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Technical Efficiency of Ethiopian Reinforcement Bar Manufacturing Firms

Hanamariam Chanyalew[1]

Abstract

In this study, the technical effectiveness of rebar production companies in Ethiopia's basic metal industry is investigated. In the fiscal year 2021/22, it used the Data Envelopment Analysis (DEA) method. The study employed an output-oriented model with a constant return scale (CRS) assumption. Based on the study, 54.6% of the firms manufacturing reinforcement bars are operating with technical inefficiency. The findings illustrated that firms are in a vicious cycle because of the severe iron deficiency in the country, given that iron or steel as a raw material has a significant contribution to firms' technical efficiency compared to other production factors considered in this study. Extreme deficiency of iron and steel and foreign currency, lack of quality scrap metal and price fluctuation, constant electric power interruption, shipment delay, and a lack of genuine spare parts were identified as external challenges. While poor work culture and discipline, inadequate and poor technological updates and transformation, and a high knowledge and skill gap were internal challenges, Therefore, to effectively utilize the potential of the industry, efforts are required to improve institutional strength, infrastructural development, and the availability of foreign currency and raw materials.

Keywords**:** Technical efficiency, data envelopment analysis, reinforcement bar, firms

[1]E-mail: pacificstarsocean@gmail.com

Introduction

Effective use of those limited resources is required in a society where resources are growing scarcer and human needs and demands are increasing. Efficiency is the capacity to produce the most output from a predetermined quantity of inputs (Farrell, 1957). The level of production currently generated and the output that could be produced with the same resources are compared in terms of efficiency. Technical production efficiency quantifies how closely actual labor resembles higher efficiency (Fare & Lovell, 1978). If a business can generate a large amount of output from a small amount of input, it is technically efficient.

Both iron and steel industries are regarded as the foundation of the world economy. The sector is important in and of itself because of the industry's extensive and robust backward and forward linkages with other sectors. With an estimated global turnover of 900 billion USD, the iron and steel business are the second-largest industry in the world after the oil and gas sector, making it a crucial industry in and of itself. Also, it is a significant supplier of raw materials to the thermal, tidal, and solar energy sectors. Nearly everything in our environment is either made of metal or was produced using metal-based tools and machines (World Steel Association, 2012). Without this industry, there wouldn't have been electric power, electric motors, automobiles, ships, railroads, electric motors, or turbines. Large oil refineries, modern bridges, modest household items like knives and forks, as well as other infrastructure, would not have existed. (Ocheri, Agbo, Daniel, & Ajani, 2017).

Although South Africa and Egypt are the two major producers on the continent of Africa, neither nation has the resources, either in terms of cash or raw materials, to meet the demand of the entire continent. Both the basic metal and engineering industrial sub-sector and the manufacturing industry as a whole do poorly in Ethiopia. At the end of 2015, the manufacturing sector's overall GDP contribution to the nation was barely 6.8 percent (Tolcha, 2017). The goal of this study is to assess the technical effectiveness of Ethiopian rebar manufacturing companies in the basic metal sector. Numerous developing nations, mostly Asian nations like China, India, Vietnam, and Taiwan, as well as some African nations like Egypt and South Africa, are engaged in the manufacture of iron and steel and supply it to domestic and foreign markets, with China accounting for the largest proportion (World Steel Association, 2020).

Using ADLI, the Ethiopian government's GTP I and II project the nation as one of the middle-income nations (Agricultural Development Led Industrialization). To achieve this, the manufacturing sector—which includes Ethiopia's basic metal and engineering industries—is selected as a strategic sector (MOFED, 2016). By the end of the plan term, the metal and engineering sector of the nation is predicted to manufacture 376 billion rubles worth of goods and earn USD 448 million in export revenue. Also, 81.41kg and 46,000 more jobs are anticipated to be added to the per-capita steel consumption and employment, respectively (MOI & GTP, 2015).

Of 60 industries, just 52%, or 343,105 tons of production, were achieved in 2016. About 4.85 billion birrs worth of goods were produced by the sector, which is significantly less than the 15.17 billion Br quarterly plan. In addition, out of the 4.85 billion Br in total money created, basic metal produced 3.37 billion Br. The production rate was expected to be 33.8 and 50.7 billion Birr in 2012-2013 and 2014-2015, respectively, however the actual figures for both years were 19.02 and 30.14 billion Br (Fortune, 2016). The GDP contribution of Ethiopia's basic metal industry in 2014 was approximately 0.40%, and its export performance that year was the lowest of all the sectors and subsectors at 8%. Even when compared to other African nations like Kenya, which consumes 65 kg, Egypt, which consumes 94.7 kg, South Africa, which consumes 67.0 kg, or the average for all of Africa, which is 42.5 kg, Ethiopians consume about 12 kg of steel per capita, which is a very low level. It is also too low when compared to China, which has the fastest-growing economy in the world, which consumes 132.2 kg (World Steel Association, 2021).

Manufacturers of reinforcement bars (Rebar), a crucial supplier to Ethiopia's rapidly developing construction industry, dominate this subsector of the basic metal industry. which has the second-highest GDP contribution (18% share) in the country and accounts for 77.3% of growth in the industrial sector. Yet, the businesses were only able to produce 50% of their individual annual production capacities. Throughout the fiscal years 2017/2018 and 2020/2021, the production of Ethiopian rebar manufacturing businesses fluctuated and decreased from 396,849.50 tons to 319,396.86 tons (MIDI, 2020).

Efficiency is one of the key determinants of competitiveness in both domestic and international markets. Efficiency is "creating an output as large as possible from a given set of inputs," according to Farrell (1957). Using stochastic frontier analysis (SFA), Workneh and Desalegn (2015) examined the technical efficiency of Ethiopia's basic metal and engineering sectors throughout the financial years 2008 to 2012 and discovered a reduction in efficiency. Gelaye (2017) used the same methodology to assess the technical efficiency of the sub-sectors and discovered an average cumulative technical efficiency of 55.3% across the board. The lack of empirical research on the technical efficacy of Ethiopian rebar manufacturing companies—or the basic metal industry—motivated this study. By employing data envelopment analysis methodologies to examine these organizations' technological efficiency, this study aims to make a useful contribution.

The primary goal is to evaluate the technical efficiency of Ethiopian rebar manufacturing enterprises. Identifying the production factor(s) that contribute to a firm's technical efficiency as well as the external and internal challenges such firms are facing are two significant aims. The specific goals are to evaluate the technical competence of Ethiopian rebar producing enterprises. In light of these, the study tries to respond to the following questions: How efficiently are resources used by Ethiopian rebar manufacturers? Which aspect of production enhances a company's efficiency? What challenges—internal and external—must Ethiopian rebar producers face?

Literature Review

Efficiency and Measurement Approaches

Efficiency, according to Farrell (1957), is the ability to get the most out of a given set of inputs. Farrell (1957) created the first method for measuring efficiency based on specific inputs and outputs of organizations or enterprises utilizing just one input and one output. Efficiency, according to Farrell (1957), is a technique that can be used to compare the firm's real performance to a benchmark efficiency score. Efficiency has to do with waste reduction and how much output can be produced with the available level of inputs. Analyzing input utilization and output level has been the foundation for measuring efficiency.

While economic efficiency, as in the econometric approach, can be calculated using both quantities and prices and separated into technical and allocative components, technical efficiency can be estimated just using quantities. The purely technical, or physical, aspect has to do with the capacity to reduce waste by either producing more output than input allows or by using less input than output permits. Technical efficiency research can therefore be focused on either enhancing output or saving input. The allocative, or price, component is the capacity to combine inputs and outputs in the best possible ratios based on current pricing (Lovell, 1993).

Technical efficiency in a production unit is the achievement of the highest output from a given number of inputs while considering physical production relationships. (1957, Farrell). Models are divided into non-parametric and parametric frontiers according to Farrell's method of assessing technical efficacy. Non-parametric frontier models do not impose any functional form on the production frontiers or make any assumptions about the error term when measuring technical efficiency. They employ linear programming techniques, and data envelopment analysis is the most often used non-parametric technique. The production function is given a functional form by the parametric techniques, and assumptions are made about the data. The stochastic frontiers analysis (SFA) method is the most used parametric methodology (Sivakumar & Patnaik, 2000).

Data Envelopment Analysis (DEA)

The original DEA model was based on Farrell's earlier work from 1957 or possibly Debreu's work from the early 1950s, which was published in Charnes, Cooper, and Rhodes (CCR) (1978). (1951 Debreu). Farrell's empirical study only considered single-output cases, and his suggested multiple-output extensions fell short of what was needed for large-data applications (Cooper et al., 1990). In fact, Farrell used DEA to analyze 1950 data from 48 US states while accounting for four inputs and two outputs in agriculture, the field in which it was first used. The term "DEA" was originally used in the context of education, more specifically in a research on "Program Follow Through" conducted in the US in the late 1970s (Santos, Negas, & Santos, 2013). The DEA approach is predetermined by the fact that it is nonparametric and does not necessitate the clear characterization of functional linkages between inputs and outputs or the statistical distribution of inefficiency. It allows us to define efficient and inefficient manufacturers and determine a quantitative measure of efficiency, unlike other benchmarking techniques that rely on assumptions about the sort of behavior of study objects (Goncharuk, 2007).

Model-oriented and the sort of return to scale are two characteristics that can be used to categorize DEA. Based on the model orientation, such as input-oriented and output-oriented, there are two types of models. The output-oriented approach focuses on maximizing the output at a particular input level, whereas the input-oriented model contends that minimizing the input at a given level of output is best. The Charnes et al. (1978) model, commonly referred to as the CCR model, operates under the presumption that altering inputs will likewise alter outputs, imposing constraints such as a constant return to scale and convexity of input-output combinations.

Later, VCR (variable return to scale), which permits variable output that is either increasing or decreasing, was created by Barnes, Charnes, and Cooper. There is a total of four different models: the CCR (Chames, Cooper and Rhodes) and BCC (Banker, Charnes and Cooper) models for CRS (Constant Return to Scale) and VRS (Variable Return to Scale), as well as input minimization and output maximization orientations (Santos et al., 2013).

Figure 1

Input-Oriented Model DEA

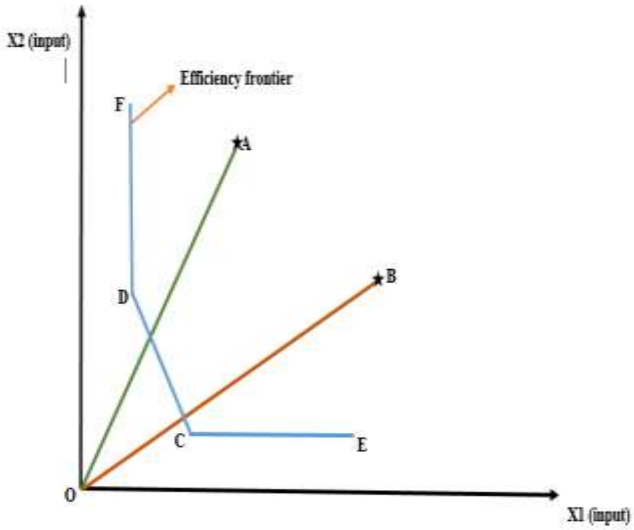
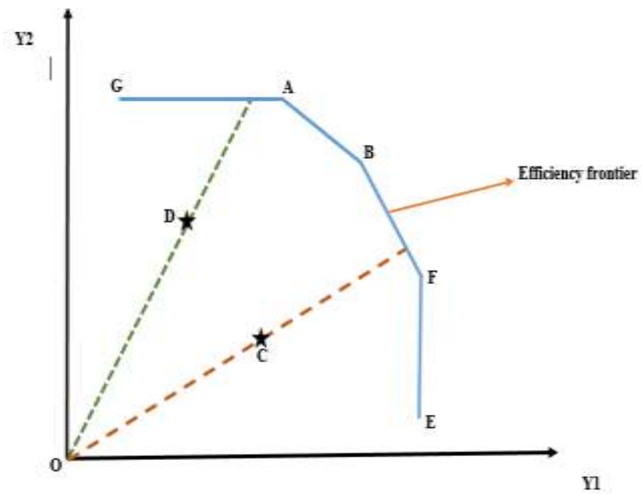


Figure 2

Output-Oriented Model DEA



Source: Own design

Slack

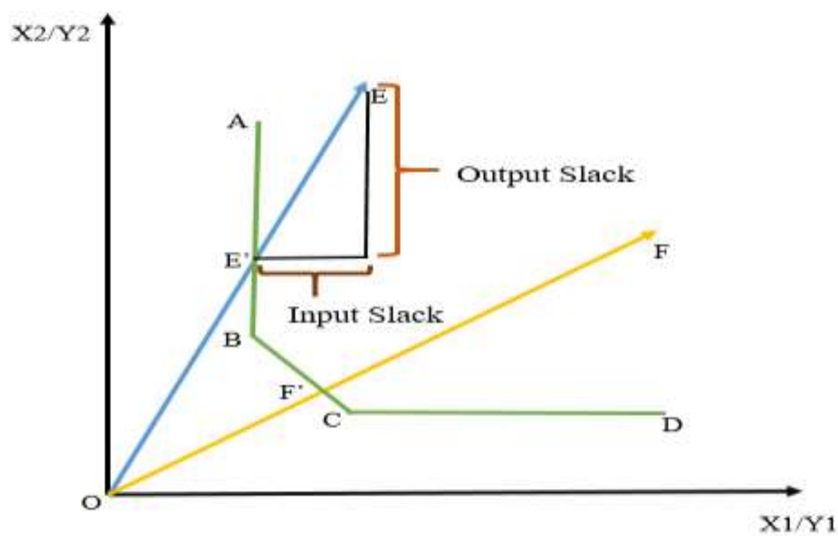
Each DMU's (Decision Making Units) performance depends on identifying the efficient frontier as shown by slack measurement. In general, non-zero input and output slacks are a sign of DEA inefficiency. Each DMU's efficiency can be determined by slack measurement, and if a DMU is found to be inefficient, slack measurement can be used to determine what has to be done to make the DMU more efficient (Park, Lim, Egilmez, & Szmerekovsky, 2016).

There is no slack for effective DMUs. However, if there are non-zero slacks, a DMU may fail to meet its efficient aim. Slack exists for inefficient DMUs, illustrating the areas in which an inefficient DMU must improve to become efficient. The input slack represents the surplus input in the input-oriented DEA model. As a result, to meet the efficiency objective or frontier, the DMU must reduce the remaining inefficiencies or input slack.

As shown in the figure below the DMUs, all A, B, C, and D are four efficient DMU that also indicate the efficiency frontier. Whereas E and F are inefficient DMUs. The distance EE' and FF' represents technical inefficiency in E and F DMUs respectively. This indicates that surplus input utilization produces the same level of output. DMU E' and F' are virtual E and F respectively. Based on Farrell (1957), the technical efficiency of DMU E and F are OE'/OE and OF'/OF respectively. Slack for inefficient DMU E is the distance BE'.

Figure 3

Graphical Representation of Slack



Source: The researcher's own design

Efficiency and Competitiveness

The efficiency and competition theory states that greater efficiency results in more competition. This is so that enterprises can increase profits by running more effectively and cutting costs. This will raise the possibility of new businesses opening up or more strong competitors entering this industry. The principle is simple: effective enterprises survive while ineffective ones fail (Witzel, 2002). One definition state that a company's efficacy and efficiency determine its competitiveness. Competition is a dynamic theory that is connected to the institutions, economic strategies, and policies that countries employ to promote commerce and development. Competitiveness, according to Kumiski, Jalowiec, Maloch, Wojtaszek, and Miciua (2020), is the capacity of an organization to develop, manufacture, and market goods and services that are superior to those of its competitors. Both price and non-price quality factors are used to determine this capability. It's a prevalent misperception that productive efficiency is necessary for survival in a hostile work environment and that its value declines as the level of competition rises (Lovell, 1993).

One of these factors that counts the most is typically seen as the level of competition in a certain country or industry since it increases the pressure on businesses to adopt better technology, cut down on organizational slack, and boost productivity. Weak competition can limit productivity increases since it permits inefficiencies to continue. The management may feel overwhelming pressure to boost productivity and adopt new technology in the absence of sufficient competition, which could result in a productivity gap when compared to best practices. In order to foresee the conditions that lead to greater productivity and the formation of high productivity levels, competition is therefore crucial. Competition narrows the performance difference within a sector, likely through the eviction of inefficient enterprises and the improvement of performance at others. (Pilat, 1996).

World Iron and Steel Industry and Economic Development

The early growth of the iron and steel industries in many of these nations' climb has been largely influenced by the potency of those industries, which are present in all major industrial economies. Iron and steel, with a global turnover of $900 billion, is the second-largest industry in the world after oil and gas (World Steel Association, 2014).

Along with the significant upstream foundry, machining, fabrication, and processing businesses as well as general services like transportation and supply, as well as large-scale economics and industrial activities related to the raw materials used in steel production, these sectors are also seeing significant uplift. Statistics show that the production of raw steel involves more than twenty distinct types of ancillary businesses and economic activities. Primary steel sector businesses are fundamentally different from other industrial firms in several ways. These are essentially strategic sectors that provide for the long-term industrial requirements of a country by serving as feeder channels to a large number of other significant institutions. Without a solid steel foundation, or at least one that can expand over time to accommodate the desired scope of general industrialization, no serious industrialization program can be envisaged.

South Korea, Brazil, Taiwan, and to a lesser extent India are some of the few rising economies that have thriving economies, and these economies owe their prosperity to well-planned steel development projects that have produced more than ancillary, downstream, and spin-off sectors. Any nation's industrial growth is built upon its steel industry. Even though the raw materials are not easily accessible domestically, every country attempts to get and control it because it is so crucial to its development (Ocheri et al., 2017).

Due to their distinctive qualities, metals will be crucial in society's shift to sustainable development. In particular, they will continue to create applications in industries like electronics, telecommunications, and aircraft to suit the needs of both the present and the next generations. There are no indications that metal scarcity will be a big problem for future generations, despite early concerns about shortages. The greatest and fastest-growing stock of metals is "metals in use," which is in addition to metal reserves. These deposits are essentially a permanent asset for civilization because metals are not consumed during production and utilization the same way that energy or degradable components are. The most well-known example of this is gold, which is still "in use" to this day to the tune of 80 percent of all gold ever mined. Theoretically, metals might be recycled endlessly and passed down from one generation to the next. Nevertheless, in reality, this is only feasible for metals used in non-dissipative applications where the metal can be recovered for a reasonable price (Norgate & Rankin, 2005).

Today's economic expansion is essentially unimaginable without steel. The modern era only developed following improvements in the method of mass-producing steel, and it is frequently seen as the beginning of the modern industrial age. Iron and steel were, in fact, said to have been the foundation of the industrial revolution. Almost 6 million people are employed globally in the steel industry, which has a direct added value of US$500 billion. The indirect effects on the steel industry include a potential for an additional $1.2 trillion in added value and 40 million jobs.

Steel-using sectors predicted economic benefit resulted in an extra $1.2 trillion in value added and 49 million new jobs worldwide. 95 million jobs and about $3 trillion in value-added represent roughly 3% of worldwide employment and 3.5% of the world's GDP, respectively (World Steel Association, 2020).

The Performance of the Ethiopian Iron and Steel Industry

Among Ethiopia's light industrial industries, metal, leather, cement, and textiles are regarded as vital subsectors for socioeconomic growth. The sub-sector is classified by the International Standard Classification (ISIC) into two groups: basic industries in metal and engineering Using ore, scrap, billets, slabs, and other resources, basic metal industries produce primary metal products such hot-rolled ribbed and plain reinforcing bars, wire rods, angles, cold-rolled tubes of various profiles, cold-rolled sheets, galvanized sheets, and tubes. On the other hand, engineering industries produce secondary items from primary metals, such as metallic structures, tanks, pressure vessels, machined parts, machinery, transport equipment, electrical and electronic equipment, and measurement and control devices (Dufera et al., 2020).

According to a research by Dametew et al. (2020), Ethiopia's basic metal industries are failing in terms of market share and GDP contribution because of a shortage of skilled labor, problems with the infrastructure, and financial constraints. In Ethiopia in 2014–15, the low value-added and small share of the metal and engineering sectors amounted for about 0.8 percent of GDP, or $US0.5 billion in value-added. These industries are expected to grow on average by more than 25% per year over the next ten years, with a GDP contribution of more than 2.5% by 2025. According to the JICA, the nation spent a total of Birr 2.76 billion on basic metal products and Birr 10.86 billion on technical goods in 2005. The imports of basic metals and engineering have a total value of $13.62 billion. In addition, a study by the Ethiopian Association of Basic Metals and Engineering Industries found that between 2008 and 2009, overall imports of metals and engineering items rose by 43%. (Gatew, 2011). Numerous problems affect the sectors, including poor production quality, manufacturing waste, inefficient resource use, unsatisfactory facility layout systems, a lack of adequate production space, issues with skilled labor, issues with research and development, a lack of cohesion, including subpar coordination, low production capacity, and effectiveness, as well as inefficient service and support delivery (Dametew et al., 2020).

Empirical Literature Review

The most popular non-parametric technique is DEA. In their 2002 study, Ma, Evans, Fuller, and Stewart analyzed the relative technical effectiveness of 88 businesses during the fiscal years 1989–1997. The authors included finished steel, crude steel, and pig iron as outputs and used energy, working capital, employment, age, net fixed capital, and labor as inputs. Dwivedi, Ghosh, and Dangayach (2013) used a non-parametric approach (DEA) based on their total sales throughout the study period to analyze the technical efficiency of 17 public and private steel enterprises in the Indian steel industry during the years 2006–2010. They used CRS and VRS models to implement both input- and output-oriented measurements. The study showed that a part of the private sector is more efficient than other firms. Eight Taiwan steel-making firms' technical efficiency was examined using DEA for 1990–2001. The study considered labor, capital, and intermediate materials as input variables (Tien, 2004).

The East African manufacturing firms (Ugandan, Tanzanian, Kenyan, and Tanzanian) technical efficiency values were calculated using the DEA approach. The study also evaluated the relationship between firm size and technical efficiency using 403 firms participating in the sectors. The authors considered capital and wages as output factors and intermediate input, age, and firm size as input factors (Aggrey, Eliab, & Joseph, 2010). Cheruiyot (2017) examined the technical efficiency of 396 firms from nine sub-sectors that operate in Kenya. The authors considered age, size, capital, and labor as input variables and sales as an output variable using the DEA approach.

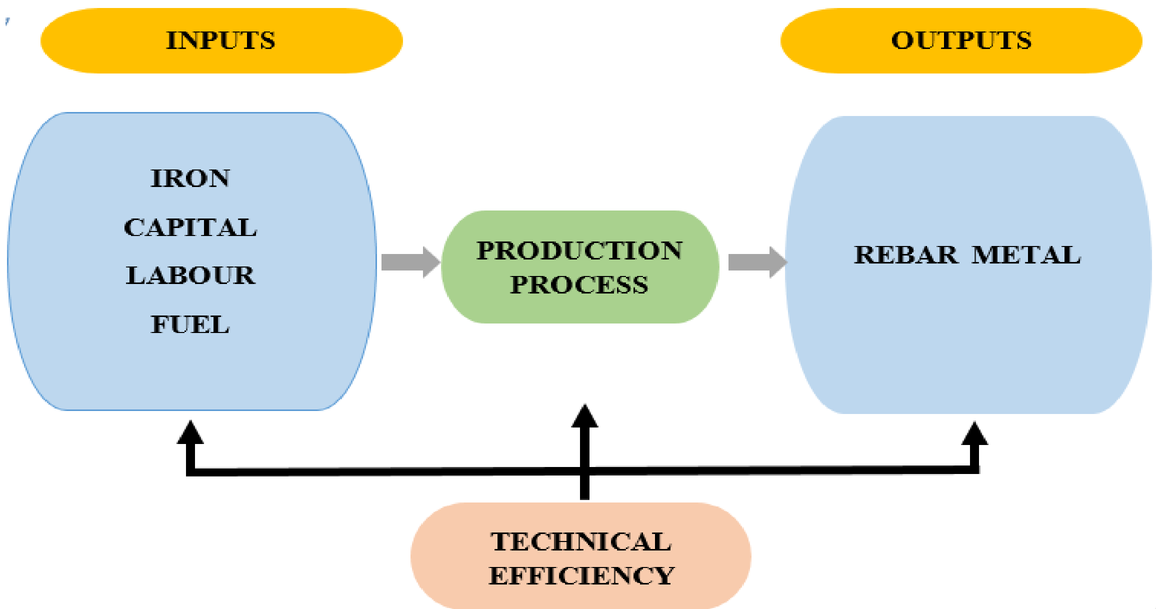
Twenty Ethiopian basic metal industries were examined by Workneh & Desalegn (2015) between 2008 and 2012 using stochastic frontier analysis (SFA). Gross output values, industrial costs, fixed assets, raw materials, wage rates for manual and non-manual labor, and salaries were used in the study as input and output variables, respectively. The investigation concluded that from the fiscal years 2008 to 2012, the basic metal production enterprises' average yearly technical efficiency was under 20%. Gelaye (2017) used stochastic frontier analysis to look analyze 146 businesses in the Ethiopian basic metal industry between 2010 and 2014. In order to demonstrate the validity of the hypothesis, the author employed the cost of raw materials, the gross value of output, fixed capital, labor, fuel, and energy as input and output variables. As a result, 45.2% of structured products, 44.4% of fabricated metals, and 44.3% of basic metal manufacturing firms' technical inefficiencies were exhibited.

Conceptual framework

The following conceptual framework is created based on the theoretical and empirical literature to assess the technical effectiveness of Ethiopian rebar manufacturing companies.

Figure 4

A Conceptual Framework



Source: The researcher's own design

Methods of the Study

Data envelopment analysis is the most popular technique for gauging technical efficacy in a non-parametric way (DEA). The original version of DEA was created in 1978 by Charnes, Cooper, and Rhodes (CCR). The relative technical efficiency of the rebar production companies in Ethiopia's basic metal industry is estimated using DEA. DEA is chosen because it can handle multiple inputs and outputs, it doesn't use a strict production function, it makes assumptions about the data, and it is appropriate for small numbers of sample size data. The firms considered are also homogenous (they use similar but not necessarily identical inputs and produce similar outputs).

CCR, which was created by Charnes, Cooper, and Rhodes and states that a change in input transfers into the same output, is used in this study. The study also uses an output-oriented approach, which suggests getting the most output possible from a given quantity of input. Due of the iron and steel industry's reliance on limited resources like money and raw materials, this model was adopted. Here is a discussion of DEA using an output-oriented model predicated on the CRS model specification.

The technical efficiency of each DMUs (Decision Making Units) is defined as the ratio of a weighted sum of input to a weighted sum of output such as$\frac{v_i x_i}{u_j y_j}$. To obtain the optimal weights the mathematical fractional non-linear programming model is written as follows;

$$Min_{ujvi} = \frac{\sum_{i=1}^{m} v_i x_{iq}}{\sum_{j=1}^{s} u_j y_{jq}}, \ldots\ldots\ldots\ldots (1)$$

Subjected to these constraints;

$$\frac{\sum_{i=1}^{m} v_i x_{iq}}{\sum_{j=1}^{s} u_j y_{jq}} \geq 1,$$

$$q = 1,2, \ldots\ldots..n$$

$$u, v \geq 0$$

Where;

u_j= weights of output j: where j= 1, ………, m

v_i= weight of input I: where i=1, …….., s

y_{jq} =amount of j produced by DMUq

x_{iq}= amount of input I used by DMUq

The above problem allows us to obtain the values of u_j and v_i that minimizes the ratio of DMUq, subjected to the constraint of all efficiency measures must be greater than or equal to zero. This problem with the above equation is it has an infinite number of solutions for u_j andv_i. To avoid this in the case of an output-oriented model, the constraint $u_j y_j = 1$ is imposed which presents a linear programming problem:

$$Min_{u'v'}(v'x_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

S.t; $u'_j y_j = 1$

$$\sum_{i=1}^{m} v_i x_{iq} - \sum_{j=1}^{s} u_j y_{jq} \geq 1$$
$$u, v \geq 0$$
$$q = 1,2, \dots \dots . . n$$

This transformation is called multiplier from of linear programming problem where u and v are replaced by u’ and v’ respectively. As a result, based on the duality of the linear programming problem it is possible to drive an envelopment form of the above problem for the output-oriented model with the CRS assumption as follows;

$$Max\phi, \lambda\phi \ \dots\dots\dots\dots\dots\dots\dots\dots \ (3)$$
$$\text{S.t; } \phi y_j + y\lambda \geq 0$$
$$x_i - x\lambda \geq 0$$
$$\lambda \geq 0$$

Selection and Description of inputs and outputs

The number of inputs and outputs is determined based on (Golany & Roll, 1989) formula n=2*(m+n), Where m is number of inputs and n is number of outputs. Table 1 provides a description of the study's inputs and outputs.

Table 1

Description of Factors Used in Technical Efficiency Analysis

Factors	Description	Measurement
Iron Raw material (I)	This includes all the iron slag or steel used to produce reinforcement bars.	Ton (t)
Capital (I/P)	This represents assets that are long-term with a life span of more than one year. It only includes the physical units which are equipment and machines used in the production process.	Birr
Power (P)	Includes the electric power used in the budget year since the industry utilizes a huge amount of electric power. The physical value of electric power is considered.	KW (Kilo Watt)
Labour (L)	Includes all workers who are permanent employees.	Number of employees
Rebar Metal produced (O/P)	This represents the amount of rebar metal and steel produced by the firms.	Ton (t)

Source: Author’s computation

Six categories are used to group 36 basic metal manufacturing companies. A non-probability purposive sampling strategy is used in this investigation. As a result, the manufacturing companies for rebar (reinforcement) are chosen from the six categories. Because of their high production capacity in comparison to other categories and since they are the largest suppliers to the construction industry, the study considered all 11 rebar producing companies in Ethiopia. In the fiscal year 2021–2022, primary data are gathered through interviews with rebar production companies in Ethiopia's basic metal sector.

Result and Discussions

DEA results and discussion

In this study, DEA is used to assess the technical efficacy of rebar production businesses in Ethiopia's basic metal industry (Data Envelopment Analysis). An output-oriented and Constant Return Scale (CRS) model is used to analyze the technical effectiveness of 11 DMUs using four input variables and one output variable (Ethiopian rebar manufacturing firms).

Technically, six out of the eleven rebar manufacturing enterprises are considered to be efficient. The technological efficient firms are SRMI, HM, ESM, SES, ACRM, and ES since their efficiency score is one. Because they had a technical efficiency score below one, the following 5 businesses are technically inefficient. NSM and RE are the most and least technically inefficient, with efficiency scores of 0.6915 and 0.99999, respectively.

Even though all six of the firms have efficiency scores of 1, making them technically efficient, ACRM is the most effective of the technically efficient firms because it has been utilized as a benchmark by six other firms equally, including itself. This also indicates that the company has been used as a benchmark by other companies five times, making it the most effective company among Ethiopian rebar production companies. The outcome reveals that the company SRMI is used as a benchmark exactly twice.

Despite being technically efficient, the firms ES, HM, SES, and ESM have not been used as benchmarks for any other firms and each have zero peers. The firms with zero peers are still theoretically efficient, but they don't possess any traits that other inefficient firms may use as a standard; rather, these firms are their own peers. Based on how frequently a firm is used as a benchmark (peer count/reference) for other firms, it is possible to rank the firms according to their individual efficiency scores. The efficiency score and the 11 companies that make up each peer group are displayed in the table below.

Table 2

Technical Efficiency of Ethiopian Rebar Manufacturing Firms and Their Rank

DMUs	Efficiency Score	Number of times used as a reference for themselves	Number of times used as a reference for other firms	Rank
Abyssinia Cold Rolling Mills (ACRM)	1	1	5	1
Steely RMI (SRMI)	1	1	2	2
East Steel (ES)	1	1	0	3
Huano Manufacturing (HM)	1	1	0	3
Ekos Steel Mill (ESM)	1	1	0	3
Sentinel Steel (SES)	1	1	0	3
Rose Ethiopia PLC (Ethiopian Iron and Steel Factory) (RE)	0.9999	0	0	4
Zhen Zhen Iron and Steel Manufacturing (ZZISM)	0.9871	0	0	5
Sino Steel (SIS)	0.937498	0	0	6
GEC Steel Manufacturing (GSM)	0.937497	0	0	7
Nazcheb Steel Manufacturing (NSM)	0.691462	0	0	8

Source: Author's computation

Slack Analysis

Businesses that are currently inefficient must either use more input or less output in order to become efficient. Based on their slack levels, all five of the study's inefficient organizations have input slacks, but none of the firms have output slack. The table shows that certain organizations require more significant modifications to achieve technological efficiency. For instance, most companies need to use less energy relative to the amount of output they produce. While manufacturing reinforcing bars, all inefficient enterprises spend more money than is necessary to achieve the same level of output. All underperforming businesses must reduce their capital consumption in order to become efficient, albeit some must do so more radically than others. All inefficient businesses, with the exception of one, must cut back on the labor they employ when producing rebar. Yet, no firm, including both efficient and inefficient firms, has any production slack.

Table 3

Input Slack and Output Target of Inefficient Firms

DMUs	Input slack			Output target
	Capital (birr)	Labour	Power (KW)	Rebar Metal
RE	75,659,120.7	128	-	30690.04
ZZISM	383,131,729.8	-	34,807.3	33,800
SIS	486,426,329.2	68.66	549.3	3,527
GSM	141,431,100.1	6.6	1,792,630.2	17,920
NSM	26,959,297.8	88.4	2,212,667.05	3,241.1

Source: Author’s computation

Production Factor Contributing to Rebar Manufacturing Firms' Efficiency

While not all production factors will have the same weight, some elements among the many production factors may have a substantial impact on a company's efficiency. The table below illustrates that of the five production factors considered in this study, iron primarily displayed higher significance in the effectiveness of the rebar manufacturing enterprises.

Table 4

Firms Rank Based on Efficiency Score and Productivity Result

DMUs	Iron Productivity	Power productivity	Capital productivity	Labour productivity	Technical efficiency score
ACRM	1.000003	2.431544	0.000196	165.35	1
SRMI	1	18.75	0.00029	294.12	2
RE	1	5.683	0.00015	117.59	4
NSM	0.6915	0.00101	0.000052	20.75	8
GSM	0.9375	0.0093	0.000072	146.09	7
HM	0.8333	2.8455	0.00081	48.91	3
SIS	0.9375	1.6535	6.56e-06	36.74	6
ZZISM	0.9871	0.8341	0.000067	238.31	5
ESM	0.625	45.54	0.000083	108.7	3
SES	0.9106	1	0.00047	98.25	3
ES	1	3.6774	0.00029	228	3

Source: The researcher's own design

Based on the efficiency score, peer count, and firm productivity among the four production elements evaluated in this study, iron is found to be leading in its contribution to the firms' accomplishment of efficiency, followed by capital. The other production factors failed to demonstrate a characteristic that would link their impact on the way enterprises making rebar metal attain efficiency. According to the firms' technical efficiency and productivity score, the three most efficient firms have the highest iron productivity, which suggests that the production factor of iron holds the key to the Ethiopian rebar manufacturing firms being efficient. Hence, the main factor in production that considerably raises business productivity is iron.

Challenges of Ethiopian Rebar Manufacturing Firms

The primary producers of rebar in the basic metal sector are Ethiopian companies. There are numerous internal and external challenges, according to the replies obtained from the rebar manufacturing companies. The following list of these external and internal problems is provided:

- **Shortage of foreign currency:** The Ethiopian rebar manufacturing firms highly emphasized the shortage of foreign currency, which is becoming the biggest challenge for the firms to operate at full potential since most of the materials for the production are imported, especially in recent years. The current budget year is witnessing the biggest shortage of foreign currency. The respondents said, "For an industry, raw materials are not available inside the country. And these necessary materials required to be imported from other countries in foreign currencies have become greatly valuable, and their shortage has halted the development of the industry. Because of this, many firms are almost at the edge of breaking down, with young and small firms closing down. As a result of the shortage of foreign currency, the industry will suffer from more underproduction and incompetence".

- **Shortage of iron and steel:** The firms and other sectors producing any kind of product that requires this material are subjected to a major deficiency of iron and steel. The firm's managers indicated that "the shortage of foreign currency is the biggest contributor to the lack of iron/steel. With the country still behind in the iron mining process (the idea of starting iron mining has been proposed by many government entities but has never been realized) and with the current shortage of foreign currency, the supply of iron and steel has been deteriorating". The lack of iron in the process of rebar metal production has contributed to underproduction in the industry and the industry never being competent. The respondents said, "With the lack of raw materials like iron and steel, the process of manufacturing reinforcement bars is subjected to a decline in production, which is why many firms are performing below their full capacity". And with the basic metal industry being the biggest supplier for the engineering industry and the rebar manufacturing firms being the biggest supplier for the largest contributor to the country's GDP, the lack of iron and steel in the construction sector is and will continue to significantly affect the growth of many industries given the industry having the biggest supply chain.

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- **Lack of genuine spare parts:** According to the respondents, since the firms possess a variety of equipment and machinery, spare parts are highly required. For the firms to operate at full potential and with less downtime, quality spare parts are required. According to the respondents, "for both sudden failures of machinery or planned maintenance, availability of spare parts, especially authentic ones, is becoming rare in the country with the foreign currency shortage becoming extensive. The lack of genuine parts isn't only affecting our firms' current production capacity but also future production because of the shorter machinery life span caused by bad and poorly performing spare parts. As a result, future firm growth is jeopardized".
- **A continuous electric power interruption:** Firm managers reflected: "The Ethiopian basic metal industry as a whole, requiring a large supply to operate the equipment and machinery, has been knocked hard. Even though we have tried to build our power supply line (like transformers) and create a separate line to the production line to avoid the constant breakdown of electric power transmission lines, the challenges still exist. Yes, we have mitigated interruption of electricity because of the failure of electric transmission equipment, but our firms are still suffering from electric power interruption".
- **Shipment delay:** According to the respondents, for an industry that depends solely on imported goods, shipment delay is indeed a challenge many rebar manufacturing firms are facing. The Ethiopian Shipping and Logistics Corporation being the only agency operating in the country for importing any kind of goods from abroad, acquiring all the products firms need for production in time has been difficult. The corporation has a limited number of ships, containers, and storage space for enough goods required by every small or large enterprise or company to be delivered. Any firm that requires imported materials has to wait for the Ethiopian shipment containers to free up as well as for the ships to return from wherever they went, for there is no other shipment organization positioned at the port of Djibouti other than the Ethiopian shipping and logistics shipment services enterprise. A firm manager said, "I have to wait at least weeks and mostly months to receive what we ordered because of three reasons. First, there are not enough ships to go wherever we ordered the product, so I have to wait for ships to be free or go to the same route; second, when there are ships available, there aren't enough containers; and third, when there are ships and containers available, my goods have to wait for weeks to be unloaded from the ship because there is not enough space. As a result, shipment delays are affecting our companies' production. If there were other ports and shipping corporations, this problem maybe will get relief".

Besides the challenges caused by external factors the firms also highlighted factors that are creating internal challenges. This includes:

- **Poor work discipline and work culture**: For an industry with high demand, on-time delivery, and large production, high employee productivity, strong discipline, and a positive work culture are required. Respondents said, "Their firm employs many labors, particularly those with little academic progress, who show poor work culture and discipline that is presenting a challenge for managers as well as for a company that aims to be competitive".

- **Weak technological update and transformation**: for the industry to be productive, efficient, and competitive, continuous technological updates and transformation are required. The respondents added, "Indeed, we notice the technological upgrade in the industry, but there have been two issues that are challenging. First, the technological upgrades executed by international firms are too expensive for us to afford the technology. The second issue is that the transformation of technology is tough because of two reasons: first, there is a high knowledge and skill gap in the industry, and second, the educational system in the country is not oriented by the industry needs, thus finding educated and trained employees is hard".

Conclusion and Recommendations

Conclusion

For the fiscal year 2021–2022, the study looked at the technical effectiveness of 11 reinforcing bar manufacturing companies in Ethiopia. The study used Data Envelopment Analysis (DEA), with iron, capital, labor, and power as the input variables, and rebar metal generated by the enterprises as the output variable. According to the study's findings, 54.6% of Ethiopia's rebar manufacturing companies run inefficiently technically. Using iron and steel and a firm's technical proficiency are two of the four production parameters that were considered. Iron therefore shown to have made a substantial contribution to the technical effectiveness of the enterprises. The improvements required in the operations of the inefficient firms are carried out using the results of slack analysis and output targets. The results indicated that there are only input slacks within all five inefficient firms.

The results of the interview demonstrated that some of the external challenges the firms face include a severe lack of iron or steel as a raw material and foreign currency, frequent power outages, a shortage of high-quality scrap metal and price fluctuations, shipment delays, and a lack of genuine spare parts. Internal issues include a lackluster work environment and lack of discipline, inadequate technological transfer, and gaps in knowledge and competence. In general, given the extensive backward and forward linkages across industries, businesses can contribute to national growth by improving their technical efficiency and tackling the issues they are now facing.

Recommendation

For efficient firms to increase their competitiveness in the global market as well as enhance their productivity, they need to adopt new technology; otherwise, there won't be any improvement since the firms are already on the efficiency frontier. Given the strong nexus between technical efficiency and the production factor iron, the firms need to formulate a strategy for better utilization of iron, and the government needs to address the shortage of iron to increase firms' productivity and competitiveness. Educational institutions and the industry itself need to adopt industry-oriented training and educational systems to address the knowledge and skill gaps as well as the poor technology transfer. Preserving quality scrap metal and creating a substantial market for it since it can partly substitute imported iron should get enough attention from concerned parties.

While being a substantial industry and part of a strategic sector, it is heavily dependent on imported raw materials and faces difficulties such as a lack of foreign currency and raw materials, frequent power outages, and shipment delays, to name a few. In order for the industry to operate at its full potential and contribute to the national economy, as is seen in other industrialized as well as emerging countries, the government must pay appropriate attention to alleviating the problems and providing the required support. According to the MIDI report and data gathered directly from the companies, foreign investors dominate the Ethiopian basic metal industry as a whole. While this isn't necessarily incorrect, it does lessen local investors' participation and contribution and create a market where locally owned businesses are unable to compete or thrive. The researcher asks further researchers to investigate the technical efficiency and factors that affect the other five categories of Ethiopia's basic metal sector.

References

Aggrey, N., Eliab, L., & Joseph, S. (2010). Firm Size and Technical Efficiency in East African Manufacturing Firms. *Current Research Journal of Economic Theory*, 69-75.

Charnes, A., Cooper, W., & Rhodes, E. (1978). Measuring the efficiency of Decision-making units. *European Journal of Operational Research*, 429-444.

Cheruiyot, K. J. (2017). Determinants of Technical Efficiency in Kenyan Manufacturing Sector. *African Development Review*, 44-55.

Cooper, W. W., Seiford, L. M., & Zhu, J. (1990). DATA ENVELOPMENT ANALYSIS History, Models and Interpretations. *Journal of Econometrics,*1-39.

Cullinane , K., Wang , T.-F., Song , D.-W., & Ji, P. (2006). The technical efficiency of container ports: Comparing data envelopment analysis and stochastic frontier analysis. *Transportation Research Part A*, 354-374.

Dametew, A. W., Kitaw, D., & Ebinger, F. (2020). Enhancing Basic Metal Industry Global Competitiveness through Total Quality Management, Supply Chain Management & Just-In-Time. *Optimization in Industrial Engineering*, 27-46.

Debreu, G. (1951). The Coefficient of resource utlization . *Econometrica*, 273-292

Dwivedi, A. K., Ghosh, P., & Dangayach, G. S. (2013). Efficiency measurement of Indian steel industry using data envelopment analysis. *Int. J. Operational Research,* 386-400.

Dufera, Solomon & Bhaskaran, Jagadeesan & Singh, Balkeshwar & Tadele, Beza. (2020). Status and Challenges of Advanced Manufacturing Technology Transfer and Implementation In Ethiopia. 7. 1480-1493

Fare, R., & Lovell, C. A. (1978). Measuring the technical efficiency of production. *Journal of Economic Theory*, 150-162.

Farrell, M. J. (1957). The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society*, 253-281.

Gatew, G. (2011). Technology Transfer as a Vehicle for Industrial Development Case of Basic Metals and Engineering Industries.

Gelaye, Y. (2017). productive technical efficiency of Ethiopian basic metal and engineering industries: a stochastic frontier approach. Semantics Scholar. https://www.semanticscholar.org/paper/PRODUCTIVE-TECHNICAL-EFFICIENCY-OF-ETHIOPIAN-BASIC/23986bedb5553af02e368c6af3bf68caa9fce1f3.

Ghosh, A., Sarkar, A., & Guha, B. (2021). Comprehensive efficiency measurement of five major Indian Steel companies using data envelopment analysis and factor analysis. *Malaya Journal of Matematik*, 31-36.

Golany, B., & Roll, Y. (1989). An Application Procedure for DEA. *OMEGA Int. J. of Mgmt Sci*, 237-250

Goncharuk, Anatoliy. (2007). Using the DEA in efficiency management in the industry. International Journal of Productivity and Quality Management - Int J Prod Qual Manag. 2. 10.1504/IJPQM.2007.012413.

Kuźmiński, Ł., Jalowiec, T., Maśloch, P., Wojtaszek, H., & Miciuła, I. (2020). Analysis of Factors Influencing the Competitiveness of Manufacturing Companies. *European Research Studies Journal*, 217-227.

Lovell, C. (1993). Production Frontiers and Productive Efficiency. *oxford university press*, 3-67

Ma, J., Evans, D. G., Fuller, R. J., & Stewart, D. F. (2002). Technical efficiencyand productivitychange of China's iron and steel industry. *Int. J. Production Economics,* 293-312.

Brian Mazorodze (2019): Trade and efficiency of manufacturing industries in South Africa, The Journal of International Trade & Economic Development, DOI: 10.1080/09638199.2019.1640273

Metal and Engineering Industry Underperforms. (2016, November 15). Fortune. https://allafrica.com/stories/201611150627.html

MIDI. (2020). annual report.

MOFED. (2016). annual report.

https://mof.govmu.org/Documents/Annual_Report/MOFED_Annual_Report-FY_2016-17.pdf

MOI, & GTP. (2015). *Ministry of Industry: Growth and Transformation Plan.* Addis Ababa: Ministry of Finance and Economic Development.

Norgate, T. E., & Rankin, W. J. (2005). The role of metals in sustainable development.

Ocheri, C., Ajani, O., Daniel, A., & Agbo, N. (2017). The Steel Industry: A Stimulus to National Development. *Journal of Powder Metallurgy & Mining*, 156.

Park, Yong Shin; Lim, Siew Hoon; Egilmez, Gokhan; and Szmerekovsky, Joseph, "Environmental Efficiency Assessment of U.S. Transport Sector: A Slack-based Data Envelopment Analysis Approach" (2016). *Mechanical and Industrial Engineering Faculty Publications*. 18. https://digitalcommons.newhaven.edu/mechanicalengineering-facpubs/1

Pilat, D. (1996). COMPETITION. PRODUCTIVITY AND EFFICIENCY. *OECD Economic Studies.*

Santos, Jorge & Negas, Elsa & Cavique, Luis. (2013). Introduction to Data Envelopment Analysis. 10.1007/978-94-007-5739-4_3.

R Settu, Dr. K Padhmanaban. Role of iron and steel industry in the promotion of Indian economy¬: A study. International Journal of Commerce and Management Research, Volume 2, Issue 11, 2016, Pages 44-50.

Parameswaran, M. (2002) Economic reforms and technical efficiency: firm level evidence from selected industries in India. CDS working papers, no.339. Trivandrum: CDS.

Tien, H.-H. (2004). Estimating the Efficiency of Taiwan's Steel-Making firms. *the international centre for the study of East Asian Develeopment*, 1-15.

Tolcha. (2017). Trends, Challenges and Prospects of Advanced Manufacturing Technology Transfer and Implementation: A case of Ethiopian Basic Metal and Engineering Industries (BMEIs). *Adama Univeristy*.

Witzel, M. (2002). A short history of efficiency. *Business Strategy Review*, 38-47.

Workneh, H., & Desalegn, G. (2015). Competitiveness of Ethiopian Industries: The case of Metal and Metal Products Industry. *journal of Trade and Business,*1-52.

World Steel Association. (2012). World steel in figure 2012. https://worldsteel.org/steel-topics/statistics/world-steel-in-figures/.

World Steel Association. (2021). 2021 world steel in figures. https://worldsteel.org/steel-topics/statistics/world-steel-in-figures/

World Steel Association. (2014). Steel Statistical Yearbooks 2014. https://worldsteel.org/steel-topics/statistics/steel-statistical-yearbook/

World Steel Association. (2020). Steel Statistical Yearbooks 2020. https://worldsteel.org/steel-topics/statistics/steel-statistical-yearbook/.