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SCHOOL OF GRADUATE STUDIES

PRODUCTION BEHAVIOUR AND TECHNOLOGY: A PRODUCTION FUNCTION APPROACH

A STUDY BASED ON SPECIFIC ETHIOPIAN MANUFACTURING INDUSTRIES

TADDESE AYELIGNE

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253

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PRODUCTION BEHAVIOUR AND TECHNOLOGY: A PRODUCTION FUNCTION APPROACH

A STUDY BASED ON SPECIFIC ETHIOPIAN MANUFACTURING INDUSTRIES

A thesis submitted to the School of Graduate Studies, Addis Ababa University

In Partial Fulfilment of the Requirements for the Degree of Masters of Science
in Economics
(Economic Policy Analysis)

BY

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ADDIS ABABA
SEPTEMBER, 2000

ACKNOWLEDGMENT

This research has been accomplished with the help of many people to whom I am indebted. First my appreciation is to my advisor, Dr. Getachew Asgedom, for his valuable comments and suggestions while writings my thesis. I owe special thanks to my dear friend, Wondrad Worku, who provide me his personal computer for my research work that helped me a lot and solved many problems. I whole heatedly thank him for that.

I would like to express my special appreciation to my father and mother who raised me with strong advice that "Those who hate and think education as too costly will exercise the alternative... Ignorance." My appreciations is also to my sister, brothers, parents again and my uncle who assisted me financially and in other aspects during my career as a self sponsored student.

I would like also to give thanks to my lecturers from Oxford University, Dr.Ajay Tandon, and from Addis Ababa University, Economics Department (Dr.Alemu Mokonnen, Dr.Alemayehu Seyoum, Ato Getachew Yosep and Dr. Gebrehiwot Ageba) who taught me in dedication. My thanks in this regard also extends to my lecturers at the Joint Facility for Electives (JFE) in Nairobi, Kenya, while studying selective courses, advanced Econometrics and Corporate Finance and Investment. I give thanks also to the African Economic Research Consortium (AERC) for sponsoring my stay and my eduction at the JFE.

Finally my appreciations is also to my dear friends Dawit Mekonnen, who is working in the Central Statistical Authority, and who provided me the necessary data for my research on time.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES AND ANNEXES

ABSTRACT

The growth of the industry sector is the base for the development of any country both technologically and economically. Ethiopian being one of the Least Developed Country (LDCs), it suffers a lot from technological backwardness and hence poor economy. This paper tries to investigate the production behaviour and determine the rate of technological progress of selected industries of the Ethiopian manufacturing sector over the period 1978-1998 using results from the Cobb-Douglas and the constant Elasticity of Substitution (CES) production functions and the Growth Accounting technique.

The empirical results reveal that except one in the rest industry groups covered in the study labour input contributed more for the increase in output. It also shows that while three industry groups exhibited a constant returns to scale, other industries exhibited increasing returns to scale in their production processes. Furthermore, low substitution possibility between capital and labour inputs in the production process has been observed. Finally, regarding the type of technology of production and the rate of technological progress, labour intensive technology was found to be the basic feature and the rate of technological progress was very low, less than 5%, over the period of the study.

CHAPTER 1

INTRODUCTION

1.1 Background

The industry sector is the base for the development of any country both technologically and economically. This is evidenced from the growth and development of many Western Europe countries, after what is known as the industrial revolution or industrialization in the mid-eighteenth century, the United States, Canada, Japan and recently the East Asian Tigers.

Industrialization is a system of production that has arisen from the steady development, study, and the use of scientific knowledge. It is based on the division of labour and on specialization and uses mechanical, chemical, and power-driven, as well as organizational and intellectual aids in production. The primary objective of this method of organizing economic life, which had its genesis in the mid-eighteenth century, has been to reduce the real cost, per unit, of producing goods and services. The resulting increases in output per man-hour have been so large as to stagger the imagination.

This revolutionary rise in availability of output and supply of economic resources has been associated primarily with the development of industrial economies in, for the most part, a limited number of countries. By far, the larger part of the dramatic rise in man-hour productivity is fairly recent - most of it occurring since the turn of the twentieth century- and apparently is still continuing powerfully in those economically advanced countries where the application of modern science to output continuous to develop.

Regarding the industrialization process in the Ethiopian context, prior to the introduction of modern industries, the country has had long tradition of handicraft and various of small-scale processing which use traditional techniques based on manual labour and simple tools. These traditional processing were activities mainly involved in food processing, weaving, agricultural inputs and leather making.

Modern industries were introduced in Ethiopia in the early twentieth century. After some years of decentralization, the emergency of centralized government in the second half of the ninetieth century, and the construction of a railway line from Djibouti to Addis Ababa in the early twentieth century are considered to be the main internal and external factors for the development of industrialization in the country's history. Through the Djibouti-Addis Ababa railway line, people started to have access in the local market to imported industrial processed consumer goods and clothes and there by adopt new habits and tastes.

Before the Italian five-year occupation of the country, there were a total of 26 industries in the country located around Addis Ababa, Dire Dewa and the then Asmera. All these industries were mainly engaged in processing primary goods and were owned and managed by expatriates. After 1928, the Italians established few industries like the Dire Dewa cement and Kality food processing plants.

In the 1950s and 1960s efforts continued to expand industries in the country. From 1950-1963 alone 27 factories were established; of which 7 were food processing, 4 beverage,
7 textiles, 2 leather and shoe, 2 wood processing, 2 building materials, 1 metal and 2 printing factories. Especially, with the establishment of the Ethiopian Iron and Steel Foundry, which engaged in the production of highly demanded construction materials, the industries' contribution for development processes was greatly enhanced.

Though there was no as such a significant change in the structure of industrial output, in total 54 factories were established in the period 1964-1974. Most of these industries were light industries engaged in the production of consumer goods and as a result the production of consumption goods continued to expand but with no significant growth in the establishment of non-consumption goods producing industries.

In general, industrialization in Ethiopia began through in-ward oriented strategy based on import substitution of consumer goods rather than assisting the development of small-scale and handicraft industries.

After the 1974 revolution and the proclamation of socialism in the country, medium and large-scale industries were nationalized and the government took full responsibility to run the sector including other sectors of the economy applying the command economic policy. As a result, no significant expansion of medium and large-scale industries was seen in the country for a long period of time and the growing opportunities of both output and productivity of these industries were seriously affected by the policy during that period.

However, after 1991 the then transitional government and now the Federal Democratic Republic of Ethiopia introduced and implemented a free market economic policy that has stimulated the expansion of the private investors in the industrial sector although the private sector still focuses on small-scale industries.

Currently the total number of medium and large scale manufacturing industries has reached 762 in 1998, compared to 416 in 1978. Of the 762 medium and large scale manufacturing industries 155 are state owned and the rest, 607 are privately owned. According to Central Statistical Authority's definition medium and large scale industries include all plants that are engaged in production processes and employing ten persons or more.

However, the contribution of the industrial sector to the GDP of the economy is not significant. That is according to recent data of the Ministry of Economic Development and Cooperation (MEDaC) National Income Accounts Statistics report, the industry sector contributes only 11.60 % to the GDP of the economy in 1998.

Some empirical studies have been conducted at firm or factory level concerning their production behaviour in the Ethiopian context that are useful for decision makers to take important decisions that pave the way for the growth and expansion of these firms and factories. However, information on the production behaviour and determination of the rate of technological progress on Ethiopian manufacturing industries as a whole or at least on specific industry groups generally very scarce. Thus, a study on the production behaviour and determination of the rate of technological progress, on Ethiopian manufacturing industries is found to be very important in order to provide valuable insights about the performance of production and rate of technological progress of the industries over a given period of time.

This study focuses on estimation of the production behaviour and determination of the rate of technological progress of specific Ethiopian manufacturing industries *by industry group* for the period 1978-1998. And it covers five industry groups of the Ethiopian manufacturing industries that comprise 136 industries according to CSA 1998 report.

The five industry groups covered in this study are: Manufacture of Sugar and Sugar Confectionery, Beverage Industries, Manufacture of Textiles, Manufacture of Basic Industrial Chemicals and Chemical Products and Manufacture of Rubber and Plastic Products.

The study is organized as follows. Chapter 1 encompasses background, statement of the research problem, objective and significance of the study, the data, limitation of the study and measurements of output and inputs. Chapter 2 focuses on the theoretical micro-economic literatures on production functions, on the theories of economic growth models from macroeconomics, on method of analysis or methodology of the study and on empirical studies conducted using production functions. Chapter 3 is the core of this study and presents the empirical results of production functions for the selected Ethiopian manufacturing industries over the period of the study using the Constant Elasticity of Substitution (CES) production function. Chapter 4 focuses on the determination of the rate of technological/technical progress in these manufacturing industries based on the estimation of a Cobb-Douglas production function as well as applying the Growth Accounting technique from exogenous economic growth model. Finally, the summary and conclusion is presented in Chapter 5 of the study.

1.2 Statement of the research problem

As stated earlier, many studies have been conducted at firm or factory level, in Ethiopia, concerning their production behaviour. But it can be said that no previous study made on the production behaviour and determination of the rate of technical progress in the Ethiopian manufacturing industries as a whole or at least on specific industry groups except one study which was done twenty years before. Thus, it was difficult for policy makers to design appropriate policies based on such study concerning the production behavior and production technology of the Ethiopian manufacturing industries both at micro-level, at least for specific industry groups, and at macro-level, the whole industrial sector of the national economy.

Thus, a study on the production behaviour and determination of the rate of technical progress in the Ethiopian manufacturing industries becomes very important for designing appropriate policies that could be geared towards the development and expansion of the sector and for the development of the country economically and technologically and is believed to provide valuable information about the production behaviour and the rate of technological progress/level of technology of the specific Ethiopian manufacturing industries of their production processes over the period of the study.

1.3 Objective and Significance of the Study

The main objective of this study is to investigate the production behaviour and determine the rate of technical progress for selected industry groups of the Ethiopian manufacturing industries.

Such study is found to be very important in designing appropriate policies that contribute for the development of the country both economically and technologically.

The specific objectives of the study are the following:

(1) To determine which one of the two factor inputs used in the production process, capital or labour, contributes more for the increase in output in the specified industry groups. This enables the decision-makers to decide how much of the proportion of the new investment in these industries must be allocated to each of the factor inputs and there by make the industries more productive and profitable.

(2) To determine the scale of operation in the specified industry groups, i.e., to determine and show whether these industries operated at an increasing, constant or decreasing returns to scale.

(3) To determine whether there exists in and the extent to which there is a substitution possibility between factor inputs, capital and labour, in the specified industry groups .

(4) To determine the type of technology of the production process, i.e., to determine whether the production technology is capital intensive or labour intensive technology.

(5) To determine the rate of technological/technical progress in the specified industry groups. This helps the decision-makers so as to have a good decision accordingly and there by the specified industry groups covered in the study in particular and the country as a whole benefits a lot from such decisions for its technological development.

Given the above objectives, the study is expected to provide valuable information that can be used for the development of appropriate policies concerning the specific industry groups in particular and the Ethiopian manufacturing industries in general.

The study tries to examine the following three hypotheses on the production behaviour and rate of technological progress of the specific industry groups based on results of previous empirical studies conducted in the manufacturing industries of the country and in other countries of the world and from the real situation of the country.

(1) There is a strong empirical case for assuming that most industrial processes exhibit increasing returns to scale. And this is expected to be valid in the Ethiopian manufacturing industries.

(2) In the Ethiopian manufacturing industries, *the capital-labour substitution* possibilities between the two factor inputs is high as empirical estimates of *the elasticity of substitution* for some less developed countries show although one pervious study on this area in the Ethiopian case shows otherwise.

(3) *The rate of technological progress* in the Ethiopian manufacturing industries is insignificant or is low as the country is technologically poor.

1.4 The Data

This study uses a time-series data of the selected Ethiopian manufacturing industries. The data consists annual data on output, capital and labour inputs for each industry group for the years 1978-1998 and is available in Annex IV. The data is collected from annual statistical bulletin published by the Central Statistical Authority (CSA).

1.5 Limitation of the study

The first publication of CSA statistical annual Bulletin on survey of Ethiopian manufacturing industries was published in 1976 and hence no compiled data is available prior to year 1976. Besides, the Statistical Bulletin of year 1977 is not available. Thus the study is limited to the years 1978-1998 that makes a total of twenty one observations for empirical investigation. Thus, the limitation of the study lies in a sense that too few observations of time series data for empirical study.

In addition to this, since the study is based on industry group and not at firm level, there appears a problem of aggregation of many industries in one industry group.

1.6 Measurement of output and inputs

As clearly stated, the study focuses on the estimation of production function of the Ethiopian manufacturing industries that consists of variables on output, capital and labour inputs. Usually, however, there arises statistical and conceptual problems in the measurement of these variables and in the estimation of production function in general due to lack of reliable data of these variables measured as required. The following paragraphs describe the variables that will be used in the model; how the variables are measured and the measurement problems that are associated with the variables and alternative measurements.

1.6.1 Output measurement

In the estimation of production function, different approaches are used for measuring output. The two main approaches used for the measurement of output are the physical and value measurements. Output measured in physical quantity terms is preferred to that measured in value terms because it avoids the influence of changes in price of output and the influence of many other problems related with measuring output in monetary units.

However, since the study incorporates many industries in one industry group where the output measurement unit of one industry differs from another depending on the type of product it produces, output measured in physical quantity terms is inappropriate in this study. Thus, output measured in terms of ***value added at factor cost*** in the National Account concept terms will be used in this study.

Value added at factor cost in the National Account concept is defined as value added at market price in the National Account concept less net indirect taxes (i.e., indirect taxes less subsidies).

And value added at market price in the National Account concept is defined as the difference between the gross value of production and industrial and non-industrial costs.

Thus, value added at factor cost in the National Account concept equals gross value of production less the sum of industrial and non-industrial costs and net indirect taxes.[1]

1.6.2 Capital input measurement

In the estimation of production functions because of its heterogeneous nature, there are controversies in the measurement of capital. The measurement of capital services is complicated by the fact that capital assets are a one-time commitment and the evaluation of the services render over the life span is not necessarily determined by the outlay on the assets

Some studies used capital stock and book value as a measure of capital input in the production process. However, these types of measurements have many problems. For example using book value as measure of capital input does not show how much of the capital input that goes in to the production process. Similarly, there are a number of drawbacks in using capital stock as a measure of capital input that goes to the production process. The major drawback is that the total value of the capital stock will not be consumed at all in one-time production processes.

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[1]Industrial cost includes the cost of raw materials, fuels, and other supplies consumed, cost of industrial services rendered by others, cost of goods bought and resold with out any transformation or processing and cost of electricity consumed.

Non-industrial cost includes payments like professional fees, postage, telephone, insurance, advertising, hired transport and rental payments.

After examining some of the major drawbacks in using capital stock and book value as a measure of capital input in the production processes, this study uses ***capital consumption/ depreciation*** as a measure of capital input that goes in to the production process.

Measuring capital input that goes in to the production process using capital consumption (depreciation) is the most sound and reasonable methods compared to other measurements and is believed to represent the amount of capital input consumed in the production process in a given period of time although measuring capital input using depreciation figures is not free from some limitations.

1.6.3 Labour input measurement

There are different measurements of the amount of labour input that goes in to the production process such as man-hour, number of workers, wages and salaries and others. Although these different types of measurements have their own merits and demerits, this study uses the ***number of persons engaged in the production process*** (both permanent and casual workers) as a measurement of labour input in the production process.

Measuring labour input that goes in to the production process in terms of number of persons who are engaged is some how a reasonable measure. This is because the variation in the number of workers engaged in the production process has an effect on the variation in output as compared to monetary measures of labour input such as wages and salaries where in such monetary measures the variation in output may not necessarily be due to the variation in wages and salaries.

CHAPTER 2

LITRATURE REVIEW AND METHOD OF ANALYSIS

2.1 THEORITICAL LITRATURES

The economic theory of production is derived from (a) the behavioural premise that the decision making unit (the firm or the production manager) desires to minimise the total cost of producing any given output or specified combinations of outputs, and (b) the postulate that normally there exist alternative techniques or processes of production, with different patterns of resource (labour, capital, materials, energy) consumption and, therefore, different associated cost (International Encyclopaedia of Social Science Vol. 12,1968).

Generally, production may be defined as a process by which inputs are transformed into an output. An input is any good or service that goes into production while an output is any good or service that comes out of the production process. Production does not necessarily mean a physical conversion of raw materials in to a commodity as in manufacturing. Such processes as transportation and storage are just as good examples of production as is the manufacturing process Awh (1976).

Production processes can be studied empirically interms of either production function or cost functions. Estimates of the parameters of these functions provide valuable insights into the technology of firms and industries. The central questions relating to technology are:

(1) Whether production processes display decreasing, constant or increasing returns to scale;

(2) How technological progress affects the parameters of production processes; and

(3) At what rate technological progress has occurred.

2.1.1 The Production Function

The relationship between inputs and output in a production process of a firm or any production unit can be investigated through the application of what is known as ***the production function*** which describes the functional relationship that exists between quantities of output produced and inputs employed by a firm in the production process Asmerom (1980). Since production process represents the transformation of inputs to output, the function that describes such transformation, *the production function,* fundamentally represents what is known as *technology*. This is so because technology is nothing but refers to transformation of inputs to output(s) or the transformation from one state to another state of matter.

A production function shows the maximum output that can be produced from given quantities of inputs with a given state of technology. Such function with n variable inputs is defined as:

$$Y = F(X_1, X_2, \ldots, X_n) \qquad \text{------------------------------} \qquad (2.1.1.1)$$

where Y is output and X_i is the level of input used in the production process Awh (1976).

2.1.2 The Cobb-Douglas Production function

The relationship between inputs for production processes employed and output produced can be analyzed, generally, in three functional forms, viz., the Cobb-Douglas, the Constant Elasticity of substation (CES) and the Leontif production function. Among these the first two are the most widely used in economic literature.

The Cobb- Douglas production function takes the form:

$$Y = A K^{\alpha} L^{\beta}; \qquad (Y, K, L, A, \alpha \text{ and } \beta > 0) \quad \text{------------------} \quad (2.1.2.1)$$

Where Y is output, K is capital input, and L is labour input. The parameters α and β measure the elasticity of output with respect to capital and labour inputs respectively. A is an efficiency parameter and represents the level/state of technology. It is also referred as a Hicks-neutral productivity term Ching (1984).

Equation (2.1.2.1) is known as the "***unrestricted***" form of the Cobb-Douglas model in a sense that the parameters α and β can take any value which is greater than zero and no restriction at all in a sense that the sum of the elasticities of output must add up to unity as in the case of the restricted form of the Cobb-Douglas model which restrict so that $\alpha + \beta = 1$ Katz (1969).

The Cobb-Douglas function has the following features where some of them make it so interesting and popular:

(1) *The function is homogeneous of degree* $(\alpha + \beta)$.

The sum of the parameters ($\alpha + \beta$) has interesting economic interpretation since it gives information about the returns to scale or the scale of operation of the production process.

If ($\alpha + \beta$) > 1, increasing returns to scale prevails in the production process, i.e.,doubling the inputs will lead to more than double the output.

If ($\alpha + \beta$) = 1 constant returns to scale prevails in the production process, i.e.,doubling the inputs will lead to double the output. In this case the function is linearly homogenous.

If ($\alpha + \beta$) < 1, decreasing returns to scale prevails in the production process, i.e.,doubling the inputs will lead to less than double the output.

(2) Often the function is used in the form:

$Y= AK^{\alpha} L^{1-\alpha}$, where $\beta = (1-\alpha)$ in this special case.

This special case is referred to as "***the restricted***" form of the Cobb-Douglas production function. In such a special case where $\alpha + \beta=1$, the function is *linearly homogenous*, and accordingly constant returns to scale prevails,

(3) The function is strictly quasi-concave for positive values of K and L; and its isoquants are negatively sloped throughout and are strictly convex for positive values of K and L.

(4) It is monotonically increasing function

(5) The function yields diminishing returns to each input

(6) α and β show the output elasticity coefficient for inputs K (capital) and L (Labour) respectively

(7) α and β show the relative distributive shares of inputs K and L in the total output
Awh (1976), Chiang (1984).

The Cobb-Douglas production function is popular and is the most widely used production function in economic literatures both in the theoretical and empirical analyses. But this does not mean that the function is free from some limitations, which for certain uses may be serious.

One of the limitations of the Cobb-Douglas production function lies in that the elasticity of substitution between factor inputs is restricted to unity. Thus, when we analyse the data using the Cobb-Douglas production function, we are in a sense forcing the data into a model that implies the elasticity of substitution of unity Teshome (1980).

For over three decades the Cobb-Douglas production function had been remained with out serious criticism. As time goes, progress has been made in the context of production function and a new model in estimating a production function was formulated by generalizing the Cobb-Douglas and other production functions. This production function is what is known as the Constant Elasticity of Substitution(CES) production function Chung (1994).

2.1.3 The Constant Elasticity of Substitution (CES) Production Function

The basic feature of the input-output function (Leonief production function) is that the factor inputs are combined in a fixed proportions. The isoquants in such production function are L-shaped and as a result the elasticity of substitution coefficient between factor inputs is zero(σ=0) Teshome (1980). Another production function which is popular and that is discussed in section 2.1.2 of this study is what is known as the Cobb-Douglas production function which has unitary elasticity of substitution ($\sigma = 1$).[1]

The generalized production function which is mostly used for the estimation of the elasticity of substitution(σ) between two factor inputs of production is what is known as the Constant Elasticity of Substitution(CES) production function. The basic feature of the Constant Elasticity of Substitution production function is that it allows the elasticity of substitution to be a constant value other than unity, unlike the Cobb-Douglas function, and can vary within a broad range Chung (1994).

The function makes the elasticity of substitution an empirically determinable parameter and allows the identification of production processes governed by the factor substitution rules of the Leontief and the Cobb-Douglas production functions. This is so because as the substitution parameter(ρ) approaches to zero($\rho \to 0$), the CES function reduces to the Cobb-Douglas function and it reduces to " Fixed-proportions" or Leontief production function as $\rho \to \infty$ Chiang (1984).

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[2]The application of the elasticity of substitution formula as defined in equation (2.1.3.2) on the Cobb-Douglas production function defined in equation (2.1.2.1) gives a value of elasticity of substitution of unity, σ=1.

The CES production function is defined as:

$$Y = \gamma\,[\delta K^{-\rho} + (1-\delta) L^{-\rho}]^{-v/\rho} \qquad \text{-----------------------------------} \qquad (2.1.3.1)$$

Where Y is output; K is capital input and L is labour input.

γ is a positive constant and is efficiency parameter such that the larger the value of γ the greater the level of output from the given inputs K and L.

δ is distribution parameter($0 < \delta < 1$), ρ is a substitution parameter($-1 < \rho < \infty$).

δ and (1-δ) are known as capital and labour intensity coefficients and measure the capital and labour input's share in the total output respectively.

ν is a " scale" parameter where $\nu \neq 0$ and measures the degree of homogeneity of the function, i.e., measures the degree of returns to scale. $\nu > 1$ implies increasing returns to scale, $\nu = 1$ implies constant returns to scale and $\nu < 1$ implies decreasing returns to scale in production Awh (1976), Chiang (1984) and Chung (1994).

If the scale parameter $\nu = 1$ in equation (2.1.3.1), then equation (2.1.3.1) represents a linearly homogeneous CES production function and thus possesses the properties of a linearly homogenous production function Awh (1976).

The elasticity of substitution (σ)

The elasticity of substitution (σ) is defined as the ratio of the percentage change in the capital-labour ratio(K/L) to the percentage change in the marginal rate of substitution(MRS),i.e.,

$$\sigma = \frac{\text{Percentage change in K/L}}{\text{Percentage change in MRS}} = \frac{d(K/L)/(K/L)}{d(MRS)/MRS}$$

$$\sigma = \frac{d(K/L)\,(MRS)}{d(MRS)\,(K/L)} \qquad \text{----------------} \; (2.1.3.2)$$

where the Marginal rate of substitution(MRS) is defined as the ratio of the marginal products of the two inputs Holden and Pearson (1972).

For the functions defined in equations (2.1.2.1) and (2.1.3.1) the MRS is defined as:

$$MRS = MP_k/MP_l = \frac{\partial Y/\partial K}{\partial Y/\partial L}$$

The application of the formula for the elasticity of substitution(σ) as defined in equation (2.1.3.2) on the CES function defined in equation(2.1.3.1) gives the following result:

$$\sigma = 1/1+\rho \qquad \text{-------------------------------} \; (2.1.3.3)$$

Equation (2.1.3.3) shows that the elasticity of substitution (σ) as a function of the substitution parameter (ρ) in equation (2.1.3.1).

The elasticity of substitution (σ) is different from unity as long as the substitution parameter(ρ)

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The elasticity of substitution (σ) is different from unity as long as the substitution parameter(ρ)

is different from zero. The larger the value of σ, the flatter the isoquant, and hence the greater the substitutability. If, however, ρ equals zero, the value of the elasticity of substitution σ is exactly equal to one, and the CES function reduces to the Cobb-Douglas form. In other words, the Cobb-Douglas function is a special case of the CES production function Chiang (1984), Chung (1994).

The CES production function, in stochastic form, is defined as:

$$Y = \gamma\,[\delta\,K^{-\rho} + (\,1\text{-}\delta)\,L^{-\rho}]^{\,-v/\rho}\,e^{\varepsilon} \qquad \text{-------------------------------- (2.1.3.4)}$$

Taking natural logarithms on both sides of equation (2.1.3.4), we have:

$$\ln Y = \ln\gamma\ \text{-}\ v/\rho\ \ln[\delta\,K^{-\rho} + (\,1\text{-}\delta)\,L^{-\rho}] + \varepsilon_i \qquad \text{------------------------ (2.1.3.5)}$$

The simplest estimation of the parameters of the CES production function of equation (2.1.3.4) is possible if we replace equation (2.1.3.5) by its approximation that is linear with respect to ρ Kementa (1971).

By applying the Taylor's series formula, expanding the second term on the RHS of equation (2.1.3.5) around ρ = 0, and dropping the terms involving powers of ρ greater than two, we obtain:

$$\ln Y = \ln\gamma + v\delta\,\ln K + v(1\text{-}\delta)\,\ln L - \tfrac{1}{2}\,\rho v\delta\,(1\text{-}\delta)\,[\,\ln K\text{-}\ \ln L]^2 + \varepsilon_i \qquad \text{------------ (2.1.3.6)}$$

The right hand side of equation (2.1.3.6) can be separated in to two parts, one corresponding to the Cobb-Douglas production function and the other representing a "correction" due to the departure of the substitution parameter ρ from zero. The latter part given by the term $-\frac{1}{2}\rho\nu\delta(1-\delta)[\ln K - \ln L]^2$ will disappear if $\rho = 0$.

The "unrestricted" version of equation (2.1.3.6) is give by:

$$\ln Y = \alpha_0 + \alpha_1 \ln K + \alpha_2 \ln L + \alpha_3 [\ln K - \ln L]^2 + \varepsilon_i \qquad \text{------------(2.1.3.7)}$$

Where from equations (2.1.3.6) and (2.1.3.7) we have:

$$\alpha_0 = \ln\gamma \qquad \alpha_1 = \nu\delta$$

$$\alpha_2 = \nu(1-\delta) \qquad \alpha_3 = -\tfrac{1}{2}\rho\nu\delta(1-\delta) \qquad \text{------------- (2.1.3.8)}$$

After rearranging the terms in equation(2.1.3.8), the parameters of the function represented in equation (2.1.3.6), and hence equation (2.1.3.4), could be related to the coefficients of the model in (2.1.3.7) as follows Kementa (1971):

$$\gamma = \text{antilog}\,\alpha_0 \qquad \nu = \alpha_1 + \alpha_2$$

$$\delta = \alpha_1 / (\alpha_1 + \alpha_2) \qquad \rho = -2\,\alpha_3(\alpha_1 + \alpha_2)/\,\alpha_1\,\alpha_2 \qquad \text{----------(2.1.3.9)}$$

2.1.4 Exogenous and Endogenous Economic Growth Models

2.1.4.1 Exogenous Economic Growth Model

Technology and the Solow Model

The Solow model is built on two equations, a production function and a capital accumulation equation.

The production function in Solow's model with technology takes the form:

$$Y = F(K,AL) = K^{\alpha}(AL)^{1-\alpha} \qquad \text{------------------} \quad (2.1.4.1.1)$$

Where Y, K and L are output, capital and labour inputs respectively. *A* is a technology variable and entered in this way it is said to be "labour" augmenting or "Harrod-neutral" technology. Notice that this production function exhibits constant returns to scale.

An important assumption of the Solow model is that technological progress is "**exogenous**": in a common phrase, technology is like " manna from heaven," in that it descends up on the economy automatically regardless of whatever is going in the economy Johns (1997). Hence the name "exogenous" growth model is given to the model.

In this model the technology variable, A, is assumed to grow at some constant rate:

$$\frac{\dot{A}}{A} = g \Leftrightarrow A = A_0 e^{gt}$$

Where g is a parameter representing the growth rate of technology.

The capital accumulation equation in Solow's model is given by a differential equation of the form:

$$\dot{K} = sY - \delta K \qquad \text{--} \quad (2.1.4.1.2)$$

Where $\dot{K}$ represents the change in capital stock over time. Y is output, K is capital stock, *s* is saving rate and δ is the rate of depreciation of capital stock.

According to equation (2.1.4.1.2), the change in capital stock (K) is equal to the amount of gross investment (sY) less the amount of depreciation (δK) that occurs during the production process.

From equation (2.1.4.1.1) which is defined as:

$$Y = K^{\alpha}(AL)^{1-\alpha}$$

Dividing both sides of this equation by AL, we get:

$$\frac{Y}{AL} = \frac{K^{\alpha}(AL)^{1-\alpha}}{AL} = \frac{K^{\alpha}(AL)}{AL(AL)^{\alpha}}$$

$$\Rightarrow \quad \frac{Y}{AL} = \frac{K^{\alpha}}{(AL)^{\alpha}}$$

$$\Rightarrow \quad y = k^{\alpha} \qquad \text{--} \qquad (2.1.4.1.3)$$

Where $y = Y/AL = \frac{Y/L}{A} = y/A$ is called output-technology ratio, and

$$k = K/AL = \frac{Y/L}{A} = k/A$$ is capital-technology ratio.

From capital- technology ratio defined above and using equation (2.1.4.1.2), we develop an equation for capital-technology ratio evolving over time as follows.

$$k = K/AL$$

Taking natural logarithm on both sides, we get

$$\ln k = \ln K - \ln A - \ln L$$

Differentiating this with respect to time(t), we get

$$\dot{k}/k = \dot{K}/K - \dot{A}/A - \dot{L}/L$$

$$\dot{k}/k = \frac{sY - \delta K}{K} - g - n \;, \qquad \text{since } \dot{K} = sY - \delta K \text{ as shown in equation (2.1.4.1.2)}$$

Where $\dot{A}/A = g$ as defined previously and n represents the rate of growth of labour force(L).

In this model the labour force is assumed to grow at some rate, n, i.e.,

$$L(t) = L_o e^{nt}$$

$$\Rightarrow \quad \dot{k}/k = sY/K - \delta - g - n$$

$$\Rightarrow \quad \dot{k} = (sY/K)k - (n + g + \delta)k$$

$$= (sY/K)(K/AL) - (n + g + \delta)k, \qquad \text{since } k = K/AL$$

$$= sY/AL - (n + g + \delta)k$$

$$= sy - (n + g + \delta)k, \qquad \text{since } y = Y/AL$$

$$\dot{k} = sy - (n + g + \delta)k \qquad \text{---------------------------------} \qquad (2.1.4.1.4)$$

$$\Rightarrow \quad y = k^{\alpha} \qquad \text{--} \qquad (2.1.4.1.3)$$

Where $y = Y/AL = \dfrac{Y/L}{A} = y/A$ is called output-technology ratio, and

$$k = K/AL = \frac{Y/L}{A} = k/A \quad \text{is capital-technology ratio.}$$

From capital- technology ratio defined above and using equation (2.1.4.1.2), we develop an equation for capital-technology ratio evolving over time as follows.

$$k = K/AL$$

Taking natural logarithm on both sides, we get

$$\ln k = \ln K - \ln A - \ln L$$

Differentiating this with respect to time(t), we get

$$\dot{k}/k = \dot{K}/K - \dot{A}/A - \dot{L}/L$$

$$\dot{k}/k = \frac{sY - \delta K}{K} - g - n \ , \qquad \text{since } \dot{K} = sY - \delta K \text{ as shown in equation (2.1.4.1.2)}$$

Where $\dot{A}/A = g$ as defined previously and n represents the rate of growth of labour force(L).

In this model the labour force is assumed to grow at some rate, n, i.e.,

$$L(t) = L_o e^{nt}$$

$$\Rightarrow \qquad \dot{k}/k = sY/K - \delta - g - n$$

$$\Rightarrow \qquad \dot{k} = (sY/K)k - (n + g + \delta)k$$

$$= (sY/K)(K/AL) - (n + g + \delta)k \ , \qquad \text{since } k = K/AL$$

$$= sY/AL - (n + g + \delta)k$$

$$= sy - (n + g + \delta)k \ , \qquad \text{since } y = Y/AL$$

$$\dot{k} = sy - (n + g + \delta)k \qquad \text{---------------------------------} \qquad (2.1.4.1.4)$$

Notice that long-run equilibrium occurs at a steady state where

$$sy = (n + g + \delta)k \text{ or } \dot{k} = 0 \quad \text{in equation (2.1.4.1.4).}$$

This implies $\dot{y} = 0$ also at steady state. This is because $y = k^{\alpha}$ as can be read in equation (2.1.4.1.3).

Taking natural logarithm on both sides of this equation, we get

$$\ln y = \alpha \ln k$$

Differentiating with respect to time(t), we get,

$$\dot{y}/y = \alpha\, \dot{k}/k$$

since $\dot{k} = 0$ at steady state, this implies

$$\dot{y}/y = \alpha(0) = 0 \text{ or } \dot{y} = 0 \qquad \text{---------------------------------- (2.1.4.1.5)}$$

Now from output-technology ratio as defined in equation (2.1.4.1.3), we can derive the following important result of Solow's model with technology as follows:

$y = Y/AL = \frac{(Y/L)}{A} = y/A$, where $y = Y/L$ is output per worker or is output-labour ratio

Taking natural logarithm on both sides, we get

$$\ln y = \ln y - \ln A$$

Differentiating this with respect to time(t), we get

$$\dot{y}/y = \dot{y}/y - \dot{A}/A, \quad \text{where } \dot{A}/A = g \text{ as defined previously.}$$

At steady state, $\dot{y} = 0$ as defined in equation (2.1.4.1.5) above.

$\Rightarrow \qquad 0 = \dot{y}/y - g$

$$\Rightarrow \quad \dot{y}/y = g \qquad \text{--------------------------} \qquad (2.1.4.1.6)$$

Where g represents the growth rate of technology as defined previously and $\dot{y}/y$ is the rate of growth output per worker and represents the rate of growth of the economy.

Equation (2.1.4.1.6) says at steady state (in the long-run), the rate of growth of output per worker is equal to *the rate of growth of technology* or on the balanced growth path, the growth rate of output per worker is determined solely by *the rate of technological progress.*

Similarly, following steps in deriving equation (2.1.4.1.6) from output- technology ratio, one can derive the following result:

$\dot{k}/k = g$ from the capital-technology ratio, $k = K/AL$.

Thus, from Solow's model with technology we have the following important result:

$$g_y = g_k = g \qquad \text{--} \qquad (2.1.4.1.7)$$

Where g_y, g_k and g represent the rate of output per worker, rate of growth of capital per worker and the rate of growth of technology respectively.

That is, along a balanced growth path in Solow's model with technology, output per worker and capital per worker both grow at the rate of *exogenous technological progress*, g. Thus Solow's model with technology shows that *technological progress* is the source of sustained growth of output per worker Johns (1997).

2.1.4.2 Endogenous Economic Growth Model

As described in Solow's model with technology, technological progress is assumed "exogenous" or is considered like "*manna from heaven*" and hence the model fails to explain where technology comes from. In addition, the assumption about technology is unrealistic. These are the limitations of the model.

There is an alternative economic growth model known as the ' endogenous' economic growth model that fills the gap that the exogenous economic growth model lacks. Explaining how to relax the assumption about technology and to show where technology comes from is one of the major accomplishments of this new growth theory. Instead of assuming that growth occurs because of automatic and unmodeled (exogenous) improvements in technology, the endogenous growth theory focuses on understanding the economic forces underlying technological progress Johns (1997).

An important contribution of this new growth theory is the recognition that technological progress occurs as profit-maximizing firms or inventors seek out newer and better products so as to get high return from their invention. Adam Smith wrote " it is not from the benevolence of the butcher, the brewer, or the baker, that we expect our dinner, but from their regard to their own interest". Thus, in this way, improvements in technology, and the process of economic growth itself, are understood as an endogenous outcome of the economy Johns (1997).

The Romer Model

One of this new growth theories is the one which is developed by Paul Romer. In the Romer's model, which emphasises on the idea that the economic return from invention is the driving force for technology, ideas or stock of knowledge is the key for technological progress, that is, the Romer model endogenizes technological progress by introducing the search for new ideas by researchers interested in profiting from their invention.

Following the steps in deriving the rate of growth of output as defined in equation (2.1.4.1.6), in the Romer's model along the balanced growth path:

$$g_y = g_k = g_A \quad \text{-----------------------------------} \quad (2.1.4.2.1)$$

that is, along the balanced growth path output per capita, the capital-labour ratio and technology (stock of ideas) grow at the same rate in Romer's model.

Where the aggregate production function in Romer's model is defined as:

$$Y = K^{\alpha}(AL_y)^{1-\alpha}$$

and the accumulation equations for capital and labour are identical to those for the Solow's model, i.e.,

$$\dot{K} = sY - \delta K$$

and,

$$\dot{L}/L = n$$

Where Y, K and A are as defined in equation (2.1.4.1.1). $L = L_y + L_A$ represents total population or human resource where L_y represents number of people engaged in producing output (Y) and L_A represents number of people engaged in discovering new ideas Johns (1997).

Now the important question is "what is the rate of technological progress along the balanced growth path?" The answer to this question lies in the production function for ideas which is defined as follows.

In the Romer's model, the production function for ideas is defined as:

$$\dot{A} = \gamma L_A^{\lambda} A^{\phi} \qquad \text{--------------------- (2.1.4.2.2)}$$

Where $\dot{A}$ represents the number of new ideas produced at a given point in time, L_A is the number of people engaged in discovering new ideas (scientists and engineers), A is the stock of ideas or knowledge. λ and ϕ are parameters (where $0 < \lambda < 1$ and $\phi < 1$) represent the "duplication" and "standing on shoulders" effect respectively and γ is a constant.

In the Romer's model the rate of growth of technology or stock of ideas is given by the equation:

$$g_A = \frac{\lambda n}{1-\phi} \qquad \text{------------------------------ (2.1.4.2.3)}$$

which is derived dividińg both sides of equation (2.1.4.2.2) by A and taking natural logarithm and differentiating the resulting equation with respect to time (t).

Thus according to equation (2.1.4.2.3), the long-run growth rate of the economy is determined by the parameters of the production function for ideas (λ and ϕ) and the rate of growth of researchers, which is ultimately given by the population growth rate (n). This is an important result of the Romer's model. The intuition behind equation (2.1.4.2.3) is that a country that has more number of researchers (n) will have high rate of technological growth and hence high level of technology.

This model is applicable in advanced countries mostly in US firms that have R&D department for discovering new ideas and hence produce new product or apply new technology and can not be applied in this study because there is no data on the number of researchers (scientists and engineers), L_A, who are engaged in discovering new ideas in thė Ethiopian manufacturing industries or in the country as a whole.

Thus, this study uses Solow's model with technology which is described previously to determine the magnitude of the growth of output from the growth in inputs, capital and labour, and from the growth in technological progress although the model has its own limitations as

described previously.

2.1.4.3 Growth Accounting

In Solow's model with technology, long-run growth of out put per worker depends only on technological progress as shown in equation (2.1.4.1.6). But short-run growth can result from either technological progress or capital accumulation. Thus the model implies that determining the sources of short-run growth is an empirical issue Barro and Sala-I-Martine (1995). *Growth Accounting*, which was pioneered by Abramovitz (1956) and Solow (1957), provides a way of tackling this subject.

With out technological progress, capital accumulation runs into diminishing returns. But with technological progress, improvements in technology continually offset the diminishing returns to capital accumulation. Labour productivity grows as a result, both directly because of the improvements in technology and indirectly because of the additional capital accumulation these improvements make possible.

Following the pioneering work of Solow (1957) and predecessors, the objective of growth accounting is to break down or decompose the growth in output into contributions from growth in inputs, capital and labour, and growth in technology or growth in technological progress. The analysis starts by postulating a production function of the form:

$$Y = BK^{\alpha} L^{\beta} \qquad \text{-----------------------------------} \quad (2.1.4.3.1)$$

Where Y, K and L are as defined previously in equation (2.1.4.1.1) and B is a technology variable and represents the level of technology. B entered in this way is output augmenting and is referred as Hicks-neutral productivity term. α and β represent the share of capital and labour input respectively. Notice that in terms of the production function in equation (2.1.4.1.1),

$$B = A^{1-\alpha} \text{ and } \beta = 1-\alpha .$$

Taking natural logarithm on both sides of equation (2.1.4.3.1) , we get

$$\ln Y = \ln B + \alpha \ln K + \beta \ln L$$

Differentiating this equation with respect to time (t), we get

$$\dot{Y}/Y = \dot{B}/B + \alpha\ \dot{K}/K + \beta\ \dot{L}/L \qquad \text{---------------------------- (2.1.4.3.2)}$$

Where $\dot{Y}/Y$, $\dot{K}/K$, $\dot{L}/L$ and $\dot{B}/B$ represent the rate of growth of output, capital input, labour input and technology respectively.

Equation (2.1.4.3.2) says the rate of growth of output equals the growth rate of technology (the rate of technological progress), $\dot{B}/B$, plus a weighted average growth rates of capital and labour inputs, where the weights are the corresponding input shares.

Given the data on the quantities Y, K and L we can estimate the factor shares, α and β, and compute the growth rates $\dot{Y}/Y$, $\dot{K}/K$, and $\dot{L}/L$. The only term in equation (2.1.4.3.2) that can not be measured directly is the growth rate of technology, $\dot{B}/B$. We can measure $\dot{B}/B$ indirectly by rearranging equation (2.1.4.3.2) to get:

$$\dot{B}/B = \dot{Y}/Y - \alpha\ \dot{K}/K - \beta\ \dot{L}/L$$

Or,

$$\dot{B}/B = \dot{Y}/Y - [\alpha\ \dot{K}/K + \beta\ \dot{L}/L] \qquad \text{-------------------- (2.1.4.3.3)}$$

In other words, we can measure the rate of technological progress or the growth rate of total factor productivity (TFP) as a residual; we subtract from the $\dot{Y}/Y$ the part of growth rate that can be accounted for by the growth rates of the inputs, K and L. The part that remains, which provides an estimate of $\dot{B}/B$, is often called *Solow's residual* or simply the *residual* Barro and Sala-I-Martine (1995), Johns (1997).

Since this study applies the Cobb-Douglas production function, we can apply the Growth Accounting technique in the industry groups covered in the study to determine how much the growth in output comes from the weighted average growth rates of factor inputs, capital and labour, and how much the growth in output comes from technological progress in these industries.

2.2 Method of Analysis

Concerning the methodology, the study bases its analysis on the estimation of production function.

The Constant Elasticity of Substitution (CES) that is discussed in section 2.1.3 will be used in this study for estimation to determine the production behaviour of the selected Ethiopian manufacturing industries. Further more, the Growth Accounting technique using the estimates from the Cobb-Douglas production function will be applied in the study to determine the rate of technological progress of the Ethiopian manufacturing industries covered in the study.

Since the study uses time-series data, the time-series econometrics techniques of the *Dickey-Fuller*(DF*)* and the *Augmented Dickey-Fuller* (ADF) tests of stationarity of the variables and the Engle-Granger Cointegration test will be carried out before estimation of the parameters of the model. Depending on the results of stationarity test of the variables error-correction models will be developed to apply econometric techniques and hence to estimate the parameters of the model set for the industries by industry group.

2.2.1 The Error correction Models

As described in section 2.1.3 equation (2.1.3.4), the CES production function, in its stochastic form, that is used in this study is expressed as:

$$Y = \gamma\,[\delta\, K^{-\rho} + (1-\delta)\, L^{-\rho}]^{-v/\rho}\, e^{\varepsilon} \qquad \text{-------------------- (2.2.1.1)}$$

Where all the variables and the parameters are as defined in equation (2.1.3.1). ε is stochastic disturbance term and it is assumed to be normally distributed with mean zero and constant variance σ^2, i.e., $\varepsilon_i \sim N(0, \sigma^2)$.

The Log-linear form of the above CES production function model is:

$$\ln Y_t = \alpha_0 + \alpha_1 \ln K_t + \alpha_2 \ln L_t + \alpha_3 [\ln K_t - \ln L_t]^2 + \varepsilon_t \qquad \text{--------- (2.2.1.2)}$$

Where the subscript *t* denotes the variable across time (t) and ε_t is a stochastic disturbance term. Similarly, the Cobb-Douglas production function, in its stochastic form, that is used in this study is expressed as:

$$Y = AK^{\beta 1}\, L^{\beta 2}\, e^{\mu} \qquad \text{--- (2.2.1.3)}$$

Where all the variables and the parameters are as defined in equation (2.1.2.1) previously.

The Log-linear form of the above Cobb-Douglas production function model is:

$$\ln Y_t = \beta_0 + \beta_1 \ln K_t + \beta_2 \ln L_t + \mu_t \quad \text{----------------------------------- (2.2.1.4)}$$

Where β_0 = lnA and μ_t is a stochastic disturbance (error) term. The subscript *t* denotes the variable across time (t).

In this empirical study the unit root test show that for the five industry groups the three variables (in log) lnY, lnK and lnL are not stationary by levels(in log) even at 5 % level of significance as can be from the Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) tests results of stationarity of the variables in Annexe I.

If all the three variables (in log) lnY, lnK and lnL were stationary by levels(in log), one could apply OLS technique automatically on the transformed log-linear CES and Cobb-Douglas regression models defined in equation (2.2.1.2) and (2.2.1.4) respectively which are called cointegration or static regression equations.

Since this is not the case in this study for the three variables (in log) as described above, it is therefore needed to re-write the regression model (2.2.1.2) in an error correction model as:

$$\Delta \ln Y = \alpha_0 + \alpha_1 \Delta \ln K + \alpha_2 \Delta \ln L + \alpha_3 [\Delta \ln K - \Delta \ln L]^2 + \psi \varepsilon_{t-1} + \lambda \quad \text{-----------(2.2.1.5)}$$

for estimation of production function of the five industry groups of the Ethiopian manufacturing industries using the CES production function which will be used to study the production behaviour of the five industry groups over the period of the study.

Similarly, one has to write the regression model (2.2.1.4) in an error correction model as:

$$\Delta \ln Y = \beta_0 + \beta_1 \Delta \ln K + \beta_2 \Delta \ln L + \alpha \mu_{t-1} + \nu \quad \text{------------------ (2.2.1.6)}$$

for estimation of the parameters using the Cobb-Douglas production function where the estimates of the parameters will be used to determine the rate of technological progress or the growth rate in technology in the five industry groups over the period of the study.

Where $\Delta \ln Y$, $\Delta \ln K$ and $\Delta \ln L$ represents the first difference of the variables lnY, lnK and lnL respectively. λ and ν are stochastic disturbance (error) terms with the usual properties. The terms ε_{t-1} and μ_{t-1} are known as ***error-correction terms*** and are a one period lagged value of the residual from the cointegration (static) regression equations (2.2.1.2) and (2.2.1.4) respectively and capture the adjustment towards the long-run equilibrium.

The coefficients ψ and α are called ***error-correction coefficients*** and measure the degree or the speed of adjustment to long-run solution that enters to influence short run movements in output (in logs) or it tells us what proportion of the disequilibrium in output (in logs) in one period is corrected in the next period. ψ and α are negative and is less than unity in absolute terms, since we do not expect a 100% or instantaneous adjustment. α_0, α_1 , α_2 , and α_3 in equation (2.2.1.5) and β_0, β_1 and β_2 in equation (2.2.1.6) are parameters to be estimated.

The parameters α_1 and α_2 in equation (2.2.1.5) and β_1 and β_2 in equation (2.2.1.6) appear in the part that is the short-run dynamics of the model and clearly reflects the immediate response of lnY to a change in lnK and lnL respectively. Therefore, α_1 and α_2 in equation (2.2.1.5) and β_1

and β_2 in equation (2.2.1.6) represent the ***short-run elasticity*** of output with respect to capital and labour inputs respectively. α_0 in equation (2.2.1.5) and β_0 in equation (2.2.1.6) are intercept terms.

In these regression equations, equation (2.2.1.5) and (2.2.1.6), ΔlnK and ΔlnL capture the short-run disturbances in output whereas the error correction terms, ε_{t-1} and μ_{t-1}, in equations (2.2.1.5) and (2.2.1.6) respectively capture the adjustment towards long-run equilibrium.

Thus in this study, the regression models defined in equations (2.2.1.5) and (2.2.1.6) will be used to estimate the production function of the five industry groups of the Ethiopian manufacturing industries using the CES and Cobb-Douglas production function respectively.

The Dickey-Fuller (DF) and the Augmented Dickey-Fuller (ADF) tests of stationarity of the variable are applied also on the residual (error) terms ε_t and μ_t from the cointegration (static) regressions as defined in equations (2.2.1.2) and (2.2.1.4) respectively for the five industry groups covered in the study and the result of this test is available in Annexe II which show that for the five industry groups the residuals from the cointegration regressions defined in equations (2.2.1.2) and (2.2.1.4) are all stationery at 5 % level using equation (A.1.1) in Appendix I. Hence the three variables (in log), lnY, lnK, and lnL cointegrate for the five industry groups covered in the study.

2.2.2 Application of Growth Accounting Technique

In this study the Growth Accounting technique and using estimates of the parameters from the Cobb-Douglas production function will be applied to determine the rate of technological progress in the specified Ethiopian manufacturing industries.

As described section 2.1.2, the Cobb-Douglas production function is defined as:

$$Y = AK^{\beta 1} L^{\beta 2} \qquad \text{---} \quad (2.2.2.1)$$

The Log-Linear form of this function is:

$$\ln Y_t = \beta_0 + \beta_1 \ln K_t + \beta_2 \ln L_t \qquad \text{--} \quad (2.2.2.2)$$

Differentiating equation (2.2.2.2) with respect to time(t), we have:

$$\dot{Y}/Y = \dot{A}/A + \beta_1 \dot{K}/K + \beta_2 \dot{L}/L \qquad \text{----------------------} \quad (2.2.2.3)$$

Where, $\dot{Y}/Y$, $\dot{K}/K$ and $\dot{L}/L$ represent growth rates of output, capital and labour inputs, respectively. β_1 and β_2 are parameters to be estimated from the Cobb-Douglas regression model (2.2.1.6).

$\dot{A}/A$ measures the rate of technological progress or the rate of growth of total factor productivity(TFP) and shows that part of the rate of growth of output that can not be explained by the weighted average growth rates of capital and labour inputs and is known as ***Solow residual***.[2]

[2] According to exogenous economic growth theory of Solow model with technology, long-run growth of output per worker depends solely on technological progress/growth rate of technology. But in the short-run growth can result from either technological progress or capital accumulation. Hence it is necessary to decompose or break down the growth in output in to technical progress and growth from factor inputs accumulation.

2.3 REVIEW OF EMPRICAL LITERATURE

Basically, there are three main approaches to obtaining empirical production functions. Production functions may be obtained from: (1) technical information supplied by engineers, (2) data obtained by experiments as in agriculture, and (3) statistical analysis of cross-section or time-series data.

Many empirical investigations in estimating firm's, industries or sectors of an economy production function using time series or cross-section data use the Cobb-Douglas and the CES production functions. A number of empirical research works have been conducted by many researchers some of which are presented as follows.

Fukuchi (1995) emphasized on the technological retard and its influence to stagnant economic growth in small least-developed countries (LDCs). First, he measured the technological development by UNIDO's TCI measurement and found that the level of technical complexities in island or inland countries was lower than the normal level. He also found that the development of technical complexity is very important to industrialization in developing countries. Thus the stagnant technological improvement is one of the reasons for low growth of LDCs handicapped by smallness or isolation. Secondly, he analyzed the relation between stagnant technological improvement and the low growth of small LDCs by a simple growth model which combines the Romer-type nonlinear production function and human capital growth equation. The brain drain was explicitly considered a main hindrance of human capital formation in these LDCs.

Technical progress and production efficiency are central to economic growth and international competitiveness. However, these topics received little attention in Less Developed Countries. Taymaz (1997) attempted to measure and understand the extent and importance of technical progress and efficiency in Turkish manufacturing industries. Stochastic production frontiers for Turkish textile, cement, and motor vehicles industries are estimated by using panel data of plants for the years 1987 to 1992. The rate and direction of technical change for each industry are estimated by introducing time-dependent variables in the production function. The result indicates the existence of technical progress in the industries over the period of the study.

Ramirez (1998) investigated to see whether public investment enhances productivity growth in Mexico applying a cointegration analysis in a modified neoclassical production function. The paper begins with an overview of the role of the Mexican state in the investment process during the period 1950-93. A set of testable hypotheses is then generated from a model that incorporates, inter alia, the public capital stock as an argument in a modified neoclassical production function, and an empirical counterpart of the conceptual model is tested relating the relevant variables to the rate of GDP growth (including labor productivity growth). The results suggest that the growth in public and private investment spending has had a positive effect on the rate of productivity growth in Mexico.

Westbrook and Tybout (1993) exploited plant level panel data to estimate the returns to scale or the scale of operation of the Chilean manufacturing industries over the period 1979-1986. The authors used the Cobb-Douglas production function in their empirical study and they found the result that the observed value of the returns to scale for the sixteen industry groups covered in the study are not statistically significantly different from constant returns to scale. Katz (1969) conducted the same empirical study to determine the production behaviour and the rate of technological progress of the Argentine Manufacturing industries over the period 1946-1961 applying the CES and the Cobb-Douglas production functions and the Growth Accounting technique. He noted that there were no immediate reasons for believing that the shares of capital and labour in manufacturing output constitute poor approximations to the elasticities of out put with respect to capital and labour. The sum of the elasticities of output with respect to capital and labour inputs is not significantly different from unity. This implies that, on aggregate over the period 1946-1961, the Argentine manufacturing industries scale of operation was in the range of constant returns to scale. It was also found that the rate of technical progress in the Argentine manufacturing industries was 1.6 % over the period of the study.

Risager (1993) applied the Johansen cointegration technique to investigate the degree of substitutability between skilled and unskilled labor in construction and the metal industry in Denmark. For construction he found a high degree of labor substitutability. Factor prices are weakly exogenous so the results are consistent with the simple neoclassical model. In the metal industry relative employment and factor prices also cointegrate. The substitution elasticity is close to zero and a formal test of this hypothesis shows that it cannot be rejected. If true, this suggests a Leontief production technology or rigid working and contracting practices that prevent an adjustment of relative employment to relative wage changes, or vice versa.

The property rights hypothesis suggests that publicly owned enterprises are inherently less efficient than their private counterparts due to the difficulty of transferring ownership rights among individuals. Mohamed (1992) tested the hypothesis that publicly owned firms are conducted the same empirical study to determine the production behaviour and the rate of technological progress of the Argentine Manufacturing industries over the period 1946-1961 applying the CES and the Cobb-Douglas production functions and the Growth Accounting technique. He noted that there were no immediate reasons for believing that the shares of capital and labour in manufacturing output constitute poor approximations to the elasticities of out put with respect to capital and labour. The sum of the elasticities of output with respect to capital and labour inputs is not significantly different from unity. This implies that, on aggregate over the period 1946-1961, the Argentine manufacturing industries scale of operation was in the range of constant returns to scale. It was also found that the rate of technical progress in the Argentine manufacturing industries was 1.6 % over the period of the study.

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The property rights hypothesis suggests that publicly owned enterprises are inherently less efficient than their private counterparts due to the difficulty of transferring ownership rights among individuals. Mohamed (1992) tested the hypothesis that publicly owned firms are inherently less efficient, by estimating the relative performance of public and privately owned firms in the Malaysian manufacturing sector. He conducted a time series estimation of the Constant-Elasticity of Substitution (CES) production functions to assess public versus private firms' efficiency. His findings do not enable us to conclude that publicly owned firms' performance are inherently inferior. To a certain extent, the difference in performance between public and private firms are influenced by structural features of the market in which they operate.

One of the important sources of growth of an economy is the efficient and productive use of existing resources. Neogi and Ghosh (1994) tried to investigate the intertemporal efficiency variations in Indian manufacturing industries. The Indian industries after three decades of protected industrial culture has produced an inefficient regime. This is supposed to be corrected by the on-going economic liberalization. An application of Time-Varying Frontier Production Function approach with both fixed and variable ranking models in Indian industries helps in testing the hypothesis of inter temporal movement of technical efficiencies (TE) on which the current globalization program is based. The results are significantly conclusive: technical efficiencies have been falling over time. This along with total factor productivity(TFP) changes helps us to understand the nature of industrial development in recent past. An inquiry into the sources of inter-industry efficiency variations shows that skill, labor productivity and profit play significantly positive roles, while capital intensity works against general beliefs. Hu and Schive (1997) studied the productivity and efficiency of small manufacturing enterprises (SMEs) in Taiwan. This study estimates both average and frontier production functions for nine selected Taiwan manufacturing industries in 1986. By using two factors' transcendental logarithmic production function form, the authors compare productivity, flexibility, and technical efficiency between SMEs (defined by enterprises with less than 100 employees) and their larger counterparts. Their empirical results suggest that, in some industries, SMEs were superior to larger firms, with respect to their labor or capital productivity. In most industries, small enterprises tended to have larger partial elasticity of substitution and higher technical efficiency (measured in the estimated Farrell index). These findings show the flexibility and better internal performance of SMEs among Taiwan manufacturers.

Yao (1997) studied the impact of profit sharing and bonus payment on the performance of Chinese state owned industries in the 1980s. Employing the Kmenta approximation of a constant elasticity of substitution (CES) production function and a nonlinear simultaneous system, it is found that over half of value-added growth could be explained by bonus incentives. Labor quality was another important factor affecting firm performance. Previous studies that do not consider labor quality may have produced biased results. The positive effect of bonus payment on production found by others is, however, confirmed. Lee and Rhee (1996) analyised a set of time-series (1972-89) and cross-sectional data on eight South Korean manufacturing industries to examine the variability of South Korea's employee bonus system and the effect of the employee bonus on productivity. A test of the variability of the bonus showed that the bonus rate (ratio of the bonus to the wage) was positively influenced by industrial output, so the bonus is not merely a disguised wage. An augmented Cobb-Douglas production function estimation shows that the bonus has a positive and significant productivity effect. Capital-intensive and labor-intensive industries did not have significantly different productivity effects due to the bonus. Lastly, South Korean unions reduced labor productivity and negatively affected the productivity effect of the bonus. Also, compared productivity, flexibility, and technical efficiency between SMEs (defined by enterprises with less than 100 employees) and their larger counterparts. Their empirical results suggest that, in some industries, SMEs were superior to larger firms, with respect to their labor or capital productivity. In most industries, small enterprises tended to have larger partial elasticity of substitution and higher technical efficiency (measured in the estimated Farrell index). These findings show the flexibility and better internal performance of SMEs among Taiwan manufacturers.

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Benhabib and Spiegel (1994) using cross-country estimates of physical and human capital stocks in developing countries, the authors run the growth accounting regressions implied by a Cobb-Douglas aggregate production function. Their results indicate that human capital enters insignificantly in explaining per capita growth rates. The authors next specified an alternative model in which the growth rate of total factor productivity depends on a nation's human capital stock level. Tests of this specification indicated a positive role for human capital.

Chang (1994) used the Multi-level CES Production Function in testing for capital-energy substitution in Taiwanese manufacturing industries. The empirical results show that capital and energy are substitutes in production.

Briguglio (1998) tests the hypothesis that small country size is associated with constraints relating to economies of scale in manufacturing. The study adopts a production function approach, utilizing data from forty-three differently sized countries. The results, confirming -. sthe hypothesis, lend empirical support to the presumption that small countries face serious disadvantages in terms of production cost per unit in their manufacturing sectors, suggesting that such countries are, as a result, seriously disadvantaged in terms of international competitiveness in manufacturing trade.

Gajanan and Ramaiah (1996) estimates the substitution possibilities among different inputs for Indian manufacturing. The authors' used an indirect production function. The advantage of using an indirect production function over the cost function is that it provides estimates of both output and substitution effects. The authors found that including the output effect significantly alters the complementarity-substitutability relationship among several input pairs. The authors also derive and estimate the Morishima elasticity of substitution for an indirect production function to allow for asymmetry in substitution possibilities and its impact on relative factor shares.

Kalirajan, Obwona and Zhao (1996) investigated the total factor productivity(TFP) growth in the case of Chinese Agricultural growth before and after reforms. The authors' objective in this paper is to explain a method to decompose the sources of total factor productivity growth into technological progress and changes in technical efficiency within the framework of the varying coefficients frontier production function. An empirical application is demonstrated using the Chinese provincial-level agricultural data covering the period 1970-87. The results indicate that TFP growth in the pre-reform period was negative in twenty out of twenty-eight provinces and that it was positive in almost all provinces during the reform periods, while negative in sixteen out of twenty-eight provinces in the post-reform periods of 1984-87.

Suer (1995) analysed the production function of the UK manufacturing industries by estimating a translog cost function for the period 1955-1981. The study aims to estimate technical change parametrically. Among the conclusions arising from this estimate indications are that technological change is input biased in the food, drink and tobacco industries; and that these industries seem to have experienced deterioration in scale economies during the 1970s.

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Also finds that energy and capital inputs are complementary. This supports the argument that reductions in energy price will be accompanied by higher levels of investment.

Bumpass and Greenwade (1993) conducted an empirical study with the following two objectives: (1) estimate an aggregate production function for U.S. manufacturing and (2) estimate a demand curve for labor to establish the relationship between the real wage and cyclical movements in U.S. manufacturing using data for the period 1948 to 1983. The paper uses a measure of the "utilized" capital stock to estimate a production function and a labor demand function in lieu of the traditional measure of the "absolute" capital stock. Their major findings are: (1) Strong evidence supporting the neoclassical hypothesis of diminishing returns to labor when "utilized" capital stock is used in estimating the production function. (2) Energy price shocks of the 1970s had a significant impact in reducing manufacturing productivity and that nearly 50 percent of the decline in the growth in real wages resulted from these energy price shocks.

Dhawan and Gerdes (1997) present a methodology for estimating an index of technological change using firm-level data in a stochastic frontier production function model that takes into account time-varying technical inefficiency. In contrast to the Solow divisia index approach, econometric estimation of the index with panel data allows the researcher to separate technical progress from the stochastic measurement error. Applying the econometric methodology to a panel of 908 publicly-traded U.S. firms from the COMPUSTAT database, they found evidence of a significant downturn in general technological change for the period, 1970-89, whereas the divisia index methodology applied to the same data shows stagnation. When the sample is divided into manufacturing, services, and miscellaneous categories they found that estimates of technological change for the three groups display markedly different stochastic behavior and that the services group is the source of the downturn.

A dramatic decline in U.S. crude oil finding costs has provoked intense interest in the extent to which technical progress has mitigated the effects of resource depletion. Fagan (1997) conducted an empirical study to determine the effects of resource depletion and technical change on U.S. crude oil finding costs for the period 1977 to 1994. Analysis of depletion and technical change using data for 27 large U.S. oil producers from 1977-1994 is conducted using a translog cost function. The translog provides a flexible representation of the underlying production function, and controls for changing factor prices. The model also controls for the effect of prospect high grading. Results show that an accelerating rate of technical change reduced average finding cost 15 percent (onshore) and 18 percent (offshore) per year by 1994. Resource depletion increased cost at an average annual rate of 7 percent onshore and 12 percent offshore. Technical change was relatively labor-using both onshore and offshore.

Hsing (1996) conducted an empirical study of estimation of production function. Five different production functions for 50 states in the District of Columbia in the U.S. are estimated and compared based on the 1987 data from the Census of Manufacturers. The Cobb-Douglas function can be rejected. The CES yields a negative value of the elasticity of substitution (σ). In the translog function, the coefficient of log K_t has a wrong sign and is insignificant. The coefficient of K_t in the generalized Leontief function is insignificant at the 5% level. It appears that the new CES function (Bairam, 1989, 1991) yields the best statistical results: the elasticity of substitution (σ) is estimated to be 1.56, and total output elasticity ranges from 0.85 to 1.12, which can partly be explained by different values of the K/L ratio.

When assessing the empirical studies using production function in the Ethiopian context, some empirical investigations have been conducted at firm level but very few studies on the production behaviour of the Ethiopian manufacturing industries as a whole.

Teshome (1980) conducted an empirical study on the Ethiopian manufacturing industries by industry group. He used the Constant Elasticity of Substitution (CES) production function to investigate the production behaviour of the Ethiopian manufacturing industries over the period 1965-1975.

His empirical study shows that four industry groups: beverage, textiles, paper, and chemicals and all manufacturing industries as a whole were characterized by decreasing returns to scale of production processes. Whereas, manufacture of food, wood, non-metallic mineral products and fabricated metal products exhibit increasing returns to scale over the period of study.

Based on his empirical study result, he noted that the cross-country estimates of the elasticity of substitution as well as the estimates from Bangladesh, Kenya, Nigeria, Philippines, and Pakistan are in general higher than those obtained for Ethiopia. Besides based on the value of the elasticity of substitution he concluded that one is inclined to accept the proposition that there have been rather limited technological possibilities or flexibilities for the substitution of labour for capital in the Ethiopian manufacturing industries.

Admit (1997) conducted an empirical research to determine the technical progress in the

Ethiopian manufacturing industries. He used both the Cobb-Douglas and the CES production functions in his empirical study and the following four results obtained. First, the Ethiopian manufacturing industries as a whole registered a negative technical progress. Secondly, the production technique, in general, was capital consuming and labour saving. Thirdly, there was real sub-sectoral differences; those industries which are light and with long years of production experience recorded a positive technical progress while others did not. Finally, the private sector, in general, appeared to be more efficient in resource utilization than the public ones.

Asmerom (1980) used a linear multiple regression models in the estimation of the production function of an Ethiopia firm Viz., Anbessa Shoe Factory.

He estimated a linear production function of the factory for three periods (1970-1973, 1974-1977 and 1970-1977) with four explanatory variables of inputs which are raw material, capital input, labour input and a time trend representing technological progress.

He found that in all of the three periods output is affected only by raw materials, whereas labour input, capital input, and technological progress do not seem to be significant. He also stated that the effect or the influence of raw materials on output should not be underestimated in the estimation processes of firms production function.

Alemu (1985), Negede 91987) and Siraj 91995) conducted empirical research to determine the production behaviour of Addis Abeba Brewery, kotebe Metal Tools Factory and Ethio-Japan Textile Industry over the period 1975- 1984, 1977-1986 and 1975-1994 respectively. The researchers used the Cobb-Douglas and the Constant Elasticity of substitution (CES) productions. Their empirical findings are the same: (1) in these industries labour input found to contribute more for the increase in output than capital input does; (2) these industries were operating in the range of increasing returns to scale over the period of the study. Negede (1987) estimation result usíng the CES production function revealed low value of the distribution or the capital intensity parameter and this indicates the production process in the factory was labour intensive. And in his empirical study lower value of the elasticity of substitution was observed. The lower value of the elasticity of substitution indicates the substitution possibility between factor inputs in the factory was difficult.

These are some of the empirical literatures review on estimation of production function of firms, industries, and sector of an economy using Cobb-Douglas, CES and the translog production functions to determine the production behaviour, the scale of operation, the rate of technical progress, substitution between inputs in the production processes, technical efficiency and other related topics all over the World including Ethiopia.

From the review of the empirical literatures presented in this section the following important lessons can be drawn that are relevant to this study:

(1) Regarding the scale of operation, according to some of the empirical studies constants returns to scale revealed in the Argentine and the Chilean manufacturing industries, Katz (1969), Westbrook and Tybout (1993). Some industry groups exhibited increasing returns to scale while the rest industry groups covered in the study exhibited decreasing returns to scale in the Ethiopian manufacturing industries, Teshome (1980). In addition to these

according to firm level studies conducted in some Ethiopian manufacturing industries increasing returns to scale was found to be the scale of operation over the period of the studies, Alemu (1985), Negede (1987) and Siraj (1995).

(2) Concerning which of the two factor inputs (capital or labour) contributes more for the increase in output, according some of the empirical studies conducted at firm level on the Ethiopian manufacturing industries it was found that labour input contributes more for the increase in output than capital input does, Alemu (1985), Negede (1987) and Siraj (1995).

(3) With regards to the elasticity of substitution the cross country estimates of the elasticity of substitution for Ethiopia is lower than for Kenya, Nigeria, Bangladish, Philippines and Pakistan, Tesome (1980). This empirical study result is also supported by other researchers on the Ethiopian industries at firm level, Negede (1987).

(4) Concerning technological progress it is positive in the Turkish and the Argentine manufacturing industries, Taymaz (1997), Katz (1969). It was found to be negative in the Ethiopian manufacturing industries as a whole, Admit (1997). In an empirical study on US firms it resulted in downturn or stagnation in it in using two different methods of analysises, Dhawan and Gerdes (1997).

(5) With regards to the type of production technology used, according to an empirical study at factory level on the Ethiopian industry it was found that the factory use labour intensive technology, Negede (1987). In an empirical study on the whole Ethiopian manufacturing industries the production technique was found to be capital consuming, Admit (1997).

As described in the objective of the study, this empirical study focuses on the determination of the production behaviour and the rate of technical progress of the specified Ethiopian manufacturing industries for designing appropriate policies that are geared towards the development and expansion of the industrial sector in particular and as a result for the development of the country both economically and technologically in general. Hence, the empirical study results of this study on the specified Ethiopian manufacturing industries are presented on the following two chapters, Chapter 3 and 4.

CHAPTER 3

ESTIMATION OF PRODUCTION FUNCTION

3.1 Estimation using the Constant Elasticity of Substitution (CES) production function

As described in section 2.2, the CES production function, in its stochastic form, that is used in this study is expressed as:

$$Y = \gamma\,[\delta\,K^{-\rho} + (1-\delta)\,L^{-\rho}]^{-v/\rho}\,e^{\varepsilon} \qquad \text{------------------------------------} \quad (3.1)$$

Where all the variables and the parameters are as defined in equation (2.1.3.1) previously.

The Log-linear form of the above CES production function model is:

$$\ln Y_t = \alpha_0 + \alpha_1 \ln K_t + \alpha_2 \ln L_t + \alpha_3 [\ln K_t - \ln L_t]^2 + \varepsilon_t \qquad \text{---------} \quad (3.2)$$

Where the parameters of the function represented in equation (3.1) is related to the coefficients of the model in (3.2) as follows:

$$\gamma = \text{antilog } \alpha_0 \quad \text{------------------------------------} \quad (3.3)$$

$$\nu = \alpha_1 + \alpha_2 \quad \text{------------------------------------} \quad (3.4)$$

$$\delta = \alpha_1 / \alpha_1 + \alpha_2 \quad \text{---------------------------------} \quad (3.5)$$

$$\rho = -2\, \alpha_3 (\alpha_1 + \alpha_2) / \alpha_1\, \alpha_2 \quad \text{---------------------------------} \quad (3.6)$$

As already described in equation (2.2.1.5), the CES production function model which is used in this study for estimation of production function for the five industry groups of the Ethiopian manufacturing industries is defined as:

$$\Delta \ln Y = \alpha_0 + \alpha_1\, \Delta \ln K + \alpha_2\, \Delta \ln L + \alpha_3 [\Delta \ln K - \Delta \ln L]^2 + \psi\, \varepsilon_{t-1} + \lambda \quad \text{--(3.7)}$$

Where α_0 is a constant (intercept) term, α_1 and α_2 represent *short-run elasticity* of output with respect to capital and labour inputs as defined in equation (2.2.1.5) previously.

α_3 is an estimate which helps us to determine the substitution parameter (ρ) and hence the elasticity of substitution (σ) along with the estimates α_1 and α_2 and using equations (3.6) and (2.1.3.3). ψ is an error-correction coefficient as defined in equation(2.2.1.5) and the rest terms are as defined in equation(2.2.1.5) too.

Applying the OLS technique on the CES production function regression model defined in equation (3.7), the regression estimates for the five industry groups which is presented in Table 3.1 next page.

Table 3.1: Regression estimates of the five industry groups Using the CES production function, model (3.7)

S/R No.	Industry Group	Constant term (α_0)	Short-run elasticities α_1	Short-run elasticities α_2	α_3	Error-correction coefficient (ψ)	R^2	Dw	F
1	Beverage Industries	-0.05268 (0.04604)	0.66859** (0.12445)	1.4482* (0.61442)	0.42742** (0.13529)	-0.42264* (0.17328)	0.73	2.30	9.70**
2	Manufacture of Sugar and Sugar confectionery	-0.07773 (0.07987)	0.58906* (0.22614)	1.9075* (0.85618)	0.78517 (0.59271)	-0.89532** (0.29207)	0.58	1.91	4.84*
3	Manufacture of Textiles	-0.05985 (0.04392)	-0.38833** (0.10439)	1.070* (0.490)	0.42001** (0.08945)	-0.06053 (0.15976)	0.75	1.21	10.46**
4	Manufacture of Rubber and Plastic products	0.12608* (0.05168)	0.59069* (0.20905)	0.82963** (0.25167)	-0.40851** (0.11081)	-0.73991** (0.21712)	0.78	1.06	10.88**
5	Manufacture of Basic Industrial Chemicals and other Chemical products	-0.02808 (0.09708)	2.4116** (0.64873)	0.83757 (0.61284)	0.88527 (2.5505)	-0.60154 (0.35191)	0.67	1.76	7.01**

NB: The figures in parentheses are the estimated standard errors.

** represents the estimate/ the value is statistically significant at 1 % level, and

* represents the estimate/ the value is statistically significant at 5 % level

The test for statistical significance of individual coefficients is based on the application of t-test as defined. The test for the overall significance of the regression is based on the usual F-test.

As can be read from Table 3.1, since the estimates of coefficient α_3 for Manufacture of Sugar and Sugar Confectionery and Manufacture of Basic Industrial Chemicals and Chemical products are not statistically significant even at 5 % level of significance, we reject the CES production function model defined in equation (3.7) for these two industry groups, and hence no further analysis could be made for these two industry groups in this study using the estimates of the CES production function.

Thus, regarding the determination of which factor input contributes more for the increase in output, the returns to scale, the type of technology in the production process and the elasticity of substitution, the study is limited only to three industry groups namely Beverage Industries, Manufacture of Textiles and Manufacture of Rubber and Plastic Products where the estimated coefficients of these industry groups are statistically significant some even at 1 % level and the rest at 5 % level of significance.

Since the constant term (α_0) is statistically significant only for Manufacture of Rubber and Plastic Products, we can not talk about the efficiency parameter (γ) in the rest four industry groups.

However, for Manufacture of Rubber and Plastic products the value of the efficiency parameter is $\gamma = 1.13$ over the period of the study using the estimate for the constant term from the CES production function in model (3.7) and using equation (3.5). Assuming other variables in equation (3.7) to be constant, this indicates that the increase in efficiency of production increases output by 1.13 unit in Manufacture of Rubber and Plastic Products.

The increase in capital and labour inputs contribute positively for the increase in output in Beverage Industries and in Manufacture of Rubber and Plastic Products. In Manufacture of Textiles labour input contributes positively for the increase in output similar to the other two industry groups where as the increase in capital input contributes for the decrease in output over the period of study. This unexpected sign for capital input suspected to be the problem of the data.

In this empirical study, labour input contributed more for the increase in output than capital input does in Beverage Industries and Manufacture of Rubber and Plastic Products and contributes positively for the increase in output in Manufacture of Textiles.

The empirical result of the study that labour input contributes more for the increase in output than capital input does is a similar result of many empirical studies at firm level of most industries in Ethiopia; Alemu (1985), Negede (1987) and Siraj (1995).

The largest contribution of labour input for the increase in output is observed in Beverage Industries. That is, a one percent increase in labour input led on average to about 1.45 percent increase in output. The smallest contribution of labour input for the increase in output was observed in the Manufacture of Rubber and plastic products in that case a one percent increase in labour input led on average to about 0.83 percent increase in output.

The determination of the scale of operation ($\nu = \alpha_1 + \alpha_2$), the elasticity of substitution (σ), the type of technology of the production process are the other three important specific objectives of the study which we will come shortly besides the determination of which one of the two factor inputs, capital or labour, contributes more for the increase in output over the period of the study in the industry groups covered in the study.

The other important result reported in Table 3.1 is the error correction coefficient (ψ) which is statistically significant at 1 and 5 percent levels in Manufacture of Rubber and Plastic Products and Beverage Industries respectively. But it is statistically insignificant in Manufacture of Textiles.

For the two industry groups where it is statistically significant, the error correction coefficient ψ is negative and is less than 1 in absolute value terms as expected and it was observed that the speed of adjustment towards long-run equilibrium or the proportion of the disequilibrium in output in one period being corrected in the next period is high on average and it is greater than – 0.40 for the two industry groups.

Of the two industry groups, the largest error-correction coefficient (in absolute value terms) and hence the fastest speed of adjustment towards long-run equilibrium was observed in the Manufacture of Rubber and Plastic Products where ψ = - 0.74.

The main reason for such significantly high, in absolute value terms, error-correction coefficient or high speed of adjustment towards long-run equilibrium in Manufacture of Rubber and Plastic Products is expected to be due to the fact that a significant increase in output since 1993 as can be read from the data table in Annexe III.

Using estimates of the CES production function defined in equation (3.7) and applying equation (3.4), the scale of operation ($\nu = \alpha_1 + \alpha_2$) of the three industry groups of the Ethiopian manufacturing industries is reported on Table3.2.

Table 3.2: Scale of operation of the Three industry groups

S/R No.	Industry Group	$\nu = \alpha_1 + \alpha_2$	Returns to scale (based on the *t-test*)
1	Beverage Industries	2.11679 [1.7256]	Constant returns to scale
2	Manufacture of Textiles	0.68167 [-0.6581]	Constant returns to scale
3	Manufacture of Rubber and Plastic products	1.42032 [1.5728]	Constant returns to scale

NB: The figure in bracket [ ] represents the computed *t-value* applying hypothesis testing of Linear Equality Restrictions and using the estimated coefficients and the variance-covariance matrix.

As discussed earlier, we are interested to determine the scale of operation of the industry groups covered in the study, i.e., to determine whether the industry groups covered in the study operated at increasing, constant or decreasing returns to scale over the period of the study.

As can be read from Table 3.2, it is found that the three industry groups (Beverage, Textiles and Manufacture of Rubber and Plastic Products) were operating, in the short run, in the range of constant returns to scale of operation based on the *t-test* result of hypothesis testing linear equality restriction. That is, a one percent increase in capital and labour inputs led to a one percent increase in output in these industry industries . The results are not in support of the a priori hypothesis stated in section 1.3 that says there is a strong empirical case for assuming that most industrial production processes exhibit increasing returns to scale.

Using estimates of the CES production function regression model defined in equation (3.7) and using equations (3.6) and (2.1.3.3), the elasticity of substitution (σ) of the three industry groups is reported in Table 3.3 below.

Table 3.3: Value of Elasticity of substitution (σ) of the three industry groups

S/R No.	Industry Group	Value of elasticity Substitution(σ)
1	Beverage Industries	1.151
2	Manufacture of Textiles	0.421
3	Manufacture of Rubber and Plastic products	0.297

The elasticity Substitution (σ) tells how much percentage change in relative factor input prices will bring about how much percentage change in factor proportions. Thus a one percent change in relative factor prices brought about a 1.15 percent, 0.42 percent and a 0.30 percent change in factor proportions in Beverage Industries, Manufacture of Textiles and Manufacture of Rubber and Plastic Products respectively. Thus, the elasticity of substitution is a very simple way of describing how technology would change in response to change in relative factor input prices.

As shown in Table 3.3, the estimated value of elasticity of substitution of the three industry groups is very small, almost close to zero except for Beverage Industries. This is similar to the previous empirical study results by Teshome (1980) and Negede (1987). Note also that this empirical study is not in support of the a priori stated hypothesis in section 1.3 that says in the Ethiopian Manufacturing industries the capital-labour substitution possibilities between the two factor inputs is expected to be high.

The fact that the value of the elasticity of substitution lies between zero and one in Manufacture of Textiles and Manufacture of Rubber and Plastic Products indicates that the production process in these two industry groups lies between the Leontief and the Cobb-Douglas production technology. Both industry groups data resemble to fit more the Leontife type technology than the Cobb-Douglas since the value of the elasticity of substitution in these two industry groups is close to zero than close to unity. Of the two industry groups, Manufacture of Rubber and Plastic Products data appears to fit more the Leontife type technology.

As discussed earlier, we are interested to determine the scale of operation of the industry groups covered in the study, i.e., to determine whether the industry groups covered in the study operated at increasing, constant or decreasing returns to scale over the period of the study.

As can be read from Table 3.2, it is found that the three industry groups (Beverage, Textiles and Manufacture of Rubber and Plastic Products) were operating, in the short run, in the range of constant returns to scale of operation based on the *t-test* result of hypothesis testing linear equality restriction. That is, a one percent increase in capital and labour inputs led to a one percent increase in output in these industry industries . The results are not in support of the a priori hypothesis stated in section 1.3 that says there is a strong empirical case for assuming that most industrial production processes exhibit increasing returns to scale.

Using estimates of the CES production function regression model defined in equation (3.7) and using equations (3.6) and (2.1.3.3), the elasticity of substitution (σ) of the three industry groups is reported in Table 3.3 below.

Table 3.3: Value of Elasticity of substitution (σ) of the three industry groups

S/R No.	Industry Group	Value of elasticity Substitution(σ)
1	Beverage Industries	1.151
2	Manufacture of Textiles	0.421
3	Manufacture of Rubber and Plastic products	0.297

The elasticity Substitution (σ) tells how much percentage change in relative factor input prices will bring about how much percentage change in factor proportions. Thus a one percent change in relative factor prices brought about a 1.15 percent, 0.42 percent and a 0.30 percent change in factor proportions in Beverage Industries, Manufacture of Textiles and Manufacture of Rubber and Plastic Products respectively. Thus, the elasticity of substitution is a very simple way of describing how technology would change in response to change in relative factor input prices.

As shown in Table 3.3, the estimated value of elasticity of substitution of the three industry groups is very small, almost close to zero except for Beverage Industries. This is similar to the previous empirical study results by Teshome (1980) and Negede (1987). Note also that this empirical study is not in support of the a priori stated hypothesis in section 1.3 that says in the Ethiopian Manufacturing industries the capital-labour substitution possibilities between the two factor inputs is expected to be high.

The fact that the value of the elasticity of substitution lies between zero and one in Manufacture of Textiles and Manufacture of Rubber and Plastic Products indicates that the production process in these two industry groups lies between the Leontief and the Cobb-Douglas production technology. Both industry groups data resemble to fit more the Leontife type technology than the Cobb-Douglas since the value of the elasticity of substitution in these two industry groups is close to zero than close to unity. Of the two industry groups, Manufacture of Rubber and Plastic Products data appears to fit more the Leontife type technology.

The isoquants of Manufacture of Rubber and Plastic Products seem to follow L-shape and are asymptotic to particular levels of capital and labour which implies that the inputs were used approximately in equal proportions indicating that the inputs were used close to perfect complements than being substitutes in production.

Notice that when the elasticity of substitution (σ) is zero, the inputs used in the production process are perfect complements. And when the elasticity of substitution (σ) equals infinity, the inputs are perfect substitutes.

In general, what one conclude from these values of the elasticity of substitution is that there was low substitution possibility between capital and labour in these two industry groups over the period of investigation, that is to say, the substitution possibility between capital and labours was difficult in the two industry groups.

However, for Beverage Industries since its value of elasticity of substitution is close to one, it can be said that the production process in this industry group approximately fits the Cobb-Douglas technology, that is to say that the Cobb-Douglas technology best fits the data than the Leontife or the Linear production function.

Using estimates of the CES production function in equation (3.7) and applying equation (3.5), the value of the distribution parameter(δ) of the three industry groups is reported in Table 3.4.

Table 3.4: The value of the distribution parameter(δ)of the three industry groups

S/R No.	Industry Group	Value of the distribution parameter(δ)
1	Beverage Industries	0.316
2	Manufacture of Textiles	- 0.570
3	Manufacture of Rubber and Plastic products	0.416

In contrary to our expectation the value of the distribution parameter (δ) for Manufacture of Textiles is negative. This negative result is obtained because the estimate of capital input is negative which is not expected.

As shown in Table 3.4, the value of the capital intensity coefficient equals 0.32 and 0.42 for Beverage Industries and Manufacture of Rubber and Plastic Products respectively. This implies that the labour intensity coefficient equals 0.68 and 0.58 for Beverage Industries and Manufacture of Rubber and Plastic Products respectively.

The relatively low value of the capital intensity coefficient and hence the relatively high value of the labour intensity coefficient over the period of the study in Beverage Industries and Manufacture of Rubber and Plastic Products indicate that in these two industry groups the type of production technology is relatively more of labour intensive technology of the production process. This shows that labour input's share in the total output is greater than capital inputs share in these two industry groups.

Furthermore, it can be said that the result of this empirical study goes with the country's real situation in a sense that many of the industries in the country are labour intensive.

CHAPETR 4

DETERMINATION OF THE RATE OF TECHNOLOGICAL PROGRESS

4.1 Estimation using the Cobb-Douglas production function

As described in equation (2.2.1.6), the Cobb-Douglas production function model which is used in this study is defined as:

$$\Delta \ln Y = \beta_0 + \beta_1 \Delta \ln K + \beta_2 \Delta \ln L + \alpha \mu_{t-1} + \nu \qquad \text{------------------------} \quad (4.1.1)$$

Where β_0 is a constant (intercept) term, β_1 and β_2 represent *short-run elasticity* of output with respect to capital and labour inputs. α is an error-correction coefficient as defined in equation (2.2.1.6).

The regression result of the Cobb-Douglas production function model is reported in Table 4.1.

Table 4.1: Regression estimates using the Cobb-Douglas production function regression model(4.1.1)

S/R	Industry Group	Constant term(β_0)	Short-run elasticities β_1	β_2	Error-correction coefficient (α)	R^2	Dw	F
1	Beverage Industries	0.00759 (0.0630)	0.25081 (0.1208)	0.50828 (0.85734)	* -0.54464 (0.21076)	0.33	0.91	2.61
2	Manufacture of Sugar and Sugar Confectionery	-0.00351 (0.0696)	* 0.54630 (0.22623)	** 2.7127 (0.69864)	** -0.82523 -(0.27204)	0.63	1.45	** 9.27
3	Manufacture of Textiles	0.0178 (0.0607)	-0.08593 (0.12618)	1.2118 (0.78096)	-0.31624 (0.21035)	0.31	1.37	2.45
4	Manufacture of Rubber and Plastic products	-4.0047 (2.7734)	0.11095 (0.06388)	0.31212 (0.30068)	* -0.64228 (0.24572)	0.37	2.51	2.79
5	Manufacture of Basic Industrial Chemicals and Chemical Products	-0.03761 (0.0689)	** 1.8074 (0.48061)	* 1.1010 (0.5001)	* -0.68976 (0.2750)	0.61	1.57	** 8.18

NB: The figure in parenthesis ( ) represents estimated standard errors.

* represents that the estimate/ the value is statistically significant at 5 % level

** represents that the estimate/ the value is statistically significant at 1 % level.

Note that since the two elasticity coefficients for Beverage Industries, Manufacture of Textiles and Manufacture of Rubber and Plastic Products are not statistically significant using the Cobb-

Douglas production function, it is difficult to determine the rate of technical progress for these three industry groups on the basis of such results. Thus it is decided to limit the discussion on the remaining industries. That is, regarding the determination of technological progress the study is limited only to two industry groups where their estimated elasticity coefficients are statistically significant using the Cobb-Douglas regression model. These two industry groups are Manufacture of Sugar and Sugar Confectionery and Manufacture of Basic Industrial Chemicals and Chemical Products.

Although it is not a subject of discussion in this chapter, as presented in Table 4.1, labour input contributes more for the increase in output in Manufacture of Sugar and Sugar Confectionery which is a similar result to the other industry groups discussed in chapter 3. However, in Manufacture of Basic Industrial Chemical and Chemical Products Capital input was found contributing more for the increase in output over the period of the study.

Using the two elasticity coefficients estimates from the same table and applying hypothesis testing of testing linear equality restriction as defined in Appendix III, the two industry groups returns to scale were found operating in the range increasing returns to scale with the computed t-values 3.062 and 3.249 for Manufacture of Sugar and Sugar Confectionery and Manufacture of Basic Industrial Chemicals and Chemical Products respectively. The result is in support of the a priori stated hypothesis that is described in section 1.3 and is contrary to the result obtained for the other three industry groups using the CES production function estimation.

4.2 Determination of the rate of technological progress

Applying equation (2.2.2.3) using the estimates of the parameters β_1 and β_2 from the Cobb-Douglas production function regression model (4.1.1) which are reported in Table 4.1 and the growth rates of output, capital and labour inputs as shown in Annexe V, the rate of technological progress in the two industry groups is reported in Table 4.2.1.

Table 4.2.1: The rate of technological progress in the two industry groups

S/R No.	Industry Group	Rate of Technological progress
1	Manufacture of Sugar and Sugar Confectionery	4.90 %
2	Manufacture of Basic Industrial Chemicals and Chemical products	3.44 %

This empirical finding show the two industry groups of the Ethiopian manufacturing industries register positive technical progress over the period of the study although it is low. Admit (1997) result is contrary to this result. His findings show the Ethiopian manufacturing industries registered negative technical progress.

Table 4.2.1 depicts that the rate of technological progress in Manufacture of Sugar and Sugar Confectionery and Manufacture of Basic Industrial Chemicals and Chemical Products is relatively low and is less than 5 % for both industry groups over the period of study. Of the two industry groups, relatively high rate of technological progress is observed in Manufacture of Sugar and Sugar Confectionery.

The low rate of technological progress in these two industry groups is an indication of the real picture of the Ethiopian manufacturing industries that are characterized by low level of technology.

In general, the low rate of technological progress is consistent with our expectation regarding the rate of technological progress of the Ethiopian manufacturing industries.

CHAPTER 5

SUMMERY AND CONCLUSION

The World consists of economies of all shapes and size. There are very rich countries, and there are very poor ones. Some economies are growing rapidly, while others are not growing at all.

As described in chapter 2 , the conclusion from economic growth models is that the long-run growth rate of the economy solely depends on technological progress. And as it is known, the industrial sector accounts the largest share where modern science and technology could be applied. It can therefore be the source of growth for an economy, if a country has the resource base to do, both human and financial.

A highly significant rate of growth of the economy, especially in developed countries, and in the world economy as a whole as compared to the previous times is the result of what is known as industrialization or the industrial revolution.

Being one of the least developed countries, the industrial sector in Ethiopia currently contributes not more than 12 % of the GDP. The Ethiopian manufacturing industries are mainly engaged in the production and process of primary household consumption goods such as food, textile products, shoe, beer, beverage and so on.

The establishment of heavy industries which produce machineries, equipments, construction materials, spare parts, etc, that are essential to speed up and promote growth in other sectors and build a strong economy have not yet established in the country.

Although the study is a preliminary attempt to determine the production behaviour and the rate of technological progress of specified Ethiopian manufacturing industries, it is believed to provide valuable information about the production behaviour and level of technology of the specified Ethiopian manufacturing industries over the period of the study.

That is, the study focuses on the determination of the production behaviour and the rate of technological progress of the specified Ethiopian manufacturing industries with the objective of providing valuable information that could be used for the development of appropriate policies that are geared towards the development and expansion of the specific industry groups covered in the study in particular and to the sector in general that would contribute for the country's development both economically and technologically.

Given this objective it was observed that labour input contributed more for the increase in output over the period of the study in the four industry groups, namely, Beverage Industries, Manufacture of Sugar and Sugar Confectionery, Manufacture of Textiles, and Manufacture of Rubber and plastic products. Where as capital input contributed more for the increase in output in one industry group, namely, Manufacture of Basic Industrial Chemicals and Chemical products.

The empirical study shows that three industry group, namely, Beverage Industries, Manufacture of Textile and Manufacture of Rubber and Plastic Products exhibited constants returns to scale. Where as Manufacture of Sugar and Sugar Confectionery and Manufacture of Basic Industrial Chemicals and Chemical Products exhibit increasing returns to scale.

With regard to the elasticity of substitution, there was low substitution possibility between capital and labour inputs in production process, especially in Manufacture of Rubber and Plastic Products and Manufacture of Textiles. The low values of elasticity of substitution indicate that the inputs were used more or less in equal proportions.

As far as the type of technology of the production processes is concerned, it was found that both Beverage Industries and Manufacture of Rubber and Plastic Products use relatively labour intensive technology than capital intensive technology which is the basic feature of many industries in the country.

Finally, regarding the rate of technological progress, it was found that the rate of technological progress both in Manufacture of Sugar and Sugar Confectionery and Manufacture of Basic Industrial Chemicals and Chemical Products is low which does not exceed 5 % for both industry groups over the period of the study.

As can be seen from the results, this empirical study is believed to have provided valuable information about the production behaviour and the rate of technological progress of the specific Ethiopian manufacturing industries covered in the study.

According to this empirical study, the consistent results that labour input contributed more for the increase in output; low value for the capital intensity parameter and therefore high value of the labour intensity coefficient and hence the adoption of labour intensive technology in most of the industries covered in the study show that the Ethiopian manufacturing industries are light industries. These findings coupled with the empirical finding of low rate of technological progress are believed to describe the basic features of the Ethiopian manufacturing industries.

Based on the empirical results the following policy recommendations are suggested (1) that the government and the private owners use these labour intensive industries efficiently; (2) that the government design appropriate policies and look for means so that the market out let for the product of these industries (both domestic and abroad) and their efficiency increase. This paves the way for the transformation of the Ethiopian manufacturing industries, in the long-term, to heavy industries that use capital intensive technology and which are believed to bring significant change in the country's development both technologically and economically.

In addition to these policy recommendations, it is also recommended that the government create conducive environment and incentive packages that encourage investors towards investment in the industry sector.

As described in section 1.5 of the study, the study has the limitation in that there are few observations for the empirical study and is based on industry group which is the aggregate of many industries . Given these limitations the study is open for further and detail studies on the subject based on many observations and on disaggregated firm level data.

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APPENDICES

APPENDIX I: The Dickey-Fuller(DF) and the Augmented Dickey-Fuller(ADF) test of stationarity of the variables

For empirical studies using time series data, the first step before estimation process is to test whether the variables are stationary or test the order of integration of the variables through the ***Unit Root test.***

Stationarity of a variable can be tested using what is known as the sample autocorrelation function which is simply the ratio of sample covariance at a given lag length to sample variance.

An alternative test of stationarity of a variable that has recently become popular is what is known as the ***Unit root test*** and the test for *unit root* is conducted using what are known as the Dickey-Fuller(DF) and the Augmented Dickey-Fuller (ADF) tests.

Dickey and Fuller (1979) consider three different regression equations of the following types that can be used to test for the presence of a unit root which are known as ***the Dickey-Fuller(DF) tests.***

$$\Delta Y_t = \rho Y_{t-1} + \varepsilon_t \qquad \text{------------------------------ (A.1.1)}$$

$$\Delta Y_t = \alpha_0 + \rho Y_{t-1} + \varepsilon_t \qquad \text{---------------------------- (A.1.2)}$$

$$\Delta Y_t = \alpha_0 + \alpha_1 t + \rho Y_{t-1} + \varepsilon_t \qquad \text{--------------------------- (A.1.3)}$$

where *t* is time or trend variable.

The difference between regression equation (A.1.1) and the other two regression equations lies in the inclusion of a constant or an intercept term (α_o) and a trend term (t).

In each of the three regressions the null hypothesis is $H_o : \rho = 0$ or there is unit root which implies that Y_t is non- stationary. And the alternative hypothesis is $H_A : \rho < 0$ which implies Y_t is stationary. The decision rule is: we reject the null hypothesis in favour of the alternative iff the computed τ(tau) statistic value from the regressions above exceeds the critical value in absolute value terms.

If the error term ε_t is autocorrelated, one modifies regression equation (A.1.3) as follows:

$$\Delta Y_t = \alpha_o + \alpha_1 t + \rho Y_{t-1} + \alpha_i \sum_{i=1}^{k} \Delta Y_{t-i} + \varepsilon_t \quad \text{------------} \quad (A.1.4)$$

Regression equations (A.1.1) and (A.1.2) can be modified as did for regression equation (A.1.3).

The null hypothesis in the regression equation (A.1.4) is still $H_o : \rho = 0$ against and the alternative hypothesis $H_A : \rho < 0$ as in the regression equations (A.1.1) to (A.1.3).

When the Dickey-Fuller test is applied to models like (A.1.4), it is called ***the Augmented Dickey-Fuller(ADF) test***. The ADF test statistic has the same asymptotic distribution as the Dickey-Fuller(DF) statistic, so the same critical values can be used.

ANNEX I: Unit Root test result using the Dickey-Fuller(DF) and Augmented Dickey-Fuller(ADF) tests

(1) Unit Roots test results of Beverage Industries

Variable	DF test result			ADF test result		
	With out constant and trend	With constant included	With constant and trend	With out constant and trend	With constant included	With constant and trend
lnY	1.0033	-0.77538	-1.4119	0.61424	-1.7383	-2.4874
lnK	0.49477	-0.60876	-3.2770	1.5144	0.74471	-1.4615
lnL	1.5363	-3.2613	-2.4643	1.0395	-2.8921	-2.3908
ΔlnY	-2.7159	-2.7534	-2.6556	-2.4665	-2.5384	-2.4459
ΔlnK	-11.795	-12.164	-13.247	-6.7967	-7.1877	-7.6814
ΔlnL	-3.0979	-3.2913	-3.5004	-2.4970	-2.7430	-3.1912

Δ represents the first difference of a variable.

Note:

- The critical values both for DF and ADF tests with out constant and trend are - 2.697 and - 1.96 at 1 % and 5 % level of significances respectively.

- The critical values both for DF and ADF tests with constant included are - 3.83 and - 3.029 at 1 % and 5 % level of significances respectively.

-The critical values both for DF and ADF tests with constant and trend are - 4.535 and - 3.675 at 1 % and 5 % level of significances respectively.

(2) Unit Roots test results of Manufacture of Sugar and Sugar Confectionery

Variable	DF test result			ADF test result		
	With out constant and trend	With constant included	With constant and trend	With out constant and trend	With constant included	With constant and trend
lnY	0.50440	-0.98424	-1.4992	0.78634	-0.46575	-0.96950
lnK	0.22886	-1.8200	-1.6057	0.13692	-1.2127	-0.81931
lnL	1.7567	1.1446	-0.83955	2.2346	1.8098	0.099847
ΔlnY	-6.3044	-6.2479	-6.4154	-3.1682	-3.0519	-3.1955
ΔlnK	-6.3383	-6.1399	-6.2125	-2.5231	-2.4451	-2.4150
ΔlnL	-5.6314	-6.5727	-7.0733	-2.6490	-3.3582	-3.4901

(3) Unit Roots test results of Manufacture of Textiles

Variable	DF test result			ADF test result		
	With out constant and trend	With constant included	With constant and trend	With out constant and trend	With constant included	With constant and trend
lnY	0.11437	-2.1630	-2.0982	0.10145	-2.6979	-2.6128
lnK	0.69110	-1.7561	-4.2052	1.1141	-1.1734	-3.5765
lnL	-0.35707	-1.4958	-2.0144	-0.34931	-1.6751	-1.9766
ΔlnY	-4.0092	-3.9007	-3.7702	-3.6164	-3.5174	-3.3838
ΔlnK	-6.2245	-6.3935	-6.2044	-4.5810	-5.1107	-4.9342
ΔlnL	-4.2092	-4.1133	-4.4944	-3.8727	-3.7800	-4.5088

(4) Unit Roots test results of Manufacture of Rubber and Plastic Products

Variable	DF test result			ADF test result		
	With out constant and trend	With constant included	With constant and trend	With out constant and trend	With constant included	With constant and trend
lnY	0.88905	-0.88797	-1.6104	0.93151	-0.78982	-1.5727
lnK	1.3254	-0.26423	-1.9965	1.9437	0.58944	-1.2326
lnL	0.33328	-1.6215	-1.5778	0.33303	-1.6430	-1.6158
ΔlnY	-4.7049	-4.7749	-4.7083	-2.9602	-3.0624	-3.0049
ΔlnK	-5.5720	-6.2552	-6.6906	-2.7431	-3.3316	-3.9085
ΔlnL	-4.2278	-4.1398	-4.0031	-2.8416	-2.7847	-2.6512

(5) Unit Roots test results of Manufacture of Basic Industrial Chemicals and Chemical Products

Variable	DF test result			ADF test result		
	With out constant and trend	With constant included	With constant and trend	With out constant and trend	With constant included	With constant and trend
lnY	1.3101	-0.32594	-1.1327	1.0270	-0.76088	-1.7550
lnK	1.2184	-1.0869	-2.2606	1.1447	-1.0511	-2.4377
lnL	1.3823	-0.58558	-0.94592	1.2113	-0.77056	-1.1382
ΔlnY	-2.9841	-3.1623	-3.2090	-3.1284	-3.4410	-3.4831
ΔlnK	-4.8789	-5.0334	-4.7283	-4.7846	-5.4539	-5.1034
ΔlnL	-3.6571	-3.9096	-3.8918	-2.5032	-2.8121	-2.7994

ANNEXE II: Cointegration test result using DF and ADF tests

(1) Cointegration test results of Beverage Industries

Residual From	DF test result			ADF test result		
	With out constant and trend	With constant included	With constant and trend	With out constant and trend	With constant Included	With constant and trend
CES regression model (2.2.1.2), ε_t	-2.3959	-2.2558	-2.1334	-2.5664	-2.4346	-2.3119
Cobb-Douglas regression model (2.2.1.4), μ_t	-3.5837	-3.4212	-3.1116	-2.4597	-2.3433	-2.1490

Note:

-The critical values both for DF and ADF tests with out constant and trend are -2.706 and - 1.961 at 1 % and 5 % level of significances respectively for stationarity test of the residual(ε_t) from CES regression model (2.2.1.2).

-The critical values both for DF and ADF tests with out constant and trend are - 2.697 and - 1.96 at 1 % and 5 % level of significances respectively for stationarity test of the residual(μ_t) from Cobb-Douglas regression model (2.2.1.4).

-The critical values both for DF and ADF tests with constant included are - 3.857 and - 3.04 at 1 % and 5 % level of significance respectively for stationarity test of the residual(ε_t) from CES regression model (2.2.1.2).

-The critical values both for DF and ADF tests with constant included are - 3.83 and - 3.029 at 1 % and 5 % level of significance respectively for stationarity test of the residual(μ_t) from Cobb-Douglas regression model (2.2.1.4).

-The critical values both for DF and ADF tests with constant and trend are - 4.574 and - 3.692 at 1 % and 5 % level of significance respectively for stationarity test of the residual(ε_t) from CES regression model (2.2.1.2).

-The critical values both for DF and ADF tests with constant and trend are - 4.535 and - 3.675 at 1 % and 5 % level of significance respectively for stationarity test of the residual(μ_t) from Cobb-Douglas regression model (2.2.1.4).

ANNEXE II: Cointegration test result using DF and ADF tests

(1) Cointegration test results of Beverage Industries

Residual From	DF test result			ADF test result		
	With out constant and trend	With constant included	With constant and trend	With out constant and trend	With constant Included	With constant and trend
CES regression model (2.2.1.2), ε_t	-2.3959	-2.2558	-2.1334	-2.5664	-2.4346	-2.3119
Cobb-Douglas regression model (2.2.1.4), μ_t	-3.5837	-3.4212	-3.1116	-2.4597	-2.3433	-2.1490

Note:

-The critical values both for DF and ADF tests with out constant and trend are -2.706 and - 1.961 at 1 % and 5 % level of significances respectively for stationarity test of the residual(ε_t) from CES regression model (2.2.1.2).

-The critical values both for DF and ADF tests with out constant and trend are - 2.697 and - 1.96 at 1 % and 5 % level of significances respectively for stationarity test of the residual(μ_t) from Cobb-Douglas regression model (2.2.1.4).

-The critical values both for DF and ADF tests with constant included are - 3.857 and - 3.04 at 1 % and 5 % level of significance respectively for stationarity test of the residual(ε_t) from CES regression model (2.2.1.2).

-The critical values both for DF and ADF tests with constant included are - 3.83 and - 3.029 at 1 % and 5 % level of significance respectively for stationarity test of the residual(μ_t) from Cobb-Douglas regression model (2.2.1.4).

-The critical values both for DF and ADF tests with constant and trend are - 4.574 and - 3.692 at 1 % and 5 % level of significance respectively for stationarity test of the residual(ε_t) from CES regression model (2.2.1.2).

-The critical values both for DF and ADF tests with constant and trend are - 4.535 and - 3.675 at 1 % and 5 % level of significance respectively for stationarity test of the residual(μ_t) from Cobb-Douglas regression model (2.2.1.4).

(2) Cointegration test results of Manufacture of Sugar and Sugar Confectionery

Residual From	DF test result			ADF test result		
	With out constant and trend	With constant Included	With constant and trend	With out constant and trend	With constant Included	With constant and trend
CES regression model (2.2.1.2), ε_t	-3.6849	-3.6022	-3.5808	-2.9120	-2.8461	-2.8003
Cobb-Douglas regression model (2.2.1.4), μ_t	-3.3809	-3.2223	-3.1733	-3.1247	-2.9957	-2.9614

(3) Cointegration test results of Manufacture of Textiles

Residual From	DF test result			ADF test result		
	With out constant and trend	With constant Included	With constant and trend	With out constant and trend	With constant Included	With constant and trend
CES regression model (2.2.1.2), ε_t	-2.5722	-2.4950	-2.3934	-3.1878	-3.0895	-2.9661
Cobb-Douglas regression model (2.2.1.4), μ_t	-2.2204	-2.1558	-2.0914	-2.6370	-2.5553	-2.4818

(4) Cointegration test result of Manufacture of Rubber and Plastic Products

Residual from	DF test result			ADF test result		
	With out constant and trend	With constant Included	With constant and trend	With out constant and trend	With constant Included	With constant and trend
CES regression model (2.2.1.2), ε_t	-3.5352	-3.4381	-3.3250	-3.7933	-3.6768	-3.6147
Cobb-Douglas regression model (2.2.1.4), μ_t	-3.8089	-3.7123	-3.7821	-3.5127	-3.4210	-3.7094

(5) Cointegration test results of Manufacture of Basic Industrial Chemicals and Chemical Products

Residual From	DF test result			ADF test result		
	With out constant and trend	With constant Included	With constant and trend	With out constant and trend	With constant Included	With constant and trend
CES regression model (2.2.1.2), ε_t	-3.1916	-3.1368	-3.0440	-3.4068	-3.3336	-3.1816
Cobb-Douglas regression model (2.2.1.4), μ_t	-2.8339	-2.7637	-2.9256	-3.1922	-3.1085	-3.1933

ANNEXE III: No. of Manufacturing Industries by industry group in year 1998

S/R No.	Industry Group	No. of industries in 1998
1	Beverage Industries	26
2	Manufacture of Sugar and Sugar Confectionery	8
3	Manufacture of Textiles	33
4	Manufacture of Rubber and Plastic Products	26
5	Manufacture of Basic Industrial Chemicals and Chemical Products	43
	Total	136

ANNEXE III: No. of Manufacturing Industries by industry group in year 1998

S/R No.	Industry Group	No. of industries in 1998
1	Beverage Industries	26
2	Manufacture of Sugar and Sugar Confectionery	8
3	Manufacture of Textiles	33
4	Manufacture of Rubber and Plastic Products	26
5	Manufacture of Basic Industrial Chemicals and Chemical Products	43
	Total	136

Annex IV: The Data

Time Series data of Out Put (Y) by Industry Group (1978-1998) Value Added at factor cost

(In '000 Birr)

Industry Group/Year	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Manufacture of Sugar and Sugar Confectionery	29346	86929	73920	85784	52646	95653	85667	77317	64211	45059	44500
Beverage Industries	51995	48068	52664	54996	55071	64394	51757	78014	81756	78622	75633
Manufacture of Textiles	115733	102249	135857	139281	148441	127533	125988	83478	97737	116797	121397
Manufacture of Basic Industrial Chemicals and Chemical Products	12760	15275	19148	13919	19418	28958	30209	31955	31386	41418	30727
Manufacture of Rubber and Plastics Products	9592	18924	13345	15902	25549	25885	27497	31238	35579	34646	35499

Time Series data Out Put (Y) by Industry Group (1978-1998) Value added at factor Cost

(In '000 Birr)
(Continued)

Industry Group/Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Manufacture of Sugar and Sugar Confectionery	53041	58274	63640	35836	65849	63048	148758	206409	217679	201954
Beverage Industries	53462	45068	37334	43981	72185	175864	216430	193715	180123	173832
Manufacture of Textiles	95995	91994	61136	50134	131697	166123	165394	156634	140099	124020
Manufacture of Basic Industrial Chemicals and Chemical Products	17685	18922	11975	14024	42113	62968	58106	50743	81740	152976
Manufacture of Rubber and Plastics Products	15898	19723	11447	15641	34304	55016	51004	55903	81100	86850

Time Series data of Capital input (K) by Industry Group (1978-1998) Capital Consumption /Deprecation

(In '000 Birr)

Industry Group/Year	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Manufacture of Sugar and Sugar Confectionery	8099160	6131440	4711850	7350950	6349040	9116640	8394390	7781260	6855250	5832410	4823070
Beverage Industries	1665660	13976430	4567010	5335530	5819640	5606450	6878150	9190320	8851290	8309260	7668070
Manufacture of Textiles	6479580	6478480	6868460	11126570	10078190	9786320	9173430	8276840	6388420	20735760	19883010
Manufacture of Basic Industrial Chemicals and Chemical Products	1015800	1490010	1570350	1320150	1480650	1730900	2005750	2150650	1876550	2260780	2310800
Manufacture of Rubber and Plastics Products	1283530	1193420	1105230	1371070	1461670	1629620	1721420	1446670	1301060	1279620	1302480

Time Series data of Capital Input (K) by Industry Group (1978-1998) Capital Consumption/Depreciation

(In '000 Birr)
(Continued)

Industry Group/Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Manufacture of Sugar and Sugar Confectionery	4148140	3615480	4079650	3424730	3230300	4366780	4744870	9626080	5624810	8718360
Beverage Industries	6639990	6819350	6112710	7561460	9995220	22946860	19249000	27219050	30891770	31832280
Manufacture of Textiles	18118490	22845220	30913510	33029520	11652070	52798800	51592640	45232750	44651810	38404730
Manufacture of Basic Industrial Chemicals and Chemical Products	1930450	1950250	1810750	1805650	2130850	2425650	2480900	2210150	2550650	2830750
Manufacture of Rubber and Plastics Products	1202390	1015860	7896920	4344640	8776470	12493260	12676960	26114860	31405340	29661580

Time Series data of Labour in Put (L) by Industry Group (1978-1998) No. of Persons engaged in the Production Process

Industry Group/Year	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Manufacture of Sugar and Sugar Confectionery	2432	3195	3190	3194	3212	3250	3198	3214	3319	3311	3300
Beverage Industries	4620	5154	5577	6210	7159	6953	6921	7822	8283	8766	8888
Manufacture of Textiles	28670	28540	29351	30057	31676	32281	36447	32530	32600	35972	37462
Manufacture of Basic Industrial Chemicals and Chemical Products	1436	1568	1761	2058	2065	2147	2788	2290	2240	2600	2457
Manufacture of Rubber and Plastics Products	2026	2220	2395	2510	2732	2852	3054	3137	3101	3338	3585

Time Series data of Labour input (L) by Industry Group (1978-1998) No. of Persons engaged in the Production Process

(Continued)

Industry Group/Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Manufacture of Sugar and Sugar Confectionery	3366	3368	3612	3361	4314	3983	4070	4384	4847	5704
Beverage Industries	7892	7845	7702	7742	7421	7391	8060	7749	7602	8169
Manufacture of Textiles	29117	28507	30421	30176	31712	31900	30960	28417	27239	25116
Manufacture of Basic Industrial Chemicals and Chemical Products	1647	1774	1744	1757	1812	2127	2701	2847	3714	4155
Manufacture of Rubber and Plastics Products	1662	1716	1743	1765	1796	2030	2009	2224	2421	3092

ANNEXE V: Average Growth rates of Output (Y), Capital (K) and Labour (L) inputs over the period 1978-1998

INDUSTRY GROUP/ YEAR	Average growth rate of Output $(\dot{Y}/Y)$	Average growth rate of Capital input $(\dot{K}/K)$	Average growth rate of Labour input $(\dot{L}/L)$
Manufacture of Sugar and Sugar Confectionery	19.96 %	4.93 %	4.56 %
Manufacture of Basic Industrial Chemicals and Chemical Products	21.12 %	5.95 %	6.29 %

Note:

- Annexe V table is reproduced from the Data table in Annexe V applying the following formula:

$$\dot{A}/A = \frac{(\Delta A/\Delta t)}{A} \quad \text{in the discrete case}$$

Where $\frac{(\Delta A/\Delta t)}{A} = \frac{A_t - A_{t-1}}{A_t}$ since $\Delta t = 1$ in this case as the years are consecutive.

A_t is the level or the value of the variable A at time t;

A_{t-1} is the value of the variable A at time t-1 or one year before in this case.

Time Series data of Labour in Put (L) by Industry Group (1978-1998) No. of Persons engaged in the Production Process

Industry Group/Year	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Manufacture of Sugar and Sugar Confectionery	2432	3195	3190	3194	3212	3250	3198	3214	3319	3311	3300
Beverage Industries	4620	5154	5577	6210	7159	6953	6921	7822	8283	8766	8888
Manufacture of Textiles	28670	28540	29351	30057	31676	32281	36447	32530	32600	35972	37462
Manufacture of Basic Industrial Chemicals and Chemical Products	1436	1568	1761	2058	2065	2147	2788	2290	2240	2600	2457
Manufacture of Rubber and Plastics Products	2026	2220	2395	2510	2732	2852	3054	3137	3101	3338	3585

Time Series data of Labour input (L) by Industry Group (1978-1998) No. of Persons engaged in the Production Process

(Continued)

Industry Group/Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Manufacture of Sugar and Sugar Confectionery	3366	3368	3612	3361	4314	3983	4070	4384	4847	5704
Beverage Industries	7892	7845	7702	7742	7421	7391	8060	7749	7602	8169
Manufacture of Textiles	29117	28507	30421	30176	31712	31900	30960	28417	27239	25116
Manufacture of Basic Industrial Chemicals and Chemical Products	1647	1774	1744	1757	1812	2127	2701	2847	3714	4155
Manufacture of Rubber and Plastics Products	1662	1716	1743	1765	1796	2030	2009	2224	2421	3092

ANNEXE V: **Average Growth rates of Output (Y), Capital (K) and Labour (L) inputs over the period 1978-1998**

INDUSTRY GROUP/ YEAR	Average growth rate of Output $(\dot{Y}/Y)$	Average growth rate of Capital input $(\dot{K}/K)$	Average growth rate of Labour input $(\dot{L}/L)$
Manufacture of Sugar and Sugar Confectionery	19.96 %	4.93 %	4.56 %
Manufacture of Basic Industrial Chemicals and Chemical Products	21.12 %	5.95 %	6.29 %

Note:

- Annexe V table is reproduced from the Data table in Annexe V applying the following formula:

$$\dot{A}/A = \frac{(\Delta A/\Delta t)}{A} \quad \text{in the discrete case}$$

Where $\frac{(\Delta A/\Delta t)}{A} = \frac{A_t - A_{t-1}}{A_t}$ since $\Delta t = 1$ in this case as the years are consecutive.

A_t is the level or the value of the variable A at time t;

A_{t-1} is the value of the variable A at time t-1 or one year before in this case.

Declaration

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

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