MEASUREMENT AND SOURCES OF TECHNICAL INEFFICIENCY IN ETHIOPIAN MANUFACTURING INDUSTRIES

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Abstract

The inability of firms to operate at full capacities, the low levels of manufactured exports and the decline of labour and capital productivities for the past ten years are some reflections of technical inefficiencies among the Ethiopian manufacturing industries. 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 361 firms which are categorized under nine industrial groups during the study period, i.e. 1998-2002. A translog stochastic frontier production function is found to better represent the production technology of food processing, beverage, textile, wood & furniture, paper & printing, rubber & plastics and non-metallic mineral industries and a Cobb-Douglas stochastic frontier function is found to be a better representation for leather and chemical industries. A half-normal distribution for the inefficiency term is found to be a better assumption for predicting the technical efficiency levels for all sub-sectors, except for food processing industries where the truncated normal distribution for the inefficiency term is a better assumption for predicting technical efficiencies among the firms in food processing industries. The null hypothesis that all firms in each sub-sector are fully technically efficient is rejected for all sub-sectors which proves the inappropriateness of (average) production functions. Most of the discrepancy between observed and the frontier level of output was due to technical inefficiency rather than external factors that are outside firms' control for all sub-sectors. This result indicated the existence of technical inefficiency among the Ethiopian manufacturing industries and there is a chance, at least in the short run, to increase their production only by improving their technical efficiency. The null hypothesis that the inefficiency effects are not functions of the explanatory variables is also rejected for all sub-sectors. The predicted technical efficiencies for each sub-sector are estimated using the maximum likelihood estimation technique indicating that there exists technical inefficiency among the firms in each sub-sector and the mean technical efficiencies are ranged between 62 and 80 percent. Generally, firm size, ages of a firm, type of ownership, firm's location around Addis Ababa and the amount of incentive paid to workers are found to be important variables in explaining the variation in technical efficiencies among the firms. Moreover, firm size and age of a firm tended to have a non-linear relationship with the level of technical inefficiency for most sub-sectors. The result of the study also indicated that the technical efficiency of firms was decreasing during the study period for most sub-sectors, except for textile and chemical industries. Hence, based on the results of the study a need arises to support Ethiopian manufacturing industries through provision of credit, better marketing strategies, training of workers, accelerating the slow pace of privatization and designing effective incentive payment strategies so that the existing levels of technical efficiencies could be enhanced and the level of production of the industries could be improved.

Keywords: Ethiopian manufacturing industries, Technical efficiency, Stochastic frontier production functions.

Table of Contents

CHAPTER THREE LITERATURE REVIEW

CHAPTER FOUR DATA AND METHODOLOGY

CHAPTER FIVE EMPRICAL RESULTS AND DISCUSSIONS

CHAPTER SIX CONCLUSIONS AND POLICY RECOMMENDATIONS

LIST OF FIGURES

LIST OF TABLES

APPENDIX

CHAPTER ONE
INTRODUCTION

1.1 Background

The low level of economic development in Ethiopia has been reflected by a poor performance of industrial activities and the dominance of agriculture over other sectors. Moreover, the fact that income elasticity of demand is generally higher in manufacturing goods than for primary goods imply the need for increasing the manufacturing productive efficiency. This does not mean neglecting the agricultural sector, rather improvement in the performance of the productivity of the primary sector should be in line with a relatively high level of industrialization.

The contribution of industry, particularly manufacturing industry[1], to the overall national income is one of lowest in the world. For instance, in 2001 the contribution of manufacturing to the national income was about seven times less than the share of agriculture, which was 52%. It was also less than half of the average for sub-Saharan Africa. Moreover, through out the decade its share remained, if anything, stagnant or declining. The manufacturing sector is the least developed even by African standard.

The dwarf manufacturing sector currently generate a value added (at factor cost) worth less than 300 billion US dollars annually-the maximum recorded annually being 280 million in 2001. This implies a per capita production of less than five dollars per year, and hence the inevitable dependence on imports for even basic manufactured goods. Since the second half of the 90's, growth of the manufacturing sector has been limited on average to 1.8 percent annually. Moreover, being dependent on agriculture and imports for its inputs, growth over the years has been marked by a cycle of variation (EEA, 2003/04).

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[1] In this study manufacturing industry refers to those large and medium scale manufacturing industries which use power driven machinery and employ 10 persons and above, according to Central Statistical Authority (CSA) definition.

Regarding the structural linkages of manufacturing with the rest of the domestic economy, internally loose as well as unbalanced forward & backward linkages between economic sectors characterizes it. In terms of raw material inputs, manufacturing is more strongly linked to the external economy rather than to its own and the rest of the domestic economy. According to EEA (2003/04) the degree to which manufacturing satisfies its raw material demand from internal sources is about 55 percent, depending on the external sector for nearly the remaining half. The problem is more serious when we consider the linkage with agriculture in which domestic manufacturing supplies only 1.3% of the manufactured goods demand in the agricultural sector.

Assessing the manufacturing sector in terms of employment creation, the sector employed about 94,310 Ethiopians in 2001, which was only 2.7 percent of the total employment in the overall manufacturing (medium and large scale, small scale, cottage and the informal) sector of the country, CSA (2001).

Overall, the Ethiopian manufacturing industry is characterized by its poor performance in terms of its employment creation, in terms of its contribution to the overall national income, in terms of the type of goods produced, and so on. It is widely believed that one of the major contributing reasons for this poor performance is the low level of productive efficiency existing in the sector.

Conceptually, factors affecting the efficiency of an economic unit of production, such as a firm, can be classified in two categories: those within the firm's sphere of direct influence and those outside a firm's control. Factors within the firm's sphere of direct control are those referred to as technology. These factors can further sub-divided into two groups. One group has to do with the efficiency of each input, which can change quite independently of the input's quantity in production and also independently of the amount and efficiency of any other input combined in production. This group includes factors such as the influence of education and training on labour productivity, new technology embodied in machinery, and so on. The other group of factors affect the efficiency of different inputs simultaneously and the efficiency of interaction among different inputs in a production process. It includes management of a firm, layout of physical plants, economies of scale, efficiency in the management of product portfolio, and other factors that take advantage of what is called economies of scope. On the other hand, factors which are outside the firm's control include high levels of protection, inappropriate industrial policies and so on, EEA (2003/04).

In view of this, the study will examine the sources of productive inefficiencies in the Ethiopian manufacturing industries concentrating on those related to technical inefficiencies by giving a special attention to those factors that are under the control of the firm.

1.2 Statement of the Problem

It is well known that Ethiopia is one of the poorest countries in the world. In order to increase the standard of living of the people, the pace of economic development must be accelerated. Although the manufacturing industries will play a vital role by creating new jobs and tremendously increasing exports and displacing imports in this development process, the contribution of the sector has been stagnant in the last two decades due to the low level of efficiency of the manufacturing industries.

One of the factors that reveal this low level of efficiency is the change in the total number of firms after the reform in 1991. According to EEA (2003/04), despite the fact that the total number of firms has increased by a certain amount in this period, labour employment has not shown almost any change. The likely reason suggested for the poor growth in employment is that firms are not operating at their full capacities which is highly related with the inefficiency among the manufacturing industries. Currently, the Ethiopian manufacturing industries are producing at half of their capacities which also leads to poor resource utilization and lower level of production.

The low level of manufactured exports and its little contribution to the country's foreign exchange earnings is also a reflection of the inefficiency within the sector. According to EEA (2003/04) in seven years period, from 1996-2002, the share of the manufactured export to the total exports of the country figures only about 10 percent on average. The overwhelming majority of manufacturing firms are producing relatively low quality goods for domestic consumption which is due to, at least partly, the lack competitiveness of the sector in the international markets and hence the low level of efficiency within the firms.

According to the same report, the productivities of labour and capital have been declining from time to time. For instance, between 1996 and 2002, labour productivity has declined from 4580 dollars per worker per year to 3460 dollars per worker per year. Over the same year period, it has declined on average by 3.6 percent annually. The same is true for capital productivity, that is, within the same period it has declined from 1080 dollars per unit of capital to 540 dollars per unit of capital. It is obvious that at least in the case of industries where productivities are not only low but also declining, competition even in the domestic market, would be relatively very difficult. This fall in productivity also implies increasing unit cost of production and thus induced further deterioration in efficiency.

Therefore, as part of the total (economic) efficiency, measuring the extent of technical efficiency and identifying the sources for the technical inefficiency in the Ethiopian manufacturing industries is found to be indispensable.

1.3 Objectives of the study

The general objective of the study is to measure the level of technical [In]efficiency in each of the industrial groups and to show if there are possibilities to increase output in the sector without changing the existing level of inputs and technology environment. In addition to the above general objective, the specific objectives of study are the following:

- To assess the determinants of technical [In]efficiency in the Ethiopian Manufacturing Industries.
- To assess whether each industrial group improved its technical efficiency overtime and,
- To draw policy recommendations based on the results of the study.

1.4 Hypotheses

The study tried to examine the following hypotheses on the production function and firm specific characteristics based on results of previous empirical studies conducted in the Ethiopian manufacturing industries and other countries.

- The Ethiopian manufacturing industries are characterized by technically inefficient way of production so that the conventional (average) production function is not an appropriate production function to represent the production technology of each industrial group.

- The inefficiency within each of the industrial group is attributable to their firm specific characteristics.

1.5 Significance of the Study

In any country, specially in developing countries like Ethiopia where it was found very difficult to register a significant economic growth by relying on agriculture, improving the efficiency of the manufacturing sector with out demanding additional resources will be very crucial in reducing the chronic poverty and in achieving a higher economic growth, at least in the short run. Thus, after predicting the level technical efficiencies of the manufacturing industries and identifying those factors that affect the technical efficiency of each sub-sector, the study could enable policy makers to design effective strategies and appropriate industrial policies that will improve the performance of manufacturing industries in Ethiopia.

1.6 Limitations of the Study

Lack of firm level data for some variables such as educational level of the workers, managerial capacities of the industries and so on has been a hindrance to capture the effect of these important variables on technical efficiency of Ethiopian manufacturing industries.

1.7 Organization of the Study

The introductory part of the study has been discussed in the previous sections. The rest of the paper is organized as follows: Chapter two reviews the profile of the medium and large scale manufacturing industries in Ethiopia. In chapter three, we present the review of literature part and chapter four discusses the data and methodology used for the study. In chapter five empirical results and discussions about the results are presented and in the last chapter, i.e. chapter six, conclusion and policy recommendations are discussed.

CHAPTER TWO

OVERVIEW OF THE ETHIOPIAN MANUFACTURING SECTOR

2.1 History, Policies and Strategies

Even though Ethiopia has had a long tradition in the development of handicrafts and cottage manufacturing industries, the introduction of modern manufacturing is only a 20-th century Phenomenon. According to MEDaC (1999) the emergence of a strong central government which resulted in political stability and the construction of the Ethio-Djibouti railway were notable early 20-th century events which contributed to the introduction of modern manufacturing in Ethiopia. Furthermore, expansion of towns and the settlement of foreigners, which in turn increased the demand for imported commodities, was also the basis for industrial development. The domestic production of manufactured goods was also necessitated by the increasing problem of transporting bulky imported commodities like wood, clay, etc.

According to the same report, during the early periods of the imperial regime there were around 25 factories in the major urban centers of the country of which 22 of them were established by private entrepreneurs. A number of manufacturing industries also came into existence in the 1940's and 1950's owing mainly to the strong relations with the then governments of United Kingdom and the United States of America. Nevertheless, industrial development gained strong momentum only after World War II when the government began to take conscious effort towards the development of the sector. Generous tax incentives, high levels of tariff protection and easy access to credit on favorable terms helped to attract inflows of foreign capital to the manufacturing sector.

During this regime, the role of the government was relatively small with full ownership of not more than 13 manufacturing establishments in which it had a more than 50 percent share in five of the thirteen establishments while it had a less than 50 percent share in the rest of the establishments. The majority of the manufacturing industries, especially the large-scale establishments, were foreign owned and heavily protected from external competition. They were also dependent on imported goods for full utilization of their installed capacity (MEDaC, 1999).

The military regime which came to power in 1974 nationalized all private large and medium scale manufacturing establishments. With its strong emphasis on medium and large-scale establishments, the regime also saw the set up of a number of government owned manufacturing industries though the private sector initiative was severely curtailed. The attempt towards the development of large and medium scale manufacturing was through favoring government owned enterprises in allocation of resources like foreign exchange, labour and credit. The enterprises were also granted market monopoly for their output though they were operating under a highly centralized system of management whereby the level, quality of production and prices were determined through central planning (MEDaC, 1999).

The development strategies followed by this regime brought about no significant change with regard to the structure of the manufacturing sector in such away that the sector was dominated by light and consumer goods producing industries that are concentrated in the major urban centers mainly Addis Ababa and the surrounding towns. The sector was also highly capital intensive and dependent on imported inputs having poor forward and backward linkages with the rest of the economy.

After the establishment of the ruling government in 1991 the government started to rationalize its role in the economy through encouraging the active participation of the private sector. Since then, the government has begun to take some reform measures that could enhance the poor performance of the manufacturing sector in the country. The 'Public Enterprises Reform' which was initiated in August 1992 was one of the reform measures. This reform was aimed at enhancing efficiency, productivity and competitiveness in public enterprises through the granting of managerial autonomy and responsibility (MEDaC, 1999). Given this autonomy, enterprises were detached from government budget subsidy on the one hand, and denied of preferential access to credit, labour, foreign exchange and other services on the other hand.

The other reform measure undertaken by the government was the issuance of the new Labour Code. The code was intended to give management autonomy and adequate flexibility to allocate labour resources and economic grounds while ensuring the legitimate rights of employers (MEDaC, 1999). The Labour Code also sought for industrial peace and coordination among employers and employees with minimum government intervention. The exchange rate reform was also one of the major policy reforms undertaken by the government which has a great importance for all economic sectors, especially the manufacturing sector because of its relatively higher import intensity.

Overall, the introduction of manufacturing industries in Ethiopia goes back to early 20-th century and the sector has a history of almost a century. Even though the sector has existed for such period in the country, its contribution to the overall economy was not significant. The policies and strategies followed by the different regimes are among the contributing reasons for this poor performance of the sector. In fact, the imperial and the post-military regimes have a relatively better policies which were aimed at creating conducive environment for private investment and encouraging entrepreneurs to actively participate in the sector while the military regime was characterized by its discouraging policies of the private sector and during this regime almost all of the enterprises were publicly owned and administered centrally which made the enterprises less efficient and less productive.

2.2 Value Added in the Manufacturing Sector

According to MEDaC (1999), value added in Ethiopian manufacturing Industries has been on the decline during the early periods of the military regime at an average rate of 2.4 percent per annum. This decline in value added was mainly attributed to the continued dependence of the manufacturing industries on imported inputs for their production.

After the reform in 1991, value added at current factor cost showed a remarkable growth averaging at 38 percent per annum until the mid 1990's and kept on increasing until 2003 although there were some fluctuations. Among the manufacturing industries metal, non-metallic mineral and leather industries have attained high annual growth rates of value added followed by food processing, wood & furniture and chemical industries. It is also known that the reform program allowed private industries to operate in the sector so that the share of these industries from the total value added of the manufacturing sector increased from 6 percent in 1992 to about 27 percent in 2003.

2.3 Distribution of Manufacturing Industries

During the post-reform period, i.e. after 1991, the number of firms that are operational in the sector significantly increased to an average of 629 firms each year as compared to 389 firms in the pre-reform period, i.e. during the military regime. This was mainly due to the increase in the number of private firms following the change of government in 1991 which brought about a new policy measure that allows private industries to operate in the manufacturing sector. During this period, there were around 475 privately owned firms on average which is a much larger figure as compared to the small number of privately owned firms, i.e. 198 firms on average, during the pre-reform period.

Despite the increase in the number of firms after the post-reform period, the sector is dominated by few sub-sectors of the manufacturing industry. For instance, in 1995 food processing and beverages, wood and furniture, textile and non-metallic mineral industries constitute 31, 13, 10 and 10 percent, respectively. These industries together accounted for 63 percent of the total manufacturing industries. The above figure is almost similar in 2003 whereby the industries constitute 30, 17, 7, and 11 percent, respectively and accounts for 65 percent of the total manufacturing industries.

Regarding the distribution of firms across regional states, they are distributed unevenly and the distribution is highly skewed. For instance, as shown in table 2.1 below in 2003 Addis Ababa alone accounted for 59 percent of the total manufacturing industries in the country followed by the Oromiya regional state which accounted for about 14 percent. The two regions combined accounted for about 73 percent of the total manufacturing industries.

Table 2.1 Regional Distribution of Firms in 2003

Regions	Number of Firms	Share in Percent
Tigray	55	5.7
Afar	6	0.62
Amhara	78	8.0
Oromiya	137	14.2
Somalie	5	0.51
S.N.N.P	76	7.6
Gambella	3	0.31
Harari	16	1.66
Addis Ababa	568	58.9
Dire Dawa	24	2.5
Total	965	100

Source: - Report on Large & Medium Scale Industries Survey (CSA, 2003)

Notes - S.N.N.P refers to the Southern Nations, Nationalities and Peoples Regional State.

- The Benishangul Gumuz regional state is not included in table 2.1 due to absence of a single manufacturing industry in the region.

The Amhara Regional State, the second populous region, accounted only for 8 percent and S.N.N.P for only 7.6 percent of the total manufacturing. The reason for the high concentration of firms around Addis Ababa is the lack of different infrastructural facilities like transportation, electricity and communication, the lack of adequate financial institutions in other regional states and so forth. The other regional states together constitute not more than 20 percent of the total manufacturing industries in the country.

2.4 Employment in the Sector

The role of manufacturing in creating employment is very much limited as compared to the agricultural sector which provides employment opportunity for an estimated 85 percent of the total population. According to MEDaC (1999) during the pre-reform period employment in the manufacturing sector grew by 1.1 percent per annum in the face of about 5 percent growth in urban population. The situation does not seem to have improved significantly after the reform program although annual growth rates of manufacturing employment averaged 2.2 percent for the period 1992 to 1997.

This little growth in the manufacturing employment is attributed to the emergence of private manufacturing establishments following the retrenchment measures and privatization programmes in 1994. According to MEDaC (1999), the private manufacturing employment has been growing at about 39 percent per annum for the period 1992 to 1997. This figure has shown an increment and reached 42 percent in 2001.

The share of the growing private manufacturing from the overall manufacturing in terms of employment creation has been also improving after the reform program. For instance, during the mid 1990's its share was around 22 percent of the total manufacturing employment and this share has increased to 42.8 percent during the early 2000's. On the other hand, the employment in public enterprises have been declining at a rate of 1.8 percent per annum after the reform program due to the lower attention given for publicly owned manufacturing industries.

2.5 Size and Age Structure of Manufacturing Industries

2.5.1 Size Structure

Nowadays, the fierce international competition has put limitations to the minimum size of firms to attain minimum unit cost of production to be internationally competitive. Given other factors, the larger the size the lower the cost of production, and hence the better competitiveness status though this does not imply small firms are inefficient. Another significant advantage of large firms is the capability to internalize all costs and externalities there by reducing the dependency and adverse impact of external factors. Therefore, there is a need to acquire an optimal size of firms which could allow enough room to be cost effective (EEA, 2003/04).

When we consider the concept of firm size, it is mostly related with the employment capacity of the firm. Therefore, a larger firm employs a larger number of workers and a smaller firm employs a smaller number of employees whereby the number of workers for each category is determined according to some standard classifications. EEA (2003/04) classified firms into seven categories based on their employment capacities using the medium and large scale industries survey data for the year 2002. The disaggregation reveals that those firms which employ less than 26 and between 26 and 50 workers constitute 70 percent of the manufacturing firms. Despite this sheer number of firms, these employment groups account only for 11 percent of the labour force, 5.6 percent of the total wages and salaries, 6 percent of the value added and 9 percent of the capital asset of the manufacturing sector.

On the other hand, large size firms (i.e., those firms employing between 500 and 1000 and over 1000 workers each) only account for 5.6 percent of the total firms. However, they have dominant shares in many respects such that they constitute 54 percent of the employment, 60 percent of the total wages and salaries, 60 percent of the value added and 52 percent of the capital stock of the sector (EEA, 2003/04). The remaining small & medium size firms constitute 25 percent of the total manufacturing firms and account for 35 to 40 percent of the value added and capital asset of the sector.

2.5.2 Age Structure

Latest generation machinery and equipment are relatively high-tech oriented, and hence technically more efficient and more productive than older ones. Therefore, the age structure of firms reflects the degree of hardware complexity and efficiency and, in turn, the technical competitive status of firms in addition the gain in efficiency due to experience.

To examine this EEA conducted a survey in 2002 and found that the number of newly established firms has been increasing in the last 10 years. As shown in table 2.2, 52 percent of the total manufacturing firms were in operation for no longer than 10 years, with 21 percent of them being less than five years old.19 percent of the manufacturing industries are aged between 11 and 20, while the remaining 29 percent are aged above 20 years.

Table 2.2 Age Structure of Firms in 2000

Age structure of Firms (yrs)	No. of Firms	Share (Percent)
<5	181	21
6-10	267	31
11-15	124	14
16-20	50	5
21-30	93	11
>30	142	18

Source: Report on the Ethiopian Economy, EEA (2003/04)

Since the progress in technology is continuous and dynamic, it is difficult to draw any boundary on the age structure to determine for how long a given technology will remain technically efficient and competitive. However according to EEA (2003/04), based on general experience, depreciation of plants, particularly in developing countries, lasts for about 10 to 15 years, even though hard wares may not remain efficient enough throughout the whole period. In light of this general premise, the report indicated that 50 percent of the manufacturing firms might have difficulty to be technically productive enough to compete with new generation firms.

2.6 Manufactured Sales and Export

Industrial groups like food, beverages, textile and leather which concentrate on consumer goods production have been dominating the market for manufactured exports during the post-reform and pre-reform periods. Sales performance by the above mentioned industrial groups accounted for more than three-fourth of the total annual sales revenue of the manufacturing sector in the early 1980's and it has declined to about two-third during the mid 1990's (MEDaC,1999). After the reform program, the sales revenue of the manufacturing sector has been growing at a relatively faster rate averaging about 28 percent per annum up until 1996/97 due to the surge in the manufacturing output and the liberalization of domestic and external trade sectors since the reform program. According to EEA (2003/04), this manufacturing sales revenue has shown an appreciable increase, on average, 31 percent annually within the period of 1996-2002 even though there has not been a consistent trend. During this period, the firm-level export earning was dominated by a few firms like the pre-reform period. According to the different annual surveys of CSA between 1996 and 2002, on average, 28 percent of the total manufacturing industries have been exporting to different countries. Of these industries, on average, 95 percent of the manufacturing export comes only from four industries, namely leather tanning, sugar, textiles and spice processing. For instance, within the seven years period their total share in the manufacturing exports reached a maximum of 99 percent in 2001 and a minimum of 90.9 percent in 1997. This depicts how the manufacturing export is dominated by the above-mentioned four industries. In addition, among these industries the leather industry which exports most of its products accounts for 70 percent of the total manufacturing export alone on average during the same period. Thus export in Ethiopia is, nevertheless, an affair of very few industries.

From 1996 until the early 2000's the total export earnings of the sector was only 48.92 million dollars per annum on average. A maximum earning in export is gained in 2002 which was 93.44 million dollars and a minimum of 13.82 million dollars in 1997. The figure is quite very low as compared to the total export earning of the country. Its share figures only about 10 percent, on average, over the same period noted above. In fact, in 2001 & 2002 manufacturing exports accounted for relatively larger proportions, 20 and 15 percent, mainly as a result of a steep fall in coffee price, the major export-earning commodity of the country.

CHAPTER THREE
LITERATURE REVIEW

3.1 Theoretical Review of Literature

3.1.1 Introduction

The neo-classical theory of production is based on the notion of efficiency, i.e., firms are efficient and whatever inefficiency comes in the process of production is due to external shocks or statistical noise which is entirely beyond their control. This idea is emphasized in the textbook definition of a production function which gives the maximum possible output for given quantities of inputs. One problem with the notion of maximum is that nobody can recognize it simply by observing the actual level of output unless the observed output assumed to be the maximum. Such an assumption is not realistic since different industries do produce different levels of output even if they use the same level of every observed input. One way of explaining the difference in observed outputs among producers is through differences in productive efficiency.

In light of this, production efficiency has received a considerable attention in economic literature in recent years, although the concept of efficiency is complex and a difficult one. Much of the literature on efficiency is based directly or indirectly on the seminal work of Farrell (1957) who argued that efficiency could only meaningfully be gauged in a relative sense, as a deviation from the best practice of representative group of producers. Therefore, Farrell's consideration led to deviate from estimating 'average' production functions to frontier production functions.

According to the same article the performance of firms is often measured in terms of economic efficiency which is decomposed into technical and allocative efficiencies. Although the main concern of the study is technical efficiency, the concepts of both types of efficiencies are presented in the following sections.

3.1.1.1 Technical Efficiency

Technical efficiency is defined as the ability of a firm to produce a certain level of output with a given level of inputs. A producer is said to be technically inefficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input and if a reduction in any input requires an increase in at least one other input or a reduction in at least one out put. Thus, a technically inefficient industry could produce the same output with less of at least one input, or could use the same inputs to produce more of at least one output. Farrell (1957) also noted that if economic planning is to concern itself with particular firms, it is important to know how far a given firm can be expected to increase output by simply increasing its efficiency, without absorbing further resources. Therefore, technical efficiency is considered an important determinant of productivity growth and international competitiveness in any economy. It is also considered an important factor which contributes to the stability of production.

Technical efficiency is measured in terms of a relationship between actual output to the frontier output. In other words while measuring technical efficiency, one should use the true production frontiers instead of average production frontiers. This is because the estimator of the intercept which is obtained from the average production function is downward biased, and therefore the resulting estimate is not efficient. Suppose producers' use input X$\in \Re_{+}^{K}$ to produce scalar out put Y$\in \Re_{+}$ with technology:

$$Y_i = f(X_i, \alpha_i)\exp(V_i - U_i) \quad \text{...} (1)$$

Where α_i is a vector of technology parameters to be estimated and i = 1,2,...,N producers. The random disturbance term V_i is intended to capture the effects of statistical noise and is assumed to be independently and identically distributed as $N(0, \delta_v^2)$.

The disturbance term U_i is assumed to be distributed independently of V_i to satisfy $U_i \geq 0$. The deterministic production frontier is $f(X_i, \alpha_i)$ and the stochastic production frontier, which represents the maximum feasible output, is $f(X_i, \alpha_i)\exp(V_i)$. The non-negative error component U_i represents technical inefficiency attributed to firm specific factors that make it operate below the maximum level of production.

Battese and Coelli (1988) identified two ways of measuring the technical efficiency of the i-th firm depending on how we define the level of production of each firm in our model. If the frontier production function in equation (1) is defined in terms of the original units of production then the technical efficiency of the i-th firm will be:

$$TE_i = (X_i\alpha - U_i)(\bar{X}_i\,\alpha)^{-1} \qquad \text{.......(2)}$$

Where $\bar{X}_i$ represents the mean of the input levels for the i-th firm. The corresponding measure of (mean) technical efficiency of the firms in the industry, is given by:

$$TE = 1 - \left(\mu + \frac{\delta\phi(-\mu/\delta)}{1-\phi(-\mu/\delta)}\right)(\bar{X}\,\alpha)^{-1} \qquad \text{.......(3)}$$

Where $\phi(.)$ represents the density function for the standard normal random variable, $\bar{X}$ is the mean of the input levels for the firms in the industry, μ and δ are mean and standard error of the inefficiency term, respectively.

On the other hand, if the frontier production in equation (1) is defined as the logarithm of production, then the production for the t-th period will be $\exp(Y_{it})$. In this case the suggested measure of technical efficiency for the i-th firm is given as:

$$TE_i = \exp(-U_i) \qquad \text{.......(4)}$$

This measure of technical efficiency is equivalent to the ratio of the production for the i-th firm in any given period t (i.e., $\exp(Y_{it}) = \exp(X_{it}\alpha + V_{it} - U_{it})$), to the corresponding value if the firm effect U_i was zero, (i.e., $\exp(X_{it}\alpha + V_{it})$). The technical efficiency measure in equation (4) is not dependent on the level of factors inputs for the given firm, which is not the case for the technical efficiency measure in equation (2). The mean technical efficiency of firms in the industry that corresponds to the measure of equation (4) is given by:

$$TE = \left\{ \frac{1-\phi[\delta - (\mu/\delta)]}{1-\phi(-\mu/\delta)} \right\} \exp(-\mu + \frac{1}{2}\delta_u^2) \quad \dots\dots (5)$$

Where $\phi(.)$, μ and δ is are as defined in equation (3) and δ_u^2 is the variance of the technical inefficiency term U_i.

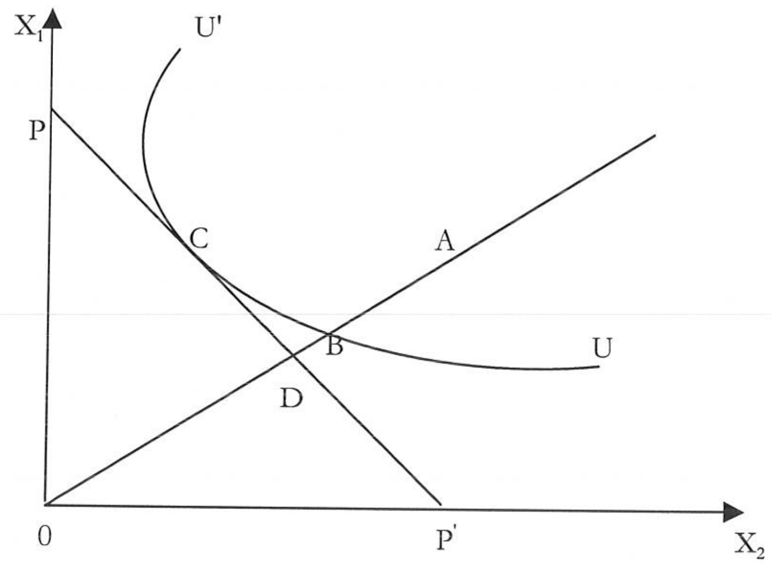
3.1.1.2 Allocative Efficiency

Although the main concern of this study is measuring technical efficiency of the manufacturing sector in Ethiopia as stated in the earlier section, it will be very important to review the concept of allocative efficiency as it is the other component of the total economic efficiency and for other comparison purposes. Allocative efficiency is defined as the ability of a firm to choose the oprimal input proportions given relative prices and output. In other words, it is the ability of a firm to maximize its profit by equating marginal revenue product of inputs to their respective marginal costs (the principle of equimarginal principle). This follows from individual utility maximization only under perfect competition. In particular, a perfect market in factors and products must exist and each firm must be able to predict with reasonable confidence the out come of each array of production, sales decisions, etc at its disposal.

3.1.1.3 Comparison Between Technical and Allocative Efficiencies

Assuming that the frontier production function is known, though in reality it can only be estimated, we can appreciate the concepts of technical and allocative efficiencies even more with the help of a diagram. Consider a firm using two inputs X_1 and X_2 to produce output Y, and assume that the firm's production function is represented by $Y = f(X_1, X_2)$. Assuming also constant returns to scale it is possible to graph the frontier as the efficient unit isoquant UU' as shown in figure 3.1below:

Fig. 3.1 Technical and Allocative Efficiencies



Source: Jha, R. and Sahin, B.S. (1993)

Suppose a firm uses quantities of inputs, defined by point A, to produce a unit of output. The technical inefficiency of that firm could be represented by BA, which is the proportional reduction in all inputs that could theoretically be achieved without any reduction in level of output produced. This is usually expressed in percentage terms by the ratio $\frac{BA}{OA}$. The technical efficiency (TE) of a firm is then given by:

$$TE_i = \frac{OB}{OA} \qquad \text{(6)}$$

$$= 1 - \frac{BA}{OA}$$

It will take a value between zero and one, and hence provides an indicator of the degree of technical inefficiency of the firm. A value of one indicates the firm is fully technically efficient. For instance, at point B the firm is technically efficient because it lies on the efficient isoquant.

If the input price ratio, represented by the slope of the isocost line PP', in figure 3.1, is known, allocative efficiency may also be calculated. The allocative efficiency of a firm operating at point A is defined to be the ratio

$$AE_i = \frac{OD}{OB} \qquad \text{...(7)}$$

Since the distance DB represents the reduction in production costs that would occur at the allocatively (and technically) efficient point C, instead of at the technically efficient, but allocatively inefficient point, B.

The total economic efficiency (EE) is then represented by the ratio

$$EE_i = \frac{OD}{OA} \qquad \text{...(8)}$$

Which is the product of technical efficiency and allocative efficiency, i.e.,

$$EE_i = \left[\frac{OD}{OA}\right] \equiv \left[\frac{OB}{OA}\right]\left[\frac{OD}{OB}\right] \qquad \text{...(9)}$$

The total economic inefficiency can also be illustrated as $\left(1 - \frac{OD}{OA}\right)$ which suggests the possible reduction in cost by moving away from point A (the observed point) to point C (the cost minimizing point).

3.1.2 Frontier Approaches for Efficiency Measurement

Although there are different approaches[2] for measuring the efficiency of firms, frontier approaches are the widely applicable methods for efficiency measurement. Moreover, frontier production functions have been the subject of considerable econometric research during the last two decades. The development of frontier approach opened a wide range in the area of measure of efficiency (Forsund et al., 1980). The word frontier may meaningfully be applied either to the maximum possible output which can be produced from given quantities of a set of inputs or the minimum level of cost at which it is possible to produce some level of out put, given input prices or the maximum profit that can be attained given out put price and input prices. Currently, the frontier function is widely utilized to analyze efficiency for a variety of reasons. First, it is consistent with the underlying economic theory of optimizing behavior. Second, deviations from a frontier have a natural interpretation as a measure of the level of efficiency with economic units pursues their technical or behavioral objectives. Third, information about the structure of the frontier and about the relative efficiency of economic units has many implications (Bauer, 1990) (Cited in Awoke, 2001).

Frontier approaches are mainly composed of two components: deterministic and stochastic. Further, deterministic frontiers are sub-divided into non-parametric, parametric and statistical frontiers.

3.1.2.1 Deterministic Non-Parametric Frontiers

According to Forsund et al. (1980) the beginning point for any discussion of frontiers and efficiency is the work of Farrell (1957), who provided definitions and a computational framework for technical and allocative inefficiencies. Farrell's approach is non-parametric in the sense that he simply constructs the free disposal convex hull of the observed input-output ratios by linear programming techniques. This is thus supported by a subset of the sample with the rest of the sample points lying above it. This procedure is not based on any explicit model of the frontier or the relationship of the

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[2] Other approaches include techniques like partial and total productivity, production function and profit function for efficiency measurement.

observations to the frontier. The technical inefficiency of an observation is then measured relative to this frontier.

The principal advantage of this model is that no functional form is imposed on the data. However, it has two major weaknesses: First, its assumption of constant returns to scale is restrictive, and its extension to non-constant returns to scale technologies is cumbersome. Second, the frontier is computed from a supporting subset of observations from the sample, and is therefore particularly susceptible to extreme observations and measurement error (Forsund et al., 1980).

As a result, his approach is extended, proved and applied by Farrell and Fieldhouse (1962), Seitz (1970, 1971), Todd (1971), Afriat (1972), Dugger (1974) and Meller (1976) (cited in Forsund et al., 1980).

3.1.2.2 Deterministic Parametric Frontiers

Although the first Farrell's non-parametric approach has won few adherents, a second approach which is also proposed by him was proved to be more fruitful. He proposed computing a parametric convex hull of the observed input-output ratios to determine a production function that obeys constant returns to scale. He recommended the Cobb- Douglas from for the sake of expressing the frontier in a simple mathematical form. Although the mathematical expression of the Cobb-Douglas from is simple, Farrell was aware of the unnecessary assumption of constant returns to scale. Unfortunately Farrell did not follow up on his own suggestions, and it was over a decade before anyone else did it.

Aigner and Chu (1968) were the first to follow Farrell's suggestion. They specified a homogenous Cobb-Douglas production function and required all observations to be on or beneath the frontier. Their model is written as:

$$\ln Y = \ln f(x) - U \qquad \text{...} \quad (10)$$

$$\ln Y = \alpha_0 + \sum_{i=1}^{n} \alpha \ln X_i - U, \quad U \geq 0$$

Where Y_i is the i-th firm output; $f(X)$ is a suitable functional from (e.g. Cobb-Douglas or translog) of inputs vector X_i for the i-th observation and of α is a vector unknown parameters, and U_i is firm specific technical inefficiency which forces Y to be less than or equal to $f(X)$.

The elements of the parameter vector $\alpha = (\alpha_0, \alpha_1, \alpha_2, ..., \alpha_n)'$ may 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 vector of residuals, since U represents technical inefficiency.

The principal advantages of the parametric approach over the non-parametric approach are the ability to characterize frontier technology in a simple mathematical form, and the ability to accommodate non-constant returns to scale. This does not that mean the parametric approach is free from limitations. It imposes a limitation on the number of observations that can be technically efficient. For instance, when the linear programming algorithm is used in a homogenous Cobb-Douglas case, there will in general be only as many technically efficient observations as there are parameters to be estimated. The other limitation is, as in the case of non-parametric approach, the estimated frontier is supported by a subset of the data and is therefore extremely sensitive to outliers.

The absence of statistical properties of the estimates produced by this approach is also another limitation. That is, mathematical programming procedures produce 'estimates' without standard errors, t-ratio, etc. This is because no assumptions are made about the regressors or the disturbances in (10), and without some statistical assumptions, inferential results cannot be obtained (Forsund et al., 1980).

3.1.2.3 Deterministic Statistical Frontiers

Deterministic parametric frontiers can be made amenable to statistical analysis by making some assumptions. It was Afriat(1972) who first explicitly proposed this model and he developed a deterministic statistical model as follows:

$$Y_i = f(X)e^{-U} \qquad \text{.......(11)}$$

$$\ln(Y_i) = \ln[f(x)] - U$$

Where Y_i, $f(X)$, X_i, and $U_i \geq 0$ are as defined in (10). From $U_i \geq 0$ it follows $0 \leq e^{-u} \leq 1$. In this model the observations on U are assumed to be independently and identically distributed (iid) and X is assumed to be exogenous (independent of U). It should be stressed that the choice of a distribution of U is important because the maximum likelihood estimates (MLE) depend on it in a fundamental way, i.e., different assumptions for the distributions lead to different estimates.

Different people have proposed different distributions for U. For instance, Afriat (1972) proposed a two-parameter beta distribution for U and that the model be estimated by the maximum likelihood estimation technique. Richmond (1974) and Schmidt (1976) have proposed a gamma distribution and an exponential distribution for U, respectively (cited in Forsund et al., 1980).

The use of maximum likelihood in the frontier setting is not without limitations. The major weakness with this estimation technique is that there do not appear to be good a priori arguments for any of the distributions stated above. The other problem related with maximum likelihood is that the range of the dependent variable (output) depends on the parameters to be estimated which violates one of the regularity conditions invoked to prove the general theorem that maximum likelihood estimators are consistent and asymptotically efficient.

An alternative method of estimation is provided by Richmond (1974) (cited in Forsund et al., 1980) which is based on the ordinary least squares method, called Corrected Ordinary Least Squares (COLS). This method provides consistent estimates by shifting the COLS constant parameter estimate upward until no residual is positive. The difficulty with COLS technique is that, even after correcting the constant term, some of the residuals may still have the 'wrong' sign so that these observations end up above the estimated production frontier. This makes the COLS frontier a somewhat awkward basis for computing the technical efficiency of individual observations. Another difficulty with the COLS technique is that the correction to the constant term is not independent of the distribution assumed for U.

In addition to the above mentioned difficulties related with estimation, deterministic statistical frontiers assume all firms share a common family of production, cost and profit functions, and all variations in firm performance is attributed to variations in firm efficiencies relative to the common family of frontiers. The notion of a deterministic frontier shared by all firms ignores the very real possibility of that a firm's performance may be affected by factors entirely outside its control (such as poor machine performance, input supply breakdowns, and so on), as well as by factors under its control (inefficiency). Therefore, to lump the effects of exogenous shocks, both fortunate and unfortunate, together with the effects of measurement error and inefficiency in a single one-sided error term and to label the mixture 'inefficiency' is somewhat questionable.

3.1.2.4 Stochastic Frontiers

The stochastic frontier production function which was independently proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977), involves unobservable random variable associated with the technical inefficiency of production of individual firms in addition to the random error in deterministic statistical frontiers (Battese and Coelli, 1995). The error term in the stochastic frontier models is composed of a systematic component which captures the effects of measurement error, other statistical 'noise' or random 'shocks' outside the control of the production unit and a one-sided error component which captures the effects of inefficiency relative to the 'best' stochastic frontier. The presence of the variable which captures a firm's inefficiency solves the bounded-range problem encountered in frontier model and the presence of the statistical noise allows the frontier to be stochastic.

The stochastic model may be written as:

$$Y_i = f(X,\alpha)\exp(V-U) \qquad (12)$$

Where $Y_i, X_i, \alpha, U_i \geq 0, f(X)$ as defined in (10) and V is the statistical 'noise'.

In this model the stochastic production function is $f(X)\exp(V), V$ having some systematic distribution to capture the random effects of measurement error and exogenous shocks which cause the placement of the deterministic part $f(X)$ to vary across firms. Technical inefficiency relative to the stochastic production frontier is then captured by the one-sided error component $\exp(-U), U > 0$. The condition $U > 0$ ensures that all observations lie on or beneath the stochastic production function.

The basic assumption of the model is that V and U are independent and X is exogenous. Using this assumption we can obtain direct estimates of the stochastic production frontier model using either maximum likelihood or COLS methods (Forsund et al., 1980). It is important to note that whether the model is estimated by maximum likelihood or by COLS, the distribution of U must be specified. Aigner et al., (1977) and Menusen and Van den Broeck (1977) considered exponential and half-normal distributions for U and Stevenson (1980) has shown how the half-normal and exponential distributions can be generalized to truncated normal and gamma distributions, respectively (cited in Forsund et al., 1980).

Many empirical studies involving both cross-sectional and time-series data have assumed that the firm effects have half-normal distribution (i.e., $\mu = 0$). If the value of μ is zero or negative, then the distribution of the firm effects is such that there is highest probability of obtaining firm effects in the neighborhood of zero. In this case, the majority of firms would have high technical efficiencies. However, if the value of μ is positive, then a relatively larger number of firms would have firm effects which were significant positive values and such firms would have smaller values of technical efficiencies.

Until the early 1980's the major criticism towards stochastic frontiers was that there was no way of determining whether the observed performance of a particular observation compared with the deterministic frontier is due to inefficiency or to a random variation in the frontier. In other words, it was not possible to decompose individual residuals into their two components and to estimate technical inefficiency by observation. However, after the appearance of the paper by Jondrow, et al. (1982) a solution was suggested for the problem mentioned above. They suggested that the conditional distribution of U_i given E_i can be used to obtain an estimator of U_i since E_i contains information about U_i. They further suggested that either the mean or the mode of this distribution can be used as a point estimator on U_i and they showed how to derive these estimators given the distributions of U_i and V_i (Battese et al., 1989).

Stochastic frontier models have been applied to a variety of data sets because of their advantages over the deterministic frontiers through incorporating the two error components. Further more, the main attraction of the stochastic frontier model is the possibility it offers for a richer specification, particularly in the case of panel data. The model also allows for, among other things, a formal statistical testing of hypothesis and the construction of confidence intervals. Because of all these aspects, this model seems most attractive and the study employed the model using firm's panel data to predict technical efficiency.

3.1.3 Production Frontiers and Panel Data

The majority of previous empirical studies which used frontier models have been using cross-sectional data because of the assumption that error terms are independently distributed across observations. Also, with cross-sectional data it is required to make parametric assumptions about the distribution of the residual and the inefficiency term in order to separate the residual from inefficiency. Schmidt and Sickles (1984) indicated that stochastic frontier models using cross-sectional data suffer from three serious difficulties.

First, the technical inefficiency of a particular firm (observation) can be estimated but not consistently. We can consistently estimate the (whole) error term for a given observation, but it contains statistical noise as well as technical inefficiency. The variance of the distribution of technical inefficiency, conditional on the whole error term, doesn't vanish when the sample size increases.

Second, the estimation of the model and the separation of technical inefficiency from statistical noise require specific assumptions about the distribution of the technical inefficiency term(e.g., half-normal) and the statistical noise (e.g., normal). It is not clear how robust one's results are to these assumptions. Another way to emphasize this point is to note that the evidence of technical inefficiency is skewness of the production function error, and not anyone will agree that skewness should be regarded as evidence of inefficiency.

Third, it may be incorrect to assume that inefficiency is independent of the regressors. If a firm knows its level of technical inefficiency, for example, this should affect its input prices.

All the three problems are potentially avoidable if one has panel data[3]; say T observations on each of N firms. The technical inefficiency of a particular firm can be estimated consistently as $T \to \infty$. This is because adding more observations on the same firm yields information not attainable by adding more firms. The other advantage of panel data is that one need not make such strong distributional assumptions as are necessary with a single cross-section. Panel data also permits the simultaneous investigation of both technical change and technical efficiency change overtime, given that technical change is defined by an appropriate parametric model and the technical inefficiency effects in the stochastic frontier model are stochastic and have the specified distribution. As a result, more recently attention has been made to apply frontier production functions in the analysis of panel data on firms involved in production.

Different people have developed various types of panel data models in relation to stochastic frontier production functions. Among them, Schmidt and Sickles (1984) specified a model to measure stochastic frontier production function using panel data assuming the inefficiency to be time-invariant. Their model is written as:

$$Y_{it} = \beta_i + \sum_j \beta_j X_{jit} + V_{it} \quad \text{...}(13)$$

$$\beta_i = \beta_0 - U_i$$

Where $i(i = 1,2,..., N)$, $t(t = 1,2,...,T)$ and $j(j = 1,2,..., K)$ represents firm, time and input respectively; Y_{it} is log of output, X_{it} is vector of log of inputs, V_{it} is the white noise component and U_i is the non-negative time-invariant technical inefficiency. The assumption of constant efficiency

3 Baltagi (2001) defines panel data as the pooling of observations on a cross-section of households, countries or firms over several time periods which can be achieved by surveying a number of households or firms and following them overtime.

overtime presumes that weaknesses that are attributable to firms themselves are inherently in their very nature and their impact is invariant with time. The model can be estimated using the within estimator treating $U_i \geq 0$ as fixed. A dummy variable for each firm can be introduced to the model or OLS can be applied to the within transformed data. During this, the intercept will be recovered as the means of the residuals to each firm. The within estimator allows U_i and X to be correlated. The estimator of β_0 then can be obtained as the $\max(\beta_i)$. From this, it is apparent that $U_i (U_i = \beta_0 - \beta_i)$ will be zero at point where $\beta_0 = \beta_i$ and the corresponding firm in the sample is fully efficient.

The within estimator will not provide the estimated values of time-invariant regressor coefficients. The generalized least squares (GLS) and maximum likelihood estimator (MLE) methods give the estimates assuming the U_i, with some specific distribution, are random and uncorrelated to the regressors.

Cornwell et al., (1990) extended the generalized Schmidt and Sickles (1984) approach to relax the assumption of time-invariant on U_i by allowing time-varying efficiency for each firm. The model can be written as:

$$Y_{it} = \beta_{it} + \sum_j \beta_j X_{jit} + V_i \quad \text{.......................} (14)$$

$$\beta_{it} = \theta_{i1} + \theta_{i2} t + \theta_{i3} t^2$$

Within estimator, GLS or MLE methods can be applied to estimate the model. Firm specific effects, β_{it}, are regressed on a constant, time and time-squared. Their estimates will be consistent as T gets larger. The model allows the frontier intercept to vary overtime and the efficiency level to vary over firms and over time.

A more flexible formulation of technical inefficiency model for panel data was proposed by Kumbhakar (1990). It is written as:

$$Y_{it} = \beta_{it} + \sum_j \beta_j X_{jit} + V_{it} - U_{it} \quad \text{.......................................} (15)$$

$$U_{it} = \gamma(t) U_i = (1 + \exp(bt + ct^2))^{-1} U_i$$

Where the firm effects are represented as a product of a deterministic part, $\gamma(t)$, which is an exponential function of time and a time-invariant random effect, U_i. Appropriate distributional assumption on the technical inefficiency component is needed in order to get the required estimates using MLE methods. The need for a restrictive distributional assumption on the technical inefficiency component is considered as the main disadvantage of the model.

Battese and Coelli (1992) developed a stochastic frontier production function model for panel data by expressing firm effects as a product of exponential function of time and time- invariant, U_i, as follows:

$$Y_{it} = \beta_0 + \sum_j \beta_j X_{jit} + V_{it} - U_{it} \quad \text{.......................................} (16)$$

$$U_{it} = \eta_{it} U_i = (\exp(-\eta(t-T))) U_i$$

Where η is an unknown parameter to be estimated and $U_i, i = 1,2,..., N$, is independently and identically distributed non-negative random variable, obtained by truncation (at zero) of the normal distribution with unknown mean, μ, and unknown variance δ^2.

The advantage of this model is that if $\eta > 0$, then as t increases U_{it} will decrease monotonically which means that as the firm proceeds overtime, its inefficiency level monotonically decreases and the firm proceeds towards the frontier. Similarly, if $\eta < 0$, then inefficiency increases overtime. Therefore, the testable hypothesis offered by the model is that efficiency monotonically decreases or increases overtime. However, the hypothesis of fluctuating efficiency cannot be tested in this model.

In a similar approach, Battese and Coelli (1995) defined the technical inefficiency effect, U_{it}, in stochastic frontier model as:

$$U_{it} = Z_{it}\delta + W_{it} \quad \text{.......... (17)}$$

Where Z_{it} is a (1 X M) vector of explanatory variables associated with technical inefficiency of production of firms overtime; δ is an (M X 1) vector of unknown coefficients; and W_{it} are unobservable random variables, which are obtained by truncation of the normal distribution with mean zero and unknown variance, δ^2, such that the point of truncation is, $-Z_{it}\delta$ i.e., $W_{it} \geq -Z_{it}\delta$. These assumptions are consistent with U_{it} being a non-negative truncation of the $N(Z_{it}\delta, \delta^2)$.

This model is used in the study for the simultaneous estimation of the parameters of the stochastic frontier and the model for technical inefficiency effects using maximum likelihood estimation technique.

3.2 Empirical Review of Literature

3.2.1 General

A number of empirical studies have been conducted regarding technical efficiency of manufacturing industries in different countries and some of the studies are presented as follows.

Tyler and Lee (1979) empirically analyzed a two factor stochastic frontier Cobb-Douglas function to cross-sections of Colombian small-scale enterprises data for five industries to measure their technical efficiencies. The results from the maximum likelihood estimates of stochastic frontier production function indicated that the industries have a mean efficiency measure between 0.554 and 0.987 in which metal processing industries have the highest mean efficiency while apparel industries have the lowest. In addition, iteration is performed by Newton's iteration convergence procedure with the OLS consistent estimates as the initial estimates. To compare with the maximum likelihood estimates the results of OLS inter-firm Cobb-Douglas estimates are also presented. The results of both procedures, while similar, possess some important differences. As expected, on the stochastic frontier the intercept term, indicating the level of technical efficiency is greater than in the OLS 'average' function.

Page (1980) examined the extent of technical and price inefficiency in Ghana's manufacturing industries after selecting three industries. All the three industries exhibit relatively high levels of average efficiency. Actual output for the representative firm is more than 70% of predicted output using linear programming production function and more than 90% of predicted output using the residuals of the OLS estimates. According to the study these high levels of efficiency probably reflect both the age and structure of the individual industries.

Pit and Lee (1980) measured technical efficiency and source of technical inefficiency for fifty Indonesian weaving industries using log linear Cobb-Douglas stochastic production model for the periods 1972, 1973 and 1975. After running regression, it was found that larger firms are more efficient than smaller firms, younger firms were more efficient than older firms and domestically owned firms were more efficient than foreign owned firms.

Anderson and Frantz (1985) estimated a production frontier using linear programming to measure technical efficiency and sources of technical inefficiency among Mexican Apparel Assembly Plants. The result indicated that the average efficiency ratio is only 0.47, which suggests the existence of X-inefficiency. Factors such as structural environment work environment, labour-force flows, administrative-control factors, and monetary-payment plans are found to affect significantly the technical inefficiency among the different firms.

Green and Mayes (1991) examined technical inefficiency of the manufacturing industry in the UK based on data for 19,023 establishments in 151 industries. They fitted a translog stochastic frontier production function by decomposing the residual in two components; one measuring inefficiency and the other unobservable random factors. The principal finding was that technical inefficiency is found across a wide range of industries. Even the industries that show the greatest international competitiveness do not necessarily have below average spreads of inefficiency with them.

Jaforullah (1996) tried to investigate the technical inefficiencies of some manufacturing industries in Bangladesh. A cross-sectional data for 19 four-digit manufacturing industries is used to estimate their technical efficiencies. They employed two variants of Cobb-Douglas production function, homogenous and constant returns to scale to represent the production frontiers of the industries. Three alternative distributions were used to model the random inefficiency term: half normal, truncated normal and exponential. It was found that there is a considerable scope for the industries to increase their technical efficiencies since their efficiencies range from only 29.2 % to 86.8 %.

Nasraollah (1997) asked whether there is any difference in technical efficiency between private and public firms and the relationship between technical efficiency and size in his study on 250 textile companies in Iran, for the period 1992. A non-parametric mathematical programming (DEA) approach to frontier production function has been used and he found that most of the enterprises operated at the efficiency level. Public enterprises were found to be inefficient compared to private firms and there existed a negative relationship between number of employees (labour) and technical efficiency indicating that the smaller firms were more efficient than large firms.

Lundvall and Battese (1999) did a study on firm size, age and efficiency for Kenyan manufacturing firms by applying translog stochastic frontier production function for unbalanced panel of 235

Kenyan manufacturing firms in the food, wood, textile and metal sectors separately. They investigated whether technical efficiency is related to age and size. It was found that firm size has a positive and significant effect in wood and textile sectors and age is significant only in textile sector.

Karunarante (2001) analyzed empirically the technical efficiency reaped by Australian manufacturing industries following the implementation of microeconomic reforms over the past three decades. The technical efficiency scores have been estimated for the manufacturing industries using a combined stochastic production frontier inefficiency model that is free from simultaneity bias. A maximum likelihood technique is used to estimate the model parameters using panel data set covering a cross-section of 8 industries spanning a time-series of 26 years (1969-1995). Generalized likelihood ratio tests rejected the null hypothesis that trade liberalization and technology transfer had no significant impact on effective rate of assistance and technical efficiency and technology proxies such as intra-industry trade and capital deepening are negatively correlated during the study period.

Sonderbom & Teal (2002) investigated both technical and allocative inefficiency in Ghana's manufacturing industries. The study used panel data collected in face-to-face interview with firm's management from 1991 to 1997. They reached a conclusion that technical inefficiency is not lower in firms with foreign ownership or older firms and its dispersion across firms is similar to that was found in other economies. They also found that firm age does not significantly affect the efficiency of firms. In addition, they observed that large firms face far higher relative labor costs than small firms.

Assefa and Matambalya (2002) have examined the level of technical efficiency of small and medium enterprises in Tanzania for 148 sampled enterprises. They used a cross sectional data for the period 1999/ 2000 and they estimated a Cobb-Douglas Production function using maximum likelihood technique to measure technical efficiency. The findings indicate that high levels of technical inefficiency, which reduce their potential output levels significantly, characterize the Tanzanian small and medium enterprises. Assisting these firms to improve their technical efficiency through adequate supply of inputs, markets and credit facilities and undertaking extensive infrastructural development and training are suggested as important measures to alleviate the problem.

Njikam (2003) employed a single stochastic production function to estimate the firm-level technical efficiency of Cameroon's manufacturing industries and he also investigated whether the trade reform generates gain to manufacturing firm level technical efficiency. He pooled the pre and post reform data and found that average technical efficiency increased in six of the eight sectors following trade reform. The post trade reform firm- level technical efficiencies increased on average at annual rate of 1.39%, while prior to trade reform they decreased on average at the annual rate of 0.76%. Before the trade reform, the restricted trade regime coupled with macroeconomic and political instability negatively affected firm-level technical efficiency. Post-trade reform potential determinants of firm's technical efficiencies include export share and import penetration rate.

Ram Mohan and Ray (2003) examined the technical efficiency in public and private sectors in India during the post-reform years. The study compares the performance of state owned enterprises with those of private sector firms in respect of technical efficiency. The comparison is made in different sectors over the period 1991-92 to 1998-99 using a balanced panel data. No conclusive evidence of superior performance on the part of the private sector is found after employing data envelopment analysis to measure the technical efficiency.

Roudaut (2003) estimated a stochastic frontier in a panel of manufacturing industries in
Cote d'Ivoire to investigate the impact of the business environment on technical efficiency levels for the years 1994 and 1995. He found that informal firms are less technically efficient but their managerial performances are close to those of formal firms. A positive relation between size and efficiency is also found.

Mukherjee and Ray (2004) have also conducted a study which analyzes state level data from the manufacturing sector in India for the period 1986-87 to 1999-00 to study the efficiency dynamics of a 'typical' firm in the pre and post reform years. Using non-parametric method of Data Envelopment Analysis they utilize super- efficiency models to rank the states interms of their performance and investigate the dynamics of the efficiency ranking overtime. They found no major change in the efficiency of states after the reforms. Nor is there any evidence of convergence in the distribution of efficiency in the post-reform period.

3.2.2 Empirical Literature from Ethiopia

To the best of our Knowledge, much studies have not been undertaken regarding the technical efficiency of manufacturing industries in Ethiopia. However, there are some studies which are conducted by different people in this area and we have tried to review them although it might not be exhaustive.

Alemu (1992) investigated the relationship between efficiency of Ethiopian public manufacturing enterprises and the policy environment to which they are subjected for the period 1983 and 1988 by using allocative and technical (X)efficiency. It was found that there was a divergence between economic and financial profitability due to government pricing and trade policy. Two groups that discouraged technical efficiency were identified and these are the organizational structure and the incentive system. It was concluded that: first, the incentive system should be linked with real measure of performance, second rehabilitation and restructuring of marginally inefficient enterprise is necessary to take them efficient and third avoiding discrimination in terms of policy among public enterprises and special treatment to industrial public enterprise like subsidized interest rate.

Admit (1998) analyzed the trend and extent of total factor productivity the Ethiopian manufacturing sector and found that the sector as a whole exhibits negative total factor productivity growth. However, it was also realized that there were sub-sector differences: sectors that are light and had long production experience recorded positive total factor productivity growth, while others did not. The result also indicated that the private sector, in general, appeared to be more efficient in resource use than the public ones.

Rebeka (2001) examined whether there is technical efficiency gain due to privatization by taking a panel data for 25 privatized large and medium scale manufacturing industries covering a period of seven years (1992/93-1998/99) using stochastic frontier model. The impact of privatization on technical efficiency is then analyzed and it is found that for food processing sector, there has been a positive effect of privatization in improving technical efficiency where as for beverage, textile and leather industries the effect of privatization is found to be negative on technical efficiency. For non-metal and wood, printing and chemical industries, it was found that there is no significant impact of privatization. The results suggest that for sectors with competitive behavior there has been a positive effect of privatization in technical efficiency while for sectors with non-competitive behavior privatization is found to have a negative impact on technical efficiency.

Worku (2003) estimated a stochastic frontier production functions for two groups of firms: tanneries and leather processing industries to check whether or not there are technical efficiency differences among these industries for the period of 1996-1999. Mean technical efficiency of tanneries was about 83 percent. Contrary to the widely held view, exporting tanneries were not more efficient except that they employed capital intensive technologies, which might have allowed them to produce good quality products. Large scale firms were more efficient perhaps because of higher scale economies. Overall, technical efficiency was declining at an increasing rate in tanning industry, and shortage of raw materials, use of absolute machineries and failure to effectively utilize the prevailing technology are the most prevalent constraints.

Overall, most of the empirical studies reveal that the manufacturing industries in different countries are characterized by technical inefficiencies and these inefficiencies are attributed to different firm specific characteristics depending on the production behavior of each manufacturing industries.

CHAPTER FOUR
DATA AND METHODOLOGY

4.1 Source of Data and Coverage

The study uses firm level data on large and medium scale industries and the main source of data is the annual survey of large and medium scale manufacturing industries conducted by Central Statistical Authority (CSA). Both raw data and data from various statistical bulletins published by the authority are used in the study. Since the raw data set is in terms of value at current price, it is converted to constant price by deflating using appropriate deflators. An implicit sectoral deflator is used to deflate gross value of production, wages and salaries and industrial cost, while investment deflator is used to deflate capital (or fixed assets). The study covers those large and medium scale manufacturing industries at national level during the survey period 1998-2002.

In this study among the manufacturing industries that are categorized under different industrial groups, nine industrial groups are considered in the study which constitute about 89 percent of the total manufacturing industries in country. These industries together employed around 94 percent of the workers in the manufacturing sector. In terms of gross value of production, they produce around 88 percent of the total production in the sector. Furthermore, 99 percent of the capital of the sector is also employed in these industries (CSA, 2003). The grouping of the industries is based on two-digit ISIC (International Standard Industrial Classification) although the survey report of CSA follows both the two-digit and four-digit classifications.

The main criteria employed in delineating divisions and groups (the two-digit and four digit categories) include the characteristics of the activities producing units which are strategic in determining the degree of the units and certain relationships in an economy. The major aspects of the activities considered are the character of the goods and services produced, the uses to which the goods and services are put, the inputs, the process and the technology of production. In delineating the divisions of ISIC, attention was also given to the range of kinds of activities frequently carried out under the same ownership or capital control and to potential differences in scale and organization that exist between enterprises. Additional criteria used in establishing divisions and groups were the pattern of categories at various levels of classification in national classifications (UN, 1990).

Based on this United Nations criteria the Ethiopian large and medium manufacturing industries are divided into different industrial groups of which 9 of them are included in this study as stated earlier. These include food processing, beverages, textile, leather, wood & furniture, paper & printing, chemical, rubber & plastics and non-metallic mineral industries. The selection of firms within each sub-sector is based on balanced panel data requirement such that those firms with complete observation and which are operational in the study period are covered.

As shown in table 4.1 below among the industrial groups in the study 84 food processing industries are included which constitute about 23 percent of the total manufacturing industries in the study. 58 wood & furniture manufacturing industries are also included in the study which make 16 percent of the total manufacturing in the study. Around 12 percent of the total manufacturing industries are the 43 non-metallic mineral industries followed by 39 paper & printing industries constitute around 11 percent of the manufacturing industries. The textile industries included in the study are similar to those of the paper & printing industries whereby 38 industries are included which also make around 11 percent of the total manufacturing industries in the study.

Table 4.1 Number of Firms Covered in the Study within Each Industrial Group

	Industrial Group	№ of Firms	Percent
1	Food Processing	84	23.27
2	Beverages	16	4.43
3	Textile	38	10.53
4	Leather	30	8.31
5	Wood and Furniture	58	16.07
6	Paper and Printing	39	10.80
7	Chemicals	32	8.86
8	Rubber and Plastics	21	5.82
9	Non-Metallic Minerals	43	11.91
	Total	361	100.00

Source: Author's Computation

Among the total 361 manufacturing industries 32 of them are chemical industries which accounts for 9 percent of the total manufacturing followed by 30 leather industries which constitute around 8 percent of the total manufacturing industries. The rest of the manufacturing industries that are included in study are rubber & plastics and beverage industries. As shown in the table 4.1, these industries are relatively small in their number whereby the industries are 37 in total and they together constitute only 10 percent of the total manufacturing industries in the study.

4.2 Descriptive Analysis of the data

The summary statistics for the variables included in the frontier production function and in the inefficiency model are presented in table 4.2 below.

Table 4.2 Summary Statistics on the Variables included in the Study for the Panel

Food Processing

Variables	Minimum	Maximum	Mean	Std. Deviation
Gross Value of Production	55,182	310,000,000	11,000,000	31,296,065
Capital	133	57,000,000	4,547,746	9,267,157
Labour	2905	19,000,000	687,246.30	2,061,819
Industrial Cost	25,400	75,000,000	6,112,373	11,334,532
Size	10	1910	104	218
Age	7	61	19	11
Incentive	0	13,000,000	216,242	1,022,129

Beverages

Variables	Minimum	Maximum	Mean	Std. Deviation
Gross Value of Production	407,902	140,000,000	48,000,000	38,618,735
Capital	285,626	82,000,000	18,000,000	19,476,716
Labour	50,320	7,887,528	2,599,615	2,095,736
Industrial Cost	233,957	46,000,000	14,000,000	12,579,221
Size	23	752	328	213
Age	9	26	14	4
Incentive	0	4,020,354	911,507	1,012,275

Textile

Variables	Minimum	Maximum	Mean	Std. Deviation
Gross Value of Production	101,409	69,000,000	14,000,000	18,545,868
Capital	1,768	80,000,000	7,951,385	14,656,286
Labour	33,080	14,000,000	2,305,826	3,135,480
Industrial Cost	32,129	43,000,000	8,240,607	11,294,137
Size	12	3,226	518	686
Age	7	48	24	11
Incentive	0	2,436,049	337,170	495,154

Cont'd

Table 4.2 Cont'd

Leather

Variables	Minimum	Maximum	Mean	Std. Deviation
Gross Value of Production	198,000	170,000,000	17,000,000	25,846,541
Capital	199,678	63,000,000	7,302,255	9,401,686
Labour	18,000	7,483,730	1,086,931	1,662,213
Industrial Cost	126,584	130,000,000	12,000,000	18,014,927
Size	10	832	169	221
Age	7	54	21	12
Incentive	0	13,000,000	395,133	1,426,076

Wood and Furniture

Variables	Minimum	Maximum	Mean	Std. Deviation
Gross Value of Production	33,539	23,000,000	1,631,235	3,394,425
Capital	433	9,670	800,934	1,761,355
Labour	2520	2,018,021	265,643	436,352
Industrial Cost	8189	9,883,091	768,188	1,592,802
Size	10	206	45	50
Age	7	87	32	21
Incentive	0	706,158	40,846	115,203

Paper and Printing

Variables	Minimum	Maximum	Mean	Std. Deviation
Gross Value of Production	138,138	62,000,000	7,026,893	11,389,593
Capital	18,230	13,000,000	2,193,585	2,676,056
Labour	39,226	5,718,907	779,451	1,208,438
Industrial Cost	8,139	25,000,000	3,236,318	4,965,848
Size	11	585	101	139
Age	7	52	22	11
Incentive	0	2,629,000	137,527	325,710

Cont'd

Table 4.2 Cont'd

Chemical

Variables	Minimum	Maximum	Mean	Std. Deviation
Gross Value of Production	202,501	77,000,000	12,000,000	13,618,165
Capital	55,106	79,000,000	1,871,262	14,714,221
Labour	19,181	3,033,772	598,526	607,761
Industrial Cost	144,184	44,000,000	7,189,733	8,444,877
Size	11	414	94	91
Age	7	48	21	11
Incentive	0	1,912,059	141,714	231,043

Rubber and Plastics

Variables	Minimum	Maximum	Mean	Std. Deviation
Gross Value of Production	270,092	43,000,000	8,676,471	10,931,300
Capital	194,368	29,000,000	5,577,477	5,637,355
Labour	27,308	3,237,811	558,655	704,405
Industrial Cost	84,930	24,000,000	4,926,886	6,093,688
Size	12	902	110	152
Age	7	63	23	15
Incentive	0	2,263,058	170,322	390,543

Non-Metallic Minerals

Variables	Minimum	Maximum	Mean	Std. Deviation
Gross Value of Production	37,524	88,000,000	5,045,890	12,116,667
Capital	4	150,000,000	5,286,642	20,152,652
Labour	2,400	4,530,382	457,772	859,198
Industrial Cost	16,541	44,000,000	2,601,031	6,567,620
Size	10	575	73	112
Age	7	55	19	12
Incentive	0	3,741,899	145,936	506,841

Source: Author's Computation

Note - See section 4.3 for the definition of the variables.

It is revealed on table 4.2 that the average gross value of production is the highest in beverage industries which was around birr 48 million and the lowest in wood & furniture industries which was around birr 1.6 million. The standard deviation for gross value of production is also higher for beverage industries which indicates a higher variation in terms of production within the sub-sector. On the other hand, wood & furniture industries have the lowest deviation from their mean production which implies the relatively small variation among wood and furniture industries in terms of gross value of production.

Since the beverage industry is at the top in terms of average gross value of production, it also employed a relatively huge amount of average capital, nearly 18 million, as compared to other industrial groups. A smaller amount of capital is employed in wood and furniture industries which is expected since their gross value of production is smaller as compared to others. A relatively small average labour cost is also observed in wood & furniture industries. Even though some sub-sectors like chemical industries have higher gross value of production and employ a huge amount capital, they incurred a relatively small amount of average labour cost because of the capital-intensive nature of their production technology.

In terms of size of the industries, the textile industry is characterized by its high employment rate which is highly related to the specific nature of the industry. Among the firms in this sub-sector, the maximum amount of labour employed is around 3226 persons which is by far larger than any of the sub-sectors included in the study. In sub-sectors like food processing, leather and wood & furniture, the minimum number of labour employed is around 10 persons which depicts a large variation within each sub-sector in terms of the number of persons employed.

The average amount of industrial cost incurred is the highest in beverage industries and the lowest in wood & furniture industries. Even though beverage industries incurred the highest mean industrial cost, the variation among the firms is much bigger in leather industries. On the other hand, the variation in terms of industrial cost among firms is found to be the lowest in wood and furniture industries.

When we see the age of firms in each sub-sector, the average age is found to be between 14 and 32 years. This depicts that the emergence of manufacturing industries in Ethiopia is a new phenomenon. The firms in wood & furniture industries are relatively older while those firms in the beverage industry are relatively new. Most of the firms in the textile, leather, paper & printing, chemical and rubber & plastics sub-sectors are established during the past two decades although some of them are established during 1960's. This is highly related with the relatively conducive environment created for the establishment of new manufacturing industries after the change of government in 1991.

Table 4.2 also shows that the amount of incentive paid for workers in the form of commissions, bonuses, professional and hardship allowances, etc differs significantly within and across the sub-sectors. In all sub-sectors the minimum amount of incentive paid is zero while the maximum is around birr 13million in food processing and leather industries. This high variation is also expressed in the average amount of incentive paid in each sub-sector. For instance, the average amount of incentive paid for the workers in the beverage industry is around birr 911,507 whereas in wood and furniture industries the average amount is only birr 40,846 annually.

4.3 Methodology

As mentioned in section 3.1.3 of the literature review part, the panel data model developed by Battese and Coelli (1995) is used for measuring the technical efficiency of firms using a stochastic frontier production function. Provided the inefficiency effects are stochastic, the model also permits the estimation of both technical change in the stochastic frontier and time-varying technical inefficiencies. Moreover, the parameters of the stochastic frontier and the inefficiency models can be estimated simultaneously, given appropriate distributional assumptions associated with cross-sectional data on the firms included in the study.

They formulated the stochastic frontier production model as follows:

$$Y_{it} = f(X_{it} : \beta) + E_{it} \quad \text{...} \quad (18)$$

Where Y_{it} denotes the production at t-th observation $(t = 1,2,...,5)$ for the i-th firm $(i = 1,2,.., N)$, X_{it} is $(1XK)$vector of values of known functions of inputs of production and other explanatory variables associated with the i-th firm at the t-th observation, β is a $(KX1)$ vector of unknown parameters to be estimated, 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 the above model $f(X_{it} : \beta)$ represents a certain production technology which could be specified as Cobb-Douglas (C-D), constant elasticity of substitution (CES), translog, etc. Nowadays, flexible functional forms such as the translog form are usually recommended rather than the restrictive Cobb-Douglas form. Furthermore, the translog function is the only one of the flexible functional form which is readily used for direct estimation of the production function.

In fact, this study will not merely focus on the explanation of the pros and cons of the two functional forms given above. Rather the likelihood ratio test[4] is performed to identify which production technology will better represent the technology of each of the industrial group included in the study[5]. Therefore, the empirical models that we used for estimation of technical efficiency of manufacturing industries in the study are both C-D and translog frontier production functions which are given as follows:

$$\ln Y_{it} = \alpha_0 + \sum_{i=1}^{5} \alpha_i \ln X_{it} + E_{it} \quad \text{...(19)}$$

$$\ln Y_{it} = \alpha_0 + \sum_{i=1}^{5} \alpha_i \ln X_{it} + 1/2 \sum \sum_{j} \beta_{ij} \ln X_{jt} + E_{it} \quad \text{...(20)}$$

Where Y_{it} is Gross Value of Production (in Birr) for the i-th firm, $(i = 1,2,.., N)$, in the t-th observation $(t = 1,2,...,5)$; X_{it} and X_{jt} are vectors of inputs such as capital (in Birr), labour in terms of wages and salaries paid, and industrial cost (in Birr) for the i-th firm in the t-th year of observation; α's and β_{ij}'s are unknown parameters to be estimated; and E_{it} is as defined in (18).

Given C-D and translog frontier production functions and the assumptions of each of the models, prediction of the technical efficiency of i-th firm at the t-th observation is based on the conditional expectation of U_{it} which is given by:

$$TE_{it} = \exp(-U_{it}) \quad \text{...(21)}$$

---

[4] The likelihood ratio statistic, λ, is defined as follows:

$$\lambda = -2\ln[L(H_0)/L(H_1)] = 2[\ln L(H_1) - \ln L(H_0)]$$

Where $L(H_0)$ and $L(H_1)$ are the maximum values of the likelihood function over the null and alternative hypotheses, H_0 and H_1 respectively. If the null hypothesis that defines the constrained parameter space is true, then λ is asymptotically distributed as χ^2 or as mixed χ^2 with K degrees of freedom where K is the number of restrictions imposed by the null hypothesis. The restrictions imposed by the null hypothesis are rejected when λ exceeds the critical value (Samad and Patway, 2003).

[5] See chapter 5 for the test whether C-D or translog production function better represents the technology of each industrial group in the study.

Where U_{it} s are non-negative random variables, which are assumed to be independently distributed with mean μ_{it} and variance δ^2.

To determine why some industries are less efficient than others, the technical inefficiency model for each industrial group is specified as follows:

$$\mu_{it} = \delta_0 + \delta_1 SIZ_{it} + \delta_2 SIZSQR_{it} + \delta_3 AGE_{it} + \delta_4 AGESQR_{it} + \delta_5 LOCT_{it} + \delta_6 OWNR_{it}$$
$$\delta_7 INCT_{it} + \delta_8 TIM_{it} \quad \ldots\ldots \quad (22)$$

Where μ_{it} is as defined above, δ_i's unknown parameters to estimated and the variables $(SIZ, AGE, \ldots, TIM)$ are as defined in section 4.4.

The method of maximum likelihood is used for simultaneous estimation of the parameters of the stochastic frontier and the model for the technical inefficiency effects using the computer program, FRONTIER 4.1c, Coelli (1994). The likelihood function of the model is expressed in terms of the variance parameters, $\delta^2 = \delta_V + \delta_U^2$ and $\gamma = \frac{\delta_U^2}{\delta_V^2 + \delta_U^2}$. The parameter, γ, measures the discrepancy between the frontier attributable to technical inefficiency. It has a value between zero and one. The value of zero indicates that the non-negative random variable, U_{it}, is absent from the model while the value of one shows the absence of statistical noise or exogenous shocks from the model and hence low level of firm's production compared to the best practice (the maximum output) of the other firm that is totally a result of firm specific technical inefficiency.

4.4 Definitions of Variables

Those variables that are included in equations 19, 20, and 22 are defined as follows:

Gross Value of Production (GVP): is a combination of sales value of all products of the establishment, the net change between the beginning and end of the reference period in the value of finished goods and the value of work in progress, the value of industrial services rendered to others, the value of goods bought and resold without any transformation or processing and other receipts.

Fixed Capital (CAP): represents those assets of the establishments with a productive life of one year or more. It shows the net book value at the beginning of the reference year plus new capital expenditure minus the value of sold and disposed machineries and equipment and depreciation during the reference period.

Labour (LAB): in the frontier production function labour is proxied by the amount wages and salaries paid to the workers in each sub-sector. This is done because the heterogeneity of labour is not only in terms of biological make-up of the workers but also in terms different attributes like education and work experience. Therefore, wages and salaries are presumed to better consider such differences and better represents the extent of labour input use. This variable includes all payments in cash or in kind made to the workers during the reference year in connection with the work done for the establishments

Industrial Cost (INCT): includes the cost of raw materials, fuels, electricity and other supplies consumed and cost of industrial services rendered by other firms.

Size and Size Squared (SIZ and SIZSQR): in equation (22) size of the firm is proxied by the number of workers engaged in the reference year. Size squared is included in the model to allow for U-shaped relationship between firm size and technical efficiency in the sense that the marginal impact of increased size diminishes overtime.

Age and Age Squared (AGE and AGESQR): in the inefficiency model, firm age is included to capture the effect of experience on the technical efficiency of manufacturing industries. Like size squared, age squared is included in the model because of the strong diminishing returns in the learning-by-doing process so that the gains in technical efficiency from experience are eventually exhausted (Lundvall and Battese, 1999).

Location (LOCT): 1 if the firm is located around Addis Ababa, 0 otherwise. This variable is included in the inefficiency model to examine whether the location of a firm within each sub-sector matters in determining the technical efficiency of firms.

Ownership (OWNR): 1 if the firm is privately owned totally or partially, 0 if the firm is totally owned by the government. An inclusion of this variable will help us to consider if there is any difference on the impact of technical inefficiency due to the different types of ownership within each sub-sector.

Incentive (INCT): represents the amount of incentive paid to workers in the form of commissions, bonuses, professional and hardship allowances, food, lodging, and medical benefits, pension, life and causality insurance schemes, etc. the payment is either in cash or in kind during the reference period.

Time (TIM): Time (1, 2, 3, 4 and 5) is included in the inefficiency model to examine the effect of time on technical efficiency of firms in each sub-sector.

CHAPTER FIVE

EMPRICAL RESULTS AND DISCUSSIONS

5.1 Tests of Different Hypotheses

It is worthwhile to discuss some of the tests we carried out before we directly go to the discussion of our results. Four types of tests are undertaken and the first one is related to whether the technology of each industrial group included in the study is better represented by Cobb-Douglas or translog production functions.

Table 5.1 Hypothesis Testing on the Stochastic Frontier Cobb-Douglas and Translog Production Functions for each Industrial Group

Industrial Groups	Log-Likelihood	Value of λ	Critical Value*	Decision
$H_0 = \beta_{11} = \beta_{12} = ... = \beta_{33} = 0$				
Food Processing	-329.17	39.56	12.59	Reject H_0
Beverages	-89.23	102.42	12.59	Reject H_0
Textile	-191.30	63.62	12.59	Reject H_0
Leather	-110.91	8.78	12.59	Accept H_0
Wood & Furniture	-146.13	34.42	12.59	Reject H_0
Paper & Printing	-192.01	47.44	12.59	Reject H_0
Chemical	-100.02	-47.46	12.59	Accept H_0
Rubber & Plastics	-80.27	60.94	12.59	Reject H_0
Non-Metallic Minerals	-135.48	18.44	12.59	Reject H_0

Source: Author's Computation

* The critical values correspond to 5 percent level of significance

As shown in table 5.1, given the specification of Cobb-Douglas or translog stochastic frontier production function, the null hypothesis that the Cobb-Douglas production technology is a better representation for the firms in each sub-sector is rejected for all sub-sectors, except for leather and chemical industries. The log-likelihood ratio tests indicate that the rest seven industrial groups (i.e., food processing, beverages, textile, wood & furniture, paper & printing, rubber & plastics and non-metallic mineral industries) are better represented by the translog production technology.

Table 5.2 Hypothesis Testing on the Distribution of U_{it}

Industrial Groups	Log-Likelihood	Value of λ	Critical Value*	Decision
$H_0 : \mu = 0$				
Food Processing	-328.66	38.54	3.84	Reject H_0
Beverages	-39.86	3.68	3.84	Accept H_0
Textile	-159.85	0.72	3.84	Accept H_0
Leather	-111.35	0.88	3.84	Accept H_0
Wood & Furniture	-130.07	2.40	3.84	Accept H_0
Paper & Printing	-168.28	-0.02	3.84	Accept H_0
Chemical	-101.69	3.34	3.84	Accept H_0
Rubber & Plastics	-49.87	0.14	3.84	Accept H_0
Non-Metallic Minerals	-127.99	3.46	3.84	Accept H_0

Source: Author's Computation

* The critical values correspond to 5 percent level of significance.

Another test which checks whether the technical efficiency levels for the firms in each sub-sector are better estimated using a half normal or a truncated normal distribution of U_{it} is shown in table 5.2. The table indicates that only the technical efficiency levels for the firms in food processing industries are better estimated with the truncated normal distribution of U_{it} while the technical efficiency levels for those firms in other sub-sectors are better estimated with half normal distribution of U_{it}.

Table 5.3 Hypothesis Testing on Deciding Whether Technical Inefficiency is Absent from the Model or not

Industrial Groups	Log-Likelihood	Value of λ	Critical Value*	Decision
$H_0 : \gamma = \delta_0 = ... = \delta_8 = 0$				
Food Processing	-361.86	104.94	18.31	Reject H_0
Beverages	-82.45	85.18	16.92	Reject H_0
Textile	-190.51	61.32	16.92	Reject H_0
Leather	-150.37	78.04	16.92	Reject H_0
Wood & Furniture	-203.60	147.06	16.92	Reject H_0
Paper & Printing	-180.98	25.40	16.92	Reject H_0
Chemical	-143.41	83.44	16.92	Reject H_0
Rubber & Plastics	-59.83	19.92	16.92	Reject H_0
Non-Metallic Minerals	-147.94	39.90	16.92	Reject H_0

Source: Author's Computation

* The critical values correspond to 5 percent level of significance

The null hypothesis that technical inefficiency in each sub-sector is absent from the model is also tested given either Cobb-Douglas or translog stochastic production function. The log-likelihood ratio tests shown in table 5.3 for each sub-sector indicate that the null hypothesis that technical inefficiency is absent is rejected for all the sub-sectors. This result suggests the existence of technical inefficiency among the firms in Ethiopian manufacturing sector and thus the inappropriateness of the average production function which assumes all the firms are fully technically efficient.

Table 5.4 Hypothesis Testing on the Joint Significance of the Explanatory Variables Included in the Inefficiency Model

Industrial Groups	Log-Likelihood	Value of	Critical Value*	Decision
$H_0 = \delta_1 = ... = \delta_8 = 0$				
Food Processing	-355.27	91.76	15.51	Reject H_0
Beverages	-64.81	49.90	15.51	Reject H_0
Textile	-189.24	29.39	15.51	Reject H_0
Leather	-140.26	57.82	15.51	Reject H_0
Wood & Furniture	-155.59	51.04	15.51	Reject H_0
Paper & Printing	-180.76	25.16	15.51	Reject H_0
Chemical	-128.80	54.22	15.51	Reject H_0
Rubber & Plastics	-59.48	19.22	15.51	Reject H_0
Non-Metallic Minerals	-140.99	26.00	15.51	Reject H_0

Source: Author's Computation

* The critical values correspond to 5 percent level of significance

Finally, as shown in table 5.4 the null hypothesis that the inefficiency effects are not a function of the explanatory variables or factors which are attributable to the technical inefficiency existing among the Ethiopian manufacturing industries is rejected for all sub-sectors confirming that the joint effect of these variables on technical inefficiency is found to be statistically significant.

5.2 Production Function

As opposed to other production function models efficiency studies concentrate on the specification of the error term for prediction of technical efficiency while the estimation of elasticity as characteristics of production process is only secondary interest. Due to this, the maximum likelihood estimates of the coefficients of the production function are not of immediate interest to this study also. Therefore, we tried to give some explanations to the coefficients of the variables for both the Cobb-Douglas and translog stochastic production functions.

For those sub-sectors, i.e. leather and chemical industries, where the production technology is represented by Cobb-Douglas production function the relationship between the traditional input variables and the level of output turned out to have expected signs. However, the parameter estimates of all the production inputs are found to be statistically significant at 5 percent significance level only for leather industries whereas in chemical industries it was only industrial cost that is found to be significantly affecting the level of production. The other two input variables, capital & labour, are not statistically significant at the conventional 5 and 10 percent significance levels. On the other hand, in those sub-sectors where the production technology is represented by the translog stochastic production frontier, most of the parameter estimates are statistically significant at both 5 and 10 percent significance levels even though some parameter estimates are not found to be significant at both significance levels. From the parameter estimates that are found to be statistically significant, some of the coefficients turned out to have unexpected relationships with the level of output.

For instance, as shown in table 5.5, in beverage industries the impact of labour on the level of output produced is found to be negative. This could be due to a large amount of labour that is employed on a relatively small amount of capital. Capital is also found to have a negative relationship with the level of production in paper & printing industries which could be as a result of old and technologically backward machineries used by the industry. In textile industries, industrial cost (or raw material) is observed to have an inverse relationship with the level of output produced. The possible explanation for this result could be an over commitment of raw materials to the production of different types of products in the industry.

In flexible functional forms, like translog production function, this kind of unexpected results could be observed also due to the multicollinearity problems often associated with such flexible functional forms. In a production function analysis, correlation between some of the explanatory variables is expected. Collinearity among economic variables is an inherent and age-old problem leading to problems of multicollinrearity. Some have, therefore, suggested that multicollinearity is not necessarily a problem unless it is very high (Gujarati, 1995). In efficiency estimation, since the primary interest is to predict the degree of technical efficiency, some degree of multicollinearity can be tolerable.

Table 5.5 Maximum Likelihood Estimates for the Parameter of the Cobb-Douglas or Translog Stochastic Frontier Production Functions for the Nine Industrial Groups

Variable	**Food Processing**	**Beverages**	**Textile**	**Leather**	**Wood and Furniture**
Frontier Function					
Constant	1.87**	-5.95*	11.07*	0.67	2.60*
	(0.95)	(2.18)	(1.41)	(0.47)	(0.47)
CAP	0.075	2.04*	0.80*	0.176*	0.095
	(0.10)	(0.72)	(0.14)	(0.046)	(0.06)
LAB	-0.06	-2.44*	0.925*	0.128*	0.30**
	(0.18)	(0.62)	(0.344)	(0.039)	(0.17)
INDC	0.74*	2.31*	-0.645*	0.73*	0.30**
	(0.21)	(0.51)	(0.27)	(0.039)	(0.16)
(CAP) *(CAP)	0.072	0.092**	0.0056		0.0066*
	(0.076)	(0.056)	(0.0088)	-	(0.0019)
(CAP) *(LAB)	0.0018	-0.06	-0.062*		0.0035
	(0.019)	(0.058)	(0.02)	-	(0. 015)
(CAP)*(INDC)	-0.016	-0.30*	-0.075*		-0.022**
	(0.018)	(0.04)	(0.013)	-	(0.012)
(LAB)*(LAB)	0.087*	0.18*	0.002		0.068*
	(0.019)	(0.033)	(0.024)	-	(0.023)
(LAB)*(INDC)	-0.10*	0.0074	0.096*		-0.14*
	(0.022)	(0.042)	(0.029)	-	(0.049)
(INDC)*(INDC)	0.04*	0.062*	0.057*		0.095
	(0.016)	(0.025)	(0.018)	-	(0.03)*
Inefficiency Model					
Constant	-12.31*	-	-	-	-
	(1.42)				
SIZ	0.013*	0.033*	-0.092*	-0.018*	-0.041*
	(0.0025)	(0.0088)	(0.002)	(0.0068)	(0.011)
SIZSQR	-0.00002*	-0.00004*	0.0000026*	0.000019*	0.00008*
	(0.000004)	(0.000012)	(0.0000006)	(0.000007)	(0.00003)
AGE	0.57*	-1.49*	0.12*	-0.20*	-0.063*
	(0.082)	(0.36)	(0.047)	(0.073)	(0.022)
AGESQR	-0.0069*	0.057*	-0.055*	0.014*	0.0005*
	(0.001)	(0.019)	(0.002)	(0.0042)	(0.00024)
LOCT	-0.026	0.039	-1.26*	1.15	0.69*
	(0.21)	(0.65)	(0.44)	(0.80)	(0.22)
OWNR	0.26	-4.29*	-0.16	-2.12**	-0.25
	(0.25)	(1.31)	(0.48)	(1.09)	(0.24)
INCT	-0.57*	-2.89**	-0.83*	-1.04*	0.00019
	(0.08)	(1.46)	(0.27)	(0.40)	(0.00018)
TIM	0.76*	1.01*	-0.32*	0.57*	0.28*
	(0.093)	(0.327)	(0.11)	(0.23)	(0.076)
Variance Parameters					
$\delta^2 = \delta_u^2 + \delta_v^2$	1.69*	1.59*	1.14*	1.12*	0.52*
	(0.156)	(0.27)	(0.15)	(0.26)	(0.078)
$\gamma = \delta_u^2 / (\delta_u^2 + \delta_v^2)$	0.92*	0.96*	0.92*	0.87*	0.82*
	(0.012)	(0.0094)	(0.03)	(0.04)	(0.04)
Log-Likelihood	-309.39	-39.86	-159.85	-111.35	-130.07
Mean TE	0.76	0.76	0.62	0.74	0.80
Observations	84	16	38	30	58

Cont'd

Table 5.4 Cont'd

Variable	Paper and Printing	Chemical	Rubber and Plastics	Non-Metallic Minerals
Frontier Function				
Constant	9.62*	1.40*	-1.25	1.02
	(1.72)	(0.32)	(1.09)	(0.76)
CAP	-1.04*	0.038	0.15*	0.067
	(0.30)	(0.027)	(0.053)	(0.093)
LAB	0.73**	0.052	0.18*	0.15
	(0.45)	(0.045)	(0.022)	(0.16)
INDC	0.097*	0.87	0.67	0.85*
	(0.026)	(0.04) *	(0.44)	(0.18)
(CAP) *(CAP)	0.018	-	0.035	0.0017
	(0.026)		(0.022)	(0.003)
(CAP) *(LAB)	0.052	-	0.28	0.047*
	(0.043)		(0.35)	(0.013)
(CAP)*(INDC)	0.039	-	0.56	-0.047*
	(0.041)		(0.86)	(0.014)
(LAB)*(LAB)	0.032	-	0.037	-0.027**
	(0.048)		(0.065)	(0.015)
(LAB)*(INDC)	-0.16*	-	-0.12*	0.0014
	(0.044)		(0.045)	(0.018)
(INDC)*(INDC)	-0.35	-	-0.30*	0.018
	(0.37)		(0.045)	(0.014)
Inefficiency Model				
Constant	-	-	-	-
SIZ	-0.044*	-0.069*	0.0042*	-0.014*
	(0.019)	(0.017)	(0.0016)	(0.0044)
SIZSQR	0.000072*	0.00014*	-0.000003	0.00003*
	(0.000032)	(0.000039)	(0.000002)	(0.000008)
AGE	-0.097**	0.29*	0.05	-0.17*
	(0.057)	(0.094)	(0.039)	(0.052)
AGESQR	0.0052	0.0057	-0.0012**	0.0011
	(0.0038)	(0.004)	(0.00068)	(0.0008)
LOCT	0.04	-3.94*	-0.47**	-0.29
	(0.12)	(0.88)	(0.25)	(0.34)
OWNR	-1.23**	-1.55*	-0.29	0.34
	(0.69)	(0.70)	(0.31)	(0.31)
INCT	-0.39	-1.24*	-0.00017**	0.19*
	(0.38)	(0.43)	(0.00009)	(0.067)
TIM	0.185**	-0.45*	0.11**	0.11
	(0.115)	(0.18)	(0.063)	(0.097)
Variance Parameters				
$\delta^2 = \delta_u^2 + \delta_v^2$	0.83*	1.86*	0.20*	0.84*
	(0.21)	(0.32)	(0.06)	(0.11)
$\gamma = \delta_u^2 / (\delta_u^2 + \delta_v^2)$	0.72*	0.95*	0.48*	0.87*
	(0.093)	(0.014)	(0.16)	(0.027)
Log-Likelihood	-168.28	-101.69	-49.87	-127.99
Mean TE	0.75	0.74	0.80	0.77
Observations	39	32	21	43

Notes - Source: Author's Computation

- Figures in Parentheses are standard errors.
- Significance levels of 5 and 10 percents are indicated by * and **, respectively.

5.3 Prediction of Firm Level Technical Efficiencies

For all sub-sectors, the results of maximum likelihood estimates as shown in table 5.5 indicate that, there are significant inefficiency effects associated with production, which is in line with the test presented in table 5.3. This is evident from the estimates of the discrepancy parameter γ which are 0.92, 0.96, 0.92, 0.87, 0.82, 0.72, 0.95, 0.48 and 0.87 for food processing, beverages, textile, leather, wood & furniture, paper & printing, chemical, rubber & plastics and non-metallic mineral industries. This means that around 92, 96, 92, 87, 82, 72, 95, 48, and 87 percent of the discrepancies between the observed output and the frontier output levels are due to technical inefficiency. This implies that Ethiopian manufacturing industries are characterized by inefficient way of production. Moreover, the very high value of γ indicates that much of the shortfall of observed output from the frontier output is due to technical inefficiency, i.e. due to those factors within the control of the firm rather than statistical 'noise' or external 'shocks'. Furthermore, the significance of γ in the inefficiency model justifies the use of stochastic frontier model and the associated method of maximum likelihood estimation.

Once it is proved that there exists a significant level of technical inefficiency among Ethiopian manufacturing industries, prediction of the level of technical efficiency for the firms in each sub-sector is found to be very important. Constructing an index of technical efficiency provides a good picture of the extent of variation in its level among firms which will have important implications for the industrial policy formulation in the country. Based on this, the frequency distribution of the predicted technical efficiencies for each industrial group or sub-sector is discussed with the help of tables 5.6 to 5.14.

As shown in table 5.13 below the predicted technical efficiency values for food processing industries vary from 14 to 94, 51 to 95, 6 to 95, 2 to 88 and 2 to 87 percent in 1998, 1999, 2000, 2001 and 2002, respectively. This indicates the existence of high variation in technical efficiency of firms in the sub-sector. It is also observed that the variation is increasing during the study period (see also **Appendix I**).

During the early periods of the study, some firms were able to operate at an efficiency level of 90 percent and above while at the end of the study period any of the firms in the industry fail to score this efficiency level. The number of firms which were operating at efficiency level of 40 percent and below have been increasing during the study period. This shows the increase in technical inefficiency of firms under the existing level of inputs and technology environment.

Table 5.6 Frequency Distribution of Technical Efficiencies in **Food Processing** Industries

	Percent of Firms (%)				
Efficiency Levels	**1998**	**1999**	**2000**	**2001**	**2002**
≤ 0.40	1.20	0.0	7.10	3.60	9.50
0.40-0.50	1.20	0.0	0.0	2.40	3.60
0.51-0.60	1.20	2.40	3.6	3.60	2.40
0.61-0.70	1.20	1.2	3.6	10.70	11.90
0.71-0.80	36.90	32.10	44.0	52.4	64.30
0.81-0.90	56.00	60.70	38.1	27.4	8.30
≥ 0.91	2.40	3.60	3.60	0.0	0.0
Mean	0.80	0.81	0.74	0.74	0.68
Maximum	0.94	0.95	0.95	0.88	0.87
Minimum	0.14	0.51	0.06	0.02	0.02
Std. Deviation	0.10	0.06	0.16	0.14	0.18
Number of Firms	84	84	84	84	84

Source: Author's Computation

The sample averages of technical efficiencies for firms in food processing industries are found to be 80, 81, 74, 74 and 68 percent in 1998, 1999, 2000, 2001 and 2002, respectively. These figures also indicate that average technical efficiency of firms relative to the frontier level has been decreasing during the study period. A panel mean technical efficiency of 76 percent for food processing industries indicates that there exists a 24 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.

The predicted technical efficiency values for beverage industries vary from 40 to 76, 49 to 93, 5 to 89, 1 to 92 and 48 to 95 percent in 1998, 1999, 2000, 2001 and 2002, respectively. Table 5.7 shows a higher variation is observed in 2001 and low variation is observed in 1999 (see also **Appendix I**). In 1999 and 2002 there was no firm which was operating at an efficiency level of 40 percent and below while 6.3 percent of the firms in both years were operating at an efficiency level of 91 percent and above. The converse is true in 1998 and 2000 where no firm has scored over 90 percent level of efficiency while 6.3 percent of the firms in beverage industry scored 40 percent and below in both years.

Table 5.7 Frequency Distribution of Technical Efficiencies in **Beverage** Industries

	Percent of Firms (%)				
Efficiency Levels	**1998**	**1999**	**2000**	**2001**	**2002**
≤ 0.40	6.3	0.0	6.3	6.3	0.0
0.41-0.50	6.3	6.3	6.3	6.3	6.3
0.51-0.60	6.3	12.5	6.3	0.0	0.0
0.61-0.70	12.5	6.3	6.3	12.5	12.5
0.71-0.80	12.5	25.0	25.0	18.8	31.3
0.81-0.90	56.3	43.8	50.0	50.0	43.8
≥ 0.91	0.0	6.3	0.0	6.3	6.3
Mean	0.76	0.77	0.74	0.74	0.78
Maximum	0.89	0.93	0.89	0.92	0.95
Minimum	0.40	0.49	0.05	0.01	0.48
Std. Deviation	0.15	0.14	0.22	0.22	0.11
Number of Firms	16	16	16	16	16

Source: Author's Computation

The sample average technical efficiencies for beverage industries are found to be 76, 77, 74, 74 and 78 percent in 1998, 1999, 2000, 2001 and 2002, respectively. This shows that their average technical efficiencies were decreasing during the early years of the study period while it was increasing at the end of the study period. The industry was relatively highly efficient in 2002 and less efficient in 2000 and 2001. Like the food processing industries, the panel mean technical efficiency is found to be 76 percent which implies that with the existing level of production inputs and technology, those firms in the beverage industry could have improved their technical efficiency by 24 percent so that they could be able to produce at the frontier level of production.

For firms in the textile industry the variation in terms of predicted efficiencies is higher as compared to the food processing and beverage industries. For instance, the minimum variation during the study period is observed in 2002 which was around 25 percent while in both sub-sectors that are discussed earlier the maximum variation observed is lower than this figure. It was in 2000 that a maximum of 29 percent variation is observed whereby a firm with minimum efficiency score was only 2 percent while the maximum was as high as 91 percent. The variation among the firms during each year is presented in **Appendix I**.

The distribution of efficiency score for textile industries is also skewed towards the two extreme efficiency levels whereby 23.7, 26.3, 26.3, 31.6 and 18.4 percent efficiency levels are observed in 1998, 1999, 2000, 2001 and 2002, respectively in the range of 40 percent and below while 39.5, 26.3, 28.9, 34.2 and 36.8 percent efficiency levels in those years considered earlier are observed in the range between 81 and 90 percent.

Table 5.8 Frequency Distribution of Technical Efficiencies in **Textile** Industries

	Percent of Firms (%)				
Efficiency Levels	**1998**	**1999**	**2000**	**2001**	**2002**
≤ 0.40	23.7	26.3	26.3	31.6	18.4
0.41-0.50	2.6	15.3	13.2	0.0	7.9
0.51-0.60	2.6	5.3	5.3	2.6	0.0
0.61-0.70	7.9	0.0	2.6	13.2	7.9
0.71-0.80	23.7	23.7	21.1	15.8	23.7
0.81-0.90	39.5	26.3	28.9	34.2	36.8
≥ 0.91	0.0	2.6	2.6	2.6	5.3
Mean	0.64	0.60	0.58	0.62	0.68
Maximum	0.90	0.91	0.91	0.92	0.96
Minimum	0.03	0.07	0.02	0.01	0.03
Std. Deviation	0.27	0.26	0.29	0.27	0.25
Number of Firms	38	38	38	38	38

Source: Author's Computation

As shown in table 5.8, in terms of average technical efficiency of firms in textile industries, the values as compared to food processing and beverage industries are found to be lower in such away that the average technical efficiencies scores are only 64, 60, 58, 62 and 68 percent in 1998, 1999, 2000, 2001 and 2002, respectively. In 2002 where the mean technical efficiency is relatively the highest, the variation in technical efficiencies among firms is found to be the lowest. A 62 percent mean technical efficiency for the panel indicates that those firms in the textile industry are far below from the frontier output level by an amount of 38 percent which could have been improved with proper utilization of the available resources and the existing technology.

The estimates of predicted technical efficiency for firms in the leather industry vary from 67 to 95, 55 to 91, 11 to 94, 2 to 92 and 3 to 84 percent in 1998, 1999, 2000, 2001 and 2002, respectively. As shown in table 5.9 the highest variation is observed in 2001 which was around 21 percent while the lowest is observed in 1998 which was around 6 percent (see also **Appendix I**). Even though there was less variation in 1998, no firm was able to operate at an efficiency level of above 90 percent where as in the rest of the years few firms were able to operate at this efficiency level.

Table 5.9 Frequency Distribution of Technical Efficiencies in **Leather** Industries

	Percent of Firms (%)				
Efficiency Levels	**1998**	**1999**	**2000**	**2001**	**2002**
≤ 0.40	23.7	26.3	26.3	31.6	18.4
0.41-0.50	2.6	15.8	13.2	0.0	7.9
0.51-0.60	2.6	5.3	5.3	2.6	0.0
0.61-0.70	7.9	0.0	2.6	13.2	7.9
0.71-0.80	23.7	23.7	21.1	15.8	23.7
0.81-0.90	39.5	26.3	28.9	34.2	36.8
≥ 0.91	0.0	2.6	2.6	2.6	5.3
Mean	0.84	0.78	0.72	0.67	0.70
Maximum	0.95	0.91	0.94	0.92	0.84
Minimum	0.67	0.55	0.11	0.02	0.03
Std. Deviation	0.06	0.08	0.17	0.21	0.16
Number of Firms	30	30	30	30	30

Source: Author's Computation

For firms in the leather industry the mean technical efficiency levels relative to the frontier level are found to be 84, 78, 72, 67 and 70 percent in 1998, 1999, 2000, 2001 and 2002, respectively. This implies that the actual level of output on average is 16, 22, 28, 33 and 30 percent less than the frontier output level during the production year in that order. The panel mean technical efficiency is obtained to be 74 percent which indicates that 26 percent of the differences between the actual level of output and the frontier output level is resulted due to technical inefficiencies.

In wood and furniture industries the variation in terms of predicted efficiencies is lower as compared to other sub-sectors discussed earlier. The maximum amount of variation observed was around 15 percent in 2002 while a minimum amount of 8 percent variation is observed in 2002 (see also **Appendix I** for the variation among each of the firms). In this sub-sector, most firms were operating at an efficiency level of 70 percent and above while only a few number of firms operate at an efficiency level of 50 percent and below during the study period. At the beginning of the study period, non of the firms were operating at an efficiency level of 50 percent and below where as few firms were operating at this efficiency level at the end of the study period.

Table 5.10 Frequency Distribution of Technical Efficiencies *in* **Wood and Furniture** Industries

	Percent of Firms (%)				
Efficiency Levels	**1998**	**1999**	**2000**	**2001**	**2002**
≤ 0.40	0.0	1.7	1.7	3.4	1.7
0.41-0.50	0.0	0.0	1.7	1.7	3.4
0.51-0.60	3.4	3.4	5.2	5.2	5.2
0.61-0.70	1.7	6.9	5.2	10.3	8.6
0.71-0.80	20.7	25.9	20.7	24.1	36.2
0.81-0.90	46.6	44.8	46.6	36.2	29.3
≥ 0.91	27.6	17.2	19.0	19.0	15.5
Mean	0.84	0.81	0.81	0.78	0.77
Maximum	0.95	0.93	0.94	0.95	0.95
Minimum	0.56	0.37	0.40	0.38	0.03
Std. Deviation	0.08	0.11	0.11	0.13	0.15
Number of Firms	58	58	58	58	58

Source: Author's Computation

Table 5.10 shows there is a consistent decline in mean technical efficiency of wood and furniture industries whereby it declines from 84 to 81 percent in 1999, 81 to 78 percent in 2001 and 78 to 77 percent in 2002 though it remained constant between 1999 and 2000. In1998, where the mean technical efficiency of firms in wood & furniture industries was the highest, the variation in terms of efficiency scores among the firms is found to be the lowest. The converse is true in 2002 where the mean technical efficiency of firms is the lowest while the variation is found to be the highest. In this sub-sector, the panel mean technical efficiency is around 80 percent which implies that firms in wood and furniture industries could have increased their output levels by 20 percent with the available resources and without changing the existing technology.

The estimates of predicted technical efficiency values for paper and printing industries vary from 43 to 94, 8 to 91, 31 to 92, 23 to 91 and 7 to 90 in 1998, 1999, 2000, 2001 and 2002, respectively. As shown in table 5.11, the variation among firms with respect to efficiency scores ranged from 13 to 18 percent which shows that the variation across the study period is some how similar and not fluctuating over time (see also **Appendix I**). In 1998, where we observed the lowest variation, no firm was operating at an efficiency level of 40 percent and below where as in 2002, where the variation reaches at a relatively higher level, no firm could attain an efficiency level of above90 percent.

Table 5.11 Frequency Distribution of Technical Efficiencies in **Paper and Printing** Industries

	Percent of Firms (%)				
Efficiency Levels	**1998**	**1999**	**2000**	**2001**	**2002**
≤ 0.40	0.0	2.6	5.1	10.3	5.1
0.41-0.50	5.1	2.6	5.1	2.6	10.3
0.51-0.60	2.6	5.1	5.1	10.3	7.7
0.61-0.70	17.9	17.9	10.3	12.8	7.7
0.71-0.80	15.4	10.3	17.9	7.7	17.9
0.81-0.90	51.3	59.0	53.8	53.8	51.3
≥ 0.91	7.7	2.6	2.6	2.6	0.0
Mean	0.79	0.77	0.75	0.73	0.73
Maximum	0.94	0.91	0.92	0.91	0.90
Minimum	0.43	0.08	0.31	0.23	0.07
Std. Deviation	0.13	0.16	0.16	0.18	0.18
Number of Firms	39	39	39	39	39

Source: Author's Computation

During those years considered in the study, a consistent decline in mean technical efficiency is also observed in this sub-sector like wood and furniture industries. The decline was from 79 to 77 percent 1999, 77 to 75 percent in 2000 and 75 to 73 percent in 2002 though it remained constant between 2001 and 2002. In 1998, where the variation is found to be the minimum, the amount of mean technical efficiency scored is found to be the maximum. On the other hand, in 2001 and 2002 where the variation is relatively higher, the amount of mean technical efficiency scored is found to be the lowest. For paper and printing industries the panel mean technical efficiency is found to be 75 percent which implies there exists a 25 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.

In chemical industries, the level of predicted technical efficiency vary from 45 to 91, 3 to 91, 3 to 91, 3 to 95 and 46 to 91 percent during the production years of 1998, 1999, 2000, 2001 and 2002. The variation in terms of predicted technical efficiencies is found to be the highest in 2000 and 2001 while it is the lowest in 1998. Only about 3.1, 6.2, 12.5, 9.4, and 3.1 percent of the firms operated at a technical efficiency level of 50 percent & below in those years considered earlier, where as about 40.6, 40.6, 40.7, 46.9 and 50 percent of the firms operated at a technical efficiency level of above 80 percent during the production years in that order. The variation in technical efficiency at firm level is reported in **Appendix I**.

Table 5.12 Frequency Distribution of Technical Efficiencies in **Chemical** Industries

	Percent of Firms (%)				
Efficiency Levels	**1998**	**1999**	**2000**	**2001**	**2002**
≤ 0.40	0.0	3.1	12.5	6.3	0.0
0.41-0.50	3.1	3.1	0.0	3.1	3.1
0.51-0.60	3.1	0.0	3.1	6.3	0.0
0.61-0.70	25.0	25.0	21.9	9.4	15.6
0.71-0.80	28.1	28.1	21.9	28.1	31.3
0.81-0.90	37.5	37.5	34.4	37.5	46.9
≥0.91	3.1	3.1	6.3	9.4	3.1
Mean	0.76	0.74	0.71	0.73	0.78
Maximum	0.91	0.91	0.91	0.95	0.91
Minimum	0.45	0.03	0.03	0.03	0.46
Std. Deviation	0.11	0.16	0.20	0.20	0.10
Number of Firms	32	32	32	32	32

Source: Author's Computation

Table 5.12 shows the mean technical efficiency levels for firms in chemical industries are found to be 76, 74, 71, 73 and 78 percent in 1998, 1999, 2000, 2001 and 2002, respectively while the mean panel mean technical efficiency is found to be 74 percent. This shows that about 24, 26, 29, 27 and

22 percent differences between the observed and the frontier levels of output is due to technical inefficiency during the study period. Compared to other years of production, chemical industries performed less in 2000 where high variation among firms in technical efficiencies was also observed.

Predicted technical efficiency scores in rubber & plastics industries ranged from 48 to 96 percent in 1998, 59 to 96 percent in 1999 and 54 to 95 percent, 26 to 96 percent and 42 to 92 percent in 2000, 2001 and 2002, respectively. In this sub-sector, a relatively high variation in technical efficiency scores is observed in 2001 and a relatively low variation is observed in 1999(see also **Appendix I**). Table 5.13 shows during those periods where minimum variation is observed, i.e. 1999 and 2000, no firm was operating at an efficiency level of 50 percent and below where as during the period where the variation is relatively higher, i.e. 2001, few firms were operating at the efficiency level considered earlier. During the early periods of the study, the number of firms which were operating at an efficiency level of above 80 percent were around 77 percent and this number has been declining during those 5 years considered in the study and reached around 14 percent at the end of the study period.

Table 5.13 Frequency Distribution of Technical Efficiencies in **Rubber and Plastics** Industries

	Percent of Firms (%)				
Efficiency Levels	**1998**	**1999**	**2000**	**2001**	**2002**
≤ 0.40	0.0	0.0	0.0	4.8	0.0
0.41-0.50	9.5	0.0	0.0	4.8	9.5
0.51-0.60	0.0	14.3	14.3	4.8	19.0
0.61-0.70	4.8	4.8	23.8	23.8	28.6
0.71-0.80	19.0	38.1	28.6	33.3	28.6
0.81-0.90	42.9	38.1	28.6	23.8	9.5
≥ 0.91	23.8	4.8	4.8	4.8	4.8
Mean	0.81	0.77	0.73	0.71	0.67
Maximum	0.96	0.96	0.95	0.96	0.92
Minimum	0.48	0.59	0.54	0.26	0.42
Std. Deviation	0.13	0.10	0.11	0.16	0.13
Number of Firms	21	21	21	21	21

Source: Author's Computation

Similarly, the mean technical efficiencies of rubber & plastics industries has been declining during the study period whereby it was around 81 percent in 1998 and reached 77 percent in 1999 and then declined to 73 percent in 2000. The decline continued and reached 71 in percent in 2001and finally it became 67 percent in 2002. This shows that during those five years considered in the study, firms in rubber industries couldn't keep their efficiency level as it was and they were losing it overtime. An 80 percent of panel mean technical efficiency score also indicates that there is a chance for rubber industries to improve their output levels by 20 percent using the available resources and technology environment.

Technical efficiency predictions in non-metallic mineral industries vary from 20 to 90, 51 to 94, 49 to 89, 56 to 95 and 3 to 92 percent in 1998, 1999, 2000, 2001 and 2002, respectively. The variation in terms of predicted technical efficiency ranged from 9 percent in 2001 to 16 percent in 2002 during the study period. During the period of minimum variation, i.e. 2001, all firms were operating above 50 percent efficiency level whereas during the period a relatively higher variation, i.e. 2002, around 4.7 percent of the firms were operating even at an efficiency level of 40 percent and below (see also **Appendix I**). Overall, during those periods considered in the study, most firms in non-metallic mineral industries have been operating above 70 percent technical efficiency levels.

Table 5.14 Frequency Distribution of Technical Efficiencies in **Non-Metallic Mineral** Industries

	Percent of Firms (%)				
Efficiency Levels	**1998**	**1999**	**2000**	**2001**	**2002**
≤ 0.40	2.3	0.0	0.0	0.0	4.7
0.41-0.50	2.3	0.0	2.3	0.0	0.0
0.51-0.60	2.3	9.3	11.6	2.3	4.7
0.61-0.70	9.3	16.3	20.9	7.0	9.3
0.71-0.80	27.9	27.9	37.2	30.2	25.6
0.81-0.90	55.8	44.2	27.9	48.8	51.2
≥ 0.91	0	2.3	0.0	11.6	4.7
Mean	0.78	0.77	0.74	0.81	0.77
Maximum	0.90	0.94	0.89	0.95	0.92
Minimum	0.20	0.51	0.49	0.56	0.03
Std. Deviation	0.13	0.11	0.10	0.09	0.16
Number_of Firms	43	43	43	43	43

Source: Author's Computation

Looking into the mean technical efficiency scores of non-metallic mineral industries during each production year, there would have been a production gain of 22, 23, 26, 19 & 23 percent in 1998, 1999, 2000, 2001 and 2002, respectively if the firms could have produced at the 'best' practice output level. A panel mean technical efficiency of 77 percent also implies that there exists a 23 percent difference between the observed level of output and the frontier output level that could have been increased using the existing level of inputs with out changing the production technology.

Generally, the existence of technical inefficiency among the firms in those sub-sectors included in the study and the inability of most of the firms to score an efficiency level of more than 90 percent level implies that a lot can be done to expand the production level at the existing level of inputs and technology through identifying and correcting those factors which are attributable to the existing inefficiency levels.

5.4 Factors Affecting Technical Inefficiency

In section 5.3, the technical efficiency level of those manufacturing industries considered in the study is discussed based on the maximum likelihood estimation results. However, technical efficiency scores have a very limited utility for policy and management purposes if empirical studies don't investigate the sources of technical inefficiency. Therefore, it will be very important to identify those factors which are attributable to the technical inefficiencies among the firms in each sub-sector.

Even though, variations in technical efficiency arise from different practices or techniques, it was found difficult to incorporate all factors which are expected to affect the technical inefficiency of each sub-sector due to problems related with data. In this study, a total of eight variables (size and size squared, age and age squared, location of a firm, type of ownership, amount of incentive paid to workers and the year of observations involved) are included, which are assumed to influence the technical efficiency level of those firms in each of the sub-sectors.

Based on the estimation results given in table 5.5 the size of a firm is found to have a positive and significant relationship with technical efficiency for most sub-sectors, except for food processing, beverages and rubber & plastics industries. This result is supported by the most widely argued relationship between firm size and technical efficiency which states that a firm growth leads to a more efficient way of production. Lundvall and Battese (1999) explained this as a selection process in which efficient firms grow and survive, while inefficient firms stagnate or exit the industry. The other argument towards this positive relationship is that there is positive gain in efficiency due to economies of scale. A positive relationship between firm size and technical efficiency is also reported by Taye (1996), Pitt and Lee (1981) and Lundvall and Battese (1999).

Even though most arguments support that there is a positive relationship between firm size and technical efficiency, the negative relationship found in food processing, beverage and rubber & plastics industries is not something unrealistic. This could be due to the fact that technical efficiency of small firms may be higher as a result of their being exposed to more competition than larger firms.

In our inefficiency model the square of firm size is also included and the result indicates that there is a significant negative relationship between size squared and technical efficiency for those sub-sectors where the relationship between firm size and technical efficiency is found to be positive. On the other hand, for food processing, beverage and rubber & plastics industries where firm size and technical efficiency are negatively related, the relationship between size squared and technical efficiency is positive for the three sectors and the relationship is also found to be significant, except for rubber and plastics industries. This result shows that those firms in textile, leather, wood & furniture, paper & printing, chemical and non-metallic mineral industries do not continue to benefit from increasing their firm size in terms of improving their technical efficiency. In other words, this means that as the size of a firm increases the technical efficiency of that specific firm increases only up to a certain point and it will start to decline marginally. However, the magnitude of the decline in technical efficiency is found to be close to zero for all industries.

For food processing and beverage industries, the positive relationship between size squared and technical efficiency indicates that growth of a firm will reduce the level of technical efficiency up to a certain point and it will start to have a positive impact on technical efficiency of a firm after a certain level of firm growth. However, like the other sub-sectors this effect is also found to be insignificant (close to zero) in terms of its magnitude for food processing and beverage industries.

It is evident from table 5.5 that firm age is positively related to technical efficiency and also statistically significant in beverage, leather, wood & furniture, paper & printing and non-metallic mineral industries. This implies that older firms are more technically efficient than those firms that are new. This is probably due to the learning-by-doing process which occurs through production experience. It is also argued that new firms are unaware of their abilities and require more time to decide on their optimal level of production. According to Assefa and Metambalya (2002), the least efficient firm will exit the industry overtime and the technically more efficient ones will remain. So, firms become more efficient as a result of growing stock of experience in the production process. Taye (1996) also reported a similar result for firms up to 5-8 years of age in Ethiopian manufacturing industries.

On the other hand, a negative relationship between firm age and technical efficiency is observed for food processing, textile, chemical and rubber & plastics industries and the relationship is found to be statistically significant, except for rubber & plastics industries. Perhaps, this relation could be due to the fact that when an innovation is introduced younger firms in these sub-sectors generally easily adopt it, while older firms may have to delay their adoption as it may become too expensive and costly to scrap the old technology. Thus, implying that efficiency may decrease with age because older firms tend to employ capital of an earlier vintage leading to inefficient production routines and practices. Pitt and Lee (1981) also found a negative relationship between firm age and technical efficiency in Indonesian weaving industries. The study which was undertaken by Hill and Kalirajan (1993) (cited in Lundvall and Battese, 1999) also reported a similar result.

Like size squared, age squared is also included in the inefficiency model to see the effect of an indefinite increase of firm age on technical efficiency. For those sub-sectors where the relation between firm age and technical efficiency is found to be positive, the statistically significant negative coefficients of age squared suggest that technical efficiency does not necessarily increase indefinitely as the age of a firm increase. Learning-by-doing may provide better opportunity for firms to improve their technical efficiency but the gains in technical efficiency from experience become smaller and smaller overtime and may be eventually entirely exhausted.

In food processing, textile and rubber & plastics industries, a positive and significant relationship between age squared and technical efficiency is observed. This implies that those firms in these sub-sectors could gain in efficiency due to an increase in age of the firm after sometime. The relationship is negative for chemical industries but it is found to be statistically insignificant.

The impact of location of a firm on improving technical efficiency is also assessed and firms in textile, chemical and rubber & plastics industries which are located around Addis Ababa tend to be more technically efficient than those firms outside Addis Ababa. This may be due to the fact that proximity of a firm to the capital city will enable the firm to have a better access to the necessary raw materials for production, a relatively abundant skilled manpower, easy access to information and export market which could enhance the technical efficiency of that specific firm. However, it is observed that firms in wood and furniture industries tend to be less technically efficient when they are located around Addis Ababa. Perhaps, this could be for the reason that most of the firms in this sub-sector are relatively small producers of furniture products whereby the main sources of timber for furniture production are the rural areas of the country which are very far from Addis Ababa. Therefore, a firm's location around Addis Ababa could adversely affect the technical efficiency of wood & furniture industries.

For food processing, beverage, leather, paper & printing and non-metallic mineral industries the impact of location of a firm on technical efficiency is found to be statistically insignificant. In other words, based on the maximum likelihood estimates firms in these sub-sectors don't benefit in terms of improving their technical efficiencies by locating their industries around Addis Ababa.

It is evident from the result (tables 5.5) that privately owned firms are found to be more technically efficient than those firms that are owned by the government in beverage, leather, paper & printing and chemical industries. For these sub-sectors it can be said that when firms are privately owned there will be a gain in efficiency due to the competition that occurs among the firms which makes them to properly utilize the available resources. This in turn leads to an improvement in technical efficiency. For food processing, textile, wood & furniture, rubber & plastics and non-metallic mineral industries type of ownership and technical efficiency don't have any statistically significant relationship.

Workers are expected to be motivated by the amount of incentive paid in the form of bonuses, commissions, professional and hardship allowances, etc and thereby increase the technical efficiency of firms. This is true for food processing, beverage, textile, leather, chemical and rubber & plastics industries. A statistically insignificant relationship between the amount incentive paid and technical efficiency is observed for wood & furniture and paper & printing industries. The amount of incentive paid to workers is found to bring about an adverse effect on the level of technical efficiency for firms in non-metallic mineral industries.

Finally, the effect of time on technical efficiency during the study period is investigated and the result indicates that it is only for textile and chemical industries that the technical efficiency has been increasing over the study period. For the rest of the industries, except for non-metallic mineral industries, the result shows that the deterioration in technical efficiency over the study period is significant. In other words, these industries couldn't keep their technical efficiency level and their capacity of utilizing the available resource has been declining overtime. For non-metallic mineral industries, the relationship between technical efficiency and time is found to be statistically insignificant.

CHAPTER SIX
CONCLUSION AND POLICY RECOMMENDATIONS

6.1 Conclusion

In any production process improving internal efficiency is one of the most important avenues for increasing the level of output. Given current global developments and liberalized market conditions, the survival of less efficient firms is highly questionable if they become less competitive. In light of this, the study has examined the technical efficiency levels of Ethiopian manufacturing industries and tried to identify those factors which contribute to the different inefficiency levels existing among the sub-sectors considered in the study.

A total of 361 firms are categorized under nine industrial groups based on ISIC classification and the industrial groups include food processing, beverage, textile, leather, wood & furniture, paper & printing, chemical, rubber & plastics and non-metallic mineral industries. A Cobb-Douglas or translog stochastic frontier production function involving the traditional production inputs of capital, labour and industrial cost (or raw material) was specified and the 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.

After performing the likelihood ratio test, it was observed that the Cobb-Douglas production function is a good representation for the production technology of leather and chemical industries only and the translog production function is found to be a good representation for the rest of the industries. Moreover, it is observed that the technical efficiency levels for each of the firms in all sub-sectors are better estimated using a half normal distribution for U_{it} rather than a truncated normal distribution, except for food processing industries. The likelihood ratio test was also performed to identify whether the technical inefficiency is absent from the model in each sub-sector and the result indicates that the null hypothesis that technical inefficiency is absent from the model is strongly rejected for all sub-sectors. The null hypothesis that the inefficiency effects are not a function of the explanatory variables is also rejected for all sub-sectors.

The technical efficiency level for firms in each sub-sector was predicted and the result shows that there exists technical inefficiency in all sub-sectors with a relatively higher variation among the firms. This result is also supported by the rejection of the null hypothesis that the discrepancy between the observed and the frontier output levels is due external factors outside firms' control for all sub-sectors. For most of the sub-sectors the discrepancy parameter, γ, is found to be above 80 percent which shows that most of the discrepancy between the observed and frontier level of outputs is due to technical inefficiency rather than external factors.

Mean technical efficiency levels were also predicted in line with the estimation of technical efficiencies and textile industries performed less in terms of mean technical efficiency while wood & furniture and rubber & plastics industries have performed well, relatively. The mean technical efficiency of the other industries falls between 62 and 80 percent.

The study also tried to identify those factors which contribute to the existing level of technical inefficiency and a total of 8 variables were investigated for this purpose. Among these variables, size of a firm tended to have a positive and significant relationship with technical efficiency for textile, leather, wood & furniture, paper & printing, chemical and non-metallic mineral industries. Based on the result, it was also observed these industries would not continue to benefit in terms of technical efficiency through increasing their firm size indefinitely. For food processing, beverage and rubber & plastics industries, the relationship between firm size and technical efficiency is found to be negative and statistically significant. However, the decline in technical efficiency due to firm growth in food processing and beverage industries will be reverted after some time and it will start to show a positive impact in improving technical efficiency. The relationship between size squared and technical efficiency in rubber & plastics industries is found to be statistically insignificant.

The effect of firm age on technical efficiency of firms was also examined and it was found that for beverage, leather, wood & furniture, paper & printing and non-metallic mineral industries operation of a firm for a relatively longer period brought about a positive impact on technical efficiency. On the other hand, an opposite relationship is observed for food processing, textile, chemical and rubber & plastics industries though the relationship is statistically insignificant for rubber & plastics industries. Since it is difficult to expect experience of a firm will increase technical efficiency indefinitely, age squared was also included to capture this non-linear relationship. The coefficients of age squared also showed that there is a non-linear relationship between firm age and technical efficiency for all sub-sectors, expect in chemical industries.

Proximity of a firm to Addis Ababa is found to be an important factor in terms of improving technical efficiency only for textile, chemical and rubber & plastics industries. Firms in wood & furniture industries, on the other hand, seems to be less efficient because of their location around Addis Ababa due to reasons related to supply of raw materials. In other sub-sectors, proximity of firm to Addis Ababa is not crucial in determining technical efficiency of firms. The other outcome of the study indicates that private ownership only helped beverage, leather, paper & printing and chemical industries to improve their technical efficiency. A statistically insignificant relationship between type of ownership and technical efficiency was observed for the rest of the industries.

The amount of incentive paid to workers tended to have a significant impact on increasing technical efficiency of firms in most sub-sectors, i.e., food processing, beverage, textile, leather, chemical and rubber & plastics industries. However, for wood & furniture and paper & printing industries the relationship turned out to be insignificant. With regard to the effect of time on technical efficiency, the result indicates that the technical efficiency of firms over the study period was increasing only for textile and chemical industries. In other industries technical efficiency tended to decline over the study period, except in non-metallic industries on which the relationship is found to be statistically insignificant.

6.2 Policy Recommendations

Based on the results of the study discussed in the preceding section, it is possible to forward some policy recommendations to enhance the efficiency of the manufacturing sector of Ethiopia and thereby to increase the contribution of the sector to the overall economy though the recommendations may not be conclusive.

To improve technical efficiency growth of a firm is found to be an important factor in most sub-sectors. Since firm growth is highly related with economies of scale, the government has to play a supportive role through provision of credit, implementing appropriate policies to enhance their competitiveness in the international market so that they can export their products, constructing the necessary infrastructure for smooth marketing system and looking for effective strategies for capacity building. However, caution should be taken not to increase growth of firms beyond the optimal level. For those sub-sectors where experience (proxied by age) has a positive impact towards improving technical efficiency, the policy should be geared towards assisting those firms which are relatively new through providing relevant trainings and other technical supports so that they can cope up with the experienced firms. On the other hand, for those sub-sectors where experience brought about a negative impact, the assistance should be towards introducing new technology and encouraging firms to replace their old technology with the new one.

Only a few sub-sectors are benefited due to location of their firms around Addis Ababa in terms of improving their technical efficiency. The gain in technical efficiency due to firm's location around Addis Ababa is significant only for a few sub-sectors. This could possibly indicate that there is no difference in technical efficiency of firms because firms are located around the capital city for most sub-sectors. However, for those sub-sectors where the location of a firm around Addis Ababa is important in determining technical efficiency, regional governments has to close the gap through infrastructure development like road transport and telecommunications, facilitating marketing channels and implementing appropriate industrial policies which makes the industries more efficient.

The slow pace of privatization has to be accelerated for those sub-sectors where the gain in technical efficiency is positive when a firm is owned privately because of the competitive environment created among the firms. This in turn will help the firms utilize their resources efficiently and thereby increase their technical efficiency. For most of the industries the amount of incentive paid to workers either in cash or in kind brought about a positive contribution in improving technical efficiency. Therefore, the industries have to design effective incentive payment strategies to motivate their workers and improve the level of technical efficiency.

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Appendix I Predicted Technical Efficiency of Firms in Each Industrial Group

Technical Efficiency of Firms in Food Processing Industries

Firm	Year 1998	1999	2000	2001	2002
1	0.4875	0.8784	0.7976	0.5094	0.7092
2	0.6001	0.8216	0.7564	0.7012	0.0712
3	0.7358	0.7939	0.7685	0.4112	0.3282
4	0.7341	0.8655	0.8492	0.7750	0.1129
5	0.7314	0.8463	0.3048	0.7972	0.7895
6	0.8252	0.7189	0.7815	0.7987	0.7349
7	0.7707	0.7279	0.7208	0.8051	0.5949
8	0.8094	0.7985	0.7727	0.8330	0.7605
9	0.8296	0.7987	0.7926	0.7796	0.7443
10	0.8346	0.8562	0.7497	0.7603	0.7835
11	0.7726	0.8060	0.8232	0.7761	0.7959
12	0.7224	0.5938	0.7498	0.7157	0.6252
13	0.8287	0.8061	0.3511	0.2298	0.3194
14	0.8379	0.8218	0.8286	0.7974	0.8098
15	0.7610	0.7800	0.7453	0.7503	0.7101
16	0.8298	0.7960	0.8131	0.8004	0.5462
17	0.8615	0.8058	0.7603	0.7650	0.7295
18	0.8165	0.9507	0.7774	0.8081	0.7528
19	0.8329	0.8129	0.7463	0.6536	0.7364
20	0.8366	0.8271	0.8274	0.7443	0.7674
21	0.8354	0.7600	0.7043	0.6409	0.7617
22	0.8436	0.8268	0.3312	0.8631	0.7913
23	0.7997	0.7606	0.7509	0.7073	0.6705
24	0.8523	0.8377	0.8510	0.8256	0.7920
25	0.7927	0.7547	0.6253	0.6246	0.4171
26	0.8542	0.8334	0.8239	0.8122	0.7469
27	0.7748	0.7947	0.7662	0.5945	0.6930
28	0.7856	0.8138	0.8123	0.6654	0.6945
29	0.7860	0.8167	0.5742	0.8329	0.7395
30	0.8364	0.8346	0.8376	0.7927	0.7838
31	0.7863	0.7780	0.7887	0.7730	0.4803
32	0.8176	0.8059	0.8073	0.7270	0.6169
33	0.7797	0.8042	0.7460	0.4264	0.6672
34	0.7768	0.8198	0.7825	0.7552	0.7054
35	0.8119	0.8189	0.8197	0.7483	0.7790
36	0.8543	0.8590	0.9545	0.7693	0.7076
37	0.1409	0.8578	0.9375	0.7912	0.7149
38	0.7592	0.7620	0.1762	0.0157	0.0221
39	0.8056	0.8490	0.7377	0.7586	0.7538
40	0.7840	0.8088	0.7806	0.6784	0.7898
41	0.7996	0.8873	0.7898	0.7994	0.7944
42	0.8611	0.8454	0.8269	0.8452	0.8449
43	0.8297	0.7950	0.7813	0.7617	0.7646
44	0.8075	0.8366	0.7428	0.7777	0.7203
45	0.8034	0.8447	0.8446	0.7462	0.7465
46	0.7811	0.8061	0.7543	0.7023	0.7443
47	0.8688	0.8784	0.8483	0.7639	0.7398
48	0.8318	0.8201	0.8321	0.7504	0.7447
49	0.7738	0.8107	0.7853	0.7912	0.3090
50	0.8665	0.8326	0.8121	0.7824	0.7169
51	0.7908	0.7918	0.7473	0.7140	0.6877
52	0.7988	0.8312	0.7470	0.7788	0.7169
53	0.8324	0.8052	0.8581	0.7674	0.7461
54	0.8612	0.8708	0.8818	0.8476	0.8181
55	0.8717	0.8843	0.8566	0.8493	0.8521
56	0.8371	0.8427	0.8464	0.7794	0.8179
57	0.8351	0.7808	0.7558	0.7258	0.7377
58	0.8114	0.7915	0.7703	0.7920	0.7717
59	0.8681	0.8160	0.8025	0.7844	0.7429
60	0.8516	0.8149	0.7851	0.7822	0.7575
61	0.8564	0.8242	0.8368	0.8070	0.7068
62	0.8449	0.8248	0.8109	0.8177	0.7672
63	0.8170	0.8030	0.7796	0.7572	0.7404
64	0.8050	0.7950	0.7711	0.7949	0.7159
65	0.8633	0.7906	0.7870	0.8052	0.2802
66	0.8479	0.8272	0.8165	0.8188	0.7823
67	0.8550	0.5056	0.8232	0.8164	0.7791
68	0.8720	0.8652	0.8280	0.8222	0.8197
69	0.8039	0.8058	0.8055	0.7073	0.7191
70	0.6880	0.6843	0.6705	0.5349	0.6333
71	0.7909	0.7949	0.7403	0.8229	0.6188
72	0.8284	0.9398	0.9476	0.7850	0.7477
73	0.8240	0.7758	0.8150	0.8021	0.7918
74	0.7997	0.7770	0.1245	0.6702	0.4734
75	0.7877	0.7439	0.0621	0.2693	0.0477
76	0.9392	0.8481	0.8667	0.8587	0.7436
77	0.7990	0.9161	0.5732	0.7885	0.6845
78	0.8012	0.8164	0.7923	0.8091	0.7308
79	0.9221	0.8728	0.8055	0.8431	0.7998
80	0.7917	0.7970	0.7954	0.7663	0.7465
81	0.8957	0.8426	0.8486	0.8419	0.7772
82	0.9028	0.8757	0.8730	0.8782	0.8696
83	0.8519	0.7775	0.8144	0.6691	0.7398
84	0.8218	0.8371	0.5539	0.8202	0.7532

Appendix I (cont'd)

Technical Efficiency of Firms in Beverage Industries

			Year		
Firm	**1998**	**1999**	**2000**	**2001**	**2002**
1	0.8608	0.8526	0.5684	0.0082	0.8454
2	0.8402	0.5232	0.0458	0.6592	0.7213
3	0.8732	0.8508	0.8849	0.8470	0.8044
4	0.8907	0.9301	0.8896	0.8432	0.8156
5	0.6402	0.8621	0.8694	0.8765	0.7868
6	0.8585	0.7519	0.8422	0.9026	0.8520
7	0.8462	0.8597	0.8711	0.8136	0.8687
8	0.8829	0.8658	0.8037	0.8880	0.7237
9	0.7855	0.6985	0.6646	0.6515	0.6641
10	0.4000	0.7355	0.7335	0.7237	0.6747
11	0.5048	0.4858	0.4970	0.4848	0.4807
12	0.6692	0.7853	0.8479	0.8134	0.8181
13	0.5984	0.5403	0.7477	0.7910	0.7836
14	0.8798	0.8844	0.8896	0.8150	0.8358
15	0.7965	0.8011	0.8509	0.9208	0.9456
16	0.8801	0.8244	0.7867	0.7574	0.8735

Technical Efficiency of Firms in Textile Industries

			Year		
Firm	**1998**	**1999**	**2000**	**2001**	**2002**
1	0.1120	0.1336	0.0808	0.2067	0.3800
2	0.3556	0.2804	0.3071	0.1959	0.3171
3	0.6592	0.7446	0.8622	0.7777	0.7749
4	0.5450	0.4130	0.4139	0.3299	0.2224
5	0.6703	0.7336	0.7183	0.7228	0.7102
6	0.8086	0.5039	0.4722	0.3742	0.7438
7	0.7598	0.2497	0.0257	0.7904	0.9011
8	0.8611	0.8265	0.8517	0.8091	0.7739
9	0.7891	0.7756	0.5692	0.3543	0.6343
10	0.8032	0.8457	0.7674	0.8649	0.8737
11	0.7526	0.4601	0.4174	0.7608	0.4493
12	0.8448	0.8772	0.8565	0.8527	0.8145
13	0.8455	0.7624	0.8468	0.8740	0.8581
14	0.8238	0.7970	0.6100	0.8120	0.8551
15	0.8546	0.4363	0.9012	0.8972	0.9564
16	0.8660	0.9078	0.9061	0.9155	0.9043
17	0.8673	0.8635	0.8599	0.8469	0.8567
18	0.8897	0.9024	0.8971	0.8797	0.8867
19	0.8120	0.8069	0.8595	0.8989	0.9011
20	0.8956	0.8984	0.8824	0.8333	0.8748
21	0.8915	0.8926	0.8881	0.8952	0.8761
22	0.0253	0.7747	0.8274	0.7622	0.0280
23	0.4509	0.1307	0.0498	0.0104	0.9398
24	0.1721	0.2340	0.2185	0.2391	0.2697
25	0.7914	0.0719	0.0961	0.3585	0.2109
26	0.0876	0.4005	0.0228	0.1291	0.1703
27	0.2370	0.4956	0.3082	0.2464	0.8727
28	0.6966	0.4344	0.3133	0.3092	0.6958
29	0.2637	0.2989	0.4088	0.6983	0.8726
30	0.7375	0.5943	0.4655	0.8140	0.7757
31	0.2806	0.4027	0.3395	0.2723	0.4067
32	0.3296	0.2833	0.5791	0.6850	0.7239
33	0.7580	0.5287	0.7366	0.5867	0.6113
34	0.8169	0.8066	0.7418	0.6077	0.7198
35	0.8055	0.8254	0.7883	0.8324	0.8382
36	0.7150	0.7357	0.7719	0.7499	0.7575
37	0.7721	0.7532	0.7245	0.6492	0.4748
38	0.8206	0.8023	0.7336	0.6206	0.7562

Appendix I (cont'd)

Technical Efficiency of Firms in Wood & Furniture

Firm	1998	1999	2000	2001	2002
			Year		
1	0.7298	0.7140	0.5974	0.4573	0.0314
2	0.8386	0.7132	0.7455	0.5911	0.5954
3	0.7528	0.6042	0.7200	0.7827	0.7179
4	0.8887	0.9290	0.9372	0.9333	0.7965
5	0.8965	0.8249	0.9104	0.8507	0.8729
6	0.9076	0.9096	0.9412	0.9264	0.9274
7	0.9284	0.8944	0.8965	0.9454	0.8640
8	0.9195	0.9079	0.9136	0.9196	0.9150
9	0.5752	0.8925	0.3978	0.7602	0.7583
10	0.7190	0.8587	0.8254	0.7977	0.7683
11	0.8208	0.8032	0.6096	0.8543	0.8533
12	0.5599	0.3669	0.6050	0.3805	0.9469
13	0.8368	0.8771	0.8579	0.8557	0.7928
14	0.7690	0.8147	0.7950	0.7356	0.7759
15	0.8188	0.6729	0.8722	0.5458	0.7565
16	0.7962	0.7922	0.7646	0.7373	0.8352
17	0.8776	0.8010	0.7874	0.7805	0.8075
18	0.7939	0.5999	0.7023	0.6700	0.5490
19	0.8458	0.7650	0.8154	0.9060	0.6854
20	0.8910	0.9018	0.8775	0.8334	0.8361
21	0.7748	0.7649	0.7835	0.7513	0.6708
22	0.7547	0.6219	0.4816	0.3992	0.7909
23	0.6889	0.8006	0.8246	0.8489	0.7818
24	0.8524	0.8815	0.8321	0.7938	0.7767
25	0.9100	0.8541	0.7954	0.8461	0.7810
26	0.8547	0.7799	0.8164	0.7738	0.6485
27	0.8872	0.8515	0.8497	0.8903	0.8458
28	0.7970	0.8180	0.7245	0.8291	0.5383
29	0.8354	0.8649	0.8491	0.7153	0.7580
30	0.8007	0.8519	0.8045	0.7093	0.7188
31	0.7081	0.7476	0.5975	0.6832	0.4724
32	0.8285	0.8879	0.8331	0.8566	0.7062
33	0.8374	0.7578	0.8575	0.7237	0.7558
34	0.8759	0.8986	0.8226	0.8486	0.7808
35	0.9210	0.7270	0.8267	0.6122	0.8002
36	0.9130	0.8420	0.8884	0.8494	0.8111
37	0.8398	0.8375	0.8176	0.8053	0.6914
38	0.8377	0.7688	0.8030	0.8329	0.7396
39	0.9068	0.9066	0.9155	0.6708	0.8397
40	0.8304	0.8620	0.8563	0.8524	0.8979
41	0.8251	0.8443	0.8166	0.8305	0.7498
42	0.8282	0.6756	0.5903	0.8559	0.9057
43	0.8851	0.7583	0.8637	0.7335	0.6783
44	0.9169	0.9096	0.9037	0.8969	0.7664
45	0.8396	0.8664	0.8125	0.7862	0.8154
46	0.9485	0.8515	0.8520	0.8131	0.7569
47	0.9073	0.9085	0.8391	0.5273	0.4288
48	0.7552	0.8314	0.7930	0.8283	0.8603
49	0.8409	0.7782	0.8717	0.8155	0.9328
50	0.9129	0.8351	0.8910	0.6278	0.8232
51	0.8803	0.9180	0.9251	0.9282	0.9191
52	0.8175	0.6087	0.7617	0.6810	0.8215
53	0.8969	0.8924	0.8844	0.8457	0.8460
54	0.9093	0.9007	0.9171	0.9272	0.9285
55	0.9292	0.9164	0.9135	0.9246	0.9139
56	0.9153	0.9024	0.9261	0.9075	0.8922
57	0.9189	0.9089	0.9162	0.9116	0.8924
58	0.9298	0.9274	0.9146	0.9156	0.9182

Technical Efficiency of Firms in Leather Industries

Firm	1998	1999	2000	2001	2002
			Year		
1	0.8803	0.8425	0.8219	0.8146	0.7448
2	0.8771	0.7819	0.9383	0.4184	0.5224
3	0.8970	0.8701	0.8261	0.7917	0.7712
4	0.8714	0.8157	0.8560	0.8984	0.8431
5	0.8803	0.8260	0.8149	0.8185	0.8213
6	0.8603	0.8381	0.8304	0.6465	0.7811
7	0.8485	0.8303	0.8396	0.8234	0.8262
8	0.9041	0.6712	0.8609	0.9225	0.6679
9	0.9458	0.5453	0.6808	0.6789	0.8387
10	0.8663	0.8235	0.7738	0.5651	0.4034
11	0.8469	0.8110	0.5831	0.0562	0.8024
12	0.7498	0.7548	0.3510	0.0249	0.0254
13	0.8378	0.7360	0.7044	0.6163	0.5561
14	0.8199	0.7283	0.6284	0.5170	0.6111
15	0.8595	0.8003	0.8538	0.8230	0.8035
16	0.6666	0.5798	0.6661	0.5806	0.7169
17	0.8751	0.7682	0.7660	0.7835	0.6818
18	0.7903	0.7727	0.7625	0.6156	0.6358
19	0.7867	0.7960	0.7211	0.6997	0.7525
20	0.8613	0.7008	0.7996	0.7731	0.8105
21	0.7698	0.9071	0.1128	0.7406	0.6481
22	0.7805	0.7595	0.7465	0.7276	0.7065
23	0.8444	0.7969	0.7902	0.7173	0.6596
24	0.8331	0.7927	0.7561	0.7933	0.7554
25	0.8746	0.8322	0.7739	0.6550	0.6667
26	0.8141	0.7834	0.8695	0.7263	0.7246
27	0.8101	0.7996	0.6882	0.7706	0.7635
28	0.8806	0.8248	0.6399	0.4002	0.7662
29	0.8929	0.8576	0.7306	0.7650	0.7523
30	0.9029	0.8788	0.3591	0.8023	0.8083

Appendix I (cont'd)

Technical Efficiency of Firms in Paper & Printing Industries

	Year				
Firm	**1998**	**1999**	**2000**	**2001**	**2002**
1	0.8879	0.8647	0.7631	0.7118	0.7617
2	0.8512	0.8634	0.8624	0.8807	0.8562
3	0.8954	0.8656	0.8666	0.8637	0.8605
4	0.8790	0.9068	0.7160	0.9010	0.7197
5	0.8503	0.7072	0.4410	0.2283	0.4609
6	0.4260	0.0751	0.3125	0.2703	0.8995
7	0.6935	0.8958	0.8963	0.8997	0.8940
8	0.6332	0.8040	0.7463	0.7082	0.0744
9	0.6765	0.6840	0.9190	0.8410	0.7350
10	0.7572	0.8514	0.8268	0.8566	0.8356
11	0.6565	0.5846	0.8300	0.5521	0.5643
12	0.4790	0.4134	0.3766	0.3907	0.4009
13	0.6803	0.6675	0.6105	0.6178	0.7376
14	0.7353	0.6509	0.5934	0.5383	0.4465
15	0.5260	0.5626	0.5259	0.5029	0.4843
16	0.7415	0.7002	0.6664	0.6227	0.5851
17	0.8499	0.6685	0.6420	0.6035	0.6752
18	0.6801	0.6468	0.4473	0.5909	0.5295
19	0.8469	0.8559	0.8591	0.8277	0.8362
20	0.9111	0.8657	0.7334	0.8171	0.8252
21	0.6849	0.6717	0.6609	0.6431	0.7001
22	0.8179	0.8202	0.7729	0.6187	0.7445
23	0.8398	0.8259	0.8204	0.8181	0.8139
24	0.7551	0.7223	0.7205	0.6837	0.6410
25	0.9046	0.8804	0.8725	0.8761	0.8765
26	0.8975	0.8921	0.8578	0.8464	0.8633
27	0.7263	0.8981	0.8280	0.8471	0.8398
28	0.7895	0.7749	0.7287	0.7497	0.7323
29	0.8367	0.8101	0.8082	0.8189	0.8319
30	0.9134	0.8909	0.8892	0.8834	0.8830
31	0.8728	0.8495	0.8398	0.8274	0.7963
32	0.8748	0.8788	0.8873	0.8789	0.8746
33	0.9044	0.8797	0.8596	0.8557	0.8433
34	0.8820	0.8694	0.8753	0.8887	0.8698
35	0.8717	0.8668	0.8604	0.8687	0.8721
36	0.9356	0.8621	0.8711	0.9074	0.8358
37	0.9040	0.8851	0.8744	0.8748	0.8839
38	0.8897	0.8618	0.8414	0.8524	0.8694
39	0.8794	0.8343	0.8176	0.3904	0.4788

Technical Efficiency of Firms in Chemical Industries

	Year				
Firm	**1998**	**1999**	**2000**	**2001**	**2002**
1	0.6606	0.7804	0.6775	0.7551	0.7684
2	0.8796	0.9142	0.8668	0.8134	0.8660
3	0.8223	0.8303	0.8601	0.8558	0.8622
4	0.8862	0.9047	0.9115	0.9167	0.9077
5	0.8084	0.0252	0.0307	0.7056	0.7504
6	0.6192	0.6428	0.6396	0.4975	0.6129
7	0.6949	0.7000	0.3628	0.7281	0.7150
8	0.8638	0.8773	0.8791	0.8346	0.8823
9	0.7732	0.7778	0.8244	0.8093	0.8123
10	0.8359	0.8356	0.8511	0.7880	0.8413
11	0.8654	0.8577	0.8526	0.8441	0.8712
12	0.7760	0.8287	0.6308	0.6780	0.9047
13	0.4518	0.7548	0.7976	0.5485	0.7683
14	0.8461	0.8499	0.8189	0.9549	0.8893
15	0.5659	0.6756	0.5517	0.0331	0.8212
16	0.7190	0.6245	0.7766	0.7816	0.6202
17	0.6117	0.7969	0.6928	0.6677	0.7104
18	0.6604	0.6597	0.6789	0.7116	0.7182
19	0.6588	0.6540	0.7986	0.6833	0.7287
20	0.9069	0.4967	0.4015	0.5455	0.4622
21	0.8304	0.8213	0.8029	0.8257	0.8295
22	0.7749	0.7375	0.8170	0.8779	0.8372
23	0.6713	0.6887	0.7112	0.7507	0.8111
24	0.7842	0.8133	0.8278	0.8396	0.8230
25	0.8597	0.8706	0.8956	0.8554	0.8832
26	0.8158	0.8180	0.8069	0.7714	0.6990
27	0.8186	0.8189	0.2553	0.8079	0.8640
28	0.7006	0.6635	0.6912	0.1429	0.6843
29	0.7556	0.7137	0.6216	0.8642	0.7251
30	0.7569	0.7780	0.7840	0.7366	0.7661
31	0.7730	0.7990	0.7552	0.9432	0.6948
32	0.7522	0.8015	0.9115	0.8340	0.7807

Appendix I (cont'd)

Technical Efficiency of Firms in Rubber & Plastics Industries

	Year				
Firm	**1998**	**1999**	**2000**	**2001**	**2002**
1	0.4778	0.7094	0.7596	0.6876	0.5101
2	0.8362	0.7484	0.8056	0.7800	0.7517
3	0.8417	0.7575	0.7538	0.7023	0.6419
4	0.7512	0.7760	0.7221	0.7356	0.7718
5	0.9552	0.9587	0.9495	0.9634	0.9198
6	0.4761	0.6049	0.5569	0.5202	0.4965
7	0.7277	0.7326	0.6510	0.6168	0.5390
8	0.8693	0.8227	0.6613	0.8336	0.7331
9	0.9094	0.7949	0.8116	0.7842	0.6867
10	0.7975	0.8283	0.6424	0.7998	0.7974
11	0.8520	0.8130	0.7944	0.8533	0.7213
12	0.8632	0.7777	0.6506	0.6080	0.6117
13	0.8972	0.8572	0.8221	0.7478	0.7046
14	0.8380	0.8249	0.8080	0.8169	0.5995
15	0.8972	0.5861	0.5842	0.2628	0.5058
16	0.9081	0.8928	0.8746	0.8684	0.8595
17	0.6724	0.5862	0.5364	0.4170	0.4207
18	0.9368	0.8069	0.7139	0.7532	0.6377
19	0.8643	0.7944	0.7247	0.8289	0.6399
20	0.7207	0.6515	0.8173	0.6447	0.8208
21	0.9369	0.8380	0.6778	0.7797	0.7979

Technical Efficiency of Firms in Non-Metallic Mineral Industries

	Year				
Firm	**1998**	**1999**	**2000**	**2001**	**2002**
1	0.8877	0.8677	0.8634	0.8689	0.8800
2	0.8928	0.8917	0.7428	0.7967	0.0324
3	0.8173	0.8057	0.7961	0.7659	0.8551
4	0.8575	0.9361	0.8639	0.9258	0.8519
5	0.1955	0.7159	0.7164	0.9028	0.8612
6	0.7028	0.7702	0.7662	0.7741	0.8159
7	0.8642	0.8601	0.8860	0.9178	0.9173
8	0.7413	0.7551	0.5648	0.8554	0.8068
9	0.8230	0.8699	0.8163	0.8946	0.8799
10	0.7847	0.7726	0.7500	0.7835	0.7844
11	0.7845	0.7872	0.8703	0.8482	0.8674
12	0.7405	0.8564	0.8039	0.6524	0.8423
13	0.7242	0.6389	0.6866	0.7168	0.5600
14	0.8628	0.7114	0.5411	0.7974	0.8131
15	0.7744	0.8508	0.6844	0.7243	0.7160
16	0.4733	0.6344	0.6547	0.5620	0.6723
17	0.7751	0.6696	0.6954	0.7299	0.8045
18	0.8327	0.8402	0.7027	0.7994	0.8065
19	0.8105	0.7265	0.7261	0.8357	0.6430
20	0.8975	0.7287	0.6019	0.7188	0.8448
21	0.8096	0.7405	0.7152	0.8190	0.8429
22	0.7785	0.7736	0.6782	0.7398	0.7318
23	0.8600	0.8224	0.6664	0.8221	0.8023
24	0.8295	0.7663	0.7474	0.8357	0.8141
25	0.7656	0.5380	0.7677	0.7575	0.8783
26	0.7506	0.7104	0.7449	0.8387	0.7916
27	0.7478	0.5826	0.7207	0.8832	0.6644
28	0.8226	0.8221	0.4909	0.9453	0.7838
29	0.6586	0.5135	0.7588	0.6293	0.7937
30	0.7578	0.6790	0.7604	0.8211	0.7422
31	0.8749	0.6699	0.6893	0.8091	0.8416
32	0.6851	0.6870	0.6333	0.7405	0.6720
33	0.8308	0.8560	0.8067	0.8601	0.7789
34	0.8607	0.8677	0.8542	0.8835	0.9060
35	0.8888	0.8234	0.8646	0.8639	0.8569
36	0.8579	0.8726	0.5486	0.9318	0.8883
37	0.8428	0.8253	0.7982	0.8349	0.8163
38	0.8512	0.8830	0.8490	0.8624	0.8699
39	0.8869	0.8542	0.8223	0.8370	0.7933
40	0.6971	0.6896	0.8276	0.8105	0.5928
41	0.8335	0.8527	0.7839	0.8822	0.8112
42	0.5713	0.5103	0.5523	0.6414	0.3528
43	0.8590	0.8748	0.8404	0.9096	0.8311
43	0.8590	0.8748	0.8404	0.9096	0.8311

DECLARATION

I, the undersigned declare that this thesis is my own original work and has not been presented, in whole or in part, for a degree in any other university. All references used have duly been acknowledged.

Declared by:

Name: Daniel G/Hiwot

Signature: ______________

Date: July 13, 2005

Place: Addis Ababa University, Addis Ababa