COMPARATIVE MEASUREMENT OF TECHNICAL EFFICIENCY AMONG ETHIOPIAN AND CHINESE FIRMS: THE CASE OF ROAD CONSTRUCTION SECTOR

By

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A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Economics (Economic Policy Analysis)

Addis Ababa University

School of Graduate Studies

Department of Economics

Addis Ababa

October, 2009

ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

"Comparative Measurement of Technical Efficiency among Ethiopian and Chinese Firms: The Case of Road Construction Sector."

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List of Acronyms

CGCOC	China Geo-engineering Corporation
COLS	Corrected Ordinary Least Squares
CRBC	Chinese Road and Bridge Corporation
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
EC	European Commission
EEA	Ethiopian Economic Association
EFFORT	Endowment Fund for the Rehabilitation of Tigray
EPRDF	Ethiopian People Republic Democratic Front
ERA	Ethiopian Roads Authority
GVP	Growth Value Production
HHRBC	Hunan Hunda Road and Bridge Corporation
KM	Kilo Meter
MLE	Maximum Likelihood Estimation
RSDP	Road Sector Development Program
SFA	Stochastic Frontier Analysis
USA	United States of America
UK	United Kingdom
VRS	Variable Returns to Scale

Acknowledgment

I am very grateful to **Almighty God** for always being there. It is all because of him.

My special thanks are extended to my Advisor Alemayehu Geda(PHD) for his meticulous advise, constructive comments and consistent encouragements throughout the study. I would like to thank Bahir Dar University for sponsoring and offering me the chance to participate in this program and African Economic Research Consortium (AERC) for sponsoring my stay in Arusha (Tanzania) for the Collaborative Masters Program in economics for Anglophone Africa (CMAP).

I am very much indebted to my father Ato Assefa Ketema and my mother W/o Yerom Tefera, sisters and brothers for their love, continuous support and encouragements. My warm thanks also go my friend Seblewongel Mulugeta and my cousin Derbew Kefialew for their support and encouragement throughout the study. Finally, my thanks extend to my friends who have been, one way or another, extending moral and material supports.

Abstract

Following the market oriented economic policy EPRDF employed; the number of local privately owned contractors has been increased. However, the larger share of road construction projects have been undertaken by Chinese firms and the participation of local road construction firms is limited. In light of this, the level of technical efficiencies and factors that are attributable to the existing level of technical inefficiencies are investigated simultaneously using a panel data of eight firms which are categorized in to two groups (Chinese and Ethiopian) during the study period of 2006-2008. Using a Cobb-Douglas production function, the study employed a stochastic frontier approach. As the likelihood ratio test indicates, half normal distribution is a better assumption for the inefficiency term, most of the discrepancy between actual and frontier level of output is due to technical inefficiency rather than external factors and the explanatory variables in the inefficiency model are found to be jointly significant. The technical efficiency of each group is estimated using the maximum likelihood estimation technique and the mean technical efficiency score is found to be 48% for Ethiopian firms and 52% for Chinese firms, which clearly shows the low performance of Ethiopian firms relative to Chinese firms. On the other hand, capital labour ratio, which indicates the firms' intensification, net revenue, which represents firms size and incentive per worker are found to have important effect on technical efficiency. Thus, as the results of the study indicates, there is a need of better policies and strategies such as provision of credit in order to increase the capacity of local firms and designing effective incentive payment strategies in order to improve the existing level of technical efficiency and to make the local road construction firms more competent.

Chapter One
Introduction

1.1 Background

Long term economic development crucially depends on an efficient and most productive use of scarce resources on the micro level (UN, 2004). With respect to low income countries, agriculture is still at the center of all development efforts. However, it is not possible to achieve the intended development and economic growth objectives unless it is supported by the other sectors. In this regard, the construction sector in general and road construction in particular are those that can play a vital role in the economic growth of a country (EC, 2008).

The construction sector has a significant role in the Ethiopian economy. Its share in the total GDP averaged at about 5.2 percent in the period 2002/03-2006/07 (EEA, 2006/07). The growth of the construction sector can be measured using its Gross Value Production (GVP) and it has shown an average annual growth of 9.6 percent during 1996/97-2006/07 (EEA, 2006/07). Due to the priority given in the country, road construction accounts nearly half of the government's expenditure on construction (EEA, 2006/07). The share of expenditure on road construction and maintenance to the construction GVP has averaged at about 15.1 percent per year during the period 1997/98-2005/06 (ERA, 2006/07).

In the context of Ethiopia's geography, pattern of settlement and economic activity, it is road transport that plays a crucial role in facilitating economic development (ERA, 2008).In other words, the need for people to move, to utilize resources, to improve agricultural production and market conditions, to access social facilities, and finally to ensure sustainable growth, all require transport as a catalyst (Center for Chinese Studies, 2006).

However, deteriorating roads have been a major economic problem, not only in Ethiopia, but also in Less Developing Countries (LDCs) as a whole. The experiences of many international organizations and of the major donor groups during the last 20-30 years have believed that this problem results from poor management and maintenance in addition to the lengthy periods of insecurity, violence, political and economic problems of the countries in the area (Center for Chinese Studies, 2006). With no exception, Ethiopia is one of those countries whose historical, political and social progress and monopoly market structure have led to an underdeveloped road construction sector (ERA, 2005).

Ethiopia has a limited road network (44,359Km) as compared to the size of its 1.2 million square meters landmass and estimated 79 million populations (Addis Fortune, 29 September 2008). The overall road network that is in a good condition accounts only about 53 percent (ERA, 2008). Moreover, with about 0.43 km per 1000 people, the Ethiopian road network is among the least developed in the world. Only 20% of Ethiopia's land area is located within a 10 km range of an all weather road (EC, 2008). As indicated by EC (2008), the problem of the sector is not only in limited network outreach but also in poor quality. And this condition is hampering economic development, especially in the rural areas. Although it is found in low performance, road transport represents 95 percent of motorized transport in the country (EC, 2008).

To address the aforementioned problems, the current government of Ethiopia has formulated a ten year Road sector Development Program (RSDP) in 1997 (ERA, 2008). However, Ethiopian Roads Authority (ERA) does not yet have the capacity to deal efficiently with the considerable workload it faces and continues to suffer past centralized decision making practices (EC, 2008).

As a solution to the problem of limited capacity and inefficient activities of ERA, both local and foreign companies are significantly participating in the sector. Accordingly, the Chinese firms have started to influence the sector since the late 1990's. According to the data obtained from ERA, local private contractors, local public contractor and foreign contractors have been undertaking 38 percent, 8 percent and 54 percent of the total road construction (in km) awarded during the RSDP period, respectively. Out of the 54 percent that is awarded to foreign contractors, the Chinese road construction firms accounts 40 percent.

Hence, it is crucial to measure the extent of technical efficiency in Ethiopian road construction firms relative to the Chinese firms that are involved in road construction in Ethiopia. Identifying the potential sources of technical inefficiency in the sector is also another issue that should be addressed. .Thus, this study is designed to address these two issues.

1.2 Statement of the Problem

The transportation sector of Ethiopia is highly dominated by road transportation and the construction and maintenance of roads is controlled and managed by Ethiopian Roads Authority (ERA). It is widely acknowledged that the upgrading and extension of Ethiopia's poor and sparse roads network is crucial for overall economic growth and for the integration of isolated and remote parts of the country with its widely dispersed population. However, ERA is failed to develop the road network so as to play its role for such kind of overall economic developments (EC, 2008). According to EC (2008), the major problems are from capacity constraints, project design, contract administration, approval procedures etc.

To mitigate these problems, given the free market economic policy of the country, a number of private contractors (both foreign and local) have participated in the road construction sector. The RSDP has also designed to increase the participation of the private road construction firms with a special attention to local private firms. Local and international contractors are the major implementers of federal road rehabilitation, upgrading and new construction projects under RSDP. The overall idea is that, ERA will restrict itself to regulatory and policy issues with the remainder being contracted out to the private sector including heavy road maintenance projects and routine maintenance (ERA, 2005).

As a result, foreign contractors have significantly engaged in the sector. Among the foreign firms who have involved in road construction, the Chinese firms have taken the largest share. According to the data obtained from ERA, 40 percent of the road construction work (in km) that is given to foreign firms during the RSDP is undertaken by Chinese firms.

Contrary to the role it has to play under RSDP, ERA is still carrying out construction and rehabilitation of a few road projects, some heavy maintenance projects and routine maintenance of roads by Ras Haile (a branch of ERA which engaged in road construction). In addition to this, ERA is also involving in carrying out the periodic maintenance, implementation of those rehabilitation and construction road projects in a situation where by the project is needed to complete urgently (ERA, 2008). The participation of local contractors in donors financed projects is also limited due to the eligibility criteria of pre-qualification, particularly regarding experience of past performance, equipment and financial status (ERA, 2008).

In general, both ERA and privately owned local contractors are technically inefficient and have poor performance in terms of employment creation, their contribution to national income, the type and quality of service provision, etc(EC, 2008). Thus, this study will assess the level of technical efficiency and examine the sources of inefficiency in both selected Chinese and Ethiopian firms which are engaged in the road construction sector in Ethiopia.

On the other hand, most studies about the impact of the Asian drivers are on Latin America and Asia, studies on Africa being limited (Alemayehu and Atinafu, 2008). When it comes to Ethiopia, there are still limited empirical works. Alemayehu and Atinafu (2008) and Tegegne (2006) are the two empirical works in relation to Chinese firms. However, both of them were not designed to address the issue of technical efficiency and its determinant factors in Ethiopian and Chinese road construction firms. Thus, this study is also aimed to fill the existing literature gap.

1.3 Objective of the Study

The general objective of the study is to compare the level of technical efficiency among Ethiopian and Chinese road construction firms, and to show the possibility, if there is any, of improving local contractors' performance at the given level of inputs and technological environment. In addition to this general objective, the specific objectives of the study are the following:

- To compare the level of technical efficiency of selected Ethiopian and Chinese road construction firms;
- To identify factors that are affecting the technical efficiency of selected Ethiopian and Chinese road construction firms; and
- To indicate policy measures that enhances the efficiency of Ethiopian road construction firms.

1.4 Hypothesis of the Study

The study will examine the following hypothesis on the production function and firm specific characteristics.

- Ethiopian road construction firms are characterized by technical inefficiency so that their actual output is below their frontier level of output.
- Ethiopian road construction firms are less efficient than Chinese road construction firms
- The technical inefficiency is attributable to firm specific characteristics such as level of capacity (approximated by net revenue) and capital intensification.

1.5 Significance of the Study

In Ethiopia, improving the efficiency of road construction sector with out demanding additional resources is very crucial to reduce the chronic poverty and to achieve a higher economic growth. Thus, the study will provide a certain inputs for policy makers to design appropriate and effective policies in order to improve the efficiency of Ethiopian road construction firms. In addition, the study provides sectoral information on the status and involvement of Chinese firms in Ethiopia's road construction sector. The study may also used as a basis for further study in the area.

1.6 Limitation of the Study

Lack of firm level data restricts the number of firms that are included in this study only to eight firms, four Ethiopian firms and four Chinese firms. In order to increase the number of observation the yearly data is classified in to quarterly basis and this could be considered as a limitation although it is found to be important to observe the effect of the rainy season on technical efficiency of road constriction firms. Finally, lack of firm level data for some variables such as educational level of the workers, managerial capacities of the contractors and so on has been a hindrance to capture the effect of these important variables on the technical efficiency of Ethiopian and Chinese road construction firms.

1.7 Organization of the Study

The remaining part of the study is organized as follows; Chapter two reviews the development of road construction sector in Ethiopia and the profile of selected firms. In chapter three, both the theoretical and empirical literatures have been reviewed. Chapter four is devoted to discuss the data and methodology used for the study. The data analysis and empirical findings are discussed in chapter five. Finally, conclusions and policy recommendations are given in chapter six.

Chapter Two

Review of Road Construction Sector in Ethiopia and Profiles of Selected Road Construction Firms

2.1 Road Construction Development in Ethiopia

Ethiopia is the second most populous country in sub-Saharan Africa next to Nigeria and is endowed with natural resources with 60 percent of its total land area estimated to be potentially arable (ERA, 2005). Owing to the extreme variations in its climate, topography, etc, and the existence of most major ecological systems, Ethiopia also possesses one of the largest and most diverse genetic resources in the world. Its highlands, covering about 44 percent of the total land area, accommodate about 88 percent of the population and contain 95 percent of the cultivated land, and more than 65 percent of the national livestock herd (ERA, 2005).

However, Ethiopia has the lowest road density (about 40 km per 1000 sq km) in Africa with a classified road network of only 44,359 km of which 5452 km is asphalt (ERA, 2008). During the imperial regime when ERA was established in 1951, the total road network in Ethiopia was only about 6400 km and it has been built mainly during the Italian occupation of 1936-1941 (Addis fortune, 29 September 2008).

Although it has poor performance in terms of quality and quantity, road remains Ethiopia's dominant mode of transport, carrying over 95 percent of passengers and fright traffic (ERA, 2008). This implies that the country's socio-economic development is highly relying on the road transport.

During the Imperial (1951-1973), the Derg (1974-1991) and the current (since 1992 to date) regime, the road network has been increased annually by 2.1 percent, 6.2 percent and 8.4 percent, respectively (UN, 2004). However, the role of the private sector during the first two regimes was very limited. In 1960s and early 1970s only few firms had been successfully operating as private contractors in the development of the road sector. When the socialist military government came to power in 1974, these firms were nationalized and no private contractor and consultant had existed in the road sector (ERA, 2008).

Contrary to the Derg regime, the Transitional Government of Ethiopia later EPRDF has launched market based economy. As a result, both domestic and foreign contractors began to emerge in the development of the road sector. EPRDF has also taken measures to widen the road network through increasing the participation of the local contractors and consultants and by reforming plans and programs. The ten years Road Sector Development Program (RSDP) is one of the main measures that have been taken by EPRDF. According to the data obtained from ERA, a total of 13, 215.38 km different types of road projects are awarded to the local and foreign contractors including Ras Haile for road rehabilitation, upgrading, new road construction etc. during the period between 1997 to 2007 (ERA, 2008).

In general, as indicated in the above discussion, there has been an improvement in the development of the road sector during the three regimes. However, both the quality and quantity of roads in Ethiopia is still far away from the country's demand. Thus, to solve this problem, using the limited resource the country has, much attention should be given to the efficiency of firms that are involved in road construction.

2.2 Status and Accessibility of Road Infrastructure in Ethiopia

After RSDP is launched, a significant development has been witnessed in the status of road infrastructure in the country. As Table 2.1 shows, the total road network has been increased from 26,550 km in 1997 to 44,359 km in 2008. Road density per 1000 sq. km has also showed an improvement by 67 percent during 1997- 2008. When it comes to road density per 1000 population, still there is an increment from 0.46 in 1997 to 0.56 in 2008. The total distance of asphalt, gravel and rural roads is also increased from 3708 km, 12162 km and 10680 km in 1997 to 5452 km, 14977 km and 23930 km in 2008, respectively.

It is also possible to observe the trends of the road development from Table 2.1. Except the reduction that is experienced in 2003 by gravel roads and road density per 1000 population, there has been a continuous increment in other road status indicators.

Table 2.1 Status of Road Infrastructure in Ethiopia

year	Asphalt	Gravel	Rural	Total Road network	Road Density/1000sq. km	Road density/1000population in km
1997	3708	12162	10680	26550	24.14	0.46
1998	3760	12240	11737	27737	25.22	0.46
1999	3812	12250	12600	28662	26.06	0.46
2000	3824	12250	15480	31554	28.69	0.50
2001	3924	12467	16480	32871	29.88	0.50
2002	4053	12564	16680	33297	30.27	0.50
2003	4362	12340	17154	33856	30.78	0.49
2004	4635	13905	17956	36496	33.18	0.51
2005	4972	13640	18406	37018	33.65	0.50
2006	5002	14311	20164	39477	35.89	0.53
2007	5452	14628	22349	42429	38.57	0.55
2008	5452	14977	23930	44359	40.33	0.56

Source: ERA (2008)

On the other hand, the percentage of roads that are found in a good condition has shown a significant improvement as indicated in Table 2.2.The percentage of roads in a good condition is increased from 17, 25 and 21 in 1997 to 68, 53 and 49 in 2008 for asphalt, gravel and rural roads, respectively. The highest increment has been observed in asphalt roads.

Table 2.2 Percentage of Roads in Good Condition

year	Asphalt	Gravel	Rural	Total
1997	17	25	21	22
1998	20	25	25	24
1999	25	25	25	25
2000	29	30	25	28
2001	30	30	26	28
2002	35	30	28	30
2003	43	31	30	32
2004	49	34	36	37
2005	54	40	33	39
2006	60	45	46	47
2007	64	49	46	49
2008	68	53	49	53

Source: ERA (2008)

When it comes to accessibility, distance to all weather roads has continuously declined from 20.72 km in 1997 to 12.40 km in 2008(see Table 2.3). As Table 2.3 indicates, there is a continuous reduction in the proportion of areas that are 5 km away from all weather roads. The proportion of areas that are 5 km away from all weather roads has declined by about 15 percent while the proportion of areas that are 2 km far from all weather roads has declined only by 6.3 percent during the period between 1997 and 2008.

Table 2.3 Road Accessibility in Ethiopia

year	Average distance to all weather roads	Proportion of area more than 5 km from all weather roads in %	Proportion of area more than 2 km from all weather roads in %
1997	20.72	78.56	90.80
1998	19.83	77.71	90.41
1999	19.19	77.06	90.10
2000	17.43	75.06	89.16
2001	16.73	74.17	88.73
2002	16.52	73.88	88.60
2003	16.25	73.51	88.42
2004	15.07	71.76	87.57
2005	14.86	71.42	87.41
2006	13.93	69.85	86.63
2007	12.96	68.00	85.70
2008	12.40	66.81	85.10

Source: ERA (2008)

2.3 An Overview of Selected Ethiopian Firms

Since Ethiopia has implemented a free market economic policy in 1991 many local contractors and consultants have been entered the road construction sector. To encourage the entrance of local contractors into this industry and to create competition among them, EPRDF reduced the minimum capital requirement. As a result, over 1,020 local contractors have been licensed by the Ministry of Works & Urban Development since 1993 and join the construction industry. The share of the private sector in the total construction of roads has also increased from 73 percent in 2001/02 to 86 percent in 2002/03 (ERA, 2005).

Although an attempt is made to raise the number of local contractors' participation, almost half of the contractors, which have been licensed, did not continue in a sustainable manner in this industry (ERA, 2005). This might be due to shortage of capital, equipment and lack of experience in project management. To help ease the severe of capital and equipment constraints, at the beginning of RSDP the government awarded 14 rural road projects in 1995 with 20% advance payment to different local contractors in order to build their capacity. These contractors have been given the advance without submitting collaterals for same with the aim of enhancing their capacity .The policy in Ethiopia for those who do not have financial constraints was then becoming favorable, while the participation of the private local construction industry was not as such satisfactory (ERA, 2005).

According to the data obtained from ERA, the private sector (both local and foreign together) is contributing the highest portion in the road construction industry and it accounts about 92 percent of the total kms of roads awarded by ERA during RSDP period. The public sector Ras Haile contributes the rest 8 percent of the kms under the program. However, when the origin of the private contractors is considered, the km of roads constructed by local contractors amounts only 38 percent of the total kms awarded in the RSDP period, while the amount awarded to the foreigners accounts 54 percent. Though the locals have lower share than the foreigners, the lowest percentage accounted by the public sector is encouraging for the more entrance of the private sector and domestic contractors in the construction industry.

Table 2.4 Summary of Selected Ethiopian Firms during RSDP Period

Firm	No. of Road Projects	Amount of Projects won ('1000000' Birr)	Road constructed(in km)	Percentage of road constructed
SUR	24	3,487.497	1338	10.12
Sunshine	6	967.85	360.47	2.73
DMC	3	298.41	125	0.95
Ras Haile	15	2,893.60	1219	9.22
Total	48	7,647.36	3042.47	23.02

Source: Author's computation based on data obtained from ERA

A total of 14 privately owned local contractors are involved in the RSDP period. Among them, this study selects three privately owned local contractors namely SUR construction, Sunshine construction and DMC construction, which together accounts 27 percent out of the 38 percent of kms that are awarded to private local firms and 14 percent of the total road construction (in km) during the RSDP period. In addition to these three firms, the study also include Ras Haile, which is the only local contractor owned by the government and accounts 8 percent of the total road construction (in km) during the RSDP period (See Table 2.4). As indicated in Table 2.4, the amount of projects that are won by these four firms is ranged from 298.41 million birr by DMC construction to 3,487.497 million birr by SUR construction. A total of 48 road construction projects has undertaken by these four firms. The profile of all the four selected firms is presented as follows.

SUR Construction

SUR Construction is established by the Endowment Fund for the Rehabilitation of Tigray (EFFORT) in 1992 with an initial capital of Birr 108 million as a General Contractor Grade One (GC1). Since its establishment, SUR has accomplished 22 road projects (approximately 1100 km), 37 various building projects as well as airfield and hydropower projects. The total worth of all those projects 2007/2008 is about Birr 2 billion with vast experience in asphalt and gravel roads, buildings, airfields and hydropower projects (SUR Company Profile, 2008).

Sunshine Construction

Sunshine construction is established as a sole proprietorship business entity in 1984, and eventually evolved into a private limited company in 1993. Since its establishment, sunshine has been involved in various activates such as in road construction, real-estate development, construction of hotel buildings and in various business activities like trade, rental buildings, helicopter services, etc (Sunshine Company Profile, 2008)

DMC Construction

DMC Construction was founded in the year 1996 with a Paid-up Capital of Birr 16,310,000. The inspiring and dedicated effort of the founder coupled with the given favorable conditions from government, has resulted in the rapid growth of the company to become one of the leading construction firm. Since its establishment, the company has been engaged and successfully completed various buildings, roads and other civil infrastructure projects. Taking advantage of its vast experience in the construction works, DMC-Construction has also entered in the Real-Estate development business (DMC Company Profile, 2008).

Ras Haile

Ras haile is a state owned organization established in 1951 it is highly involved in road construction, rehabilitation, upgrading and maintenance. Currently Ras Haile is one branch of the Ethiopian Roads Authority (ERA) and it is carrying out construction and rehabilitation of a few road projects, some heavy maintenance projects and routine maintenance of roads. In general, Ras Haile is involving in carrying out the periodic maintenance, implementation of those rehabilitation and construction road projects in a situation where by the project is needed to complete urgently (ERA, 2008).

2.4 The Role of Chinese Firms in Ethiopia's Road Construction Sector

Historically, African economies were closely integrated with the former colonial powers in Europe, and with North America and Japan. However, the global economy and polity has been changed due to the rapid growth of emerging countries especially the growth of China and India (Kaplinsky and Farooki, 2008). As indicated by Kaplinsky (2008), since 1979, China has grown at a compound growth rate of 9 percent per year and if it could maintain this trend, China will be the second biggest economy in the world by 2016. Given its big size (about 20 percent of the world's population), the rapid expansion of China disrupts not only the path of the weak and poor economies in Africa but also the path of many societies in the world. That is why the newly emerging very large Asian economies (China and India) are referred to as the "Asian Drivers" (Kaplinsky and Farooki, 2008).

According to Center for Chinese Studies (2006), Chinese state owned and private companies are making strategic inroads in to African economies' construction and infrastructure sectors. As a result, the traditionally dominant European and South African companies are now replaced by Chinese state owned and private enterprises. When it comes to Ethiopia, its formal link with China in economic and technical cooperation was started in 1971. The cooperation includes provision of soft loans, grants and technical assistance (Tegegne, 2006).

China is contributing about $ 1 billion out of the $ 15 billion investment Africa has received in 2004(The Economist, 28 October 2006 as cited in Alemayehu and Atinafu, 2008). Regarding to the sectoral distribution of Chinese's investment, the construction sector, where road construction is the dominant one, has been among the top five most important sectors (Tegegne, 2006). According to Tegegne (2006), the Chinese road construction investment has undertaken in Addis Ababa, the capital city, and across region linking cities and some of the projects are grant projects though they are under taken by the Chinese companies while others are tendered and are financed by the Ethiopian government.

2.5 An Overview of Selected Chinese Firms

Foreign contractors in general and Chinese companies in particular have increased their involvement in Ethiopian road construction year after year. Foreign contractors' participation has shown a steady rise from 57.2 million birr in 1996/97 to one billion birr in 2002/03(Addis Fortune, 29 September 2008).According to the data obtained from ERA, currently there are around 10 Chinese companies operating in Ethiopia's road construction sector. Among them, four Chinese firms namely Chinese Road and Bridge Corporation (CRBC), CGC Overseas Construction (CGCOC), Hunan Hunda Road and Bridge Corporation (HHRBC) and SINOHYDRO Corporation are selected for this study. According to the data obtained from ERA, these four firms together account more than 70 percent of road construction projects that have been undertaken by Chinese firms during the period 1997 to 2007.

Table 2.5 Summary of Selected Chinese Firms during RSDP Period

Firm	No. of Road Projects	Amount of Project won ('1000000' Birr)	Road constructed(in km)	Percent of total road constructed
CRBC	7	2,773.97	824.69	6.24
CGCOC	5	2,594.42	689	5.21
HHRBC	3	1,318.89	384	2.91
SINOHYDRO	2	478.06	205.5	1.55
Total	17	7,165.34	2103.19	15.9

Source: Author's computation based on data obtained from ERA

As indicated in Table 2.5, these four Chinese firms together account about 16 percent of the total kms of road construction during RSDP period. When it comes to the amount of the project they won, CRBC has possessed the highest value while SINOHYDRO has the lowest one. In terms of the number of road projects the Chinese firms have won a small amount (only 17 projects) relative to Ethiopian firms. However, the value of the total projects does not show similar difference and this show that the Chinese firms are engaging in high value road construction projects. The profile of these four Chinese firms is presented below.

Chinese Road and Bridge Corporation (CRBC)

CRBC is a large state owned company originated from former China Road and Bridge (Group) and a leading force in the road construction industry in China. Its scope on business covers contracts for projects with in China and abroad, including survey, design, construction, consultancy and supervision of road projects, intellectualized buildings and traffic engineering works, manufacturing of road construction equipment, bridge building components and transportation vehicles, inland trade, foreign trade etc. It has 16 sole proprietorship enterprises, 34 overseas offices, 12 joint stock companies and 4 share-holding companies (including one public company)(CRBC Company Profile,2007).

The history of CRBC can be traced back to early days of the People's Republic of China. Along with the development and reform of China's social and economic system, CRBC, has developed into an international contractor after several times of restructures, formerly the Foreign Aid Office of the Ministry of Communications of PRC, then the China Road and Bridge Engineering Company in 1979 approved by the State Council, then the China Road and Bridge (Group) Company in 1997 and latest, the China Road and Bridge Corporation (CRBC) in 2005 (CRBC Company Profile, 2007).

Since its establishment, CRBC has built many magnificent roads and bridges both within and outside China. By the end of 2004, it had constructed more than 14780 km roads of various types, including 6573 km expressway, built 4405 bridges of medium nad large types, of which 857 bridges were completed on its own, with the length of 637900 meters, undertaken the construction of 25 tunnels, with the total length of 16335 meters (CRBC Company Profile, 2007).

CRBC has also entered into the international construction market since 1979 and over the past two decades it has concluded more than 500 contracts amounting to 6 billion US dollars. Its business scope has extended from road and bridge construction to sewerage and water supply, industrial and civil buildings, municipal works, railway, airport and port construction etc (CRBC Company Profile, 2007).

CGC Overseas Construction (CGCOC)

CGCOC is a public Chinese construction company with many branches in Africa and Asia. It was founded on December 5, 2002 in Beijing, affiliated with the Sinopec Star Petroleum Co., Ltd. The registered capital amounts to 290 million RMB. As the largest shareholder, Sinopec Star holds 42.1 percent stakes (CGCOC Company Profile, 2008).

CGCOC is mainly engaged in various domestic and foreign engineering construction projects, energy exploration, development and utilization, investment and trade. With its headquarters in Beijing, its business spreads throughout dozens of countries and regions in

Africa and Asia including Nigeria, Ethiopia, Angola, Chad, Cameroon, Algeria, Kazakhstan, Saudi Arabia, Nepal and so on. CGCOC also set up several domestic companies including the Shaanxi Zhongdi Energy Development & Construction Co., Ltd, the Hunan Zhongyang Engineering & Construction Co., Ltd, and the CGCOC Hansom Beijing Trading Co., Ltd. CGCOC has undertaken nearly 100 projects in areas of water conservancy, road and bridge construction, building construction, town planning and water supply (CGCOC Company Profile, 2008).

Hunan Hunda Road and Bridge Corporation (HHRBC)

HHRBC is a state owned Chinese company. It was established in 1993. HHRBC is also a national first grade enterprise with general contracting qualification for highway projects and class one qualification for bridge works construction, pavement construction and sub-grade construction as well as qualification for highway incidental facility works and tunnel works. With a registered capital of 180 million Yuan RMB and overall power of 90, 000 km, HHRBC has become a new and modern construction enterprise developing in all directions (HHRBC Company Profile, 2008).

SINOHYDRO Corporation

With registered capital of RMB 4,000 million and total assets of RMB 52,200 million, SINOHYDRO is Chinese dominant leading and largest company in water conservancy and hydropower industry. It is established in 1950 and it is constituted of 17 wholly owned subsidiaries, 10 holding companies, 33 overseas branch companies and representative offices around the world (SINOHYDRO Company Profile, 2008).

In 2007, SINOHYDRO Corporation, with both operating revenue and total assets exceeding RMB 50 billion, enters the ranks of super-large state owned enterprises whose revenue and total assets are between RMB 50 billion and 100 billion. The main business of SINOHYDRO Corporation covers investment, project financing, consultation service, construction, mechanical and electrical plant manufacturing and installation, construction equipment manufacturing and trading in the industry of water conservancy, power generation, expressway, railway, harbor and sea-route, airport, municipal public utility and building SINOHYDRO has grown from a hydropower construction enterprise to a diversified large enterprise group (SINOHYDRO Company Profile, 2008).

Chapter Three

Literature Review

3.1 Theoretical Review

3.1.1 Introduction

In microeconomics of production, technical efficiency is defined as "the maximum attainable level of output for a given level of inputs, given the current range of alternative technologies available to the farmer" (Ellis, 1993 cited in Alemu et al, 2009). According to the neo-classical theory of production, firms are efficient and any inefficiency in the process of production is due to external shocks or statistical noise which is totally beyond their control (Daniel, 2005). In line with this, economics textbooks often assume that producers are successful optimizers (Sarafidis, 2002). However, according to Sarafidis (2002), casual observation suggests that although producers may indeed attempt to optimize, they do not always succeed and some producers appear to be consistently more efficient than others. In reality, different industries do produce different levels of output even if they use the same level of every observed input. Thus comparative efficiency analysis as a measure of efficiency in the use of resources has become a major concern among policy makers (Sarafidis, 2002).

Safafidis (2002) argued that comparative efficiency analysis is a useful tool for benchmarking and incentive regulation. According to him, it can help policy makers to identify and remedy underperformance, and regulators to encourage efficiency and ensure that consumers benefit from the resulting efficiency gains. He also argued that when differences in efficiency are significant, measuring relative efficiency is an extremely important issue and that is why the measurement of productive efficiency has received a considerable attention in economic literature in recent years.

Productivity is normally perceived as the ratio of output to input, but in the presence of multiple inputs and outputs these are normally weighted by their price. Much of the literatures on efficiency are based directly or indirectly on the seminal work of Farrell (1957). As cited in Stone (2002), his work is based on the theory of Pareto optimality as developed by Koopmans (1951) and Debreu (1951). Koopmans and Debreu were concerned with the over all efficiency of an economic system broken down into interacting activities or production units (Stone, 2002). However, Farrell (1957) argued that Debreu's efficiency coefficient for the whole system could be applied to the individual independent production units of an industry, where the data for each unit were the volumes of specified inputs and outputs (Stone, 2002). That is, Farrell (1957) suggested a measure of productive efficiency of a firm that avoids the problems associated with traditional average productivity measures. Efficiency is, therefore, measured relative to a best –performance frontier that is determined by a representative peer group (Abdu, 2006 and Stone, 2002).

Farrell's (1957) basic idea is based on two efficiency measures: Input oriented measures and Output oriented measures. In the case of input oriented measures, focus is given to the measurement of variations in input use and an increase in efficiency will be achieved by reducing inputs proportionally holding outputs constant. On the other hand, output oriented measures focused on the measurement of variation in output produced and an increase in efficiency will be achieved by increasing outputs proportionally holding the input quantities constant (Abdu, 2006 and Kumbhakar and Tsionas,2006).

3.1.2 Efficiency Measurement Approaches

To estimate relative efficiency among firms, there are two major approaches: the parametric (statistical) approach and non-parametric approach. The parametric approach specifies a particular functional form for the production or cost function. In other words, it is based on parameter estimation with given functional forms (Sarafidis, 2002, Khac and Thanh, 2005 and Alemayehu and Dawit, 2008). To estimate the parameters, this approach uses econometric techniques such as simple regression analysis and Stochastic Frontier Analysis (SFA) (Sarafidis, 2002). However, the specification of a particular functional form in this approach is criticized by Khac and Thanh (2005). They argued that it is impossible to apply one technology for all different industries, or even for all firms within an industry. On the other hand, identifying an appropriate technology for each industry or firm is difficult.

Unlike the parametric approach, the non-parametric approach does not require any assumption about the functional form of the production or cost frontier. It uses mathematical programming techniques in order to find the set of weights that will maximize the efficiency score greater than 100 percent at those weights (Sarafidis, 2002). According to him, the model would reject the solution for a particular firm if the set of weights that maximize its relative performance generates scores greater than 100 percent for any other firm. Simple technique of index numbers and Data Envelopment Analysis (DEA) are the two best examples of this approach.

Based on the way the frontier is specified and estimated, Forsund et al (1980) classified the studies of frontier technology in to deterministic and non-deterministic(stochastic) approach. According to them, the deterministic frontiers are further sub-divided into non-parametric, parametric and statistical frontiers.

Frontier analysis from parametric approach and DEA and DEA-Malmquist from the non parametric approach will be discussed in the following subsection. These are some of the most frequently used approaches to measure technical efficiency of a firm.

I. Frontier Analysis

The word frontier may be applied either to maximize possible out put which can be produced from a given set of inputs or the minimum level of the of cost at which it is possible to produce some level of output at a given input prices or the maximum profit that can be attained at a given output and input prices (Daniel, 2005).Thus, the frontier production function specifies what output can be achieved, if all decisions were taken according to their best practices(Friebel et al, 2003).In line with this, Khac and Thanh (2005) argued that production function focus on maximizing outputs with given inputs and all the maximized production points will create a production frontier. However, some empirical observations lie below the frontier since the production function defines a theoretically achievable optimum. Therefore, the distance for them to the frontier indicates their level of production inefficiency (Khac and Thanh, 2005 and Frieble et al, 2003). According to Forsund et al (1980), the frontier approaches are classified in to different categories based on the way the frontier is specified and estimated. Each of them will be presented below.

A. Deterministic Non- Parametric Frontier Approach

Any discussion about frontiers and efficiency is based on the work of Farrell (1957), who provided definitions and a computational framework for technical and allocative inefficiency for the first time (Forsund et al, 1980). According to Forsund et al (1980), Farrell's (1957) approach is deterministic since no account is taken for the possible influence of measurement errors and other noises up on the frontier and all the deviations are assumed to be the results of variations in efficiencies. In this regard, Woo et al (2005) argued that early studies of technical efficiency were based on the deterministic frontier model suggested by Aigner and Chu (1968) since they do not consider the impact of random factors that may move production from the frontier.

According to Forsund et al (1980), Farrell's (1957) approach is not only deterministic but also non- parametric because the free disposal convex hull of the observed input- output ratios is simply constructed by linear programming techniques and it is not based on any explicit model of the frontier or the relationship of the observation to the frontier. Then the technical inefficiency of an observation is measured relative to this frontier.

The advantages and drawbacks of deterministic non- parametric approach are also mentioned by Forsund et al (1980). The main advantage of the model mentioned by Forsund et al (1980) is that no functional form is imposed on the data. On the other hand, the two major weaknesses of the model are identified by Forsund et al (1980). The first one is the assumption of constant returns to scale which is restrictive and its extension to non- constant returns to scale is also cumbersome. The second drawback comes from the way the frontier is calculated. That is, the frontier is computed from a supporting subset of observation from the sample which makes it susceptible to extreme values and measurement error.

B. Deterministic Parametric Frontier Approach

Unlike non-deterministic parametric approach, which is based on linear programming with out functional forms (and therefore does not guarantee statistical appropriateness), the deterministic parametric approach is based on parameter estimation of a given functional forms (Khac and Thanh, 2005).

In deterministic approach, a production function that obeys constant returns to scale is determined by computing a parametric convex hull of the observed input- output ratios (Farrell, 1957 as cited in Forsund et al, 1980).

The following homogeneous Cobb-Douglas production function is initiated by Aigner and Chu (1968) based on the work of Farrell (1957) (Khac and Thanh (2005).

$$\ln y = \ln f\,(x) - U \qquad (3.1)$$

$$\ln Y_i = \alpha_o + \sum_{i=1}^{n} \alpha_i \ln X_i - U, U \geq 0$$

Where Y_i denotes the i th firm output

f(x) represents a functional form of inputs vector x_i for the i^{th} observation

α represents a vector of unknown parameters and

U_i is firm specific technical inefficiency which forcesY to be less than or equal to f(x).

The elements of the parameter vector α can be estimated either by linear programming (minimizing the sum of the absolute values of the residuals, subject to the constraint that each residual be non- negative) or by quadratic programming (minimizing the sum of squared residuals, subject to the same constraint). Therefore, the technical efficiency of each observation can be computed directly from the vector of residuals, since u represents technical inefficiency (Daniel, 2005).

Deterministic parametric frontier has two main advantages. The first advantage is its ability to characterize frontier technology in a simple mathematical form and the second one is its ability to accommodate non- constant returns to scale (Forsund et al, 1980). Forsund et al (1980) also mentioned the following three main limitations of this approach. First, it imposes a restriction on the number of observation that can be technically efficient. That is, the number of technically efficient observations should be equal to the number of estimated parameters. Second, like the case of deterministic non-parameter frontier approach, the estimated frontier is supported by a subset of data. As a result, it is highly sensitive to extreme values (outliers). The absence of statistical properties in the estimates produced by this approach is the third limitation. Since no assumption is made about the regresses or the disturbances, the mathematical programming procedure produce estimates with out standard errors, t-ratio, etc. Thus, it is impossible to obtain inferential results.

C. Deterministic Statistical Frontier Approach

This approach can be considered as an extension of the deterministic parametric frontier approach since it adds only some assumptions (Daniel, 2005).As cited in Khac and Thanh (2005), it was Afriat (1972) who explicitly proposed the deterministic parametric frontier approach for the first time and he developed the model as follow:

$$Y_i = f(X)e^{-U} \quad \text{.........} \quad (3.2)$$

$Ln(y_i) = \ln[f(X)]\text{-}U$

Where Y_i and $f(X)$ are as defined in equation 3.1

This model is based on the following two assumptions:

Observations on U are assumed to be independently and identically distributed (iid), and X is assumed to be exogenous, that is, independent of U

Here more attention should be given to the distribution of U since different assumptions about it will lead to different estimates (Daniel, 2005).

Afriat (1972) as cited in Khac and Thanh (2005) proposed a two-parameter beta distribution for U, and then, the model will be estimated by the Maximum Likelihood Estimation (MLE) technique. However, the use of maximum likelihood estimation has faced two major shortcomings (Daniel, 2005). The first weakness is that there is no good a priori reason to use this technique. The other limitation related to MLE technique is that the range of the dependent variable (output) depends on the parameters to be estimated which violates one of the regularity conditions that appeals to prove the general theorem that maximum likelihood estimators are consistent and asymptotically efficient.

On the other hand, Richmond (1974), as cited in Forsund et al, 1980), proposed a gamma distribution for U and Corrected Ordinary Least Squares (COLS) method for estimation. The advantage of COLS method is that it provides consistent estimates by shifting the estimated COLS constant parameters upward until no residual is positive (Forsund et al, 1980). The main difficulty with COLS technique is discussed by Forsund et al (1980) is that, even after correcting the constant term, some of the residuals may still may have the "wrong" sign so that those observations end up above the estimated production frontier. This makes COLS somewhat uncomfortable to compute the technical efficiency of individual observations. Another difficulty with the COLS technique is that the correction to the constant is not independent of the distribution assumed for U.

The assumption that all firms share a common family of production, cost and profit functions and all variations in firm performance are attributed to variations in firm efficiencies relative to the common family of frontiers is another difficulty in deterministic statistical frontier approach (Forsund et al, 1980). According to him, the notion of a deterministic frontier shared by all firms ignores the very real possibility that a firm's performance may be affected by factors entirely outside its control as well as by factors under its control. He, therefore, conclude that the measure of efficiency in deterministic statistical frontier approach is questionable since it incorporate the effects of exogenous shocks together with the effects measurement error and inefficiency in a single one -sided error term.

D. Stochastic Frontier Analysis Approach

Before Stochastic Frontier Analysis (SFA) was first introduced by Aigner et al (1977) and Meeusen and Van den Broeck (1977), all frontier methods were deterministic (Daniel, 2005). In the deterministic approach, as discussed in the previous section, no account is taken in the possible influence of measurement errors and other noises upon the frontier and all the deviations are assumed to be the result of variations in efficiencies.

However, the Stochastic Frontier Approach (SFA) avoids some of the problems associated with deterministic frontiers by explicitly considering the stochastic properties of the data, and distinguishing through a composite error term between firm specific effects and random shocks or statistical noise (Miller et al, 2005). In this model, as discussed by Miller et al (2005), the frontier shifts from one observation to the next randomly.

According to Batttes and Coelli (2005), the stochastic frontier model specifies a production function and any deviation as measured by the error term is decomposed into two components. The first one is a systematic component which permits random variation of the frontier across firms and captures the effects of measurement error, other statistical noises and random shocks outside the control of the production unit. Second component is defined as a measure of technical inefficiency which captures the effects of inefficiency relative to the best stochastic frontier.

The stochastic frontier analysis (SFA) uses statistical methods to fit a frontier by making assumptions about the functional form of the production function (Forsund et al, 1980).The stochastic production frontier model can be written as follow:

$Y_i = f(X_i, \beta) + V_i - U_i$ ....(3.3)

Where Y_i denotes actual output

X_i represents a vector of inputs

β is a vector of parameters

V_i captures random effects of measurement error and exogenous shocks

U_i captures technical inefficiency related to the stochastic production function and $U_i \geq 0$

$f(X_i, \beta)$ is the deterministic part, and

$f(X_i, \beta) + V_i$ represents the stochastic frontier

The stochastic production frontier model has the following two basic assumptions:

1. V and U are independent and
2. X is exogenous.

Using these assumptions and after specifying the distribution of U, it is possible to get the estimates of the model by using either maximum likelihood or COLS methods (Forsund et al, 1980).Thus, technical efficiency relative to stochastic production frontier is captured by the one-sided error component, U_i.

There are different distributional assumptions for the error term (U_i). Aigner et al (1977) estimates the inefficiency term (U_i) in to two ways: by assuming a half – normal distribution in one estimation and an exponential distribution in the other (Ahmad et al, 2006).The other distributional assumptions include exponential distribution which is used by Meusen and Broeck (1977), truncated normal distribution which is used by Cooperman et al (1993) and Berger et al (1997),and gamma distribution which is considered by Stevenson (1980) and Greene (1990)(Ahmad et al, 2006 and Forsund et al, 1980).

Many empirical studies both involving cross- sectional and time series data have assumed half-normal distribution for the error term (Daniel, 2005). Bauer (1990) and Greene (1990) also note that the half- normal distribution has become a standard choice and this idea is confirmed by Berger et al (1993) and the Bauer et al (1998)(Ahmad et al , 2006).

Although there is no consensus on the distributional type of the inefficiency term, most of the literatures suggest that different distributional assumption tend to yield similar efficiency scores (Ahmad et al, 2006). As cited in Ahmad et al (2006) the analysis of Aigner et al (1977), Greene (1990), Altunbas and Molyneux (1994) and Bauer et al (1998) show little difference in efficiency scores when different assumptions are used for the inefficiency term.

The recognition of the error term and the principle of separating the error components from the measures of inefficiency are the main potential advantages of the Stochastic Frontier Analysis (SFA) (Alemayehu and Dawit, 2008 and Sarafidis, 2002). In addition to this, its ability to handle unmeasured heterogeneity in cross decision making units (DMU) and its ability to provide room for factors in measured sources of heterogeneity are the advantages mentioned by Alemayehu and Dawit (2008).

Further more, the main attraction of the stochastic frontier is the possibility it offers for a richer specification, particularly in the case of panel data (Daniel, 2005). According to him, the model also allows a formal statistical testing of hypothesis and the construction of confidence interval.

Although stochastic frontier approach (SFA) has all the aforementioned advantages, it is not free of limitation. According to Miller et al (2005), the main limitation of this approach lies on the distributional assumptions of the inefficiency tem (U_i). That is, the absolute levels of inefficiencies differ over different distributional assumptions on the one sided error term although the relative ranking of firms based on inefficiency calculations seems unaffected. However, Berger and Humphery (1991), citied in Miller et al (2005), solved this problem by introducing the "thick" frontier model, where a larger number of "best practice" firms support the frontier and where the estimation of inefficiency requires weaker distributional assumptions. In addition to this, Ahmed et al (2006), argued that different distributional assumption tend to yield similar efficiency scores. Thus because of all these aspects, this study will employ this model to predict technical efficiency by using firm's panel data.

II. Data Envelopment Analysis

Farrell's (1957) approach is applicable only to firms aiming at a single goal. It can not apply to examine firms aiming on multiple goals (Abdu, 2006). As a result, much detail empirical attention was not given to Farrell's (1957) for about two decades until Charnes et al (1978) used Data Envelopment Analysis (DEA) for the first time (Casu and Molyneux, 2000). Since then, there have been a large number of papers which applied and extended the methodology (Ray, 2004).

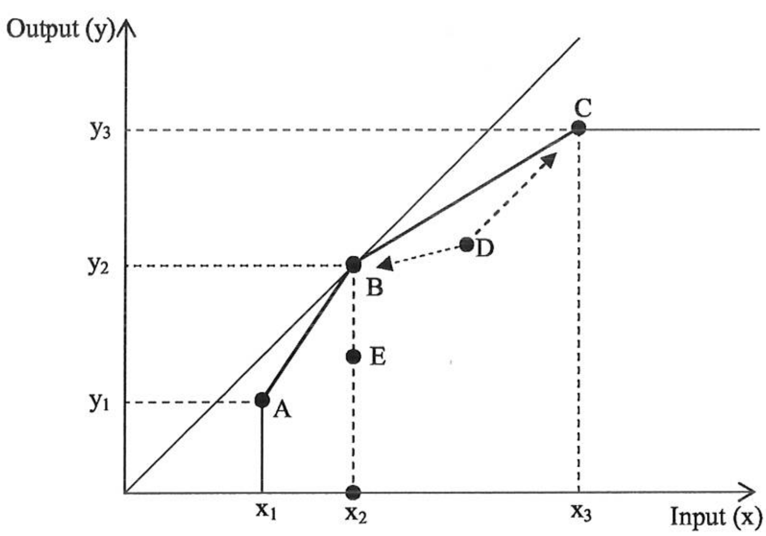
Charnes et al (1978) introduced a ratio definition of efficiency which generalizes the single – output to single- input ratio definition to multiple outputs and inputs without requiring pre assigned weights (cited in Banker et al, 1984). Charnes et al's (1978) original model was applicable only to technologies characterized by constant returns to scale but later on Banker (1984) extended it to accommodate technologies that exhibit variable returns to scale.

Nowadays, researchers and practitioners considered DEA as a commonly used approach to efficiency measurement. The term data envelopment analysis refers not only to a single method but also to a whole family of methods for the evaluation of the relative efficiency of decision making units (DMUs) (Scheel and Scholtes, 2003). The DEA model has been used for efficiency valuations of bank branches, fast food restaurants, schools, hospitals, etc (Cooper et al, 2000 cited in Scheel and Scholtes, 2003).

The DEA model sets up a linear programming model to compare the relative efficiency of a reference unit in relation to the others in the sample (Sengupta, 1996). In this model, a DMU is said to be technically efficient if and only if it is not possible to improve any of its inputs or outputs without worsening some of its other inputs or outputs (Sengupta, 1996).

The DEA production frontier is not determined by some specific functional form. In stead, it is generated from the actual data for the firm to be evaluated (Stone, 2002 and Posadas and Cabanda, 2007). Thus, the DEA frontier is formed as the piecewise linear combination of best- practice observations in the data set. As a result, the production possibility set (PPS) will be convex (Alemayehu and Dawit, 2008 and Casu and Molyneux, 2000).

Thus, the DEA efficiency score for a specific DMU is not defined by an absolute standard, but it is defined relative to the other DMUs in the specific data set under consideration (Sarafidis, 2002, Banker et al, 1984).The efficiency scores in DEA can be solved using the assumption of constant returns to scale (CRS) (Charnes et al, 1978 cited in Banker et al, 1984) or variable returns to scale (VRS) (Banker et al, 1984). The CRS assumption is appropriate only when all DMUs are operating at an optimal scale (Banker et al, 1984). However, factors like imperfect competition and constraints on finance may cause a DMU not to operate at optimal scale. As a result, the use of the CRS specification, when some DMUs are not operating at optimal scale, will result in measures of technical efficiency mixed with scale efficiency (Abdu, 2006). To separate the two efficiency scores Abdu, (2006) recommended the application of variable returns to scale. Khac and Thanh (2005) graphically summarized the difference between the CRS and VRS as follows:



Source: Khac and Thanh (2005)

In the figure, there are five points (A, B, C, D & E) associated with different levels of input and output. The line ABC describes the VRS frontier for the production process. Observations A, B, and C are on the frontier, while observations D and E lie below the frontier. There exists a ray from the origin tangent to the frontier at point B, and this ray represents the CRS of the technology represented by the data of those observations. Observation B depicts the relative technical efficiency, meaning that this firm is purely technically efficient and scale efficient due to its location on the frontier and the property of constant returns to scale (Khac and Thanh, 2005).

Although a firm may be technically efficient in an overall sense, it is possible that it is experiencing inefficiency in scale (Khac and Thanh 2005). This situation is also shown in the above figure. Observations A and C are purely technically efficient because they belong to the frontier, but they exhibit scale inefficiencies. Observation D is both scale and technically inefficient because it lies below the frontier. Theoretically, the same level of input could be used to achieve a higher level of output, which will allow this firm (at point D) to move forward to the frontier between points B and C. Observation E is purely technically inefficient because it lies below the frontier, but it is scale efficient because it produces at input level of x_2-the scale-efficient level of input for observation B (Khac and Thanh (2005).

Then, the DEA model can be specified based on the assumption of either constant returns to scale (CRS) or variables returns to scale (VRS) (Abdu, 2006, Khac and Thanh, 2005). Mathematically, CRS and VRS models can be specified as follows:

The constant returns to scale (CRS) model

According to Abdu (2006) and Alemayehu and Dawit (2008), the relative efficiency score of a DUM, which employs multiple input and output, can be defined as:

$$\text{Relative Efficiency} = \frac{\text{Weighted sum of outputs.}}{\text{Weighted sum of inputs}}$$

$$= \frac{\sum_{r=1}^{s} U_r Y_{rj}}{\sum_{i=1}^{m} V_i X_{ij}}$$

The following ratio definition of Charners et al (1978) can also be used to find the relative efficiency score of firms (Banker et al 1984, Alemayehu and Dawit, 2008).

$$Max.h_o = \frac{\sum_{r=1}^{s} U_r Y_{rf}}{\sum_{i=1}^{m} V_i X_{if}}$$

$$Subjectto : \frac{\sum_{r=1}^{s} U_r Y_{rj}}{\sum_{i=1}^{m} V_i X_{ij}}$$

$U_r, V_i > 0$ .... (3.4)

Where: r = 1…s

i = 1…m

j = 1…n

X and y represent inputs and outputs, respectively.

U and V are common weights assigned to outputs and inputs, respectively.

F represents the firm under assessment.

According to Abdu (2006), equation (3.4) can be converted in to a linear programming model by introducing the following constraint:

$$\sum_{i=1}^{m} V_i X_{if} = 1$$

Thus, the relative efficiency score of a firm f can be obtained by solving the following equation:

$$Eff = Max \sum_{r=1}^{s} U_r Y_{rf} = 1$$

$$Subjectto : \sum_{r=1}^{s} U_r Y_{rj} - \sum_{i=1}^{m} V_i X_{ij} < 0; \forall_i$$

$$\sum_{i=1}^{m} V_i X_{if} = 1$$

$U_r, V_i \geq 0; \forall r, \forall i$ ....(3.5)

The first constraint implies that all firm are on or below the frontier while the second constraints implies that the weighted sum of inputs for the particular firm equals one (Abdu, 2006).

The variable returns to scale (VRS) model

Variable returns to scale (VRS) is an extension of equation (3.4) of the CRS model after imposing a convexity constraint on it (Abdu, 2006). As he explained, VRS model enables an inefficient firm to be relatively compared with efficient firms of the same size.

Thus, by solving the following equation, it is possible to obtain the relative efficiency score of firm f:

$$Eff = Max\sum_{r=1}^{s} U_r Y_{rf} + U_o$$

$$Subjectto: \sum_{r=1}^{s} U_r Y_{rj} - \sum_{i=1}^{m} V_i X_{ij} < 0; \forall_i$$

$$\sum_{i=1}^{m} V_i X_{if} = 1$$

$$U_r, V_i \geq 0; \forall r, \forall i \quad \text{...}(3.6)$$

Where U_o represents the convexity constraint and its sign determines the returns to scale. Thus, $U_o<0$, $U_o>0$ and $U_o= 0$, indicates increasing returns to scale, decreasing returns to scale and constant returns to scale respectively (Abdu, 2006).

On the other hand, the DEA model uses the efficiency score of CRS and VRS to show scale efficiencies of firms (Abdu, 2006 and Khac and Thanh, 2005). Here, the scale efficiency is given by the ratio of CRS technical efficiency to VRS technical efficiency. Thus, a DEA score of 1 shows relative efficiency than other firms in the sample while efficiency score less than one indicates relative inefficiency (Sengupta, 1996).

In DEA model there is no danger of misspecification of the frontier since it does not need to employ an assumption for the functional form of the frontier other than the minimum piecewise and linear condition. And this behavior is considered as a major advantage of the model by Sarafidis (2002). According to him, the problem of random noise is less in DEA since any deviation from the estimated frontier is interpreted as due to inefficiency. DEA has also the advantage that it handles multiple input and multiple output models and functional form of relating inputs to outputs is not required (Banker et al, 1984).

On the other hand, DEA has also faced with limitations. A major draw back of DEA is that it attributes all deviations from the frontier to inefficiency but the deviation may be due to statistical noise or measurement errors (Sarafidis, 2002). The other limitation mentioned by Sarafidis (2002) is that DEA does not allow statistical tests of hypothesis for both the inefficiency and the structure of production function. The deterministic nature of DEA has also caused significant problems in the measurement of efficiency when there are outliers in the industry because the method envelopes outermost observation without asking whether these observations are genuine or the result of an error (Sarafidis, 2002). Because of all these limitations, Sarafidis (2002) concluded that interpreting DEA scores as measures of efficiency requires a high degree of "blind" faith in the model.

III. DEA-Malmquist

The DEA- Malmquist is a non parametric approach that uses panel data to estimate changes in total factor productivity (Posadas and Cabanda, 2007). According to Posadas and Cabanda (2007), DEA based Malmquist indices are used to measure the change in the ratio of outputs over inputs used in a production process over time. In the other hand, the Malmquist index is an index of the geometric mean of TFP index from period t and TFP index from period t+1. Fare et al (1994), as citied in Posadas and Cabanda (2007), provide the following output oriented Malmquist productivity change index:

$$M_o(X^{t+1}, Y^{t+1}, X^t, Y^t) = [\frac{D_o^t(X^{t+1}, Y^{t+1})}{D_o^{t+1}(X^{t+1}, Y^{t+1})} X \frac{D_o^t(X^t, Y^t)}{D_o^{t+1}(X^t, Y^t)}]$$

Where M_0 is the Malmquist productivity index from period t (bench mark) to period t+1 relative to input–output mixes under the constant returns to scale assumption

$D_0^{t+1}(x^{t+1}, y^{t+1})$ represents the distance from the period t observation to the period t+1 technology.

The most important characteristics of the Malmquist index is its ability to decompose the total factor productivity in to technical efficiency change (catching up effect) and technical change or technological progress (Fare et al (1994) citied Podadas and Cabanda, 2007). This decomposition is expressed by the following equation:

$$M_o(Y^{t+1}, X^{t+1}, Y^t, X^t) = \frac{D_o^t(X^{t+1}, Y^{t+1})}{D_o^t(X^t, Y^t)} X[\frac{D_o^t(X^{t+1}, Y^{t+1})}{D_o^t(X^t, Y^t)} X \frac{D_o^{t+1}(X^{t+1}, Y^{t+1})}{D_o^{t+1}(X^t, Y^t)}]^{1/2}$$

The efficiency change is measured by the first term and the second term measures technical change. In general, if the value of M_o is greater than one, it shows the existence of positive total factor productivity from period t to t+1 while a value less than one indicates a decline in total factor productivity.

3.2 Empirical Review

There are few literature on technical efficiency of the construction sector although there is a substantial literature on other different sectors such as in the railway industry (for example, Friebel et al (2003), Farsi et al (2004) and Friedriszick et al (2003)), in the manufacturing industry (for example, Fioramanti (2009) and Daniel(2005)), in hospitals (for example, Hofler and Folland (1995), Frohloff (2007), Yong and Harris(1999) and Abdu (2006)) and in the agricultural sector(for example, Kibaara (2005), Alemu et al (2009) and Hussien et al (2006)). When it comes to the specific case of efficiency measurement in the road construction sector operating in Ethiopia, no empirical study has been done. Talyitie and Hirvela (1994) also support this idea. According to them, there is a shortage of literature on the efficiency of road construction organizations' performance, or on comparisons of road agencies in different countries or in different regions of a country. Given the existing limitation, some empirical studies on efficiency of the construction sector in general and on road related issues in particular have been reviewed as follows.

Khac and Thanh (2005) measured the technical efficiency of 2,298 construction firms in Vietnam for the year 2002. Both Data Envelopment Analysis (DEA) and stochastic frontier production model had been used to asses the level of technical efficiency. The results from both approaches were found to be consistent. The average technical efficiency of these firms is 58.6 percent for DEA and 57.8 percent for stochastic frontier approach. The study also formulated the inefficiency model to observe the effect of external factors on technical efficiency scores. Again, relatively similar results are found in both approaches. The findings revealed that state firms are more efficient than non-state ones and location in Hanoi and Ho Chi Minh cities have a positive effect on technical efficiency. However, the variable capital – labour ratio does not influence technical efficiency scores in the DEA model, while it has significant positive effect in the stochastic frontier production function model. Net revenue is also included in the inefficiency model as a proxy to firm size and it is found to have no impact on technical efficiency for both DEA and stochastic frontier model.

After having an overview of recent trends in funding systems of road investment for five major nations (USA, UK, France, Germany and Japan) in the period between 1990and 2004, Yamaguchi (2008) tried to observe the effects of institutional differences on road investment and assess efficiency of road transport in these nations. Production function model, Data Envelopment Analysis (DEA) and Tornqvist index are the three methodologies that are used to derive efficiency indices. Cobb-Douglas production function was specified for the production function model. In addition to this, Multilateral Superlative Tornqvist index analysis is used to compare efficiency change among the five nations and to identify factors that explain the difference in technical efficiency. The results of the study indicated that the level of fuel tax revenue affects road investment in USA and Japan but there is no such relationship in the other three nations. In addition to this, road investment in USA, Germany and Japan was significantly affected by the general fiscal condition of the government which is indexed by primary balance although no evidence of such an effect was found in UK and France. On the other hand, efficiency of road transport was assessed in terms of how road net work affects macro-economic multi factor productivity (MEP) growth and how the road transport system as a whole is performing. In this regard, the study revealed that road capital improvement has a positive effect on macro-economic MFP growth only to the extent that physical network had been expanded. The study also indicated that with the exception of Japan, efficiency of road transport has been improving. Finally, redundancy of transport networks and sparse land use were found to be the major sources of inefficiency.

Odeck (2008) evaluated the technical efficiency of 18 road toll companies in Norway by using data from 2001 to 2004. The study employed Data Envelopment Analysis (DEA) and its subsequent Malmquist productivity indices as a framework of analysis. The findings of the study indicated that there is a potential for efficiency improvement of about 14 percent. Economies of scale were also found to have a positive effect on technical efficiency.

Niraula and Kusayanagi (2005) undertake a descriptive analysis in order to identify factors that have significant effect on the performance of construction industries in Nepal and Cambodia. 26 individuals from both Cambodia and Nepal were interviewed in the year 2002. The result of the study revealed that construction industries operate under poor performance due to lack of appropriate human resources and technologies. The rise in skill level of the construction engineers and technological development for construction management and materials production were also found to have a positive effect on the performance of the construction industry.

Rouse and Putterill (1998) examined effects of amalgamation on both technical and scale efficiencies of highway maintenance activities performed by New Zealand local authorities during 1982 - 1997. The methodologies that were used for this study are Data Envelopment Analysis and Malmquist indices. The findings indicate that amalgamation increases economies of scale and which intern improved scale efficiency. The result also indicated the existence of sustainable improvements in technical efficiency due to policy changes during and after amalgamation.

In conclusion, as briefly discussed in section 3.1.2 above, different approaches have their own advantage and disadvantage. The main advantage of the non parametric DEA model is the absence of misspecification of the frontier since it does not need an assumption about the production function of a firm (Banker et al, 1984 and Sarafidis, 2002). The problem of random noise is also less in DEA since any deviation from the estimated frontier is interpreted as due to inefficiency (Sarafidis, 2002). However, DEA suffers from three major limitations (Sarafidis, 2002). The first one is its interpretation of all deviations from the frontier. It is not always true that deviations from the frontier are due to inefficiency. I could be due to statistical noise or measurement error. The other limitation is that DEA does not allow statistical tests of hypothesis for both the inefficiency and the structure of the production function. The third limitation is due to its deterministic nature which causes a significant problem in the measurement of efficiency when there are outliers. As a result, the nonparametric DEA model is not usually recommended unless there is a high degree of blind faith in the model as concluded by Sarafiidis (2002).

When it comes to parametric frontier models, four approaches have been discussed with their advantages and disadvantages. Although all of the mentioned frontier approaches have specified a production function, the stochastic frontier approach is considered as the best because of the following reasons. The first and most important reason is its ability of decomposing the error term in to statistical noise and inefficiency term (Alemayehu and Dawit, 2008, Battes and Coelli, 2005, Forsund et al, 1980 and Sarafidis, 2002). The second reason is that it is possible to estimate both the stochastic frontier and the inefficiency model simultaneously (Battes and Coelli, 2005, Friederiszick et al, 2003 and Sarafidis, 2002). Third, the firm specific inefficiency is not measured in relation to the"best" firm, as it is done in non-parametric approaches. Hence, SFA is again less sensitive to outliers in the sample (Battes and Coelli, 2005 and Daniel, 2005). The fourth reason is regarding to statistical tests. Stochastic frontier model allows statistical tests of hypothesis for both the inefficiency and the structure of the production function (Forsund et al, 1980). Although stochastic frontier approach has all these advantages over the other approaches, it is not free from limitation. Disadvantages of this approach consist of the need of distributional assumptions for the two error components as well as the assumption of independence between the error terms and the regressors and about the production technology (Miller et al, 2005). However, efficiency levels which had been estimated using different distributional assumptions are found to be similar (Ahmed et al, 2006).

Generally, the main attraction of the stochastic frontier approach is its ability to offer a richer specification, particularly for panel data and its ability to allow statistical testing of hypotheses (Daniel, 2005).Therefore; stochastic frontier model is used for this study since the data is panel. On the other hand, Khac and Thanh (2005) used both DEA and stochastic frontier approach to measure the technical efficiency of construction firms but they found similar result. Since it has the aforementioned advantages than DEA, stochastic frontier approach is used by this study.

Chapter Four
Data and Methodology

4.1 Sources of Data and Coverage

This study uses firm level secondary data on eight road construction firms operating in Ethiopia. Purposive sampling technique is used based on the availability of data. The eight firms are selected among those firms that have been involved in federal road construction activities awarded by ERA. The main source of data is the monthly progressive report of each firm that is included in the sample. Raw data from ERA is also used. The selected eight firms are categorized in to two groups: Ethiopian road construction firms and Chinese road construction firms. The Ethiopian road construction group contains three private firms namely SUR construction, Sunshine construction and DMC construction and one public firm known as Ras Haile. The three private firms together have undertaken 35 percent and 30 percent of road construction projects that are awarded only to local private firms and to local firms during 1997-2007, respectively. Ras Haile accounts 13 percent of road construction projects that are undertaken by local firms. Thus, the four firms together have undertaken 43 percent of road projects that are awarded to local contractors. The remaining four firms that are included in the Chinese road construction group are Chinese Road and Bridge Corporation (CRBC), CGC Overseas Construction, Hunan Hunda Road and Bridge Corporation (HHRBC) and SINOHYDRO construction. More than 70 percent of road construction projects that are awarded to Chinese firms have been taken by these four public Chinese firms during the RSDP period (from 1997 to 2007).

The sample period is from 2006 to 2008. However, since both the number of firms and the sample period are not large enough to get the necessary number of observations, the yearly data is further classified into quarterly. This classification is also found to be important in order to observe the seasonality of road construction activities and the corresponding technical efficiencies. As a result, 48 observations for each group have been used. On the other hand, based on the work of Khac and Thanh (2005), three input variables (capital, labour and Materials) and one output variable (Total revenue) are used for the production function.

4.2 Methodology

4.2.1 Model Specification

Based on the justification outlined in detail in the previous chapter, this study will utilize the stochastic frontier function to measure the technical efficiency of firms. Battese and Coelli (1995) formulated the stochastic frontier model for panel data as follows:

$Y_{it}= f(X_{it};\beta) + E_{it}$ ……………………………………………………………………..……..(4)

Where – Y_{it} denotes the production at time t for the i^{th} firm.

X_{it} is a (lxk) vector of inputs associated with the i^{th} firm at the t^{th} observation.

B is a (Kx1) vector of unknown parameters to be estimated, and

E_{it} is specified as $E_{it}= v_{it}-u_{it}$ where v_{it} is the statistical noise and U_{it} is technical Inefficiency

In this model, $f(X_{it};\beta)$ represents the log-linear Cobb-Douglas stochastic production frontier. The log-linear Cobb-Douglas specification is preferred to other alternatives such as the translog mainly due to the high number of variables required by a translog form. In this study where the dataset is small, this would decrease remarkably the degrees of freedom and thus, the significance of the estimation (O'Neill et al, 1999 and Hess, 2008). Another problem associated with the high number of variables of a translog function is the potential problem with near-multicollinearity between the variables (O'Neill et al, 1999 and Hess, 2008**).** In addition, the Cobb-Douglass functional form is also used because of its advantage to interpret the estimated coefficients of the input variables since they measure elasticity in this case.

Given the Cobb-Douglas production function, equation 4 can now written as follows:

$$\ln Y_{it} = \alpha_o + \sum_{i=1}^{n} \alpha_i \ln X_{it} + E_{it} \qquad \text{………………………… (5)}$$

Where $\ln Y_{it}$ is the natural logarithm of total income of firm i at the t^{th} observation

$\ln X_{it}$ is a vector of the natural logarithm of the value of inputs for the i^{th} firm in the t^{th} observation

α,β and δ are coefficients to be estimated, and E_{it} is as defined in equation (4)

In order to determine the distribution of the inefficiency term U_{it}, the likelihood ratio test is performed. Greene (2003) defined the likelihood ratio statistics, λ, as follows:

$$\lambda = -2\ln [L (H_o)/L (H_1)] = [\ln L (H_1) - \ln L (H_o)]$$

Where $L(H_o)$ and $L(H_1)$ are the values of the likelihood function under the null and alternative hypothesis, respectively. If the null hypothesis is true, then the test statistics (λ) is usually assumed to be asymptotically distributed as a chi-square (χ^2) random variable with degrees of freedom equal to the number of restrictions imposed by the null hypothesis. Thus, the restrictions imposed by the null hypothesis are rejected when (λ) exceeds the critical value.

After the likelihood ratio test, it will be possible to identify the type of distribution (half normal or truncated normal) the inefficiency term will have. Then, based on the conditional expectation of the inefficiency term (U_{it}), the prediction of the technical efficiency of the i^{th} firm at the t^{th} observation is given by:

$$TE_{it} = \exp(-U_{it}) \quad \text{...(6)}$$

Where U_{it} is a non-negative random variables and it is assumed to be independently distributed with mean μ_u and variance δ_u^2.

After the efficiency score is estimated, its determinant factors can be identified by using the following technical inefficiency model:

$$U_{it} = \delta_o + \delta_1 KL_{it} + \delta_2 NR_{it} + \delta_3 IPW + \delta_4 NYB_{it} + \delta_5 NYBSQR_{it} + W_{it} \text{.........(7)}$$

Where KL_{it} is the capital-labour ratio for firm i at t^{th} observation

NR_{it} shows the net revenue of firm i at time t

IPW represents incentive per workers for firm i at time t

NYB_{it} and $NYBSQR_{it}$ represent the number of years in business and number of years in business Square of a firm, respectively

Given the above technical inefficiency model and the stochastic production function, all the parameters can be estimated by the maximum likelihood method using Stata 9 computer program (Friederiszick et al, 2003). The likelihood function of the model is expressed as follows:

$$\sigma^2 = \sigma_v^2 + \sigma_u^2$$

and

$$\gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$$

Where γ is a parameter which measures the discrepancy between the frontier attributable to technical inefficiency. In other words, γ represents the relative influences of forces that are under the firms control and events external to them, on technical inefficiency. σ_v^2 is the variance of the error term (V_{it}) while δ_u^2 is the variance of the inefficiency term(U_{it}).

γ has a value between zero and one. If γ is equal to zero, it implies that there is no technical inefficiency in the model while a value equal to one shows the absence of V_{it} (statistical noise or external shock) which shows low level of output is due to technical inefficiency.

4.2.2 Definition of Variables

Those variables included in equation 5, 6 and 7 are defined as follows:

Total Revenue (TR) and **Net Revenue (NR):** represent the total amount of income earned and the net revenue of the firm, respectively. Total revenue is included in the production function while net revenue is included in the inefficiency model. Total revenue indicates the total amount of output the firm produces while net revenue is considered as a measure of firm's size (Khac and Thanh, 2005). Net revenue shows the firm's performance and reinvestment capacity, particularly technological investment (Khac and Thanh, 2005).If the estimated coefficient of NR is statistically significant and has negative sign, it shows the existence of an efficient road construction firm with the highest size.

Capital (K) represents those assets at the time of establishment with a productive life of one year or more and it is included in the production function as an input. Capital shows the net book value at the beginning of the reference year plus new capital expenditure minus the value of sold and disposed equipments and machineries and depreciation during the reference period.

Labor (L) is represented by the amount of wages and salaries paid to the workers and it is considered as an input in the production function. The heterogeneity of workers is not only in terms of citizenship of the workers but also in terms of education and work experience. Therefore, wages and salaries are better approximation than number of workers to represent the extent of labor input use.

Capital-Labor ratio (KL=K/L): it represents the technical intensification of the workers. In other words, it shows whether the road construction firm is labor intensive or capital intensive. It is included in the inefficiency model as explanatory variable and if its estimated coefficient is statistically significant with negative sign, it shows the existence of technical efficiency with higher capital intensification.

Materials (MATR): it is the cost of all materials used in operation and it is included in the production function as an input. It includes the cost of raw materials, fuels, asphalt, sand, cement, and all other supplies consumed and the cost of services supplied by other firms.

Incentive per Worker (IPW): represents the amount of incentive paid to workers in the form of bonuses, allowances and overtime payment and it is included in the inefficiency model. If its estimated coefficient is found to be statistically significant with negative sign, it shows its positive impact on technical efficiency..

Number of Years in Business (NYB) and Number of Years in Business Square (NYBSQR): age represents the length of operational year of a firm. It is included in the technical efficiency model to capture the effect of experience on the technical efficiency of a firm. Age squared (NYBSQR) is included in the model because of the existence of diminishing returns in the learning –by- doing process so that the gains from experience are eventually exhausted (Lundvall and Battese, 1999, cited in Daniel, 2005).

4.3 Descriptive Analysis of the Data

Table 4.1 shows the average amount of variables that are included in the study for the selected four Ethiopian firms. As shown in Table 4.1, the highest amount of average total revenue (birr 467,109,794) is earned by SUR construction while the lowest one (55,749,864) is by DMC. This indicates the existing high variation in total revenue among selected Ethiopian firms. On the other hand, Sunshine construction has the highest mean capital-labour ratio which indicates that it is more capital intensive than the other three. Relative to others, DMC construction is the newly emerging firm with an average age of 10.625

Table 4.1 Summary Statistics of Variables Included in the Study for Selected Ethiopian Firms during 2006-2008

Variables	Mean values (Birr)			
	SUR	Sunshine	DMC	Own force
Total revenue	467109794	241488242	55749864	319405273
Material	98275600	61634203	12688300	79456389
Capital	71682974	44680452	8679540	56599930
Labour	82687592	43860921	11987065	70154374
Capital-labor ratio	1.142712	1.224107	1.056318	1.003115
Net revenue	77244278	41653915	7638241	52856342
Incentive per worker	12563.4	10984.01	5863	8162.51
Number of years in Business	14.625	22.625	10.625	55.625

Source: Author's Computation

The summary of variables included in the study for selected Chinese firms are also presented in Table 4.2. CRBC is the one with the highest average total revenue (397,542,764) while it has the lowest mean capital-labour ratio. The lowest average total revenue (102,668,952) is earned by SINOHYDRO. Relative to the selected Ethiopian firms, the sleeted Chinese firms have lower variation in average total revenue. HHRBC is more capital intensive since it has relatively the highest mean capital-labour ratio. Although it has earned the smallest average total revenue, SINOHYDRO has paid, on average, the largest incentive per worker.

Table 4.2 Summary Statistics of Variables Included in the Study for Selected Ethiopian Firms during 2006-2008

Variables	Mean values (birr)			
	CRBC	CGCOC	HHRBC	SINOHYDRO
Total revenue	397542764	368581976	168574900	102668952
Material	72605161	68854256	32795643	24895360
Capital	78463219	70942166	48673500	37623735
Labour	69744581	66875380	30686378	23895341
Capital-labor ratio	1.102362	1.113201	1.121347	1.106922
Net revenue	67801928	60796241	36896342	23786453
Incentive per worker	14796.07	16982.02	13679.1	17174.01
Number of years in Business	27.625	4.625	13.625	56.625

Source: Author's Computation

The general summary of panel variables for the two groups (Ethiopian and Chinese firms) is shown in Table 4.3. The average amount of total revenue is higher for Ethiopian firms than Chinese firms but this is due to the larger number of road projects they are awarded. The standard deviation of total revenue is also higher for Ethiopian firms than that of Chinese firms and this implies that there is high variation in total revenue among Ethiopian firms than Chinese firms (see Table 4.1 and 4.2). The average expenditure on materials is also higher for Ethiopian firms although the reverse is true in the case of average expenditure in capital. That is, the Chinese firms employed more average capital than Ethiopian firms. However, the standard deviation of both material and equipment expenditures is higher for Ethiopian firms than that of Chinese firms. This implies that there is high variation on the average amount of material and capital used among Ethiopian firms than Chinese firms. The Chinese firms employed birr 58,925,655 of capital while it is birr 45,410,724 for Ethiopian firms. When it comes to human capital, on average Chinese firms employed less than Ethiopian firms. The Ethiopian firms have also larger standard deviation of human capital employment.

The average capital –labour ratio and its standard deviation for Ethiopian firms are 1.107 and 0.126, respectively. However, the Chinese firms are characterized by higher average capital-labour ratio and lower standard deviation of capital-labour ratio. This shows that Chinese firms are more capital intensive than Ethiopian firms and there is less variability in capital-labour ratio among Chinese firms than Ethiopian firms. Similarly, the Chinese firms have earned higher average net revenue with lower standard deviation. This indicates the existence of low variation in the amount of average net revenue among Chinese firms.

The average amount of incentive per labour for Chinese firms is higher than that of Ethiopian firms while the standard deviation of incentive is higher among Ethiopian firms than Chinese firms. On the other hand, the average number of years in business for Ethiopian firms is found to be higher than that of Chinese firms.

Table 4.3 Summary Statistics of Variables Included in the Study for the Panel of Ethiopian and Chinese Firms

Ethiopian firms

Variable	Mean	Std. Dev.	Minimum	Maximum
Total revenue	270938293	13.294	220143493	337233847
Materials	63013623	7.835	55778551	87352298
Capital	45410724	10.276	40043732	144972751
Labour	52172488	11.533	42466511	94221221
Capital-labour ratio	1.106563	0.126	1.05	1.27
Net revenue	44848194	15.076	31300142	49981104
Incentive per worker	15108432	5.007	10645758	40567439
Number of years in Business	25.875	17.91989	9.25	57

Chinese firms

Variable	Mean	Std. Dev.	Minimum	Maximum
Total revenue	259342148	10.179	204037590	336270029
Materials	49787605	6.088	29132299	74002023
Capital	589256557	473	50230719	98129047
Labour	478004207	301	24246651	66885568
Capital-labour ratio	1.110958	0.031	1.14	1.19
Net revenue	47320241	11.847	19923866	61263727
Incentive per worker	18908745	4.917	10005794	38567439
Number of years in Business	25.625	19.912	3.25	58

Source: Author's Computation

Chapter Five
Empirical Results and Discussions

5.1 Tests of Different Hypotheses

It is worthwhile to discuss some of the tests that are carried out before the final estimation is undertaken. The first test is related to whether the technical efficiency levels for the firms in the two groups(i.e. Ethiopian and Chinese road construction firms) are better estimated using a half normal or a truncated normal distribution of U_{it} . As shown in Table 5.1, the log-likelihood ratio test indicates that the null hypothesis that U_{it} has a half normal distribution is accepted for both groups. That is, the technical efficiency levels for both Ethiopian and Chinese road construction firms are better estimated with half normal distribution of the inefficiency term U_{it}.

Table 5.1 Hypothesis Testing on the Distribution of U_{it}

Groups	Log-likelihood	Value of λ	Critical Value	Decision
Ho: $\mu = 0$				
Ethiopian Firms	-57.51497	0.25	6.63***	Accept H_o
Chinese firms	-58.34824	0.17	6.63***	Accept H_o

Source: Author's computation

*** indicates 1% level of significance.

The second test checks whether there is technical inefficiency in each group or not given the Cobb-Douglas production function. Here, the null hypothesis is that there is no technical inefficiency in both groups. The log-likelihood ratio tests shown in Table 5.2 for each group indicate that the null hypothesis is rejected for both Ethiopian and Chinese firms. This result shows the existence of technical inefficiency among Ethiopian and Chinese road construction firms which are included in this study.

Table 5.2 Hypothesis Testing on whether Technical Inefficiency is absent from the Model or not

Groups	Log-likelihood	Value of λ	Critical Value	Decision
Ho: $\gamma = \delta_0 = \ldots \delta_6 = 0$				
Ethiopian Firms	15.52894	146.34	6.63***	Reject H_o
Chinese firms	10.47683	137.82	6.63***	Reject H_o

Source: Author's computation

*** indicates 1% level of significance.

The last hypothesis testing is about the joint significance of the explanatory variables which are included in the inefficiency model. As indicated in Table 5.3, the null hypothesis that the inefficiency effects are not a function of the stated explanatory variables is rejected at 1% and 5% level of significance for Ethiopian and Chinese firms, respectively. This result confirms that the joint effect of the explanatory variables on technical inefficiency is found to be statistically significant.

Table 5.3 Hypothesis Testing on the Joint Significance of the Explanatory Variables in the Inefficiency Model

Groups	Log-likelihood	Value of λ	Critical Value	Decision
Ho: $\delta_o =\ldots\delta_6 = 0$				
Ethiopian Firms	-47.17528	20.24	15.09***	Reject H_o
Chinese firms	-52.61279	11.60	9.49**	Reject H_o

Source: Author's computation

***and ** indicates 1% and 5% level of significance, respectively.

5.2 Production Function Analysis

In efficiency studies, the basic interest is on the specification of the error term for the prediction of technical efficiency (Daniel, 2005). Here, the estimation of elasticity as characteristics of production process is only secondary interest. Although the maximum likelihood estimates of the coefficients of the production function are not the immediate interest of this study, some explanations are given about the coefficients of the variables in the production function to have general information about them. The result of the maximum likelihood estimation of the stochastic production function is given in Table 5.4.

The parameter estimates of all the production inputs of both Ethiopian and Chinese firms are found to be statistically significance at 1 percent significance level and all of them have the expected positive signs. The capital variable has the highest input elasticity of production for both Ethiopian and Chinese firms. This implies that the production process in the road construction sector is capital intensive and more revenue can be obtained by using more capital. The estimated coefficient of capital is 0.45 and 0.37 for Ethiopian and Chinese firms, respectively. The relatively higher marginal effect of capital suggests that the Ethiopian firms could employ more capital to earn more revenue.

On the other hand, material and labour have the lowest input elasticity of production for Ethiopian and Chinese firms, respectively. The Ethiopian firms can also generate more revenue by employing proportionally more labour than the Chinese firms since the marginal effect of labour is relatively higher for Ethiopian firms. However, the Chinese firms can earn more revenue by using relatively more materials than the Ethiopian firms since the estimated coefficient of material for Chinese firms is relatively higher than that of Ethiopian firms.

Table 5.4 Maximum Likelihood Estimates for the Parameter of the Stochastic Frontier Production Function for the Two Groups

Variable	Ethiopian firms	Chinese firms
Frontier Function Dependent Variable: Ln Total Revenue		
Constant	7.57***	9.92***
	(3.01)	(2.53)
Lnmaterial	0.246***	0.28***
	(0.101)	(0.102)
Lncapital	0.44 ***	0.37***
	(0.095)	(0.093)
Lnlabour	0.26***	0.25***
	(0.09)	(0.085)
Inefficiency Model		
Constant	18.88	19.71*
	(14.28)	(13.29)
Capital-labour ratio	-18.58 *	-15.94*
	(12.61)	(11.46)
Net revenue	-0.000000499**	-0.00000108***
	(0.000000249)	(0.000000385)
Incentive per worker	-0.00000659***	-0.00000992**
	(0.00000261)	(0.00000562)
Number of years in Business	0.197	-.0.089
	(0.249)	(.084)
Number of years in Business square	-0.0024	0.0017*
	(0.004)	(0.0013)
Variance Parameters		
$\delta^2 = \delta^2_u + \delta^2_v$	12.405 **	7.2104**
	(6.708)	(4.1639)
$\gamma = \delta^2_u / (\delta^2_u + \delta^2_v)$	0.96*	0.92*
	(0.596)	(0.678)
Log-likelihood	-43.85	-44.75
Mean TE	0.48	0.52
Observations	48	48

Source: Author's computation

***, ** and * indicates 1%, 5% and 10 % level of significance

5.3 Prediction of Firm Level Technical Efficiencies

For the panel of both Ethiopian and Chinese firms, the result of the maximum likelihood estimates, as shown in Table 5.4, indicate that there are significant inefficiency effects associated with road construction in Ethiopia which is inline with the likelihood ratio test presented in Table 5.2. This is evident from the estimates of the discrepancy parameter γ which are 0.96 and 0.92 for Ethiopian and Chinese firms, respectively. This means that about 96 percent and 92 percent of the discrepancies between the observed output and the frontier output levels are due to technical inefficiency. This implies that road construction firms in Ethiopia are characterized by inefficient way of production and much of the discrepancy of the actual output from the frontier output is due to those factors within the control of the firm rather than statistical noise or external shocks. In addition to this, the significance of γ in the inefficiency model justifies the use of stochastic frontier model and the associated method of maximum likelihood estimation.

After the existence of significance technical inefficiency is proved, prediction of the level of technical efficiency for the firms in each group is found to be very important. Ranking firms in terms of their technical efficiencies is important for policy makers to formulate appropriate policies (Dorfman and Koop, 2005, cited in Hussien et al, 2006). In view of this, the frequency distribution of the predicted technical efficiencies for Ethiopian and Chinese road construction firms is discussed with the help of Table 5.5 and 5.6.

Table 5.5 Frequency Distribution of Technical Efficiencies for Ethiopian Ffirms

	Percent of firms (%)											
	2006				2007				2008			
Efficiency Scores	1st qr.	2nd qr.	3rd qr.	4th qr.	1st qr.	2nd qr.	3rd qr.	4th qr.	1st qr.	2nd qr.	3rd qr.	4th qr.
≤ 20	0.0	0.0	25	0.0	25	0.0	50	0.0	0.0	0.0	25	0.0
21-30	0.0	25	0.0	25	0.0	25	0.0	0.0	0.0	0.0	25	0.0
31-40	25	25	0.0	25	0.0	50	25	0.0	0.0	25	25	0.0
41-50	0.0	0.0	50	0.0	0.0	0.0	0.0	50	25	0.0	25	25
51-60	0.0	0.0	25	0.0	50	25	0.0	25	50	0.0	0.0	25
61-70	25	50	0.0	25	25	0.0	25	25	25	50	0.0	50
≥ 71	50	0.0	0.0	25	0.0	0.0	0.0	0.0	0.0	25	0.0	0.0
Mean	63.5	45.5	40	50.8	49.3	40.5	35.3	51.5	56.3	61.5	29.8	55.8
Min	36	22	14	25	17	28	15	41	48	40	16	46
Max	80	64	54	77	67	59	67	67	65	74	47	63
SD	16.6	18.02	15.4	23	19.14	11.4	20.6	10.2	6.2	13.14	12.2	6.8
No.of firms	4	4	4	4	4	4	4	4	4	4	4	4

Source: Author's Computation

As shown in Table 5.5 above, the predicted technical efficiency scores for Ethiopian road construction firms vary from 14 percent in the third quarter of 2006 to 80 in the first quarter of the same year (see also Annex I).

Table 5.5 also indicates that the mean technical efficiency scores for Ethiopian firms vary from 29.8 percent to 63.5 percent. The Ethiopian firms have also the lowest mean technical efficiency score in the third quarter of all the sample years which may be due to the rainy season since it is not convenient for road construction. The mean technical efficiency of 48 percent for the panel of Ethiopian firms also indicates that there exists a 52 percent difference between the observed level of output and the frontier output level that could have been obtained using the existing level of inputs and technology.

Table 5.6 Frequency Distribution of Technical Efficiencies for Chinese Firms

	Percent of firms (%)											
	2006				2007				2008			
Efficiency Scores	1st qr.	2nd qr.	3rd qr.	4th qr.	1st qr.	2nd qr.	3rd qr.	4th qr.	1st qr.	2nd qr.	3rd qr.	4th qr.
≤ 20	0.0	0.0	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21-30	0.0	25	0.0	25	25	0.0	50	0.0	0.0	0.0	50	0.0
31-40	0.0	0.0	0.0	25	0.0	25	0.0	0.0	0.0	0.0	25	0.0
41-50	25	25	50	0.0	0.0	50	25	0.0	0.0	25	25	0.0
51-60	0.0	0.0	0.0	0.0	50	25	0.0	75	75	25	0.0	50
61-70	25	50	25	0.0	25	0.0	25	25	25	50	0.0	25
≥ 71	50	0.0	0.0	50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25
Mean	65	50	44.8	54.5	53.5	45.8	39.3	56	58.3	61.5	35.5	60.8
Min	44	28	19	30	30	36	22	51	55	48	22	52
Max	78	63	65	79	69	59	66	67	63	70	50	71
SD	12.7	14.2	16.6	22.14	14.4	8.3	17.6	6.6	3.4	9.2	10.5	7.1
No.of firms	4	4	4	4	4	4	4	4	4	4	4	4

Source: Author's Computation

On the other hand, Table 5.6 shows the predicted technical efficiency values for Chinese firms. The lowest and the highest technical efficiency scores are found to be 19 percent in the third quarter of 2006 and 79 percent in the same year, respectively. This shows the existence of high variation in technical efficiency among Chinese road construction firms. The predicted technical efficiency scores for all Chinese firms are presented in Annex I.

The mean technical efficiency scores of Chinese firms vary from 35.5 percent in the third quarter of 2008 to 65 percent in the first quarter of 2006. Alike the Ethiopian firms, the

Chinese firms are also operating with the lowest technical efficiency during the third quarter of the sample years because of the rainy season. A panel mean technical efficiency of 52 percent for the Chinese firms indicates that there exists a 48 percent discrepancy between the observed and the frontier output level. Here, the mean technical efficiency score for Chinese firms is larger than that of Ethiopian firms which shows the presence of significant difference in average inefficiency among the two groups. As mentioned by Kaplinsky and Farooki, (2008), the better performance of Chinese companies can be attributed to several factors: cost competitiveness in overall bidding price; access to cheap capital through Chinese state-owned banks; access to skilled low cost labour; access to cheap building materials through supply chains from China; and political support from the Chinese government channeled through Chinese embassies and Economic and Commercial Counsels.

5.4 Factors Affecting Technical Inefficiency

Based on the maximum likelihood estimation results, the technical efficiency levels of selected Ethiopian and Chinese road construction firms are discussed in section 5.3. However, technical efficiency scores only do not have much importance for policy making and management purposes unless they are supported by an investigation that could identify the sources of technical inefficiency. In this regard, the basic objective of this study is not only to measure the technical efficiency scores of selected Ethiopian and Chinese road construction firms but also to identify the potential sources of technical inefficiency. So that, policy makers will get an input for the formulation of policies that intend to reduce or avoid technical inefficiencies in road construction sector in Ethiopia.

Variations in technical inefficiencies arise from different practices and techniques. However, it is found to be difficult to incorporate all factors which are expected to affect the technical inefficiencies of the road construction sector in Ethiopia. This study includes a total of six variables (capital-labour ratio, net revenue, amount of incentive paid to workers, type of ownership, age and age squared) that are assumed to influence the technical inefficiency levels of those firms in both groups. Here it is important to note that the sign of estimated coefficients in the technical inefficiency model have inverse impact on technical efficiency.

For example, a coefficient that has a negative effect on the technical inefficiency will have a positive effect on technical efficiency.

As shown in Table 5.4, capital-labour ratio, net revenue and incentive per worker have positive and significant relationship with technical efficiency for both Ethiopian and Chinese road construction firms. The positive impact of capital-labour ratio and net revenue on technical efficiency is also supported by Khac and Thanh (2005). According to them, capital-labour ratio and net revenue have a positive relation with efficiency of construction firms in Vietnam and which shows the possibility to improve efficiency performance by equipping workers with more capital. The negative and significant coefficient of net revenue also implies that an increase in firm size will improve technical efficiency due to economies of scale. On the other hand, workers are expected to be motivated by the amount of incentive paid and thereby increase the technical efficiency of firms. However, the positive and statistically significant coefficients of incentive for both Ethiopian and Chinese firms are not economically significant.

The estimation result in Table 5.4 also indicates that age has a positive coefficient for Ethiopian firms and negative coefficient for Chinese firms; however, it is statistically insignificant in both cases. This implies that age of firms does not affect their efficiency. The variable age square for Ethiopian firms is also statistically insignificant and has negative sign. However, age square is found to be statistically significant and has positive sign for Chinese firms. This indicates that although age does not matter technical efficiency, indefinite increase of firm age decreases technical efficiency in Chinese firms.

Chapter Six
Summary and Conclusion /Recommendations

6.1 Summary and Conclusion

The study has examined the technical efficiency levels of selected Ethiopian and Chinese road construction firms. It also tried to identify the potential sources of technical inefficiency that exists among the Ethiopian and Chinese road construction firms.

The study considered eight road construction firms operating in Ethiopia. These eight firms are categorized in to two groups where each group has four firms. SUR construction, Sunshine construction, DMC construction and Ras Haile from Ethiopian road authority are those firms that are categorized under Ethiopian road construction firms. On the other hand, CRBC, CGCOC, HHRBC and SINOHYDRO are the other four firms that are included in the Chinese group. The study also covers a time period from 2006 to 2008 and each year is classified in to four quarters for two reasons. The first one is to increase the number of observations and the second reason is to observe the level of technical efficiency in different seasons of the year especially during the summer season when it is rainy. A traditional Cobb-Douglas production function involving the traditional production inputs of equipment (capital), man power (labour) and material cost was specified and a panel data model developed by Battese and Coelli(1995) was employed for the purpose of predicting the level of technical efficiency and identifying those factors which are attributable to the technical inefficiency that existed among the firms simultaneously.

The likelihood ratio test was used to undertake different tests before the final estimation. The first test was about the distribution of the U_{it} and it was found that U_{it} is better estimated using half normal distribution than truncated normal distribution. The likelihood ratio test was also performed to identify whether there is technical inefficiency in the model for the two groups or not and the result indicates that the null hypothesis that there is no technical inefficiency in the model is strongly rejected for both Ethiopian and Chinese firms. Finally, the null hypothesis that the explanatory variables in the inefficiency model are not jointly significant is also rejected using the likelihood ratio test.

Technical efficiency level of firms in each group was predicted and the result shows that there exists technical inefficiency in both groups with a relatively higher variation among firms. For both groups the discrepancy parameter γ is found to be above 90 percent and this indicates that most of the discrepancy between the observed and frontier level of outputs is due to technical inefficiency rather than exogenous factors. The mean technical efficiency levels were also predicted in line with the estimation of technical efficiencies and it varies from 29.8 to 63.5 percent for Ethiopian firms and from 19 to 79 percent for Chinese firms. In addition to this, the mean technical efficiencies of all firms in both groups are found to be the least in the third quarter of each year and this is due to the unfavorable condition for road construction during the rainy season. On the other hand, the mean technical efficiency levels for the panel are found to be 48 percent for Ethiopian firms and 52 percent for Chinese firms. This implies that Chinese firms are relatively more efficient than Ethiopian firms although the difference is not as expected.

Another important work of this study is the identification of those factors which contribute to the existing technical inefficiency level. Five variables were included in the inefficiency model and among them capital-labour ratio, net revenue and incentive paid per workers have a positive and statistically significant relationship with technical efficiency for both Ethiopian and Chinese firms. However, net revenue and incentive per worker are not economically significant.

The effects of age and age square were also examined and age is found to be statistically insignificant. When it comes to age square, it has a negative effect on the technical efficiency of Chinese firms and it is also found to be statistically significant. However, age square is still statistically insignificant for Ethiopian firms.

6.2 Recommendations

Based on the findings of this study, some policy recommendations mentioned below are forwarded to improve the efficiency of road construction sector in Ethiopia and there by to increase the quality and length of road network in the country since it is a crucial factor for economic growth and development.

For Ethiopian firms which are relatively less efficient than Chinese firms, the Ethiopian Government should play a vital role trough two basic ways in order to make them more competent with Chinese and other foreign road construction firms. The first one is through provision of credit which will help them to increase their capacity of employing more capital so that they would be able to increase their technical efficiency since capital-labour ratio has very strong positive effect on it. In addition to improving the capital-labour ratio, additional credit will help them to increase their size so that they will improve their level of technical efficiency by exploiting the existing economies of scale. The second role is trough implementing appropriate polices and strategies regarding to capacity building in order to increase the skill of engineers. And similar action should also be taken by Chinese government in order to further increase technical efficiency of Chinese road construction firms that are operating in Ethiopia.

When it comes to the firms themselves, they have to develop a strategy that incorporates strong monitoring and evaluation system in order to increase their net revenue which in turn will improve their efficiency level. On the other hand, the amount of incentive paid to workers is found to have a positive effect on technical efficiency although it is economically insignificant. Therefore, road construction firms should design effective incentive payment strategies to motivate their workers and improve the level of technical efficiency.

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Annex I

Technical Efficiency Scores of Ethiopian Firms

		Efficiency Scores (%)			
Year	Quarter	SUR	Sunshine	DMC	Ras Haile
2006	1	80	67	71	36
	2	62	34	64	22
	3	54	47	45	14
	4	77	31	70	25
2007	1	17	58	55	67
	2	38	59	28	37
	3	15	67	40	19
	4	54	67	44	41
2008	1	54	58	65	48
	2	62	70	74	40
	3	16	35	47	21
	4	46	61	63	53

Technical Efficiency Scores of Chinese Firms

		Efficiency Scores (%)			
Year	Quarter	CRBC	CGCOC	HHRBC	SINOHYDRO
2006	1	78	67	71	44
	2	62	47	63	28
	3	65	50	45	19
	4	74	30	79	35
2007	1	30	59	56	69
	2	44	59	36	44
	3	22	66	44	25
	4	55	67	51	51
2008	1	55	60	63	55
	2	59	70	69	48
	3	22	40	50	30
	4	71	57	63	52

Declaration

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

The examiners' comments have been dully incorporated.

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