# PRODUCTIVE TECHNICAL EFFICIENCY OF ETHIOPIAN BASIC METALS AND ENGINEERING INDUSTRIES: A STOCHASTIC FRONTIER APPROACH

**YibeltalGelaye (MSc.)**

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**Ethiopia**

# ABSTRACT

*This study figure out the level of technical efficiency and determinants of the Ethiopian Metals and Engineering industries overtime using stochastic frontier production function model. All the parameters of the frontier function and the inefficiency model have been estimated simultaneously using maximum likelihood estimation.*

*The study considered one hundred forty six Metals and Engineering industries over the period of 2010 -2014 using firm level unbalanced panel data. The empirical result indicates that the time varied Translog functional form with maximum likelihood estimation better explains the production behavior of the Metals and Engineering industries .The study estimates the average technical efficiency of the Metals and Engineering industries is 55.3%.Therefore, the results indicate that there is a great potential exists for Metals and Engineering industries to further increase the value of production by 44.7% using the available input, technology and technical efficiency improvement, thereby reducing the cost of production. It is noted that out of the four technical inefficiency factors included in the Translog model there were only two factors (investment intensity and labour capital ratio of firms) had significant effect on technical efficiency. The study further identifies that the average technical efficiency of Metals and Engineering industries vary among the industries and yearly average seems to be unstable during the study period. Therefore, in order to effectively utilize the potential of the industries, efforts have to be made in improving investment intensity, financial and non-financial capital access, availing raw material access and infrastructural and institutional development.*



***Keywords:*** *Basic Metals and Engineering industries, stochastic production function, Technical efficiency, Ethiopia*

# 1. INTRODUCTION

The iron and steel or in Ethiopian case named as Metals and Engineering Industry (MEI) industry is core industry for any nation's sustainable development. Metals Industries are concerned with the refining and production of raw metal and primary metal products, i.e., the production of metal from ore, scrap and conversion of billet, slabs etc. into primary metal products such as metal sheet, tubes, bars, wires, cables and nails; while Engineering Industries are industries which use these metal products as an input and fabricate them into various engineering products such as metallic structures, tanks, pressure vessels, machine parts, machineries, transport equipment, electrical and electronic equipment, measuring and control instruments, and others (MPDC, 1999 E.C).

Globally, the industry is the second largest industry worldwide after oil and gas with an estimated turnover of 900 billion USD per annum. Over the last 35 years, the industry has shown significant changes. In 1980, 716 million tons of steel was produced and the leading producers were Russia (21%), Japan (16%), USA (14%), Germany (6%), and China (5%) of global steel production. However, in 2014 the leading country has changed significantly, i.e., China ranks first and far ahead of other countries (60% of world steel production), and then followed by Japan (8%), USA and India (6%), South Korea and Russia (5%), Germany (3%), Turkey, Brazil and Taiwan (2%); and the world steel production reached 1665 Million tons (World Steel Association, 2015).

The Africa region, even though has two larger producers of steel; South Africa and Egypt which they are lacking capacity to supply the rest of the continent, import steel to fulfill the demand for the growing construction and infrastructural development around every corner of the continent. From the period of 2006-2012 the top five Sub-Saharan Africa countries Nigeria (20%), Angola (12%), Kenya (10%); and Ethiopia and Ghana each (8%) comprises a total of 58% share of the net import of steel of the entire continent (World Steel Association, 2014).

The level of per capita consumption of steel is treated as an important index of the level of socio economic development and living standard of the people in any country. Taiwan-China (837.1 kg), Czech Republic (582.4 kg), Japan (531.7 kg), China (510 kg), and Germany (473.9 kg) were the top five highest steel per capita consumption of the world in 2014. Among the African average steel per capita consumption of 32.4 kg in the same period; Egypt (122.1 kg) and South Africa (97.5 kg) were the two registered highest steel per capita consumption (World Steel Association, 2014).

Metals are used in every important industry: energy, construction, automotive and transportation, infrastructure, packaging and machinery, defense and heavy engineering. Besides, it is closely related to the chemical and light industry, it also delivers materials for renewable energy such as thermal, solar and tidal power. The construction sector is the largest steel consuming sector; accounting 52.2% of the global steel use in 2013. The other two sectors: Machinery and Automotive are also key steel consuming sectors, absorbing 14.2% and 11.6% of the global steel consumption respectively (World Steel Association, 2014).

Ethiopian metals and engineering industry comprises both medium and large number of state-owned enterprises including the newly established metals engineering corporation (METEC) and growing number of private sector participants that have flourished recently. According to the Central Statistical Agency, recently there are 241 medium and large scale sized firms of metals and engineering manufacturing producers. The distributions of establishments are by regional state as well as in the two city administration of Addis Ababa and Diredaw (CSA, 2014).

According to the annual 2015 report of Metals Industry Development Institute, Ethiopia's metals and engineering industries have been engaged in the areas of manufacturing Sheet metal cutting, galvanizing, cold rolling and corrugation plants; Tube and hollow section and Cold sheet metal rolling mill plants; Reinforcement bar rolling mills, wires and nail plants; Aluminum profile for window and door manufacturing plants; mechanical workshops for sheet metal and structural fabrication; truck body, bus body, trailer body, tankers manufacturing plants; Mechanical workshop for reconditioning of engines and part manufacturing plants; and Electric wire and cables, transformers, etc.

The basic metals industries are providing the required raw material to all engineering industries engaged in the manufacturing of components, spare parts, and other capital goods etc. The construction sector consumes concrete reinforcement and pre-engineered buildings, hollow sections, corrugated iron sheet, electric and communication cables, aluminum profiles, wire rods, nails and wires, etc. The agricultural sector is also a consumer of the output of these industries such as structures for green house, pipes for irrigation, etc for its requirements (MIDI[1], 2015).

However, the least developed traditional Ethiopian economy, the contribution of industry particularly, the metals and engineering industry to the overall GDP is the lowest as compared with other sectors. This is due to the sub-sector is characterized by inefficiency and low level of productivity growth which shows a stagnant value added (MPDC, 1999 E.C).

In Ethiopia, started from the 19th C on wards due to the emergence of a strong central government and political state, modern manufacturing has been started. During the imperial era; the government formulated the 1950's industrial development strategy proclamation based on import substitution; to facilitate the introduction and expansion of the industrial sector. However, due to its shortcomings it was revised in 1964. As a result of these, few numbers of manufacturing enterprises such as the Ethiopian Iron and Steel Foundry and Akaki Steel Industry were established to process reinforcement bars and corrugated sheet, Kotebe Metal Tools Factory and several sheet metal fabrication shops were also established towards the end of the imperial era (MPDC, 1999 E.C).

During the Derg era, the metals and engineering sub-sector was organized under National Metal Corporation which then established industries in the areas of industrial spare part, Tractors and Pumps. After the Derg period; the current government through the Agricultural Development-Led-Industrialization (ADLI) strategy carries out an economic development strategy with the central objectives of increasing agricultural production through the use of modern inputs and

[1] *Metals Industry Development Institute established by the government for the promotion of MEIs*

creating sufficient market for industrial products. Production of goods for overseas markets and export standard is also seen as strategy to increase competitiveness of local industries. In line with this framework there has been a number of manufacturing industries established in the areas of metals and engineering subsector (MPDC, 1999 E.C).

The Metals and Engineering Industries are heavily relying on imports since the industries are not developed enough to meet the emerging demand from user industries both quantitatively and qualitatively. The total value of imported metals and engineering products in 2012 amounted Birr 19.64 Billion while the domestic production was 126.45 Billion Birr, i.e., the country covers only 37.9% by the domestic production. In the same year the country's per capita steel consumption was 12 kg which is still low. However, there has been a recently growing up in the output of the sub-sector due to the massive investment taking place in the country, especially construction and public sector infrastructure investment led by METEC[2] and other public and private firms in supplying the existing domestic demands of large construction and infrastructural projects like large trunkey sugar factories, hydroelectric and irrigation dams, etc, and the trying of light machinery development locally rather than imported (MIDI, 2014).

By 2014, the Ethiopian government formulated a second round five-year strategic plan called the "Growth and Transformation Plan'' GTP-2 with the objective of bringing development in the country. The improvement of the efficiency of the manufacturing sectors is an essential aspect in the process of achieving the desired target of development. The metals and engineering sub-sector is among the sub-sectors in the manufacturing which has role to the attainment of the GTP target in line with by minimizing the inefficiency and increasing the volume of production; substitute the imported products and improving domestic designing and engineering capacity in order to support other domestic manufacturing. Thus, the government gives special attention to domestic improvement of efficiency in the factors of production (Ermias, 2013).

The contribution of the industrial sector to the country's GDP (12%) is small as compared to the other sectors while the growth rate (18.5%) of the sector is the highest of all. Among the industry sector, the contribution of manufacturing and construction to GDP was 4.2% and 5.6%. Due to its inefficiency the production and productivity of the manufacturing sector is low (MOFED[3], 2014).

The economic policy formulation at macro or micro level of every country needs the analysis of efficiency level of every manufacturing activity. In particular, the impact of technical efficiency give some guidance in order to develop policies aiming to achieve growth and increase the GDP share of the manufacturing sector, in particular the metals and engineering sub-sector. It helps to understand whether gains in industry productivity levels are achieved through the efficient use of inputs or through technological progress (Melaku, 2013).

However, despite the critical importance and need of the efficient metals and engineering firms to the Ethiopian economy, there is hardly possible to find any studies of analytical nature in the

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*[2] Metal Engineering Corporation a government owned corporation*

*[3] The name is changed to Ministry of Finance and Economic Cooperation (MOFEC) in 2016.*

areas of MEI of Ethiopia. But there have been studies in other sub-sectors of the manufacturing sector and also studies at the country's overall manufacturing industries. Melaku (2013) by conducting an empirical study using stochastic frontier analysis pointed out that there is large inefficiency in the Ethiopian manufacturing in general. Likewise, Gezahegn (1987) figure out that efficiency is a major problem of state owned textile industries in Ethiopia. On contrary, countries like China has been given due attention for the sector and the researcher of this paper found out research papers in this regard such as; J.W.Kim et al (2005) were examined the technical efficiency and the factors contributing to the efficiency of 52 iron and steel industry of china using a time-varying stochastic frontier model. The highest efficiency level was 97%. Degree of privatization, adoption of new technology and equipment were critical to the pursuit of efficiency in the iron and steel industry. Additionally, (Wu, 1995) using time-varying production frontier model estimate firm-specific technical efficiency and analyze the impact of firm attributes on productive performance. He took vintage capital, economies of scale, enterprise ownership and location and found that there were ample scope and space for efficiency improvement at the industry level and the efficiency gains might be possible by closing the gap between the coastal province and the rest of the country.

Actually, little or no attention has been given to the analysis of the technical efficiency of resources in the Ethiopian metals and engineering industries, in spite of the potential and strategic benefits, i.e, long term implication on the economy by creating a better enabling environment for the advancement of industrialization and downstream technologies (Kyoji, 2010). This may be gained by proper identification of the extent, causes and possible remedies of production technical efficiency in the sub-sector. Therefore, this study found out the level of technical efficiency of the sector industries and their determinants at firm level.

# 2. METHODOLOGY

## 2.1. Data and Description of Variables

**Data**

The study used firm level unbalanced panel data of large and medium scale (LMSM) Metals and Engineering manufacturing industries collected annually by the Central Statistics Authority (CSA) for the period of 2010 –2014 (note that 2010-2014 is chosen in this study for keeping the uniformity and it represents the period of 2002-2006 in Ethiopian calendar assuming that the period is past). The annual surveys conducted by CSA covers all manufacturing establishments either by private or government ownership that employ at least 10 workers and use fuel and electricity in their production. Each firm level survey comprises the data items such as gross value of output, value of fixed capital, wages and salaries of employee, cost of raw materials, cost of fuel and energy, ownership status, age, location, and a range of other related and relevant information.

Prior to using the data which represents the metals and engineering sub-sectors, a series of data consistency and data availability checks were performed and inconsistent data is left out. Accordingly, the final sample observations consists of 146 metals and engineering firms categorized under the three sub-sectors ; Basic metals manufacturing , fabricated metal product manufacturing short for fabricated metal products, except machinery and equipment and Structural metal manufacturing short for manufacturing of machinery and equipment. This classification is adopted by the CSA which uses the International StandardIndustrial Classification of All Economic Activities (ISIC). The following table (Table: 1) shows the sample distribution of firms over the panel period.

**Table: 2.1: Number of Metals and Engineering firms covered in the study period**

| S.No | Sub-sector Industry | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|
| 1 | Basic Metals Manufacturing | 34 | 34 | 25 | 35 | 34 |
| 2 | Structural Metal Manufacturing | 98 | 57 | 96 | 94 | 95 |
| 3 | Fabricated Metal products Manufacturing | 11 | 14 | 13 | 17 | 17 |
| | Total | 143 | 105 | 134 | 146 | 146 |

***Source:*** *Filtered from CSA*

Each respective firms covered in this study use their own respective raw material and technology and produces their own product categorized under basic metals product manufacturing, structural metal product manufacturing and fabricated metal product manufacturing. These are the categories which largely dominate the sub-sector manufacturing sector of Ethiopia by employment, production, and value added.

**Description of Variables**

In the study, the following variables were considered to estimate the production efficiency scores of basic metals and engineering manufacturing industries.

1. **Gross Value of Output ($Y_{it}$):** total production output of a firm is measured either in gross value of output or in terms of value added expressed as in ton of Birr. Production is the result of the interplay of capital, raw materials, labour, fuel and energy and other inputs. The study assumes that a single firm produces a single product. Hence, gross value of output of a firm in birr used as a dependent variable.
2. **Fixed Capital ($X_{1it}$):** 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.
3. **Labour ($X_{2it}$):** in the frontier productions the amount of wages and salaries paid in birr to the workers in each time are proxies for the labour input. This variable includes all payment made to permanent and temporary workers during the study period.

4. **Cost of Raw Materials ($X_{3it}$):** this includes all cost of material used in the production process measured in birr.
5. **Fuel and Energy ($X_{4it}$):** used in production process that affect the technical efficiency of metals and engineering industries since these industries are highly dependent and consumed energy as a means to transform input to outputs. The monetary value of fuel and energy expressed in terms of Birr was considered.

Knowing that firms are technically inefficient might not be useful unless the sources of the inefficiency are identified (Admassie and Matambalya, et al, 2002). Thus, the second objective of this analysis investigates the sources of the firm level technical inefficiency for the industries.

Since economic theory does not offer us a clear model to explain the determinants of technical efficiency, the study does not aim to find causal relations but only correlation between efficiency and a set of variables. Therefore, in order to suggest relevant policy ideas; identifying the factors responsible for technical inefficiency is an essential component of efficiency analysis.

The following variables were used to identify the sources of inefficiency of the firms.

1. **Investment Intensity:** It is measured by the ratio of net capital additions of the firm during the year to total employment. The expected positive relationship is not confirmed, i.e, got negative relationship.
2. **Labour-Capital Mix:** measured by the ratio of labour expressed in terms of wages and salary to fixed capital of the firms**.** Based on the assumption of surplus labour found in this country the expected sign was negative implying labour intensive manufacturing practices and the result is also confirmed.
3. **Distance:** this term is measured by the distance of industries from the main capital city, Addis Ababa.This variable is included in the inefficiency model to examine whether the location of a firm within sub-sector matters in determining the technical inefficiency of firms. And the expected negative sign as a source of inefficiency was not confirmed.
4. **Age:** firm age is included to capture the effect of experience on the technical inefficiency of industries. 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 eventually exhausted Lund Vall and Battese (1999). The expected positive relationship as a factor of technical inefficiency was confirmed. It is measured with the number of age a firm has lived started from the establishment to the end of the panel period (2014).

## 2.2. Econometric Model Specification

**Model Specification**

From the different literatures reviewed, the concept technical efficiency was defined simply as the ratio of actual output to the maximum output attainable (often called a frontier) with the given amount of inputs. As a measurement of performance, frontier analysis has been widely used not only in commercial firms, but also in many other economic areas, such as electricity, education, hospital, and public transportations.

All producers are assumed to attempt to obtain the optimum outputs, but not all of them can obtain the optimum result. Thus, the frontier describes the optimum result that producers want to and can produce given the technology level which describes efficiency as the distance between the frontier and the observed result producers actually get. Amongst the economists to suggest reasons for under-performance were Kumbhakar and Lovell (2000), where agency problems arising from asymmetric information are cited as being major reasons why producers may show a lack of constraint concern when analyzing the producers' performance.

Early studies of technical efficiency were based on the deterministic frontier model suggested by Aigner and Chu (1968), but this model cannot account for the random factors that may move production off the frontier. Subsequently, various stochastic production frontier models were introduced to take these factors into account (Woe, Lee, etal, 2005).

Studies done by Debreu (1951), Shephard (1953), Aigner and Chu (1968) and Kumbhakar and Lovell (2000) had influenced by the development of Stochastic Frontier Analysis (SFA). It was originally introduced by Meeusen and Van Den Broeck (1977) and Aigner, Lovell and Schmidt (1977). Their initial work was done by a cross-sectional data set. The panel data estimation analysis is then extended by the work of Pitt and Lee (1981), Schmidt and Sickles (1984), Kumbhakar (1990), Battese and Coelli (1988, 1992, 1995) and HamitHaggar (2009).

The study employed the productions function of panel data fitted as an output function to estimate the technical efficiency of Metals and engineering industries. It specified the production frontier proposed by Battese and Coelli (1995) which defines output as a function of a set of inputs together with technical inefficiency of production. In the model these inefficiency effects are modeled in terms of other observable explanatory variables and all parameters are estimated simultaneously. According to Kumbhakar S.C et al (2012), the inefficiency specification used by Battese and Coelli (1995) is most frequently used in empirical studies. Their model allows inefficiency to depend on some exogenous variables so that one can investigate how exogenous factors influence inefficiency. The panel data model of Battese and Coelli (1992) is somewhat restrictive because it only allows inefficiency to change over time exponentially.

The general representation of the panel data model employed in the study is:

$$\ln Y_{it} = X_{it}\beta + V_{it} - U_{it} \qquad (2.1)$$

Where;

$Y_{it}$, denotes the output of i[th]firm with cross sectional unit (i= 1,2, . . . 146) at time t[th] observation ( t = 1, 2, 3, 4, 5) of time periods. $X_{it}$ , is the column vector (1xk) of value of input of i[th] firm at time t and β is a vector of unknown parameters to be estimated. The error term $\varepsilon_{it}$ is divided into two components: the random error$V_{it}$, which shows producers specific external shocks on observed output; and the other non-negative term$U_{it}$, captures the technical inefficiency. Thus, the stochastic production function $\ln y_{it} = x_{it}\beta + v_{it} - u_{it}$; defines maximum feasible output in an environment characterized by the presence of either favorable or unfavorable events beyond the control of producers. On the other hand, the one sided non-negative error term implying that observed output lie beneath or on the stochastic production frontier.

The stochastic random error component,$V_{it}$s are assumed to be independent and identically distributed with mean 0 and constant variance i.e., ($V_{it} \sim N(0, \sigma_v^2)$ and the non-negative random error component $U_{it}$s assumed to be independently distributed, such that it is obtained by truncation (at zero) of the normal distribution with mean, and variance constant, i.e, $N^+(\mu, \sigma_u^2)$Battese and Coelli (1995).

Thus, the summation of the two random variable $V_{it}$ and $U_{it}$are expressed as $\varepsilon_{it}$ in which

$$\sigma_\varepsilon^2 = \sigma_v^2 + \sigma_u^2 \qquad \text{and} \qquad \gamma = \frac{\sigma_u^2}{\sigma_\varepsilon^2} \; (2.2)$$

Where; $\gamma$ is the variance ratio; explaining the total variation in output from the frontier level of output attributed to technical inefficiency. The $\gamma$ parameter lies between zero and one, if $\gamma = 0$ then all deviations from the frontier are due to noise, while $\gamma = 1$ indicates all the deviations are due to technical inefficiency (Battese and Coelli, 1995).

In line with this, firm level technical efficiency becomes the ratio of observed or realized output to the stochastic frontier or potential output (3.3), and the industry efficiency has been viewed as the average of the efficiencies of all the firms in the industry, i.e, the natural predictor of industry efficiency is the average of the predicted efficiencies of the firms in the sample (Battese and Coelli, 1992).

$$TE = \frac{y_{it}}{\exp(x_{it}\beta + v_{it})} = \exp(-U_{it}) \leq 1 \qquad (2.3)$$

Here $-U_{it}$ represents technical inefficiency effect and the technical inefficiency effect can be assumed to be constant over time or can vary over time. The assumption of time invariant inefficiency considers that inefficiency of the industry has persistent nature and is time irresponsive. In order to identify which model best describes the inefficiency was tested using a log likelihood ratio test, however, this study assumes that technical inefficiency changes overtime. The technical inefficiency effects as a function of time are defined as;

$$U_{it} = \{\exp[-\eta(t - T)]\}Uu_i \quad (2.4)$$

Where i=1, 2…146 and t=1, 2…..5, $u_i$are non-negative random variables associated with the technical inefficiency of production. η is unknown scalar parameter to be estimated,which determines whether inefficiencies are time varying or time invariant. If η is positive ,then – η(t-T) = η(T-t) is positive for t<T and; so exp[– η(t-T)] >1,which implies that the technical inefficiencies of firms decline over time. If η is zero, then the technical inefficiencies of firms remain constant .However, if η is negative, then – η (t-T) < 0 and thus the technical inefficiencies of firms increase over time.

However, both the Cobb-Douglas and Translog models were tested in the analysis part, the production function representing Metals and engineering manufacturing industries during the given period is translog production function. The translog functional form has advantages over other functional form especially from the Cobb-Douglas is that, the translog stochastic frontier production function is widely adopted in empirical studies, more flexible than the Cobb-Douglas production function and it also helps to see the cross input relationships (Battese and Coelli, 1992).

The stochastic production function can be specified as Cobb-Douglas or translog functional form.

The general Cobb-Douglas functional form is defined as:

$$\ln y_{it} = \beta_o + \sum \beta_i \ln x_{it} + V_{it} + U_{it} \quad (2.5)$$

The translog stochastic frontier production function of the metals and engineering industries can then be written as:

$$\ln y_{it} = \beta_0 + \beta_1 \ln x_{1it} + \beta_2 \ln x_{2it} + \beta_3 \ln x_{3it} + \beta_4 \ln x_{4it} + \frac{1}{2}\beta_{11}(\ln x_{1it})^2 + \frac{1}{2}\beta_{22}(\ln x_{2it})^2 + \frac{1}{2}\beta_{33}(\ln x_{3it})^2 + \frac{1}{2}\beta_{44}(\ln x_{4it})^2 + \beta_{12}(\ln x_{1it})(\ln x_{2it}) + \beta_{13}(\ln x_{1it})(\ln x_{3it}) + \beta_{14}(\ln x_{1it})(\ln x_{4it}) + \beta_{23}(\ln x_{2it})(\ln x_{3it}) + \beta_{24}(\ln x_{2it})(\ln x_{4it}) + \beta_{34}(\ln x_{3it})(\ln x_{4it}) + V_{it} + U_{it} \quad (2.6)$$

Where;

$y_{it}$ is value of production output in Birr for the $i^{th}$ firm, (i=1,2,…..146), in the $t^{th}$ observation period (t=1,2,…..5); $x_{it}$ are vectors of inputs such as fixed capital in Birr, Labour in terms of wages and salaries paid, industrial cost of raw material in Birr and cost of fuel and energy for the $i^{th}$ firm in the $t^{th}$ year of observation; β's and $\beta_{ij}$'s are unknown parameters to be estimated; and $\varepsilon_{it}$is as defined in equation (3.2).

The technical inefficiency effect, $U_{it}$, in the stochastic frontier model (2.7) defined:

$$U_{it} = z_{it}\delta + w_{it} \qquad (2.7)$$

Where $z_{it}$ is a vector of explanatory variables associated with technical inefficiency of firm i at time t, and $\delta$ is an unknown vector of coefficients, and the random variable, $w_{it}$ is defined to have the normal distribution truncated at $-z_{it}\delta$, i.e., $w_{it} \geq -z_{it}\delta$, and is consistent with the assumption that $U_{it}$ has the truncated normal distribution, $N(z_{it}\delta, \sigma_u^2)$(Battese and Coelli, 1995).

To determine why some of the metals and engineering industries are less efficient than others, the following technical inefficiency model used to identify the source of inefficiency:

$$U_{it} = \delta_0 + \delta_1 Z_{it} + \delta_2 Z_{it} + \delta 4_3 Z_{it} + \delta_4 Z_{it} + w_{it} \qquad (2.8)$$

Where;

$U_{it}$ is defined above, $\delta_i$ 's unknown parameters to be estimated, $w_{it}$ is defined by the truncation of the normal distribution with mean and variance, i.e, consistent with the assumption of $U_{it}$ , and the variables Investment intensity, Age, Distance from the capital city, and Labour-Capital mix are the variables used for estimation of the parameters.

### 2.2. Estimation Procedure

The parameters of the stochastic frontier model (2.1) will be estimated using maximum likelihood estimation (MLE). The MLE method has been found to be significantly better than Corrected Ordinary Least Square (COLS) where the contribution of the inefficiency effects of the total variance is large, and is the preferred estimation technique whenever possible (Coelli, Rao and Battese 1998). Additionally, Coelli (1995) suggested that the ML estimator significantly outperforms the COLS estimator when the contribution of the technical inefficiency effects to total variance output is relatively large.

The estimated parameters in the stochastic frontier models were $\beta's, \eta, \sigma_v^2$ and $\sigma_u^2$. Industry or sector efficiency was computed as the average of the technical efficiencies/inefficiency of the firms in the sample.STATA-13 software program were used to estimate the inefficiency model.

## 3. RESULTS AND DISCUSSION

### 3.1. Descriptive Results

The study examines the technical efficiency of metals and engineering industry of Ethiopia. The data set utilized in this thesis consists of companies operating in the Ethiopian metals and Engineering industry during the years 2010 to 2014. The data was extracted from the CSA annual manufacturing survey raw data bases. The data consists of maximum 146 and minimum 105 individual firms' observation throughout the panel period of five years. The following table indicates that the data is an unbalanced panel, and among the firms in 2010 twelve firms, 2011 five firms and in the remaining each study period 4, 9, and 5 firms were owned by government.

**Table 3.1: MEIs by ownership**

| S.No | Type of Ownership | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|
| 1 | Public | 12 | 5 | 4 | 9 | 5 |
| 2 | Private cooperative | 131 | 100 | 130 | 135 | 141 |
| **Total** | | 143 | 105 | 134 | 146 | 146 |

Source: Filtered from CSA

The average age of the metals and engineering industries, computed by taking 2014 as a reference period, is around 11 years of age old. The highest maximum establishment of firm's age is 53 years old which a firm was established in 1961 during the imperial era. The minimum firm age is almost one year old, which considers those firms established in 2013 and 2014. The study considered those firms who were established in 2014 as one year old firm.

**Table 3.2: MEIs Average Age and Distance**

| S.No | Statistics | Age (year) | Distance (km) |
|---|---|---|---|
| 1 | Mean | 11 | 275 |
| 2 | Max | 53 | 1066 |
| 3 | Min | 1 | 5 |
| 4 | SD | 11.7 | 358.9 |

Source: own computation

By taking the capital city (Addis Ababa) as a reference, on average a firm is far from the capital city by around 275 km. The minimum distance is 5km which a firm is located inside the capital city while the maximum distance is 1066km where a firm is located in the northern part of the country.

As indicated in table 3.3 below, the average annual production of metals and engineering industries during the period of 2010 – 2014 at industry level was birr 67.97 million. The average inputs used in the production process includes; fixed capital, wage and salaries for employed labour, cost of raw material used and cost of fuel and energy was birr 21.02 million, 1.9 million, 44.4 million, and 1.3 million, respectively.

**Table 3.3: Descriptive Statistics of MEIs (in 000 Birr)**

| Statistics | Output | Fixed Capital | Wages and Salary | Cost of Raw Material | Cost of Fuel and Energy |
|---|---|---|---|---|---|
| Mean | 67,971.33 | 21,017.42 | 1,922.48 | 44,425.30 | 1,310.84 |
| Max | 2,582,635.42 | 789,452.49 | 69,396.16 | 1,254,639.95 | 90,408.59 |
| Min | 8.06 | (389.69) | 540.00 | 400.00 | 60.00 |

| Std.Dev. | 218,607.91 | 66,985.92 | 4,949.24 | 125,461.27 | 6,653.44 |
|---|---|---|---|---|---|

Source: Own Calculation

As shown in the table 3.4 below, fixed capital grew by 94.63% on average, while wage and salary, cost of raw materials and cost of fuel and energy grew by 52.19%, 125.15%, and 34.97% respectively.

**Table 3.4: Annual Average input cost of MEIs (in 000 birr except for growth ratios)**

| S. No | Statistics | 2010 | 2011 | 2012 | 2013 | 2014 | Average Growth Rate (%) |
|---|---|---|---|---|---|---|---|
| 1 | Average Fixed Capital | 7,051.42 | 6,001.25 | 31,033.25 | 25,274.71 | 23,971.12 | 94.63 |
| 2 | Average Wages and Salary | 1,020.16 | 667.56 | 2,312.67 | 2,481.54 | 2,223.18 | 52.19 |
| 3 | Average Cost of Raw Material | 14,936.15 | 12,683.44 | 78,035.04 | 63,620.90 | 75,636.42 | 125.15 |
| 4 | Average Cost of Fuel and Energy | 721.99 | 634.66 | 1,618.22 | 1,477.11 | 1,561.75 | 34.97 |

Source: Own Calculation

The following table describes that, there was an increase in annual metals and engineering industry production with an average growth rate of 45.76% during 2010 – 2014. The partial productivity of labour which shows the value of one unit of output produced by one birr of labour increased by 13.06 % on average and capital which shows the value of output produced by one birr worth of capital increased with average growth rate of 14.42%.

The average labour-capital mix which is the ratio of wage and salaries of permanent and temporary workers to fixed capital growth rate during the study period was 1.76% which shows on average the growth rate of labour expressed in wages and salaries was greater than by 1.76% that of capital in their combination in order to produce one unit of output.

**Table 3.5: Partial Productivity of MEIs (in Birr except for ratios)**

| S. No | Statistics | 2010 | 2011 | 2012 | 2013 | 2014 | Growth rate (%) |
|---|---|---|---|---|---|---|---|
| 1 | Average Output (million birr) | 37.1 | 91.09 | 96.66 | 94.94 | 126.45 | 45.76 |
| 2 | Output per Fixed Capital | 69.336 | 33.159 | 15.572 | 16.725 | 23.437 | 14.42 |
| 3 | Output per wages and salaries | 42.249 | 40.698 | 48.084 | 36.259 | 58.867 | 13.06 |
| 4 | Labour-Capital Mix | 4.567 | 8.111 | 0.716 | 0.759 | 4.492 | 1.76 |

Source: Own computation

### 3.2. Econometrics Results and Discussion

The econometrics analysis used a comprehensive unbalanced panel dataset covering a total of six hundred seventy four observations; a cross-section of one hundred forty six industries over a period of five year (2010 - 2014) and to estimate and predict the technical inefficiency and the different parameters that affect and determine the technical efficiency of metals and engineering industries.

Before interpreting the variables and the technical efficiency estimation a hypothesis test of the null hypothesis test was conducted. Since the model base in the topic of interest in this study is the formulation of Battese and Coelli (1995), assumed that $U_{it}$has a truncated normal distribution, the likelihood function is a generalization of the likelihood for the half-normal stochastic frontier model. As a result, this model is estimated by the maximum likelihood method, the hypothesis concerning more than one coefficient is usually tested using the likelihood ratio (LR) test (Coelli et al, 2005).

The first test was conducted to choose the correct functional form which better represents the production function of the metals and engineering industries among the two common functional form of production function employed in studying technical efficiency using stochastic production frontier namely Cobb-Douglas and Translog functional form. This test is performed using log likelihood ratio test based on maximum likelihood estimation values of the two models.

In order to test the two models using the likelihood test distributed as chi-square (r) under Ho, the first step is imposing a restriction. The null hypothesis constrains the existence of all the interaction terms between explanatory variable. It ignores the effect of the interaction between fixed capital with wage and salary, fixed capital with cost of raw material, fixed capital with fuel and energy consumption, wage and salary with cost of raw material, wage and salary with fuel and energy consumption, and cost of raw material with fuel and energy consumption. Additionally it disregards the effect of the square of each of the four inputs.

$Ho=\beta_{11}= \beta_{12}= \beta_{13}= \beta_{14}= \beta_{22}= \beta_{23}= \beta_{24}= \beta_{33}= \beta_{34}= \beta_{44} =0.$

The log likelihood ratio statistics LR is given by;

$$LR = -2[LLF_0 - LLF_1]$$

Where $LLF_0$ is the value of the likelihood functions for the frontier model in which the null hypothesis (Ho) is imposed (Cobb-Douglas function) and $LLF_1$ is the value of likelihood functions of the alternative hypothesis ($H_1$) for the Translog functional form.

Reject the null hypothesis when LR>Chi-2(r) where (r) is the number of restrictions. In our case we have 10 restrictions (all interactions and quadratic terms).

If the null hypothesis is accepted we select the Cobb-Douglas functional form be the appropriate functional model and if it is rejected the Translog function will be the appropriate functional form which represents the stochastic production frontier model of the metals and engineering industry sector.

$$LR = -2[LLF_0 - LLF_1]$$

$$LR = -2[-1329.7186 – (-1316.13)]$$

LR = 27.18

Therefore the likelihood test ratio LR is 27.18. The critical value of the Chi-square distribution statistics at 5% level of significance and 10 degree of freedom equals 18.31; i.e., 27.18 is greater than the table value of 18.31. As a result of this, the null hypothesis is rejected. Hence we can conclude that the Translog functional form (Table 4.7) soundly explains the stochastic production function of metals and engineering industry sector relative to Cobb-Douglas production functional form.

The second hypothesis test performed in order to make analysis to meet the second objective of the thesis was to find out whether there is any technical inefficiency in the metals and engineering industry. This is done by imposing the restrictions on the translog model that $\gamma=Z_1=Z_2=Z_3=Z_4=Z_5=0$ where $\gamma$ is technical inefficiency and $Z_i$s are the source or the determinants of the technical inefficiency of the industry i.e. investment intensity, age, distance from the main capital city, and labour-capital mix. The alternative hypothesis, there is no technical inefficiency is not true.

For the metals and engineering industries with the selected Translog functional form, comparing the results of the computed LR with the critical value is done. The log-likelihood ratio test statistics is given by:

LR = -2[restricted Translog minus the unrestricted Translog]

LR = -2[-1326.193 – (-1302.159)]

LR = -2[24.034]

R = 48.068

From the computation, if LR value is greater than the critical value we conclude that the null hypothesis of no technical inefficiency effects on the industry is rejected, i.e, the likelihood ratio test statistics is 48.068. The critical value at 1% and 5% significance level using the Chi-square distribution with 5 degree of freedom is equal to 15.09 and 11.07 respectively. Therefore, the null hypothesis is rejected, implying that there is a technical inefficiency effect in the metals and engineering industry.

The third hypothesis tests specifies whether there is a technical inefficiency variation over time or not, i.e, the null hypothesis Ho: $\eta = 0$, which specifies that the technical inefficiency effect is time invariant. If the null hypothesis is rejected showing that the technical inefficiency effect varies significantly over time (time varying inefficiency effect). On the other hand if the value of ($\eta$) is positive indicating that the industries technical inefficiency effects decreases over time and if the ($\eta$) value is negative implying that the industries technical inefficiency increases over time.

The likelihood ratio statistics LR is given by:

LR = -2[Time invariant – Time variant]

LR = -2[-1336.23-(-1316.13)]

LR = 40.46

The likelihood test ratio LR is 40.46. Using the Chi-2 distribution critical value at 5% significance level and with 19 degree of freedom is equal to 30.14. Hence, it is strongly reject the null and accepting the alternative hypothesis of the occurrence of time varying inefficiency effect.

The following table shows the summary of the hypothesis test and the decision of the null hypothesis.

**Table 4.6: Summary of the hypothesis tests using log likelihood ratio statistics**

| S.N | Null Hypothesis | LR Test Statistics | $X^2$ Critical Value (a=0.05) | Decision |
|---|---|---|---|---|
| 1 | C-D Production Function is appropriate | | | |
| | Ho: Ho=β11= β12= β13= β14= β22= β23= β24= β33= β34= β44 =0. | 69.148 | 18.31 | Reject Ho |
| 2 | No technical inefficiency effect | | | |
| | Ho: γ=Z1=Z2=Z3=Z4=Z5=0 | 48.068 | 11.03 | Reject Ho |
| 3 | TE is time invariant | | | |
| | Ho: η = 0 | 40.46 | 30.14 | Reject Ho |

Source: own computation

### 3.2.1. Interpretation of the stochastic Production frontier Estimation Results

The Maximum likelihood Estimation result of the Translogstochasitic frontier form of the Metals and Engineering industries as indicated below presents the estimated parameters value of the coefficients and its sign at 5% and 10% level of significant. All the explanatory variables and the dependent variable were transformed in to logarithm before estimation was undertaken.

**Table 4.7: Time-varying decay inefficiency model**

| LnY | | Coef. | Std.Err | Z |
|---|---|---|---|---|
| Fixed Capital (LnX1) | β1 | 0.5158 | 0.2441 | 2.11** |
| Labour (LnX2) | β2 | 0.4631 | 0.5031 | 2.23** |
| Cost of Raw Material (LnX3) | β3 | -0.2326 | 0.2326 | -2.56*** |
| Fuel & Energy ( LnX4) | β4 | -0.4518 | 0.2266 | -1.99 |
| LnX1LnX1 | β11 | -0.0071 | 0.0195 | -0.36 |
| LnX1LnX2 | β22 | 0.0741 | 0.0307 | 2.41** |
| LnX1LnX3 | β33 | 0.0503 | 0.0119 | 4.24* |
| LnX1LnX4 | β44 | -0.0071 | 0.0134 | -0.52 |
| LnX2LnX2 | β12 | -0.2431 | 0.1186 | -2.05** |
| LnX2LnX3 | β13 | -0.0292 | 0.0310 | -0.94 |

| | | | | |
|---|---|---|---|---|
| LnX2LnX4 | β14 | 0.0158 | 0.0332 | 0.47 |
| LnX3LnX3 | β23 | -0.0140 | 0.0163 | -0.86 |
| LnX3LnX4 | β24 | 0.0110 | 0.0118 | 0.93 |
| LnX4LnX4 | β34 | -0.0435 | 0.0192 | -2.26** |
| _cons | β0 | 12.0593 | 2.1241 | 5.68* |
| Mu | μ | -2.3762 | 12.8924 | -0.18 |
| Eta | | 0.5020 | 0.1154 | 4.35 |
| sigma2 | σ2 | 3.0162 | 1.4273 | 1.1930 |
| Gamma | ϒ | 0.316 | 0.041 | 0.25 |
| sigma_u2 | σ2u | 0.3057 | 1.4251 | -2.4875 |
| sigma_v2 | σ2v | 2.7105 | 0.1610 | 2.3949 |

** , *** are significant at 5% and 10%

As we have seen before, the identified model for the stochastic production frontier is a Translog production function, the coefficients in the stochastic frontier model output (Table 4.7) do not have a direct interpretation like a Cobb-Douglas production function. Hence, the results are discussed based on the following (Table 4.8) elasticity estimates of the production function.

**Table 4.8: Output Elasticity for MEIs estimated at the mean of input level.**

| Variables | Delta-method ey/ex | Std.Err |
|---|---|---|
| Fixed Capital (X1) | 0.263423 | 0.109094 |
| Labour (X2) | 0.1224 | 0.059779 |
| Cost of Raw Material (X3) | -0.22049 | 0.22056 |
| Fuel and Energy (X4) | -0.306754 | 0.153842 |

Source: own estimation output

The elasticity estimate of the input at their mean level fixed capital and labour had a positive sign while cost of raw materials and fuel and energy got negative sign. The positive sign and level of significance at 5% of the coefficient of fixed capital indicates a one percent increase in the value of fixed capital expenditure results to a 26.34% increase in the gross value output production. While the square of fixed capital is not significant and the sign is negative which implies it is inconsistent with the rational of the existing literature. This positive and significant result of fixed capital is also consistent with the result of Habtamu (2010), Nebyou(2011), Dilbetigle(2012),and Melaku(2013) study of Pasta and Biscuit, Brewery, Textile and Garment and manufacturing industries as a whole.

The positive sign of labour expressed as the number of permanent and temporary employee of the industries at 5% level of significant results an increase in the gross value of output production by 21.24% in a one additional employment of labour as a unit of production in the production process. From this result the contribution of one additional unit of fixed capital is essentially important and significantly greater than that of one additional labour employment in order to increase the gross value of output. This shows the metals and engineering industries are highly capital intensive manufacturing sector. While  Melaku (2013) in his study on the total factor productivity and technical efficiency of the manufacturing sector of Ethiopia found out that, fabricated metals product manufacturing were labour intensive, i.e, the coefficient of labour was greater than that of capital. On the other hand, Gebeyehu (2003) in his study of technical efficiency of leather industries found that labour input had a reducing effect on the output of leather and leather products manufacturing firms.

On the other hand, the negative sign of the cost of raw material even if significant at the 10% level of significance shows there is an inverse relationship between gross value of output and cost of raw material, i.e, a reduction of a one percent in the value of cost of raw material results an increment in the gross value of output by 22.05%, keeping other variables constant. This is due to the fact that, most of the metals and engineering industries have been used imported raw materials which is highly dependent on the foreign currency results import has becoming expensive than the previous periods. More over the, the current government devaluated the national currency for five times since 2008. This negative relationship result is the same with that of Nebyou (2011) studied on the Brewery manufacturing.

Similarly, the coefficient of the cost of fuel and energy is negative but it is statistically insignificant. Even though, the variable has been important and used in most literatures, it does not able to explain the technical efficiency of the metals and engineering industries. However, the elasticity estimates indicated that a 30.66% reduction in the value of fuel and energy results a one percent increment the output if metals and engineering firms, keeping other variables constant.  But the square of fuel and energy is significant at five percent level of significant with a negative sign indicating that output is inversely related with the square of fuel and energy. This might be due to the large number of structural metal product manufacturing firms included in the estimation of efficiency outweighs the rest of the other firms.

On the other hand, when we see the interaction between the second order variables, there exists a positive interaction between labor square and fuel and energy, show that there exist an inverted U-shape relationships among the two variables, that is, after the two inputs labour square and fuel and energy square reaches to their optimum label, the output will decrease (Nebyou; 2011).

All the cross interaction parameters of fixed capital with labour, fixed capital with cost of raw material, fixed capital with fuel and energy, labour with cost of raw material, labour with fuel and energy, and cost of raw material with fuel and energy are significantly different from zero, even if, only the interaction of fixed capital with labour and fixed capital with cost of raw material parameters are significant.  This result conforms the selection of the Translog stochastic production function as an adequate representative functional model for metals and engineering industries is justified. The inconsistent of the unexpected and insignificance of some of the coefficients of the parameters might be due to the nature of the translog functional form which is exposed to a multicollinearity problems occurring from the inclusion of cross-product and a square terms of the input variables. However, the purpose of the study is to predict efficiency, tolerating and assuming the existence of some degree of multicollinearity is possible (Maddala, 1992).

### 3.2.2. Production Efficiency of ME Industry

It is assumed that the values of the inefficiency measure during prediction may be influenced by the different assumptions of the distribution of the inefficiency effect ($U_{it}$). In this study since the prediction of the inefficiency $U_{it}$ assumed to distribute a normal distribution of truncated at zero of $N^{+}(\mu, \sigma_u^2)$ Battese and Coelli (1992); despite the different distributional specification produce a relatively similar scoring of firms according to their efficiencies (Kumbhakar and Lovell 2000).

The parameter gamma (γ) indicates the ratio of the variance of firm specific variability, i.e, stochastic frontier inefficiency output to the summation of total output variability ($V_{it}$and$U_{it}$). Table (4.7) indicates ϒ is 0.3161 which shows 31.61% of the observed output variability is due to firm specific performance, where as 68.39% variability is due to random shocks, i.e, the difference or variability of output is due to the occurrence of the technical inefficiencies of the firm. Whereas when we saw the results of other sectors like past and biscuit, Brewery, and leather and leather products, the variation of output due to technical inefficiency were 16%, 86%, and 94% respectively (Habtamu 2010, Nebyou 2011, and Dilbetigle 2012).

The mean technical inefficiency score for the three sub sector of the metals and engineering industry namely manufacturing of basic metals manufacturing industry, manufacturing of structural metal products, and manufacturing of fabricated metal products were 0.44, 0.45, and 0.44 respectively. Even though, there is no significant difference in the inefficiency score among the sub-sectors industries, manufacturing of structural metal products industries had the lowest average technical efficiency.

**Table 4.9: Average Inefficiency Score of the MEIs**

| S. N | Sub Sector | Statistics | 2010 | 2011 | 2012 | 2013 | 2014 | Cumulative |
|---|---|---|---|---|---|---|---|---|
| 1 | Manufacturing of Basic Metals Industry | Average | 0.329 | 0.113 | 0.554 | 0.586 | 0.633 | 0.443 |
| 2 | Manufacturing of Structural Metal products | Average | 0.427 | 0.215 | 0.502 | 0.542 | 0.576 | 0.452 |
| 3 | Manufacturing of Fabricated Metal Products | Average | 0.214 | 0.422 | 0.478 | 0.512 | 0.594 | 0.444 |
| 4 | Metals and Engineering Sector | Average | 0.323 | 0.250 | 0.512 | 0.547 | 0.601 | 0.447 |
| | | Max | 0.818 | 0.736 | 0.741 | 0.746 | 0.808 | 0.818 |
| | | Min | 0.0008 | 0.0001 | 0.1236 | 0.1562 | 0.058 | 0.0678 |

Source: Own computation

The average technical inefficiency score of the metals and engineering industry sector during the study period was 44.7%, which means the sector experiences 55.3% efficiency in production. It also implies that, on average, the metals and engineering industries produced 55.35% of the maximum attainable output level over the period under consideration. The highest average technical efficiency score of the metals and engineering sector during the study period was 93.22% and the lowest was 18.2%, that is, 81.8% and 6.78% maximum and minimum inefficiency were attained, respectively (Table 4.9).

The figure 4.1: depicts the average technical efficiency score shows in 2011 the sector firms experienced the highest technical efficiency achievement. In the same year, among the sub-sectors the basic metals firms were experienced the highest technical efficiency achievement. While in the then period the sector firms were experienced a reduction in technical efficiency. In 2014 the sub-sector industries experienced the minimum technical efficiency in their production process. Starting from 2012 till 2014, the fabricated metals manufacturing firms experienced the highest and followed by structural metals manufacturing firms in their technical efficiency manufacturing processes.

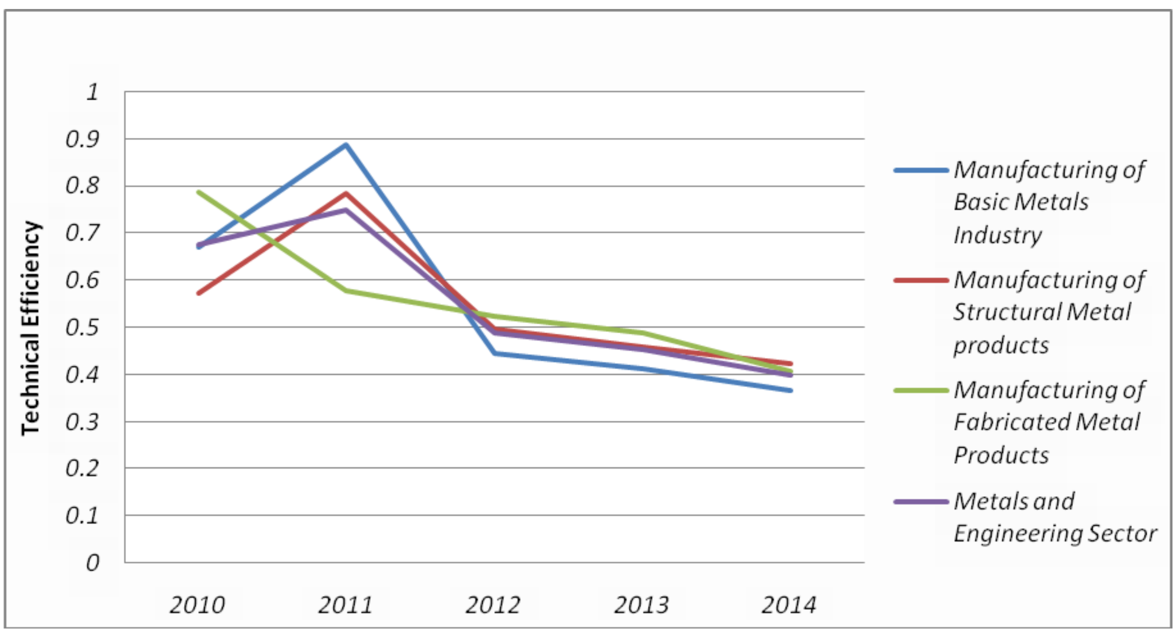


**Figure 4.1: Average MEI Technical Efficiency**

Source: Own computation

Even if it is unstable, on average metals and engineering industries sectoral technical inefficiency level increased by 24.7%, implying that there was an increment in the level of technical inefficiency during the study period. Among the three sub-sectors, the basic metals firms were experienced the highest positive inefficiency growth rate showing that starting from at the beginning of the study period, there had been experiencing a technical production capability reduction. Next to basic metals manufacturing, fabricated metal products manufacturing firms were also experienced a positive and increasing growth rate of inefficiency. While the average inefficiency of the structural metals shows a reduction in the growth rate during the study period (Tabel 4.10).

**Table 4.10: Average Technical inefficiency growth rate of MEIs**

| Year | Basic Metals | Structural Metals | Fabricated Metals | Sector Average |
|---|---|---|---|---|
| 2010 | - | - | - | - |
| 2011 | -0.658 | -0.084 | 0.972 | -0.2279 |
| 2012 | 3.926 | 0.006 | 0.133 | 1.0485 |
| 2013 | 0.058 | -0.031 | 0.072 | 0.0694 |
| 2014 | 0.079 | 0.089 | 0.159 | 0.0984 |
| **Total** | **0.851** | **-0.005** | **0.334** | **0.2471** |

Source: own computation

### 3.2.3. Determinants of Technical Inefficiency

There are a number of firm specific and non-firm specific exogenous variables which is used to explain the causes for technical inefficiencies of manufacturing firms. In this study as it was explained in chapter three only four variables are used to explain the causes for technical inefficiencies of metals and engineering industries of Ethiopia due to unavailability and incompleteness of data.

In this, in order to evaluate the results of the various determinants that affects the technical efficiency of metals and engineering industries, four determinant variables; investment intensity, age, distance and labour-capital mix were used. The variables were chosen, first from their common appearance in most manufacturing and other technical efficiency studies and literatures related with the topic of interest, and secondly, based on the sectors specific characteristics.

**Table 4.11: Technical inefficiency Determinant Estimation result**

| Ui | | Coef. | Z |
|---|---|---|---|
| Investment Intensity | Z1 | -0.0396 | -2.82** |
| Age | Z3 | 5.37E-05 | 0.38 |
| Distance | Z4 | 0.00006 | 0.37 |
| Labour-Capital Mix | Z5 | -0.027 | -1.75*** |
| _cons | β0 | -4.03104 | -0.36 |
| sigma_u | σ2u | 0.936669 | 0.61 |
| sigma_e | σ2v | 2.026642 | 1.84 |

**, *** significance at 5% and 10%

Source: own estimation

**Investment Intensity:** measured by the ratio of net capital addition of the firm to total employments during the year. The study found that the sign of the coefficient of investment intensity is negative but statistically significant at 5% significance level. The result indicates that the variable plays an important role in explaining technical inefficiency in the industry. In other words technical inefficiency declines with an increase in investment intensity.

**Labour-Capital Mix:** measured by the ratio of labour to that of fixed capital during the given study period. However, the result depicts there is a negative sign and significant at 10% level of significance, its contribution to the firms inefficiency is minimum, i.e, technical inefficiency declines with an increase in labour-capital ratio. Meaning technical efficiency of the industry would be improved by increasing the employment and productivity of labour. With one unit of fixed capital increasing the payment of labour which is either due to productivity of labour is improving and demands higher payment of wage and salaries or due to the increment in the number of personnel results higher payment for their services, results an improvement in technical efficiency. Seemingly, the result conforms to Oczkowski and Sharma (2005); a higher labor-capital ratio indicates that firms are more likely to be operating close to its technically efficient level of production.

The other variables distance and age are statistically insignificant. But the positive sign of the coefficients indicate that they have an impact on the technical inefficiency of the metals and engineering industries. For example as explained by Malerba (1992) the positive sign of age which as firms stock of experience grows and identify and eliminate previously used inefficient production methods they could became technically efficient in their production.

## 4. CONCLUSION AND POLICY IMPLICATIONS

### Conclusions

Using unbalanced panel data offive years from 2010 to 2014 the study examined the technical efficiency of 146 metals and engineering firms of Ethiopia and investigated the factors that contributed to the inefficiency of the firms. It formulates a hypothesis that all the metals and engineering firms are technically inefficient. This hypothesis was estimated by a stochastic production frontier model of Battese and Coelli (1995).

The main finding of the study revealed that; the log likelihood ratio statistics estimated using maximum likelihood estimation procedure for the metals and engineering industries were better specified by a translog production formulation. The likelihood ratio test also realized the existence of a time varied technical inefficiency in the metals and engineering firms.

The output result of the estimated input variables coefficients shows that fixed capital and wages and salary (Labour) were statistically significant and got positive sign. While the coefficients of cost of raw material and fuel and energy were negative and only cost of raw material was significant.

The cumulative average technical efficiency score of the metals and engineering industries was 55.3%., i.e., on average technical efficiency of the MEI can be raised by about 44.7%.The identified mean technical inefficiency indicates that there was a slight difference in the inefficiency score among the firms in the sector. The structural metal product manufacturing firms were experienced the highest inefficiency score (45.2%), followed by fabricated metals and basic metals manufacturing plants, 44.4%, and 44.3% respectively.

Among the four determinant variables incorporated to explain technical inefficiency, only two factors investment intensity and labour-capital ratio had a significant effect on the technical inefficiency of the metals and engineering industries.

The gamma value (ϒ) showed that 31.6% of the inefficiency was due to firm specific technical inefficiency effect while 68.39% is due to statistical noise which is beyond the control of the firms.

## Policy Implications

Based on the findings of the analysis of the technical inefficiency and its determinants of the metals and engineering industries of Ethiopia, it is going to figure out and suggest the following recommendations which are relevant for improving the technical efficiency of the sectors manufacturing industries.

- The output of the MEIs has been greatly affected by fixed capital which shows that, the metals and engineering industries of the country are practicing capital intensive production processes. This demands the availability of investment capital accesses for the industries in order to equip them with the necessary capital intensive production equipment and facilities, i.e, installing and replacing equipment/machineries and facilities, and the necessary technologies. The financial provision also supported by the availing of foreign exchange requirements to the industries since most of the machineries are imported.
- The estimation result revealed that the output of the sector is strongly influenced by cost of raw materials next to fixed capital. This is due to the fact that, most of the raw materials for the sub-sector manufacturing firms are imported and it also requires large amount of capital to provide. Hence, the respective government institutions and ministries should work regarding to this variable in order to avail the raw material for firms either in least cost or in the domestic market.
- However, the implication is low; the finding of the negative relationship of Labour-capital mix with technical inefficiency indicates that increasing the employment of labour in the sub-sector will lead firms to improve their technical efficiency. Hence, it might be essential to increase either the quantity or the quality of labour in the sub-sector manufacturing production process.
- The inversely relationship of investment intensity with the technical inefficiency of the sectors industries implied that, increasing the domestic and foreign direct

investment in the areas of metals and engineering sector has an impact on reducing the technical inefficiency.Therefore, the government should work to attract investors to invest in this sector.

- The study found that 68.39% the inefficiency arises due to statistical noise which is beyond the control of the firms; this source of inefficiency might be institutional and infrastructural problems. Therefore, the respective government bodies have to give due attention to tackle these institutional and infrastructural problems.
- The estimation result shows the technical inefficiency of metals and engineering firms of Ethiopia is almost near to half (44.7%). This revealed that there can be a gain in technical efficiency improvement by the sector industries. Therefore, the government and other stakeholders have to work in this regard.
- When doing this study, during data cleaning process it was found that some firms were only joined the sector at the end of the panel period especially in 2013 and 2014. These industries were not included in the study to get free of statistical noise and data consistency. This evidence also supported by the different reports of Metals Industry Development Institute and other respective concerned Ministries. This might be due to the recent establishment and intervention of the Metals Engineering Corporation. Therefore, as we have been observing, the role and impact of the corporation in the improvement of the sectors technical efficiency output, and value addition to the country's GDP is open area for research. Hence, it is recommended for those who would be interested to figure out the impact of the intervention and also in parallel with the context of policy framework. Beside this, studying the allocative and economic efficiency of the sector is a room for further research topic since this study is only limited to technical efficiency and determinants.

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