow}.EXR$ …………equation (4.9)

$$\begin{bmatrix} income\ of \\ institution\ i \end{bmatrix} = \begin{bmatrix} factor \\ income \end{bmatrix} + \begin{bmatrix} transfer \\ from\ other\ domestic \\ non\ government \\ institutions \end{bmatrix} + \begin{bmatrix} transfer \\ from \\ government \end{bmatrix} + \begin{bmatrix} transfer \\ from \\ RoW \end{bmatrix} \quad i\epsilon INSD$$

Where

$i\epsilon INSDNG(INSDNG' \subset INSD) = a\ set\ of\ domestic\ nongovernmental\ institutions,$

$YI_i = income\ of\ institution\ i(in\ the\ set\ INSDNG), and$

$TRII_{ii'} = transfer\ from\ institution\ i'to\ i\ (both\ in\ the\ set\ INSDNG).$

Household Consumption Expenditures

Institutions spend their income gained from different sources explained above on different activities. Consumers spend their disposable income i.e. income after tax, transfers and saving on consumption. So, the total value of consumption spending is defined as the income that remains after direct taxes, savings, and transfers to other domestic nongovernment institutions.

$EH_h = (1 - \sum_{i\epsilon INSDNG} shii_{ih}).(1 - MPS_h)(1 - TINS_h).YI_h$ ……. equation (4.10)

$$\begin{bmatrix} household\ income \\ disposable\ for \\ consumption \end{bmatrix} = \begin{bmatrix} household\ income, net\ of\ direct \\ taxes, savings, and\ transfer\ to \\ other\ non - government\ institution \end{bmatrix}$$

Where

$i\epsilon H(INSDNG \subset INSD) = a\ set\ of\ households, and$

$EH_h = household\ consumption\ expendatures$

This total value of consumption is on two categories of commodities; consumption of marketed commodities purchased at market price and consumption of home production valued at their opportunity cost.

Household Consumption Spending on Marketed Commodities

$$\mathrm{PQ_c.QH_{ch}}=\mathrm{PQ_c}\gamma^{m}_{ch} + \beta^{m}_{ch}(\mathrm{EH_h} - \textstyle\sum_{c'\epsilon C}\mathrm{PQ_{C'}}.\gamma^{m}_{c'h} - \sum_{\alpha\epsilon A}\sum_{c'\epsilon C}\mathrm{PXAC_{ac'}}.\gamma^{h}_{ac'h}$$

………..Equation (4.11)

$$\begin{bmatrix} \text{household consumption} \\ \text{spending on market} \\ \text{commodity c} \end{bmatrix} = \mathrm{f}\begin{bmatrix} \text{total household consumption} \\ \text{spending , market price of c, and other} \\ \text{commodity prices(market and home)} \end{bmatrix}$$

Where

$\mathrm{QH_{ch}}$ = quantity of consumption of marketed commodity c for household h,

γ^{m}_{ch} = subsistence consumption of marketed commodity c for household h,

β^{m}_{ch} = marginal share of consumption spending on marketed commodity c for household h

Investment demand equation

This equation calculates the fixed investment demand ($QINV_C$) using the base-year quantity of fixed investment demand $\overline{qinv}_c$ adjusted by the exogenous investment factor $\overline{IADJ}$.

Investment demand

$QINV_C=\overline{IADJ}.\overline{qinv}_c$ ………..Equation (4.12)

System constraints and macroeconomic closure

In order to get the solution of the general equilibrium, the number of equations and the number of variables have to be equal. To satisfy this, the CGE model introduced three macroeconomic balances: the current government balance, the current account balance and the Savings- Investment balance. To get these balances, again, there are different alternative closures and the user can choose the appropriate closures that reflect the objective of his/her study. The choice of any of the available closure does not sway the solution to the base simulation but it changes the results of other simulation (Lofgren et.al, 2002).

Factor and commodity markets

The equilibrium conditions require the equality between the total quantity demanded for each factor (commodity) and the total quantity for each factor (commodity).

$\sum_{\alpha \epsilon A} QF_{fa} = \overline{QFS}_f$ ……………………………………………………………Equation (4.13)

$\begin{bmatrix} demand\ for \\ factor\ f \end{bmatrix} = f \begin{bmatrix} supply\ of \\ factor\ f \end{bmatrix}$

$\overline{QFS}_f = quantity\ supplied\ of\ factor\ (exogenous\ variable)$

QF_{fa} =quantity demanded for factor f (endogenous variable) QF= quantity demanded for factor f (endogenous variable) QF

Government balance

This balance is assured when the government revenue (YG) is equal to the sum of government expenditures (EG) and government savings (GSAV).

$YG = EG + GSAV$ ……………………………………………………………………. Equation (4.14)

Current account balance

In this balance, the sum of import spending ($\sum pwm_c\, QM_c$) and factor transfers to Row($\sum trnsfr_{rowf}$) must equals to the sum of export revenue ($\sum pwe_c\, QE_c$),institutional transfers from RoW ($\sum trnsfr_{irow}$) and foreign savings$\overline{(FSAV)}$.The equation is:

$\sum_{c \epsilon CM} pwm_c . QM_c$+$\sum_{f \epsilon F} trnsfr_{rowf} = \sum_{c \epsilon CM} pwe_c QE_c + \sum_{i \epsilon INSD} trnsfr_{irow} + \overline{(FSAV)}$

……. ……………………………………………………………………………………..Equation (4.15)

Saving-Investment balance

This balance also requires the equality of total national saving and total investment.

$\sum_{i \epsilon INDNG} MPS_i\, (1 - TINS_i). YI_i$+GSAV+EXR.$\overline{FSAV}$=$\sum_{c \epsilon C} PQ_c\, QINV_c + \sum_{c \epsilon C} PQ_c . qdst_c$

………………………………………………………………………………………. Equation (4.16)

Where

$$\sum_{i\epsilon INDNG} MPS_i\,(1-TINS_i).YI_i = non-government\ saving$$

GSAV=government saving

EXR.$\overline{FSAV} = foreighn\ saving$

$$\sum_{c\epsilon C} PQ_c\, QINV_c = fixed\ investment$$

$$\sum_{c\epsilon C} PQ_c . qdst_c = stock\ change$$

To maintain the three macro-balances, this study uses three default closures of the IFPRI's CGE model for Ethiopia. For the government balance, tax rates are fixed and government saving is flexible; for the current account balance, foreign saving is fixed while real exchange rate is flexible; and for Saving-Investment balance, saving is fixed and investment is endogenous, i.e., saving-driving closure.

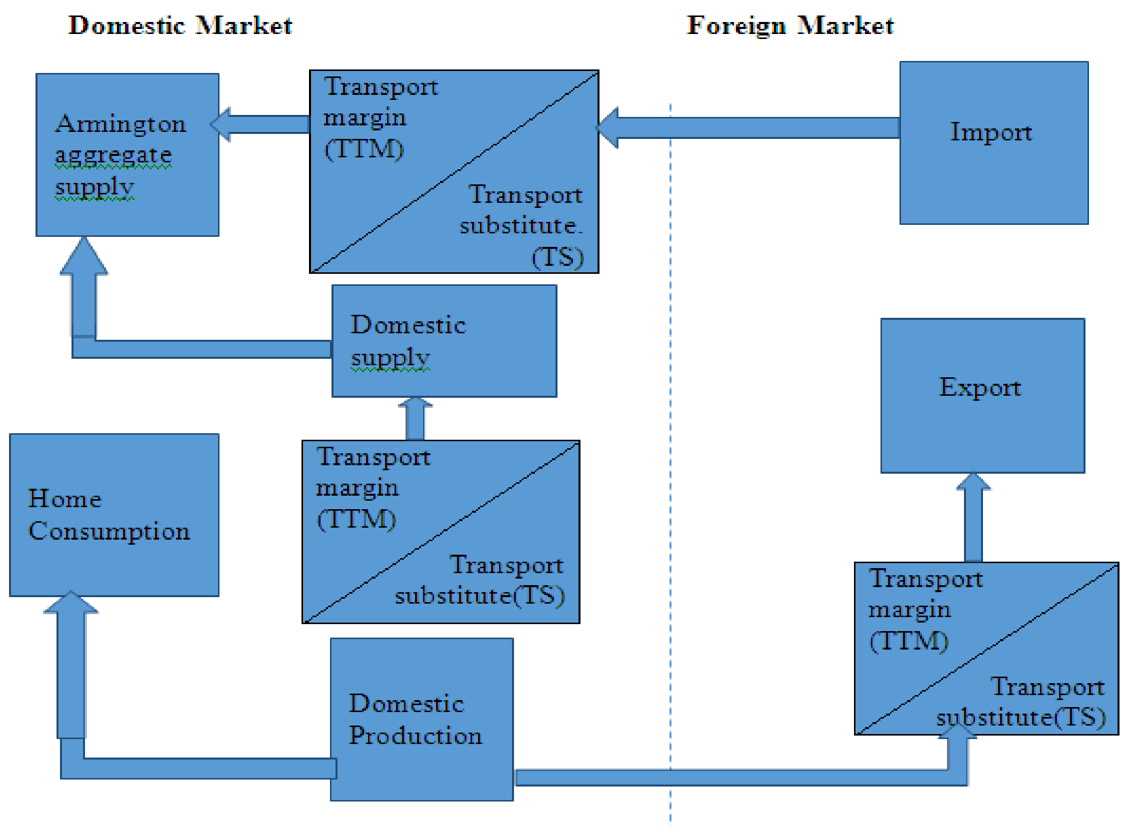
4.3.2. Between periods or Dynamic CGE block

In the previous section we have described the within-period or static component of the model. However, the impact of policy-changes includes dynamic aspects, such as the inter-temporal effects of changes in investment and the rate of capital accumulation. In order to investigate in more detail the relationship between policy changes and factor accumulation the static model is extended to a dynamic recursive model. In the extended part of the model labor supply will be determined exogenously (updated by the population growth rate, i.e. as population grows, the total labor supply increases at the same rate) while capital accumulation is determined endogenously (In a given time period the total available capital is determined by the previous period's capital stock and investment spending). Then new capital will be distributed among sectors based on each sector's initial share of aggregate capital income (Thurlow, 2004). Full specification of each dynamic equation is given in Appendix.

4.4 Linking strategy

The figure presented below clearly shows the channel through which road investment impacts the overall economy. Any domestically produced goods are either be consumed at home or supplied to the domestic market or exported abroad as is assumed in the IFPRI model described in section 4.3. If it is marketed, it has to be combined with a transport good, which might either be trade or transport services (TM) or the transport substitute produced by newly available roads (TS). The choice between *home consumption* and *marketed production* is determined by a constant elasticity of transformation (CET) function. Home consumption is only possible in agricultural sectors and basic manufacturing (i.e. food processing). Domestic goods are imperfect substitutes for foreign goods. Domestically produced goods are combined with imported supply in a Constant Elasticity of Substitution (CES) function to form the Armington aggregate which is sold on domestic markets. Domestically produced goods may also be exported, but production of exports differs from production for local markets. This is implemented using a CET function(Lofgren et.al, 2002)..

Fig 8. Linking strategy of road investment to the overall economy



Source:Hanna,2014

The strategy to link the econometric and the CGE models is as follows: first we need to translate the average percentage change of road density that is brought by the investment considered in the scenario to transport and trade margin. That is to mean keeping other variables constant what is the effect of a certain percentage change of road density to the transport and trade margin? This will be obtained (calibrated) from Hanna, 2014 result. After we get the percentage change of the trade and transport margin as a result of a certain percentage change in road density (different scenarios can be considered), we shock the econometric result in the CGE model through the trade and transport margin equation 4.6 exogenously and see the overall effects in the economy.

5. Simulation and result

5.1 Calibration

The CGE model is calibrated to a base-year dataset in order to provide a benchmark structure of the economy.

Since there is no time series data on trade and transport margin in Ethiopia (except a one year data on the SAM), an estimated road infrastructure-elasticity of the trade and transport margin on Africa countries by Hannah (2014) was taken. The CGE model has been calibrated in such a way that the trade and transport margin in the agricultural sectors has an elasticity of 0.19 with respect to road density. For other sectors an elasticity of 0.15 has been assumed (Hannah (2014), Teravaninthorn and Raballand (2009)).

5.2 Simulation

The following scenarios are considered to evaluate the overall impact of road infrastructure on the economy.

Simulation 0: This is the base case scenario and serves as a reference in the absence of any policy shock .Thus, the result of the base line simulation is used as the benchmark value so as to compare the values of different variables after the policy shocks.

Simulation 1: In this scenario, the average annual road density growth during the Plan for Accelerated and Sustained Development to End Poverty PASDEP (2005-2010) is considered. During this period the road density grew by 6%.Taking the elasticity of trade and transport margin by Hannah (2014), it is the same us reducing the trade and transport margin by 1.14%. Hence a 1.14% reduction in transport and trade margin is considered in this scenario.

Simulation 2: In this scenario, the average annual road density growth required to achieve a lower middle income level by 2025 (road density of 260km/1000km^2) is considered. During this period the road density is required to grow by 10%. Using the same elasticity, it is similar to reducing the trade and transport margin by 2 %. Hence a 2% reduction in transport and trade margin is considered in this scenario.

Simulation 3: In this scenario, the average annual road density growth during the GTP period is considered. During this period the road density grew by 20%.Taking the same elasticity of trade and transport margin, it is the same us reducing the trade and transport margin by 3.8%. Hence a 3.8 % reduction in transport and trade margin is considered in this scenario.

Simulation 4: In this scenario, the average annual road density grows by 30% or similarly the trade and transport margin reduces by 5.7 %

Simulation 5: In this scenario, the average annual road density grows by 40% or similarly the trade and transport margin reduces by 7.6%

Simulation 6 In this scenario, the average annual road density grows by 50% or similarly the trade and transport margin reduces by 9.5%.

5.3 Results and discussion

Here, the detailed results of the simulation and their interpretation are presented. The analysis is done in line with the objective. That is to mean attempt was made to see the effect of investment in road infrastructure (increase in road density or reduce in transaction cost) on major issues like its impacts on macroeconomic indicators (real GDP, absorption, investment, private consumption, real export, real import), sectorial growth effect (agriculture, industry, service), private consumption expenditure (rural poor, rural non poor, urban poor, urban non-poor), and factor income.

5.3.1 Impact of road investment on macroeconomic variables

Table 10 shows the summary of the results focusing on real GDP at factor cost (GDPFC2), fixed investment (FIXINV), private consumption (PRVCON) and absorption.

In all simulations, the macroeconomic variables have shown positive changes. In simulation 1, real GDP at factor cost reveals a 0.02% increase from base line simulation. In simulation 2, real GDP at factor cost reveals a 0.03% increase from base line simulation and in simulation 3, real GDP at factor cost reveals a 0.05% increase from base line simulation. The above results indicate the third simulation perform better compared to others.

For robustness test, three other scenarios are considered: simulation 4, simulation 5 and simulation 6.The result generally indicates that GDP at factor cost has a positive change though the magnitude is small. It grows by 10.72%, 10.75% and 10.77% respectively.

The growth pattern in general indicates that the improvement in road network which ultimately has an effect on reducing the transaction cost has a little effect on the economy unless the economy is also derived by other factors.

Private consumption also increases by 0.12% , 0.19% and 0.39% in simulation 1, simulation 2 and simulation 3, respectively, as compared to base line simulation. Similarly, real investment increases by 0.13%, 0.22% and 0.45%, respectively, in simulation1, simulation2 and simulation3 respectively.

Absorption, which is the total demand for all final marketed goods and services by all economic agents resident in an economy, regardless of the origin of the goods and services themselves, indicates that there is a 0.11%, 0.19% and 0.37 % increase in scenario 1, in scenario 2 and scenario 3 as compared to the base line scenario. The increase in the absorption as the road length increase is theoretically accepted as it relates to environment in which the road creates in terms of availing good and services at a relatively lower price. Increasing the road network in terms of quality and quantity reduces transaction cost.

Gross fixed investment which is defined as total business spending on fixed assets, such as factories, machinery, equipment, dwellings, and inventories of raw materials, positively influenced by the size in road density. Among all the macro variables, gross fixed investment shows a relatively better increment in all scenarios.

Private consumption increased by 0.12% and 0.19% and 0.39% in scenario 1, scenario 2 and scenario 3 respectively.

Table 10: Impact of road investment on macroeconomic variables (average % change per year)

Variables	Initial	Sim0	Sim1	Sim2	Sim3	Sim4	Sim5	Sim6
ABSORP	457.7369	10.14	10.25	10.33	10.51	10.72	10.89	11.05
PRVCON	338.6106	9.2	9.32	9.39	9.59	9.80	9.98	10.14
FIXINV	85.4902	12.45	12.58	12.67	12.90	13.15	13.35	13.54
GDPFC2	354.9523	10.64	10.66	10.67	10.69	10.72	10.75	10.77

Source: *Simulation results*

Table 11: Impact of road investment on macroeconomic variables (average % change from base line Simulation)

Variables	Initial	Sim1	Sim2	Sim3	Sim4	Sim5	Sim6
ABSORP	457.74	0.11	0.19	0.37	0.58	0.75	0.91
PRVCON	338.61	0.12	0.19	0.39	0.60	0.78	0.94
FIXINV	85.49	0.13	0.22	0.45	0.70	0.90	1.09
GDPFC2	354.95	0.02	0.03	0.05	0.08	0.11	0.13

Source: *Simulation results*

5.2.2. Impact of road investment on trade balance

Table 12 presents result for trade balance. Real export increases by 0.16% in simulation1 compared to base line simulation, while it increases by 0.26% and 0.53% in simulation 2 and simulation 3 as compared to the base line simulation.

Similarly, real import increases by 0.08%, 0.14% and 0.27%, respectively, in simulation 1, simulation 2, simulation3 as compared with the base line simulation.

Simulation 4, 5 and 6 indicates that both real export and import shows improvements as the road length expands(the transaction cost reduces)

Table 12: Impact of road investment on export and import (average % change per year)

Variables	Initial	Sim0	Sim1	Sim2	Sim3	Sim4	Sim5	Sim6
Export	52.14	12.39	12.55	12.65	12.92	16.12	16.92	17.17
Import	-126.51	10.64	10.72	10.78	10.91	9.71	10.13	10.26

Source: *Simulation results*

Table 13. Impact of road investment on export and import (average % change from base line simulation)

Variables	Initial	Sim1	Sim2	Sim3	Sim4	Sim5	Sim6
Export	52.14	0.16	0.26	0.53	0.81	1.05	1.29
Import	-126.51	0.08	0.14	0.27	0.42	0.55	0.68

Source: *Simulation results*

5.2.3. Sectoral impact of investment on road infrastructure

As the different sectors have differing transport intensities, a shock in transport costs will have substantially various effects on the different sectors.

Table 14 indicates that agricultural sector grow by 0.03%, 0.05% and 0.09 % in simulation,1 simulation 2 and simulation 3, respectively, compared to the base line scenario. The industrial sector grows by 0.19%, 0.32% and 0.65 %, respectively, in simulation, 1 simulation 2 and simulation 3 as compared to the base scenario. The service sector also grows by 0.05%, 0.09% and 0.17% under simulation, 1 simulation 2 and simulation 3 respectively as compared to the base line scenario. The remaining scenario (4, 5 and 6) also depicts the same growth pattern.

The result indicates investment in road infrastructure contributes more for the industrial sector than the other sectors. The next sector benefited from road infrastructure is the agricultural sector followed by the service sector.

Table 14: Sectoral impact of investment on road (average % change per year)

Variables	Initial	Sim0	Sim1	Sim2	Sim3	Sim4	Sim5	Sim6
Agriculture	174.26	7.20	7.23	7.25	7.29	7.38	7.44	7.51
Industry	36.20	13.90	14.09	14.22	14.55	15.09	15.52	16.14
Service	144.50	13.40	13.45	13.51	13.58	13.68	13.82	14.01

Source: *own computation from simulation results*

Table 15 Sectoral impact of investment on road (average % change from base line simulation)

Variables	**Sim1**	**Sim2**	**Sim3**	**Sim4**	**Sim5**	**Sim6**
Agriculture	0.03	0.05	0.09	0.15	0.19	0.22
Industry	0.19	0.32	0.65	1	1.3	1.59
Service	0.05	0.06	0.07	0.10	0.14	0.18

Source: *own computation from simulation results*

5.2.4. Impact road investment on factor income

In relation to returns to factors of production, the results from the CGE model are provided in the Table 16. Aggregate factor income has improved in all simulations. The increase in factors income is because of increase in output of activities in all the sectors (industry, service and agriculture). However, the higher growth rate in aggregate factor income is obtained in simulation 6 compared to other simulations. The average growth rate of aggregate returns rises from 10.59% in simulation 1 to 12.54% in simulation 6. It has grown by 0.18%, 0.3%, 0.56%, 0.94%, 1.12% and 1.4%, respectively, for simulation 1, 2, 3, 4, 5 and 6 compared to the baseline simulation. Therefore, returns to all factors of production increase as the road density increases.

Table 16: Impact of road investment on factor income (Average % change).

Variables	Initial	share	Sim0	Sim1	Sim2	Sim3	Sim4	Sim5	Sim6
Labor	174.0084	49.02	9.42	9.60	9.72	10.02	10.36	10.62	10.86
Capital	110.3244	31.08	9.59	9.80	9.95	10.30	10.71	11.02	11.31
Land	39.76201	11.20	11.17	11.47	11.68	12.19	12.76	13.22	13.63
Livestock	30.85749	8.69	12.17	12.44	12.62	13.07	13.58	13.98	14.35
Average		100.00	10.59	10.83	10.99	11.39	11.85	12.21	12.54

Source: *Simulation results*

It appears that households that possess a large number of farm animals, larger land size and better land quality and better human and fiscal capital benefit more from road infrastructure. Among the factors of production, the return of land grows at the fastest rate. Income from land grows by 0.3%, 0.5%, 1%, 1.5%, 2% and 2.5% for simulation 1, 2, 3, 4, 5 and 6 compared to the baseline simulation. . The reason could be as the road density increases, productivity of land would increase. The effect of roads on income is larger in a situation where poor farm households use fertilizer as fertilizer raises the return to land (Wondimu, 2012).

Table 17: Impact of road investment on factor income (average % change from base line simulation)

Variables	Sim1	Sim2	Sim3	Sim4	Sim5	Sim6
Labor	0.18	0.30	0.60	0.94	1.20	1.44
Capital	0.21	0.36	0.71	1.12	1.43	1.72
Land	0.30	0.51	1.02	1.59	2.05	2.46
Livestock	0.27	0.45	0.90	1.41	1.81	2.18
Average	0.18	0.30	0.60	0.94	1.20	1.44

Source: *Simulation results*

The poor benefit from road infrastructure because it boosts the overall factor productivity and the return to assets possessed by this group of the household (Wondimu, 2012). Factor income on the average has increased by 0.14%, 0.24%, 0.48%, 0.75%, 0.96% and 1.15% in simulation 1, 2, 3,4 ,5 and 6 compared to base line simulation. The result also shows that the income for unskilled and agricultural labor increases as the road density increases. This is mainly because of the fact that the majorities of the population lived in rural areas are dependent on either agriculture or cattle grazing which gives the expansion of road the access to the market as well as new technologies. Unlike the two type of labor, the skilled labor shows deterioration as road length increases. This particularly is the result of the structure of the economy. That is to mean that since the Ethiopian economy as is depends on agriculture, the effect of different policy scenarios on road construction is reflected on this major sector which practically engulfs unskilled labors. The effect can be positive if and only if the country undergoes a structural change or else the agricultural farming which is subsistence and require less skill should be replaced by mechanized farming that required at least semi skill labor.

Table 18: Impact of road investment on labor income (average % change from base line simulation)

Labor group	Initial(billion birr)	share	Sim1	Sim2	Sim3	Sim4	Sim5	Sim6
Skilled labor	77.52734	44.55	-0.07	-0.11	-0.22	-0.35	-0.45	-0.55
Unskilled labor	39.39778	22.64	0.20	0.34	0.67	1.06	1.36	1.63
Agricultural labor	57.08327	32.80	0.30	0.49	0.99	1.55	1.99	2.39
Average		100	0.14	0.24	0.48	0.75	0.96	1.15

Source: *Simulation results*

5.2.5 Impact of road investment on households income and expenditure

Road projects interventions improve income by altering farm gate price ratios and subsequently influencing micro level production, resource allocation and marketing decisions. Apart from the condition of road access, the effectiveness of markets and the institutions that support them will be critical in determining producer responses to the incentives created by road improvements (Wondimu, 2012).

5.2.5.1 Impact of road investment on household Income

The primary sources of income for households are factor payments generated during production. They also receive transfers from other institutions like government, other domestic institutions and the rest of the world. One can analyze the impact of investment in road on household income using Table 19.

Table 19 below indicates that as the road network increases, aggregate household income has registered positive growth. It grows by 9.5%, 9.76%, 9.56%, 10.31%, 10.59% and 10.80% in simulations 1, 2, 3, 4, 5 and 6 respectively as compared to the baseline scenario.

Table 19 also indicate household income increase by 0.14%, 0.24%, 0.48%, 0.73%, 0.97%% and 1.16% respectively for simulation 1, 2,3,4,5 and 6 as compared to the base line scenario.

One can also show that the impact of this investment on poor and non-poor households by aggregating income of households in different agro ecological zones through dividing urban and rural areas (see table 22). In general the investment in road will result in increase in real incomes of all households groups irrespective of where they live and wealth status (see table 19). Improvement in road access enhances income through reducing transaction and transport cost, enhancing competition, expanding market opportunities and improving spatial prices for goods and factors (Wondimu, 2012). Through the price mechanisms, it subsequently influences various micro level decisions, namely what to produce (the choice of the cropping pattern), how to produce (input use pattern in general and adoption of new techniques in particular), how much to produce, how much to sell and where to sell. These decisions in turn, through their effect on static and dynamic efficiency, ultimately influence the level of income farm households can generate from their fixed resources (ibid).

Table 19: Impact of investment in road on household income (average % change per year)

Household	Initial (in billion Birr)	share	Sim0	Sim1	Sim2	Sim3	Sim4	Sim5	Sim6
Rural poor	73.93	19.75	9.88	10.09	10.24	10.59	10.86	11.40	11.66
Rural non poor	261.08	69.74	9.64	9.80	9.90	10.16	10.46	10.70	10.90
Urban poor	3.83	1.02	8.8	8.91	8.98	9.17	9.40	9.50	9.70
Urban non poor	35.54	9.49	7.65	7.74	7.80	7.95	8.15	8.25	8.35
Total	374.38	100	9.5	9.65	9.76	10.03	10.31	10.59	10.80

Source: *Simulation results*

Table 20: Impact of investment in road on household income (Average % change from base line simulation)

Household	Initial (in billion Birr)	Sim1	Sim2	Sim3	Sim4	Sim5	Sim6
Rural poor	73.93	0.21	0.36	0.71	0.98	1.52	1.78
Rural non poor	261.08	0.16	0.26	0.52	0.82	1.06	1.26
Urban poor	3.83	0.11	0.18	0.37	0.6	0.7	0.9
Urban non poor	35.54	0.09	0.15	0.30	0.5	0.6	0.7
Total	374.38	0.14	0.24	0.48	0.73	0.97	1.16

Source: *Simulation results*

Identifying the role of roads in poverty reduction and pro-poor growth is critical for policy makers and transport strategist in developing countries. Assessing whether road infrastructures facilitates pro-poor growth or whether the non-poor benefiting more from road projects is critical.

As can be seen in table 21 and 22 households who are categorized in the humid poor are very responsive as the road density increases (transaction cost reduce) as compared to the remaining group. In this group the house hold income increases as road density increases by 0.31%, 0.52% and 0.9% in simulation 1, simulation2 and simulation 3 compared to the base line simulation. Secondly, the highland cereal poor and drought prone poor groups are benefited from road investment. In this groups household income increases as road density increases by 0.23%, 0.38% and 0.75% in simulation 1, simulation2 and simulation 3 as compared to the base line simulation.

In general, in all simulation and household groups the poor are more benefited as compared to the noon poor which indicates that investment in road is pro- poor.

Table 21: Impact of investment in road on household income by agro ecological zones (average % change per year)

Household	Initial(billion birr)	Share	Sim0	Sim1	Sim2	Sim3	Sim4	Sim5	Sim6
Highland cereal poor	29.5	7.88	9.89	10.12	10.27	10.64	11.09	11.39	11.69
Highland cereal non poor	109.9	29.37	9.78	9.97	10.10	10.41	10.78	11.08	11.28
Humid poor	15.7	4.2	10.33	10.64	10.85	11.36	11.23	12.83	13.13
Humid non poor	42.8	11.44	10.07	10.22	10.32	10.57	10.87	11.07	11.27
Drought prone poor	18	4.81	9.85	10.08	10.23	10.60	11.05	11.35	11.65
Drought prone non poor	41	10.96	9.83	10.01	10.12	10.41	10.73	11.03	11.23
Pastoral poor	3.8	1.02	9.98	10.19	10.33	10.68	11.08	11.38	11.68
Pastoral non poor	19.5	5.21	9.89	10.06	10.17	10.46	10.79	10.99	11.29
Farming poor	6.9	1.84	9.36	9.46	9.53	9.69	9.86	10.06	10.16
Non farming non poor	47.8	12.77	8.61	8.71	8.78	8.94	9.11	9.31	9.41
Urban poor	3.8	1.02	8.8	8.91	8.98	9.17	9.4	9.5	9.7
Urban non poor	35.5	9.49	7.65	7.74	7.80	7.95	8.15	8.25	8.35
	374.2	100	9.50	9.67	9.79	10.07	10.35	10.69	10.90

Source: *Simulation results*

Table 22: Impact of investment in road on household income by agro ecological zones (Average % change from base line simulation)

Household	Initial(billion birr)	Share	Sim1	Sim2	Sim3	Sim4	Sim5	Sim6
Highland cereal poor	29.5	7.88	0.23	0.38	0.75	1.20	1.50	1.80
Highland cereal non poor	109.9	29.37	0.19	0.32	0.63	1.00	1.30	1.50
Humid poor	15.7	4.2	0.31	0.52	0.90	1.03	2.50	2.80
Humid non poor	42.8	11.44	0.15	0.25	0.50	0.80	1.00	1.20
Drought prone poor	18	4.81	0.23	0.38	0.75	1.20	1.50	1.80
Drought prone non poor	41	10.96	0.18	0.29	0.58	0.90	1.20	1.40
Pastoral poor	3.8	1.02	0.21	0.35	0.70	1.10	1.40	1.70
Pastoral non poor	19.5	5.21	0.17	0.28	0.57	0.90	1.10	1.40
Farming poor	6.9	1.84	0.10	0.17	0.33	0.50	0.70	0.80
Non farming non poor	47.8	12.77	0.10	0.17	0.33	0.50	0.70	0.80
Urban poor	3.8	1.02	0.11	0.18	0.37	0.60	0.70	0.90
Urban non poor	35.5	9.49	0.09	0.15	0.30	0.50	0.60	0.70
	374.2	100	0.17	0.29	0.57	0.84	1.18	1.40

Source: *Simulation results*

5.2.5.2. Impact road investment on household consumption expenditure

Consumption by households is basically depends on observable household characteristics such as age, sex and household size. In addition, consumption can be affected by household's own capital or wealth and other unobservable heterogeneous characteristics of the households. However, provision of public facilities such as roads is important to facilitate production and consumption processes (Wondimu, 2010).

Household consumption grows by 9.16%, 9.25%, 9.48%, 9.71%, 9.97%, and 10.16% in simulation 1, 2,3,4,5 and 6, respectively as compared to the baseline simulation. It grows by 0.13%, 0.23%, 0.46%, 0.68%, 0.94% and 1.13% respectively as compared to the base line simulation. The consumption patter in rural poor is a bit better than the other house hold group. Similarly the consumption pattern for rural area is better than the urban area. This might be associated with the saving culture and access to roads in the rural areas compared to the urban areas. In general, household consumption raises more with investment in road infrastructure.

The simulation result also indicates that increases in road density or reduction in transport and trade margin benefit more the poor rural and urban household. The poor household benefits 0.04%,0.08% 0.14%, 0.07% ,0.38% and 0.4% higher than the non-poor household in simulation 1,2,3,4,5 and 6 respectively. The result is similar to Wondimu (2012) where the poor rural household benefited from growth in road density. But the response to a unit change in road growth is big as compared to the result of this study. Wondimu (2012) found that a 1% increase in road density increases consumption growth by 13 percent which is significant at 1% significant level. Both studies suggest that road has significant effect on rural households' consumption growth.

Table 23: Impact of investment in road on household consumption (Average % change per year)

household	Initial (in billion Birr)	Share	Sim0	Sim1	Sim2	Sim3	Sim4	Sim5	Sim6
Rural poor	70.18	20.73	9.62	9.79	9.91	10.20	10.37	10.88	11.08
Rural non poor	237.97	70.28	9.17	9.30	9.39	9.62	9.87	10.07	10.26
Urban poor	3.43	1.01	8.24	8.32	8.38	8.51	8.67	8.79	8.90
Urban non poor	27.04	7.98	6.31	6.39	6.44	6.57	6.72	6.84	6.94
Total	338.61	100	8.59	9.16	9.25	9.48	9.71	9.97	10.15

Source: *Simulation results*

Table 24: Impact of investment in road on household consumption (Average % change from base line simulation)

household	Initial (in billion Birr)	Share	Sim1	Sim2	Sim3	Sim4	Sim5	Sim6
Rural poor	70.18	20.73	0.17	0.29	0.58	0.75	1.26	1.46
Rural non poor	237.97	70.28	0.13	0.22	0.45	0.7	0.9	1.09
Urban poor	3.43	1.01	0.08	0.14	0.27	0.43	0.55	0.66
Urban non poor	27.04	7.98	0.08	0.13	0.26	0.41	0.53	0.63
Total	338.61	100	0.13	0.23	0.46	0.68	0.94	1.13

Source: *Simulation results*

Table 25: Impact of investment in road on household consumption by agro ecological zones (Average % change per year)

Households	INITIAL	Share	Sim0	Sim1	Sim2	Sim3	Sim4	Sim5	Sim6
Highland cereal poor	28.0287	8.28	9.63	9.80	9.92	10.21	10.53	10.80	11.04
Highland cereal non poor	101.6645	30.02	9.39	9.56	9.67	9.95	10.26	10.51	10.75
Humid poor	14.88678	4.40	10.08	10.35	10.54	10.99	10.76	12.38	12.57
Humid non poor	39.57851	11.69	9.67	9.79	9.86	10.06	10.27	10.45	10.62
Drought prone poor	17.13067	5.06	9.6	9.79	9.92	10.25	10.61	10.90	11.17
Drought prone non poor	37.93422	11.20	9.43	9.60	9.71	9.98	10.29	10.54	10.77
Pastoral poor	3.593093	1.06	9.73	9.88	9.99	10.24	10.53	10.76	10.98
Pastoral non poor	18.0667	5.34	9.49	9.62	9.71	9.94	10.19	10.39	10.58
Farming poor	6.541493	1.93	9.07	9.14	9.19	9.31	9.44	9.55	9.65
Non farming non poor	40.72477	12.03	7.89	7.98	8.04	8.19	8.36	8.49	8.61
Urban poor	3.425521	1.01	8.24	8.32	8.38	8.51	8.67	8.79	8.90
Urban non poor	27.03559	7.98	6.31	6.39	6.44	6.57	6.72	6.84	6.94

Source: *Simulation results*

Table 26. Impact of investment in road on household consumption by agro ecological zones (Average % change from base line simulation)

Household	Initial(billion birr)	Share	Sim1	Sim2	Sim3	Sim4	Sim5	Sim6
Highland cereal poor	28.0287	8.28	0.17	0.29	0.58	0.90	1.17	1.41
Highland cereal non poor	101.6645	30.02	0.17	0.28	0.56	0.87	1.12	1.36
Humid poor	14.88678	4.40	0.27	0.46	0.91	0.68	2.30	2.49

Humid non poor	39.57851	11.69	0.12	0.19	0.39	0.60	0.78	0.95
Drought prone poor	17.13067	5.06	0.19	0.32	0.65	1.01	1.30	1.57
Drought prone non poor	37.93422	11.20	0.17	0.28	0.55	0.86	1.11	1.34
Pastoral poor	3.593093	1.06	0.15	0.26	0.51	0.80	1.03	1.25
Pastoral non poor	18.0667	5.34	0.13	0.22	0.45	0.70	0.90	1.09
Farming poor	6.541493	1.93	0.07	0.12	0.24	0.37	0.48	0.58
Non farming non poor	40.72477	12.03	0.09	0.15	0.30	0.47	0.60	0.72
Urban poor	3.425521	1.01	0.08	0.14	0.27	0.43	0.55	0.66
Urban non poor	27.03559	7.98	0.08	0.13	0.26	0.41	0.53	0.63

Source: *Simulation results*

Overall, the effects of even a 100% increase in road infrastructure are fairly small compared to the rather large effects found in some of the results from the production-function literature. This is because Ethiopia has such a low level of road infrastructure that even doubling it leaves the country with an insufficient network. Second, even though the model covers the indirect effects through more efficient allocation of resources and an improved access to markets, it is (as are the other CGE models) not suited to cover effects such as a structural change in production or consumption induced by the shock as well as the creation of new markets that have formerly not existed. It only shows the effects, given the current structure of the economy.

6. Conclusion and policy implications

6.1. Conclusion

In this study attempt was made to examine economy wide impact of investment in road infrastructure using a recursive dynamic CGE model. The study used an updated version of the 2005/06 EDRI Social Accounting Matrix. Six simulations were done to evaluate economy wide impact of investment in road infrastructure.

Simulations with the CGE model confirm that with increasing availability of road infrastructure, there is a positive growth in the macroeconomic indicators (Real GDP, absorption, investment, private consumption, real export, and real import) though the magnitude of the effects is relatively small compared with the high investment costs and the changes varies among the different indicators. This is partly because the initial road density is so low that even doubling the availability leaves a country with a highly insufficient network. Similarly, the demand for labor, capital, land and livestock increases with increasing availability of road infrastructure. Income from livestock and land responds better compared to labor and capital as road investment increases. Welfare, measured as real consumption, increases on average and at the disaggregate level for all households. In this case the rural poor benefited more from road investment in terms of earning better income and consumption. This indicates that road infrastructure investment is a pro poor growth.

Road infrastructure affects the production sectors differently, depending on their transport intensity and their factor input requirements. In particular, the industrial and capital-intensive activities benefit, while agricultural sectors are less favored, given the relative increase in wages.
In general road infrastructure investment programmes are an instrument to support the development of a country, as increased road infrastructure has positive effects on production and welfare.

6.2. Implications

This study has some useful implications for policy and future research in relation to investment in road infrastructure.

- While expanding road access is essential, it is not, however, a remedy in that such intervention should be complemented by other policy and institutional measures that enhance the capacity of the actors to reap the benefit induced by road infrastructure.
- Expanding road infrastructure for each agro-zone according to their comparative advantage will provide important inputs for policy making.
- Given that road infrastructure through its influence on transport and transaction costs could have an influence on producers' market participation decisions, exploring the extent to which it actually holds in the Ethiopian case will provide important policy inputs.
- Currently, Ethiopia has reached at the road density of 90.5 km per thousand square km which falls far behind the average road density of lower middle income countries which is about 260 km/1000 sq.km. Therefore, it needs further attention by the government and international donors to enhance the road infrastructure in the country. In this case the RSDP is well performing and required to continue at the same rate or beyond the economy growth.
- Continuing with the road infrastructure development during the PASDEP period has less effect on the overall economic performance and welfare effect compared with the road infrastructure development during the GTP period. Continuing the road infrastructure development growth during GTP period helps to attain the road density requirement of the middle income countries as early as possible.
- As the result showed the land, Livestock holding and human & capital base of a household significantly influence its capacity to benefit from road investment. Therefore, raising the human capital base and access to other productive resources, such as education and health services, will be necessary for road infrastructure to raise household income in general and the income of the poor in particular.
- For the economy of Ethiopia to be transformed from agricultural to Industrial, the integration of efficient market will be critical. In this case it requires all markets in any regions to be interconnected so that there will be aback ward and forward linkage between agricultural and

industrial sectors. This implies that the government of Ethiopia should continue its effort in road development.

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Appendix A: CGE Static Part "Within" Model

In this appendix the full formulation of the "within "or static CGE model and between (dynamic) is specified.

Sets, Parameters and Variables in the model

Sets

$\alpha \in A$ - Activities

$\alpha \in ALEO(\subset A)$- Activities with a Leontief function at the top of the technology nest

$c \in C$– Commodities

$c \in CD(\subset C)$- commodities with domestic sales of domestic output

$c \in CDN(\subset C)$- commodities not in CD

$c \in CE(\subset C)$- exported commodities

$c \in CEN(\subset C)$- commodities not in CE

$c \in CM(\subset C)$- imported commodities

$c \in CMN(\subset C)$- commodities not in CM

$c \in CT(\subset C)$- transactions service commodities

$c \in CX(\subset C)$ - commodities with domestic production

$f \in F$- factors

$i \in INS$- institutions (domestic and rest of the world)

$i \in INSD(\subset INS)$- domestic institutions

$i \in INSDNG(\subset INSD)$- domestic nongovernment institutions

$h \in H(\subset INSDNG)$- households

Parameters (Latin Letters)

$cwts_c$ - weight of commodity c in the CPI

$dwts_c$ - weight of commodity c in the producer price index

ica_{ca} - quantity of c as intermediate input per unit of activity a

$icd_{cc'}$ - quantity of commodity c as trade input per unit c ' produced and sold domestically

$ice_{cc'}$ - quantity of commodity c as trade input per exported unit of c '

$icm_{cc'}$ - quantity of commodity c as trade input per imported unit of c '

$\text{int}a_a$ - quantity of aggregate intermediate input per activity unit

iva_a - quantity of value-added per activity unit

$\overline{mps}$ - base saving rate for domestic institution i

$mps\ 01_c$ - 0-1 parameter with 1 for institutions with potentially flexed direct tax rates

pwe_c - export price (foreign currency)

pwm_c - import price (foreign price)

$qdst_c$ - quantity of stock change

$\overline{qg}_c$ - base – year quantity of government demand

$\overline{qinv}_c$ - base – year quantity of private investment demand

$shif_{if}$ - share for domestic institution i in income of factor f

$shii_{ii'}$ - share of net income of i ' to i ($i' \in INSDNG'; i \in INSDNG$)

$\overline{tinsi}_I$ - exogenous direct tax rate for domestic institution i

$Tins01_i$ - 0 - 1parameter with 1 for institutions with potentially flexed direct tax rates

tm_c - import tariff rate

tq_c - rate of sales tax

$trnsfr_{if}$ - transfer from factor f to institution i

Parameters (Greek Letters)

α_a^{va} - efficiency parameter in the CES value – added function

α_a^{ca}-shift parameter for domestic commodity aggregation function

α_a^{q} □- Armington function shift parameter

β_{ach}^{h}- Marginal share of consumption spending on home commodity c from activity a for household h

β_{ch}^{m}- Marginal share of consumption spending on marketed commodity c for household h

δ_{ac}^{ac} - share parameter for domestic commodity aggregation function

δ_{c}^{q} - Armington function share parameter

δ_{c}^{t} - CET function share parameter

δ_{fa}^{va} - CES value –added function share parameter for factor f in activity a

γ_{ch}^{m}- Subsistence consumption of marketed commodity c for household h

γ_{ach}^{h} - Subsistence consumption of home commodity c from activity a for

House hold h

θ_{ac} - Yield of output c per unit of activity a

ρ_{c}^{va} - CES value – added function exponent

ρ_{a}^{ac} $-$ domestic commodity aggregation function exponent

ρ_{c}^{q}- Armington function exponent

ρ_{c}^{t}- CET function exponent

Exogenous Variables

$\overline{\boldsymbol{CPI}}$**-** Consumer price index

$\overline{\boldsymbol{DTINS}}$**-** Change in domestic institution tax share (= 0 for base; exogenous variable)

$\overline{\boldsymbol{FSAV}}$**-** Foreign savings (FCU)

$\overline{\boldsymbol{GADJ}}$**-**Government consumption adjustment factor

$\overline{\boldsymbol{IADJ}}$**-** Investment adjustment factor

$\overline{\boldsymbol{MPSADJ}}$-Savings rate scaling factor (= 0 for base)

$\overline{QFS}_f$ -Quantity supplied of factor

$\overline{\boldsymbol{TINSADJ}}$ **-**direct tax scaling factor (= 0 for base; exogenous variable)

$\overline{WFDIST}_{fa}$ -wage distortion factor for factor f in activity a

Endogenous Variables

DMPS - change in domestic institution saving rates (= 0 for base; exogenous Variable)

DPI - producer price index for domestically marketed output

EH_h - consumption spending for household

EXR - exchange rate (LCU per unit of FCU)

GOVSHR - government consumption share in nominal absorption

GSAV - government savings

INVSHR - investment share in nominal absorption

PA_a - activity price (unit gross revenue)

PDD_c - demand price for commodity produced and sold domestically

PDS_c - supply price for commodity produced and sold domestically

PE_c - export price (domestic currency)

$PINTA_c$ - aggregate intermediate input price for activity a

PM_c - import price (domestic price)

PQ_c - composite commodity price

PVA_a - value-added price (factor income per unit of activity)

PX_c - aggregate producer price for commodity

$PXAC_{ac}$ - producer price of commodity c for activity a

QA_a - quantity (level) of activity

QD_c - quantity sold domestically of domestic output

QE_c - quantity of exports

QF_{fa} - quantity demanded of factor f from activity a

QG_c - government consumption demand for commodity

QH_{ch} - quantity consumed of commodity c by household h

QHA_{ach} - quantity of household home consumption of commodity c from activity a for household h

$QINTA_a$ - quantity of aggregate intermediate input

$QINT_{ca}$ - quantity of commodity c as intermediate input to activity a

$QINV_c$ - quantity of investment demand for commodity

QM_c - quantity of import of commodity

QQ_c - quantity of goods supplied to domestic market (composite supply)

QT_c - quantity of commodity demanded as trade input

QVA_a - quantity of (aggregate) value-added

QX_c - aggregated marketed quantity of domestic output of commodity

$QXAC_{ac}$ - quantity of marketed output of commodity c from activity a

TABS - total nominal absorption

$TINS_i$- direct tax rate for institution i ($i \epsilon$ INSDNG)

$TINS_{ii'}$ - transfer from institution i’ to i (both in the rest INSDNG)

WF_f - average price of factor f

YF_f - income of factor f

YG - government revenue

YI_i - income of domestic non-government institution

YIF_{if} - income to domestic institution i from factor f

Equations of the Model
STATIC PART Price Block

1. Import price

$$PM_C = pwm_C.(1 + tm_C).EXR + \sum_{c' \epsilon CT} PQ_c.icm_{c'c} \qquad c\epsilon CM$$

2. Export price

$$PE_C = pwe_C.(1 - te_C).EXR - \sum_{c' \epsilon CT} PQ_{c'}.ice_{c'c} \qquad c\epsilon CE$$

3. Demand price of domestic non-traded goods

$$PDD_C = PDS_C + \sum_{c' \epsilon CT} PQ_{c'}.icd_{c'c} \qquad c\epsilon CD$$

4. Absorption

$$PQ_C(1 - tq_C).QQ_C = PDD_C.QD_C + PM_C.QM_C \qquad c\epsilon(CD \subset CM)$$

5. Marketed output value

$$PX_C.QX_C = PDS_C.QD_C + PE_C.QE_C \qquad c\epsilon CX$$

6. Activity price

$$PA_a = \sum_{c\epsilon C} PXAC_{ac}\,.\,\theta_{ac} \qquad \alpha\epsilon A$$

7. Aggregate intermediate input price

$$PINTA_a = \sum_{c\epsilon C} PQ_c\,.\,ica_{ca} \qquad \alpha\epsilon A$$

8. Activity revenue and costs

$$PA_a.QA_a = PVA_a.QVA_a + PINTA_a.QINTA_a \qquad \alpha\epsilon A$$

9. Consumer price index

$$\overline{CPI} = \sum_{c\epsilon C} PQ_c\,.\,cwts_c$$

10. Producer pric index for non-traded output

$$DPI = \sum_{c\epsilon C} PDS_c\,.\,dwts_c$$

Production and Trade block

11. Leontief Technology: Demand for Aggregate Value- Added

$$QVA_a = iva_a.QA_a \qquad a\epsilon AlEo(\subset A)$$

12. Leontief Technology: Demand for Aggregate Intermediate Input

$$QINTA_a = inta_a.QA_a \qquad a\epsilon AlEo(\subset A)$$

13. Value-added and factor demands

$$QVA_a = \alpha_a^{va}\left(\sum_{f\epsilon F}\delta_{fa}^{va}\, QF_{fa}^{-\rho_a^{va}}\right)^{\frac{-1}{\rho_a^{va}}} \qquad \alpha\epsilon A$$

14. Factor Demand

$$WF_f\overline{WFDIST}_{fa} = PVA_aQVA_a\left(\sum_{f\epsilon F\prime}\delta_{fa}^{va}\,.\,QF_{fa}^{-\rho_a^{va}}\right)^{-1}\delta_{fa}^{va}QF_{fa}^{-\rho_{a-1}^{va}} \qquad \alpha\epsilon AF\epsilon F$$

15. Disaggregated intermediate input demand

$$QINT_{ca} = ica_{ca}QINTA_a \qquad \alpha\epsilon A;\, c\epsilon C$$

16. Commodity production and allocation

$$QXAC_{ac} + \sum_{h\epsilon H} QHA_{ach} = \theta_{ac}QA_a \qquad \alpha\epsilon A;\, \alpha\epsilon CX$$

17. Output aggregation function

$$QX_{ca}{=}\alpha_a^{ac}.\left(\sum\nolimits_{\alpha\epsilon A}\delta_{ac}^{ac}.\,QXAC_{ac}^{-\rho_c^{ac}}\right)^{-\frac{1}{\rho_a^{ac}-1}} \qquad c\epsilon CX$$

18. First –order condition for output aggregation function

$$PXAC_{ac} = PX_cQX_c\left(\sum_{\alpha\epsilon A\prime}\delta_{ac}^{ac}\,.\,QXAC_{ac}^{-\rho_c^{ac}}\right)^{-1}\delta_{ac}^{ac}.\,QXAC_{ac}^{-\delta_c^{ac-1}} \quad \alpha\epsilon A;\, c\epsilon CX$$

19. Output transformation(CET) function

$$QX_c = \alpha_c^t.\left(\delta_c^t.\,QE_c^{\rho_c^t} + (1-\delta_c^t)QD_c^{\delta_c^t}\right)^{\frac{1}{\rho_c^t}} \qquad c\epsilon(CE\cap CD)$$

20. Export-domestic supply ratio

$$\frac{QE_C}{QD_c} = \left(\frac{PE_c}{PDS_c}.\frac{1-\delta_c^t}{\delta_c^t}\right)^{\frac{1}{\rho_c^{t-1}}} \qquad c\epsilon(CE\cap CD)$$

21. Output transformation for non-exported commodities

$$QX_c = QD_c{+}QE_c \qquad c\epsilon(CD\cap CEN)\cup(CE\cup CDN)$$

22. Composite supply (Armington) function

$$QQ_c = \alpha_c^q\left(\delta_c^qQM_c^{-\rho^q} + \left(1-\delta_c^q\right).\,QD_c^{\rho^q}\right)^{\frac{1}{\rho^q}} \qquad c\epsilon(CM\cap CD)$$

23. Import-domestic demand ratio

$$\frac{QM_C}{QD_c} = \left(\frac{PDD_c}{PM_c} \cdot \frac{\delta_c^q}{1-\delta_c^q}\right)^{\frac{1}{1+\rho_c^q}} \qquad c\epsilon(CM \cap CD)$$

24. Composite supply for non-imported outputs and non-produced imports

$$QQ_c = QD_c + QM_c \qquad c\epsilon(CD \cap CMN) \cup (CM \cup CDN)$$

25. Demand for transaction service

$$QT_c = \sum_{c'\epsilon C'}(icm_{cc'} . QM_{c'} + ice_{cc'} . QE_{c'} + icd_{cc'} . QD_{c'}) \qquad c \in CT$$

Institutional Block

26. Factor income

$$YF_f = \sum_{\alpha\epsilon A} WF_f . \overline{WFDIST}_{fa} . QF_{fa} \qquad f\epsilon F$$

27. Institutional factor income

$$YIF_{if} = shif_{if}\left[\left(1 - tf_f\right) . YF_f - trnsfr_{rowf} . EXR\right]$$

28. Income of domestic, on-government Institutions

$$YI_i = \sum_{f\epsilon F} YIF_{if} + \sum_{f\epsilon INSDNG'} TRII_{ii'} + trnsfr_{igov} . \overline{CPI} + trnsfr_{irow} . EXR \qquad i\epsilon INSDNG$$

29. Intra-institutional transfers

$$TRII_{ii'} = shii_{ii'}(1 - MPS_{i'}) . (1 - TINS_{i'}) . YI_{i'} \qquad i\epsilon INSDNG\ ; i'\epsilon INSDNG'$$

30. Household consumption expenditure

$$EH_h = (1 - \sum_{i\epsilon INSDNG} shii_{ih}) . (1 - MPS_h)(1 - TINS_h) . YI_h \qquad h\epsilon H$$

31. Household consumption demand for marketed commodities

$$PQ_c QH_{ch} = PQ_c \gamma_{ch}^m + \beta_{ch}^m (EH_h \text{-} \sum_{c'\epsilon C} PQ_c \gamma_{c'h}^m - \sum_{a\epsilon A} \sum_{c'\epsilon C} PXAC_{ac} \gamma_{ac'h}^h) \quad c\epsilon C;\ h\epsilon H$$

32. Household consumption demand for home commodities

$$PXAC_{ac} QHA_{ach} = PXAC_{ac} \gamma_{ach}^h + \beta_{ach}^h (EH_h \text{-} \sum_{c'\epsilon C} PQ_c \gamma_{c'h}^m - \sum_{a\epsilon A} \sum_{c'\epsilon C} PXAC_{ac} \gamma_{ac'h}^h) \quad c\epsilon C;\ h\epsilon H$$

33. Investment demand

$$QINV_C = \overline{IADJ} . \overline{qinv}_c \qquad c\epsilon CINV$$

34. Government consumption demand

$$QG_C = \overline{GADJ} . \overline{qg}_c \qquad c\epsilon C$$

35. Government revenue

$$YG = \sum_{i\epsilon INSDNG} TINS_i . YI_i + \sum_{c\epsilon CM} tm_c . pwm_c . QM_c . EXR + \sum_{c\epsilon C} tq_c . PQ_C . QQ_c + \sum_{f\epsilon F} YIF_{govf} + trnsfr_{govrow} . \text{EXR}$$

36. Government expenditure

$$EG = \sum_{c\epsilon C} PQ_c . QG_c + \sum_{i\epsilon INSDNG} trnsfr_{i\,gov}\, \overline{CPI}$$

System Constraint Block

37. Factor market

$$\sum_{a\epsilon A} QF_{fa} = \overline{QFS}_f \qquad f\epsilon F$$

38. Composite commodity markets

$$QQ_c = \sum_{a\epsilon A} QINT_{ca} + \sum_{h\epsilon H} QH_{ch} + QG_c + QINV_c + qdst_c + QT_c \qquad c\epsilon C$$

39. Current account balance for the rest of the world (in foreign currency)

$$\sum_{c\epsilon CM} pwm_c \,.\, QM_c + \sum_{f\epsilon F} trnsfr_{rowf} = \sum_{c\epsilon CE} pwe_c \,.\, QE_c + \sum_{i\epsilon INSD} trnsfr_{irow} + \overline{FSAV}$$

40. Government balance

$$YG = EG + GSAV$$

41. Direct institutional tax rates

$$TINS_i = \overline{tins}_i(1 + \overline{TINSADJ}.tins01_i) + \overline{DTINS}.tins01_i \qquad i\epsilon INSDNG$$

42. Institutional saving rates

$$MPS_i = \overline{mps}_i(1 + \overline{MPSADJ}.mps01_i) + DMPS.mps01_i \qquad i\epsilon INSDNG$$

43. Saving-investment balance

$$\sum_{i\epsilon INSDNG} MPS_i(1 - TINS_i).YI_i + GSAV + EXR.\overline{FSAV} = \sum_{c\epsilon C} PQ_c \,.\, QINV_c + \sum_{c\epsilon C} PQ_c \, qdst_c$$

44. Total absorption

$$TABS = \sum_{h\epsilon H}\sum_{c\epsilon C} PQ_c \, QH_{ch} + \sum_{a\epsilon A}\sum_{c\epsilon C}\sum_{h\epsilon H} PXAC_{ac} \, QHA_{ach} + \sum_{c\epsilon C} PQ_c \, QG_c + \sum_{c\epsilon C} PQ_c \, QINV_c + \sum_{c\epsilon C} PQ_c \, qdst_c$$

45. Ratio of investment to absorption

$$INVSHR.TABS = \sum_{c\epsilon C} PQ_c.QINV_c + \sum_{c\epsilon C} PQ_c \,.\, qdst_c$$

46. Ratio of government consumption to absorption

$$GOVSHR.TABS = \sum_{c\epsilon C} PQ_c \, QG_c$$

APPENDEX B. ‘’The between’’ model

1. Average capital rental rate

$$AWF_{ft}^{a} = \sum_{a}\left[\left(\frac{QF_{fat}}{\sum_{a'} QF_{fa't}}\right) WF_{ft}.WFDIST_{fat}\right]$$

2. Share of New Capital

$$\eta_{fat}^{a} = \left(\frac{QF_{fat}}{\sum_{a'} QF_{fa't}}\right)\left(\beta^{a}\left(\frac{WF_{ft}.WFDIST_{fat}}{AWF_{ft}^{a}} - 1\right) + 1\right)$$

3. Quantity of new capital by sector

$$\Delta K_{fat}^{a} = \eta_{fat}^{a}.\left(\frac{\sum_{a} PQ_{ct} QINV_{ct}}{DV}\right)$$

4. Unit price of capital

$$PK_{ft} = \sum_{c} PQ_{ct}\frac{QINV_{ct}}{\sum_{c'} QINV_{c't}}$$

5. Average capital rental rate

$$QFS_{ft+1} = QFS_{ft}\left(1 + \frac{\sum_{a} \Delta K_{fat}^{a}}{QF_{fat}} - 1\right)$$