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# Total Factor Productivity and Technical Efficiency in the Ethiopian Manufacturing Sector

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## Abstract

In this paper a Stochastic Frontier Model is used to examine the technical efficiency and total factor productivity (TFP) growth in the Ethiopian manufacturing sector over the period 1996–2009. TFP growth is decomposed into technical change (progress), technical efficiency change, and scale effect. With a firm level unbalanced panel data collected by CSA, individual estimations are made for each industrial group categorized by two digit ISIC except a three digit ISIC for food and beverage industrial groups. The empirical results indicate existence of large inefficiencies, inefficiency that explains at least 14 percent of output variation among firms. TFP has shown better progress after 2001/02 and the growth is largely explained by technical change which is a shift in production frontier. The effect of efficiency change is very small as most industrial groups have time invariant efficiency. In addition, the scale effect is zero or very small because most industrial groups have constant returns to scale or small deviation from constant returns to scale.



**Keywords**: Ethiopian manufacturing, stochastic frontier analysis, technical change, technical efficiency, total factor productivity

# 1. Introduction

## 1.1. Background

Total factor productivity (TFP), in a simply way, is defined as output per unit of inputs. It is the ratio of aggregate output index to aggregate input index and measures the efficiency of all inputs in a production process. In other word, TFP is the portion of output not explained by the amount of inputs used in production. This is known as a “residual.” The original idea that output may not be wholly explained by amount of inputs was raised by scholars like Fabricant (1954), Abramovitz (1956), Kendrick (1956), and Solow (1957). Fabricant (1954) argued that if increase in national income per capita is above the increase in total input per capita, the source of economic advance is improving efficiency. Little was known about the causes of productivity change and Abramovitz (1956) defined the residual as “a measure of our ignorance.”

With the works of Solow (1957), the analysis of TFP got wide attention and became included in the so called Solow growth theory. In the Solow growth theory and other productivity models, the analysis of TFP, at macro or micro level, starts with the production function of the type $Y_{it} = A_{it}F(X_{it})$, relating the output (Y) of a generic unit (firm/industry/country) *i* at time *t* to a vector of inputs (X) and with the term A describing how much output a given unit is able to produce from a certain amount of inputs, given the technological level (Del Gatto et al. 2011). The TFP index is then: $TFP_{it} = A_{it} = Y_{it}/F(X_{it})$, which is the ratio of output produced to total inputs employed.

Earlier works mainly focused on the estimation of TFP growth, and TFP is accordingly measured by the Solow residual in the growth accounting model. TFP growth is the result of change in efficiency of an economic production, which is the result of technological change. This TFP growth is believed to be the only source of long run growth. For instance, using a growth accounting method Young (1992) found no total factor productivity growth in Singapore and argued that Singapore will only be able to sustain further growth by reorienting its policies from factor accumulation toward the considerably more subtle issue of technological change. In line with this, Krugman (1994) stated that sustained growth in a nation's per capita income can only occur if there is a rise in output per unit of input.

While the growth accounting is mainly a macro analysis, there are many other methods used to study TFP at an individual (firm/plant) level. Micro analysis is increasingly applied to study TFP. It is mainly related with how inputs are efficiently utilized at a firm level. The increasing attention towards firm level studies is because of the increasing availability of establishment level data, and focus of growth theories on non-competitive markets. Such markets cause inefficiency as firms deviate from the efficient allocation of inputs and optimal production level. The Solow growth theory assumes perfect competition—which is less likely to prevail, especially in developing economies—and exogenous technological progress, which determines the productivity of inputs. However, the new growth theories acknowledge the existence of market imperfections and endogenous determination of technological progress via investment in human capital.

To discuss how TFP is measured at micro level, it is important to review the basic microeconomic theories of production. In microeconomic theory, producers are assumed to maximize their profit. The production theory starts by defining the production function, the technology that firms use to convert input/s into output/s. The production curve/frontier, a graphic depiction of the production function, represents the boundary of the maximum output that can be obtained from a given input vector (or the minimum input usage required to produce any given output vector). In this way the optimization problem involves determining the amount of inputs that minimizes the cost of producing a given level of output or that maximizes output for a given cost outlay. Accordingly, the traditional practice of production analysis involves estimating production and cost functions assuming that firms operate on their production curve (frontier), i.e. firms are assumed to be technically efficient.

However, not all producers succeed in utilizing the minimum inputs required to produce outputs they choose to produce, given the technology at their disposal (Kumbhakar and Lovell 2000). Producers, for reasons such as management inefficiencies, market related problems, and other internal and external factors, may not be able to produce the maximum possible output (technical efficiency) or attain minimum cost (allocative efficiency) in production, which results into non-optimal profit. Thus, not all producers are output (technical), cost (allocative), or profit efficient. This observation gave rise to the study of firms' technical and allocative efficiency.

The growth accounting method of TFP analysis considers technical change as an equivalent with TFP growth. However, technical change is one factor that contributes to TFP growth. Improvements in technical, allocative, and scale efficiency of firms are also important factors that affect TFP growth. Consequently, unlike the macro level productivity analysis which considers technical change as TFP growth the micro level productivity analysis decomposes TFP growth into its components: technical change, changes in technical/ allocative efficiency, and scale efficiency.

### 1.2. Research objectives

In the past two decades Ethiopia has been following the agriculture led industrialization development strategy to transform its economy. Despite the tremendous efforts made and the economic growth achieved, the Ethiopian economy remains beleaguered by structural problems. Still the manufacturing sector is small and has a relatively stagnant share of GDP. Table 1.1 shows agriculture, industry, and manufacturing value added share of GDP (for Ethiopia and Sub-Saharan Africa (SSA) excluding South Africa and Nigeria). Ethiopia's agriculture share of GDP is much larger than the SSA average and remained to be the largest sector of the economy in the past decades. In contrast, shares of industry and manufacturing are much lower in Ethiopia than the average for SSA and their shares remained to be very small throughout the period. In this respect the Ethiopian economy needs a more dynamic growth so that it can reduce its dependence on the fragile, rainfall dependent, and climate change vulnerable agricultural sector.

**Table 1.1. Agriculture, industry, and manufacturing share of GDP, and percentage growth of value added, for Ethiopia and sub-Saharan Africa (2000–2009)**

| Year | Agriculture, Value added | | | | Industry, Value added | | | | Manufacturing, Value added | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ethiopia | | SSA[a] | | Ethiopia | | SSA[a] | | Ethiopia | | SSA[a] | |
| | % of GDP | % growth | % of GDP | % growth | % of GDP | % growth | % of GDP | % growth | % of GDP | % growth | % of GDP | % growth |
| 2000 | 49.9 | 3.1 | 27.6 | 0.7 | 12.4 | 5.3 | 27.4 | 3.6 | 5.5 | 7.5 | 11.3 | 6.2 |
| 2001 | 47.7 | 9.6 | 27.8 | 6.0 | 13.0 | 5.1 | 26.7 | 5.5 | 5.7 | 3.6 | 11.2 | 3.5 |
| 2002 | 43.5 | -1.9 | 26.7 | 0.3 | 13.9 | 8.3 | 27.1 | 7.3 | 5.7 | 1.3 | 11.1 | 1.8 |
| 2003 | 41.9 | -10.5 | 26.7 | 2.3 | 14.1 | 6.5 | 26.9 | 4.8 | 5.7 | 0.8 | 11.0 | 2.7 |
| 2004 | 44.2 | 16.9 | 25.7 | 3.2 | 14.1 | 11.6 | 28.2 | 9.3 | 5.3 | 6.6 | 11.0 | 4.8 |
| 2005 | 46.7 | 13.5 | 25.2 | 4.7 | 13.0 | 9.4 | 29.5 | 7.0 | 4.8 | 12.8 | 10.8 | 4.9 |
| 2006 | 47.9 | 10.9 | 24.1 | 4.1 | 12.7 | 10.2 | 30.4 | 8.7 | 4.5 | 10.6 | 10.8 | 4.3 |
| 2007 | 46.2 | 9.4 | 22.8 | 3.9 | 13.3 | 10.2 | 30.4 | 10.5 | 5.0 | 8.3 | 10.6 | 8.4 |
| 2008 | 43.8 | 7.5 | 22.4 | 2.8 | 13.0 | 10.4 | 31.0 | 5.9 | 4.8 | 7.1 | 10.0 | 5.1 |
| 2009 | 50.7 | 6.4 | 23.5 | 4.2 | 10.7 | 8.9 | 28.0 | 0.7 | 4.0 | 12.3 | 10.2 | 4.7 |

Source: African Development Indicators Database (World Bank 2011).
Note: a/ SSA = sub-Saharan Africa excluding South Africa and Nigeria.

Structural change is one of the important steps in economic development. Most growth theories argue that the way to growth is through capital (both human and physical) accumulation and improved factor productivity which is possible by technological advancement. Technological progress is particularly the means for sustained long-run growth. Ethiopia has scarce and limited resources which prevent massive capital accumulation for industrial development. Given this limitation, improvement of factor productivity through efficient utilization of resources and technical change via learning-by-doing, adoption of new technologies, and imitation are possible means to increase industrialization in the country.

Productivity analysis and decomposition of TFP into its components are important inputs in the policy making process. Analysis of the trend and decomposition of TFP growth, and in particular the impact of technical change, efficiency change, or scale efficiency will give some guidance in order to develop policies aiming to achieve economic growth and increase the GDP share of the manufacturing sector. It helps understand whether gains in industry productivity levels are achieved through the efficient use of inputs or through technological progress.

Some studies have been done on agricultural productivity in Ethiopia. A study by Ferenji and Heidhues (2004) using a cross sectional-time series data from rural farm households for the period 1994 to 2001 showed a decrease in TFP of teff production. Bachewe and Taffesse (2011) on the other hand found an annual TFP growth of 3.7 percent using the Annual Agricultural Sample Survey (1997/98–2008/09) of CSA, and an annual TFP growth of 4.6 percent using seven rounds of the Ethiopian Rural Household Survey (ERHS). They also found that output growth for the period was mainly driven by growth in cultivated area and traditional inputs such as labour and livestock. They then proposed a future growth driven by a further increase in TFP.

Unlike agricultural productivity, there are limited studies about productivity in the manufacturing sector. Admit (1998) analyzed the technical progress of the manufacturing sector in Ethiopia for the period 1976–1995 using a Cobb-Douglas, Constant Elasticity of Substitution (CES) and translog models. The results showed a zero or negative TFP growth. He also found a variation in the trend of TFP growth across sectors. TFP increased in sectors such as tobacco, paper, plastic, and leather while it was stagnant or decreasing in other sectors. Gebreeyesus (2008) using the annual CSA census of medium and large manufacturing industries found that the Ethiopian manufacturing sector exhibited an annual average productivity growth of about 9.3 percent between 1996 and 2003, with entry and exit of firms being the major source of productivity growth.

There are studies (Soderbom 2011; Siba and Soderbom 2011; Bigsten and Gebreeyesus 2007; and Bigsten and Gebreeyesus 2009) which used the CSA panel data on large and medium manufacturing industries to study issues such as performance, growth, and productivity of firms. However, little has been done on TFP and efficiency change of the manufacturing sector. A study by Mohammed (2008) analyzed TFP and competitiveness of textile and garment industries using a Stochastic Frontier Analysis (SFA) and a panel data from the LMMIS (Large and Medium Manufacturing Industries Survey) (2001–2005). He found a negative TFP growth and that these sectors are uncompetitive, even in the domestic market.

Given importance of the issue and limited researches being undertaken to date, this paper has studied TFP growth and technical efficiency of the different Ethiopian manufacturing industrial groups. It has also decomposed the TFP growth into its components, i.e., technical change, technical efficiency change, and scale efficiency change (scale component).

## 2. Manufacturing sector in Ethiopia

### 2.1. Contribution of the manufacturing sector

In a process of economic growth the private sector is the main actor. However, its contribution is largely limited to the existence of a liberal market, a market with no or less state owned enterprises and limited governmental market intervention. In the absence of such market, the sector cannot perform its activities which are required to bring satisfactory changes in the economy. In this respect, the Ethiopian manufacturing sector had been progressive in the imperial period until the overthrow of the regime in 1974. During the following Derg regime the private sector was discouraged because of nationalization of companies and the ceiling imposed on the amount of capital the private sector could invest. The economy was governed by a central command system which left limited space for market forces to operate. This resulted in slower progress in most sectors of the economy and economic growth was at its bare minimum.

The effects of planned economy had come to an end when the current regime took power in 1991 and started liberalizing the market. Market oriented economic reforms such as decentralization and privatization have been introduced into the economy. The government has been trying to provide a better environment to increase participation of the private sector in the economy and recently has increased the policy emphasis on manufacturing growth. The government is providing many incentives to increase investment in different sectors and to promote export. As a result, the economy has showed a rapid progress, especially after 2003 where the GDP growth increased from an average 2.7 percent per annum for the period 1997–2003 to an average of 11 percent for the period 2004–2010 (see Table 2.1).

However, the manufacturing sector in Ethiopia is still at its infancy. In comparison with the agriculture and service sectors, the manufacturing sector, for example, has a limited share in terms of production, employment, and exports. In 2009, the industry share of GDP value added was 10.7 percent while that of manufacturing was 4 percent (Worldbank 2011). These shares are smaller than the Sub-Saharan averages of 28 percent and 10.2 percent for industry and manufacturing, respectively. Estimates by MoFED (2011) also show an almost constant manufacturing share of GDP at about 5 percent, with a contribution of about

3.5 percent coming from medium and large manufacturing and about 1.5 percent coming from small and cottage industries. Although the small and cottage industries have a limited GDP contribution, their contribution to the employment of unskilled and semiskilled labor is better than that of medium and large manufacturing firms. Employees of micro and small manufacturing enterprises are mostly owners (own-account workers) of the enterprises. According to CSA's 2003 survey, 1.3 million persons were engaged in micro manufacturing enterprises while only 98,000 persons were employed in small manufacturing enterprises (cited in Altenberg 2010).

According to CSA's annual survey of medium and large manufacturing industries, the growth rate of employment has increased from an average of 2.06 percent for the period 2000/01–2004/05 to 11.4 percent for the period 2005/06–2009/10. Although this growth is encouraging, the total number of employment in medium and large manufacturing industries is still very small. For instance, for the year 2009/10, after a very large employment growth of 25.7 percent, total employment of the sector reached 185,000. Based on MoFED's (2011) estimation, the average growth of manufacturing production (at a constant price) was 9.5 percent for the period 2005/06–2009/10. Even though the sector's share of GDP has not changed and albeit its small contribution to employment generation, the sector is doing well and is increasing at least at the pace of the rate of economic growth and has maintained its share. Furthermore, the number of firms is growing at a rapid pace except for the year 2009/10.

**Table 2.1. Growth of GDP, employment, and number of firms of the manufacturing sector**

| Year | Manufacturing sector's GDP growth (at 1999/2000 prices)[a] | | | Employment in LMMI[b] | | Growth of number of firms in LMMI[b] |
|---|---|---|---|---|---|---|
| | LMMI | SCI | Average | Total no. of employment | Growth of employment | |
| 2001/02 | 0.2 | 3.2 | 1.3 | 98,136 | 4.94 | 14.20 |
| 2002/03 | 1.4 | -0.4 | 0.8 | 101,404 | 3.33 | 6.16 |
| 2003/04 | 7.7 | 4.5 | 6.6 | 105,381 | 0.04 | 11.30 |
| 2004/05 | 11.6 | 15 | 12.8 | 109,150 | 3.58 | 2.40 |
| 2005/06 | 13.7 | 4.9 | 10.6 | 118,406 | 8.48 | 6.20 |
| 2006/07 | 9.5 | 6 | 8.3 | 124,554 | 5.19 | 16.01 |
| 2007/08 | 12.6 | 5.6 | 10.3 | 130,305 | 4.62 | 33.56 |
| 2008/09 | 10.3 | 6.4 | 9.1 | 147,193 | 12.96 | 14.12 |
| 2009/10 | 13.6 | 7 | 11.6 | 185,086 | 25.74 | -1.18 |

Source: a/ MoFED (2010/11). b/ Compiled from CSA's Large and Medium Manufacturing surveys.
Notes: LMMI = Large and Medium Manufacturing Industries. SCI = Small scale and Cottage Industries.

One challenge of the manufacturing sector is that it is largely limited to simple agro-processing activities (sugar, grain milling, edible oil production, leather tanning) and production of basic consumer goods (beer, footwear, textiles, and garment) (Altenberg 2010). As shown in Table 2.2 below, in the 2009/10 CSA's manufacturing survey about 26 percent of the total firms were engaged in food and beverage production and contributed about 33 percent and 35 percent of the total manufacturing sector's employment and value added, respectively. Industries that might help accumulate technological capabilities and create dynamic inter-industry linkages—such as chemical, electrical and electronics, metal-processing, and other engineering industries—are almost non-existent (Altenberg 2010). For instance, firms engaged in the production of machinery and equipment accounted for about

0.5 percent of the total value added and 0.7 percent of the employment of the sector (CSA 2010). Lastly, most establishments are located in urban areas and are not evenly distributed over the country, with Addis Ababa and Oromiya region taking the largest share.

**Table 2.2. Distribution of establishments, value added, and employment across the different industrial groups and distribution of firms across regions**

| Industrial group | % of firms (of total no. of firms) | | % share of value added | | % share of employment | | Regional Distribution | |
|---|---|---|---|---|---|---|---|---|
| | 2005/06 | 2009/10 | 2005/06 | 2009/10 | 2005/06 | 2009/10 | Region | % share of establishments (2009/10) |
| Food and beverage | 29.90 | 26.30 | 40.38 | 34.95 | 30.12 | 32.48 | Addis Ababa | 40.29 |
| Textiles | 3.30 | 1.85 | 3.41 | 6.26 | 18.66 | 11.55 | Oromiya | 20.76 |
| Chemicals | 4.30 | 4.40 | 4.86 | 8.10 | 4.79 | 6.04 | SNNP | 13.44 |
| Paper and paper products | 7.00 | 5.66 | 5.35 | 4.89 | 6.81 | 5.40 | Amhara | 10.68 |
| Non-metallic minerals | 12.20 | 22.20 | 15.70 | 19.24 | 8.52 | 10.53 | Tigray | 9.16 |
| Rubber and Plastic | 5.00 | 6.40 | 8.87 | 7.38 | 5.83 | 7.49 | | |
| Leather | 5.06 | 5.24 | 4.37 | 2.34 | 1.79 | 2.17 | | |
| Basic Iron and Steel | 1.40 | 1.80 | 3.92 | 1.52 | 4.90 | 5.39 | | |
| Metal Products | 8.50 | 7.00 | 3.04 | 6.93 | 6.68 | 5.78 | | |
| Total | 76.66 | 80.30 | 90.00 | 91.60 | 88.10 | 86.83 | | 94.33 |

Source: Compiled from CSA's Large and medium manufacturing industries survey reports (2005/06–2009/10).

## 2.2. Previous studies on the manufacturing sector's productivity and efficiency

As discussed above, the manufacturing sector has limited contribution to the overall economy of the country. The sector has been left behind and became unable to follow other sectors of the economy, specifically agriculture and service sectors. Dependence on light industries, low productivity, inefficiency, and lack of finance are some of the problems which have been pointed by researchers as factors which limited the contribution of the sector to employment, production, and export earnings.

Demeke et al. (2006) had assessed growth of labor productivity in the manufacturing sector for two periods, before reform (Derg regime) (1984/85–1991/92) and after reform (EPRDF regime) (1992/03–2001/02). They calculated growth of labor productivity by deducting the weighted average employment growth from the weighted average output growth, where weights are given by output share of each production sector. The weighted average employment growth for the whole sector stood at 3.5 percent before the reform and 5.9 percent after the reform. Similarly, the weighted average output growths were found to be negative 4.7 percent before the reform and (positive) 12.5 percent after the reform. Labor productivity growth was calculated to be negative 8.1 percent before the reform and (positive) 20.2 percent per annum after the reform. Their labor productivity growth analysis by industrial groups indicated the highest growth of 8.8 percent in the food and beverage industrial group while the growth on the other industrial groups was relatively small, at 3.5 percent. In contrast, a marginal increase in labor productivity (average growth of 2.4 percent per annum after the reform) was found using employment shares as weights. The study also found a declining trend in real capital productivity and fluctuations in real labor productivity after the reform period.

Nega and Moges (2002) in their study on productivity and competitiveness of the Ethiopian leather sector argued that competitiveness cannot be ensured by having large resource endowments nor does lack of technological capacity explains uncompetitiveness. Irrespective of availability of abundant labor resources, they found the Ethiopian leather sector to be uncompetitive. In the study, labor productivity and total factor productivity of the tanning and footwear industries were found to be small and comparable to the TFP of other developing countries two decades back. The authors observed a declining trend for the period 1995–1999. TFP of the tanning industry fell from 4.49 in 1995 to 3.22 in 1999 showing an average annual decrement of 10.01 percent. Similarly, TFP of the footwear industry decreased from 2.48 to 1.58 showing an average annual decrement of 11.74 percent. The study showed that the worsening TFP was the basic reason for the decrease in labor productivity. The researchers identified factors such as lack of improvement in the management of firms, selection of inputs, timely maintenance provision, efficiency in the supply and stock holding of raw materials, and supply of utilities as the reasons for the worsening TFP.

Kuma (2002) studied labor productivity, total factor productivity, and technical efficiency of the Ethiopian manufacturing sector in a way to analyze the effect of trade liberalization. He found an average labor productivity of 4.07 and TFP of 2.37 for the period 1991/92–1999/00. He also found 1.75 percent and 5.84 percent average growths of labor productivity and TFP, respectively. Furthermore, he showed that most sectors in the manufacturing field were inefficient and the inefficiency was greater among large firms than small firms. Mohammed (2008) found a declining technical efficiency and TFP in the textile and garment industries for the period 2001–2005.

With regard to technical efficiency, Gebeyehu (2003) has assessed technical efficiency of leather industries for the period 1996–1999. In his descriptive partial productivity analysis he showed that the value of output produced by one Birr worth labor input declined for both exporting and non-exporting firms though the rate was relatively higher among the latter. The technical efficiency of the tanning industry showed large inefficiency and the inefficiency was increasing over the period—the technical efficiency deviation of firms increased from 3.3 percent in 1996 to 28 percent in 1999. Another study by Bekele and Belay (2007) showed a mean technical efficiency of 75.6 percent among grain mill products manufacturing firms and 40.5 percent of the sampled grain mill firms were operating below the estimated industrial mean technical efficiency level.

An important factor to consider is the status of the Ethiopian manufacturing sector's productivity and efficiency compared to other countries. Kinda et al. (2009) produced estimates of labor productivity, TFP, and technical efficiency for a group of countries from the Middle East and northern Africa (MENA), Sub-Saharan Africa, Latin America, East Asia, and South Asia, using data from World Bank Investment Climate Surveys. In this study, the different industrial groups observed for Ethiopia include textile, leather, garment, agro processing, and wood and furniture. Among the 22 sampled countries Ethiopia was ranked 20 in labor productivity, TFP, and technical efficiency, and ranked 16 in relative unit labor costs. Among the seven African countries included in the study (South Africa, Morocco, Egypt, Ethiopia, Tanzania, Algeria, and Zambia), Egypt was ranked last in productivity (partial and total) and efficiency, followed by Ethiopia. Ethiopia's high unit labor cost, lower productivity, and lower technical efficiency make it less competitive in the world market; this holds for all developing countries included in the study.

Other researchers (Soderbom 2012; Bigsten and Gebreeyesus 2009; Bigsten and Gebreeyesus 2007) have also analyzed some issues related to productivity of the manufacturing sector in Ethiopia. Soderbom (2012) found higher value added per worker among large firms than that of small firms and recommended that an increase in number of large firms would rise value-added per worker and GDP per capita of the country. Bigsten and Gebreeyesus (2009) studied firm productivity and exports and found higher productivity among exporting firms than among non-exporting firms. Another research by Bigsten and

Gebreeyesus (2007) showed that higher labor productivity affects firm growth positively, implying that more productive firms grow faster than less productive firms.

To conclude, though there is lack of comprehensive research about TFP and technical efficiency of the manufacturing sector in Ethiopia in recent years, the reviewed empirical works indicate that the sector is characterized by inefficiencies and low productivity. Its competitiveness in the international market and its contribution to export earnings is also weak. Partial reasons for the lower productivity and efficiency could be use of old techniques (lack of new technologies), relative smallness in size, lack of competition (not being able to involve in exports) and also lack of research and development activities. Other reasons that hinder firms to work at their full capacity include shortage of supply of raw materials, lack of capital, and absence of demand. According to the CSA's (2009) manufacturing survey report 34.6 percent of the firms reported shortage of raw materials as their first reason not to operate at full capacity followed by absence of market demand as reported by 10 percent of the firms.

## 3. Methodology

To address the objectives of the study, both descriptive and econometric analyses are used. The econometric analysis applied is known as a stochastic frontier analysis. It is the established way of measuring change in TFP and decomposing it into its components: changes in technical efficiency, technical progress, and scale efficiency. As discussed earlier, increase in production can result from two broad categories: increasing factors of production (both primary and intermediate inputs) and increase in TFP. The increase in TFP can be the result of the three factors (components) of TFP growth.

As presented in Del Gatto et al. (2011), methodologies for productivity estimation can be broadly categorized into frontier and non-frontier approaches. The non-frontier approach employs either deterministic techniques, which include growth accounting and index numbers, or econometric methods, which include growth regression and proxy numbers. The frontier approach includes two basic methods, data envelopment analysis (DEA) (a deterministic method) and stochastic frontier analysis (SFA) (an econometric method). Frontier models differ from non-frontier models in the assumption that observed production units do not fully utilize their existing technology (Del Gatto et al. 2011). The frontier models are superior by incorporating inefficiencies which in many cases arise in the production sector. When production is not efficient, productivity change may result not only from technical change but also from improvements in efficiency of production. Thus, the frontier approach is preferred to the non-frontier approach so as to decompose change in TFP into its components.
At micro level the two competing frontier models used to estimate TFP and efficiency analysis are SFA and DEA. The SFA is based on parametric econometric analysis while DEA is a non-parametric mathematical programming method. The following comparisons of the two models are drawn from Jacobs et al. (2006).

- Both approaches use different methods to define the frontier. While the SFA uses economic theories, DEA uses the observed data to determine the frontier. In this regard, the SFA is less flexible and specification of the functional form for the frontier is needed a priori. In contrast, DEA is highly flexible and uses the actual data rather than theory to determine the shape and position of the frontier. In addition, the monotonic assumptions of the parametric function are too restrictive, and DEA is able to account for segments of the frontier where a smooth relationship is not apparent in the data. However, DEA frontier is sensitive to observations that may have unusual types, levels, or combinations of inputs and outputs.

- Though DEA appears to perform better than SFA in terms of flexibility, SFA allows for the possibility of modeling and measurement error. SFA makes some assumptions about the error terms and the functional form. Unlike the DEA, the assumptions and functional forms considered in SFA are moderately subject to statistical tests. SFA also allows standard econometric tests which may be applied to guide the decision about which explanatory variables to include in the model. Furthermore, though both methods are susceptible to the influence of outliers and small sample sizes DEA is more vulnerable to outliers. Small sample sizes do not prevent the application of DEA, but as with all parametric estimation processes SFA estimates are likely to be more imprecise in small sample sizes (Banker et al. 1993, cited in Jacobs et al. 2006).

Though it is difficult to argue SFA is superior to DEA or vice versa, for this study I used SFA so as to overcome the following drawbacks of DEA. First, DEA is sensitive to small measurement errors. Second, DEA is a non-parametric technique and statistical hypothesis tests are difficult. Third, DEA doesn't incorporate the stochastic nature of production and it attributes any discrepancy between observed and potential output to inefficiency. In addition, DEA analysis may lead to unexpected results and is suspicious to outliers. DEA neglects inefficiencies resulted from omitted variables, unobserved measurement errors, and stochastic noise, which may result in a possible upward bias of inefficiency scores (Del Gatto et al. 2011). SFA overcomes all these shortcomings of DEA. Furthermore, the data used in this study are relatively large and hence it is possible to avoid outliers and the analysis is not vulnerable to problems related with small sample size.

Many studies have been undertaken to study TFP of manufacturing industries by using SFA. For instance, Kim and Shafi'i (2009), Donghyun Oh et al. (2009) and Kim (2003), Ikhsan (2006), and Hammit-Haggar (2009) have used SFA to study TFP of manufacturing industries in Malaysia, Korea, Indonesia, and Canada, respectively. Mandal and Madheswaran (2009) have also used SFA to study TFP of the Indian cement industry.

### 3.1. Stochastic Frontier Analysis

Many studies in the 1950s and 1960s had influenced the development of SFA. Some of these studies include Debreu (1951), Shephard (1953), and Aigner and Chu (1968) (all cited in Kumbhakar and Lovell 2000). However, SFA is originally introduced by two papers nearly simultaneously published by two teams, Meeusen and van den Broeck (1977) and Aigner et al. (1977). The original works were mainly applicable to cross-section data. The analysis is then extended to allow for panel data estimation by Pitt and Lee (1981), Schmidt and Sickles (1984), Kumbhakar (1990), and Battese and Coelli (1992) (all cited in Hamit-Haggar 2009). The study used the primal approach (analysis using production frontier). The following derivations are heavily drawn from Kumbhakar (2000) and Battese and Coelli (1992). The starting point is to define the production function as:

$$y_{it} = f(x_{it}, t; \beta)\exp(v_{it} - u_{it}), i = 1, 2, ..., N, t = 1, 2, ..., T \qquad (1)$$

where $y_{it}$ is output of firm *i* at time *t*, *f(.)* is the production technology, *x* is a vector of inputs, and *t* is a time variable which reflects technical change. The error term is composed of two components. The first is a statistical random disturbance term, $v_{it}$, which captures producer-specific external shocks on observed output. The stochastic production frontier $f(x_{it}, t; \beta)\exp(v_{it})$ defines maximum feasible output in an environment characterized by the presence of either favorable or unfavorable events beyond the control of producers.

The second is a non-negative random variable, $u_{it}$, which captures technical inefficiency, i.e. the shortfall of observed output from the potential output. It is a one sided non-negative error term implying that observed output lie beneath or on the stochastic production frontier. In this case technical efficiency (TE) is defined by the ratio of observed output to potential output, $y_{it} / f(x_{it}, t; \beta)\exp(v_{it}) = \exp(-u_{it}) \leq 1$.

The stochastic random error component, $v_{it}$, is assumed to follow the conventional assumption that they are identically and independently distributed with zero mean and variance $\sigma_v^2$ (i.e., $v_{it} \sim N(0, \sigma_v^2)$). In Battese and Coelli (1992) the non-negative error component which measures technical inefficiency, $u_{it}$, is assumed to be an independently and identically distributed non-negative truncation at zero of the $N(\mu, \sigma_u^2)$ distribution. In this formulation technical inefficiency can be time varying or not. With availability of panel and relatively longer time dimension, it is hard to assume time invariant inefficiency measures. Through time producers are capable to identify their strengths and weakness, factors that reduce their inefficiencies, and find solutions. Thus, testing whether the inefficiency term is time invariant or not is an important exercise and if inefficiency is time varying the exercise allows calculating changes in technical efficiency overtime. Battese and Coelli (1992) specified a time varying technical inefficiency which is an exponential function of time as:

In equation (2) $\eta$ is the parameter which determines rate of change in technical efficiency and whether technical efficiency is time varying or not. It indicates increase, decrease, or constancy of technical efficiency in the observed data, if $\eta$ is positive, negative, or zero, respectively.

Inclusion of *t* as a regressor in the production function (equation (1)) is to calculate the productivity change (so called exogenous technical change). This technical change ($TC_{it}$) is measured by the derivative of the logged production function with respect to time.

$$TC_{it} = \frac{\partial \ln f(x_{it}, t; \beta)}{\partial t} \qquad (3)$$

Total change in output ($\dot{y}$) can be derived by taking the log of $y_{it}$ in equation (1) and totally differentiating it with respect to time.

$$\frac{d \ln y_{it}}{dt} = \frac{d \ln f(x_{it}, t; \beta)}{dt} - \frac{\partial u_{it}}{\partial t}$$

$$\Rightarrow \dot{y} = \frac{\partial \ln f(x_{it}, t; \beta)}{\partial t} + \sum_j \frac{\partial \ln f(x_{it}, t; \beta)}{\partial \ln x_j} \frac{d \ln x_j}{dt} - \frac{\partial u_{it}}{\partial t}$$

Then after defining the output elasticity of input $x_j$ by $\varepsilon_j = \frac{\partial \ln f(x_{it}, t; \beta)}{\partial \ln x_j}$, the above equation can be rewritten as:

$$\dot{y} = \frac{\partial \ln f(x_{it}, t; \beta)}{\partial t} + \sum_j \varepsilon_j \frac{d \ln x_j}{dt} - \frac{\partial u_{it}}{\partial t} \qquad (4)$$

Equation (4) decomposes the three sources of output growth:

i. The exogenous technical change ($TC_{it} = \partial \ln f(x_{it}, t; \beta) / \partial t$) which shifts the production function upward or downward.

ii. Technical efficiency change (TEC$_{it}$ = $-\partial \boldsymbol{u}_{it} / \partial \boldsymbol{t}$) which shows the movement of producers towards the frontier (best practice production level).

iii. Change in input use, which is given by $\sum_j \varepsilon_j \frac{d \ln x_j}{dt}$ component of the output growth equation.

With no assumption made about the return to scale (RTS), total factor productivity change is, as defined in the Solow residual, total change in output net of changes in the level of inputs used. It can be calculated by subtracting the weighted growth of factor inputs from the growth of output in equation (4):

$$\dot{TFP} = \dot{y} - \sum_j s_j \dot{x}_j, \quad \text{where } s_j \text{ is expenditure share of input j}$$

$$\dot{TFP} = TC + TEC + \sum_j \varepsilon_j \dot{x}_j - \sum_j s_j \dot{x}_j$$

$$\Rightarrow \dot{TFP} = TC + TEC + \sum_j (\varepsilon_j - s_j) \dot{x}_j$$

The return to scale is RTS = $\sum_j \varepsilon_j$ and defining $\lambda_j = \varepsilon_j / \sum_j \varepsilon_j$, the above equation can be rearranged to allow the decomposition of TFP growth into its components as (Del Gatto 2011):

$$\dot{TFP} = TC + TEC + (RTS - 1) \sum_j \lambda_j \dot{x}_j - \sum_j (\lambda_j - s_j) \dot{x}_j \qquad (5)$$

The first two components of equation (5) are already explained as technical change (shift in production frontier) and technical efficiency change (movement towards the frontier). The third term measures the contribution of scale effects to TFP growth. If the production technology exhibits constant returns to scale (RTS = 1), this term will cancel out. However, if the production technology exhibits increasing returns to scale (RTS > 1) or decreasing returns to scale (RTS < 1) changes in quantity of inputs will contribute positively or negatively to TFP growth, respectively. The forth component, which measures the effect of changes in allocative efficiency, captures the impact of deviations of inputs' normalized output elasticities from their expenditure shares or, somewhat less clearly, of input prices from the value of their marginal products (Kumbhakar and Lovell 2000).

In this study, however, I considered only the three components, technical change, technical efficiency change, and scale effect. Identifying allocative efficiency needs availability of price information and is based on the assumption of a perfect competition market. Under the assumption of perfect competition elasticities of output with respect to each input are assumed to be equal to the expenditure share of each respective factor. But, the assumption of perfect competition is not practical in developing countries like Ethiopia where there is a pervasive market failure (such as information asymmetry) and economies of scale.
The translog stochastic frontier production function is widely adopted in empirical studies. It is more flexible than the Cobb-Douglas production function and it also allows to test if the frontier really follows a Cobb-Douglas function. The translog stochastic frontier production function can then be written as:

$$\ln y_{it} = \beta_0 + \beta_t t + \frac{1}{2}\beta_{tt} t^2 + \sum_j \beta_j \ln x_{jit} + \sum_j \beta_{tj} t \ln x_{jit} + \frac{1}{2}\sum_j \sum_k \beta_{jk} \ln x_{jit} \ln x_{kit} + v_{it} - u_{it} \quad (6)$$

Equation (6) and equation (2) can be jointly estimated using maximum-likelihood estimation. Accordingly the components of TFP change can be computed by the first order derivatives of equation (6) and equation (2):

$$TC_{it} = \partial \ln f(x_{it}, t; \beta) / \partial t = \beta_t + \beta_{tt} t + \sum_j \beta_{tj} \ln x_{jit}$$

$$RTS = \sum_j \varepsilon_j = \sum_j (\beta_j + \beta_{tj} t + \sum_k \beta_{jk} \ln x_{kit})$$

$$\lambda_j = \varepsilon_j / \sum_j \varepsilon_j$$

$$TEC = -\frac{\partial u_{it}}{\partial t}$$

Technical change (technical progress) refers to a shift in the production frontier and is defined by the first order derivatives of the production frontier with respect to time. This shows whether the production frontier changes through time via technological changes. Technical efficiency change refers to the change of efficiency of the firm/industry with time. This change is only possible if the production entity has a time varying efficiency. Thus, for those with time varying efficiency, the technical efficiency change is calculated by taking the first order derivative of the log of equation (2) with respect to time.

### 3.2. Data

The study used firm level panel data of large and medium manufacturing industries collected annually by CSA for the period 1996–2009. The annual surveys conducted by CSA covers all manufacturing establishments that employ at least 10 workers and use electricity in production. Information regarding gross value of production, costs of materials, number of employees, total wages paid, energy expenditure, fixed capital, among other issues are largely covered in the surveys.

Manufacturing establishments are categorized by the ISIC [1]. The industrial groups covered in this study are manufactures of food products, beverages, non-metallic mineral products, chemical and chemical products, rubber and plastic products, fabricated metal products (except machinery and equipment), textiles, publishing and printing, tanning and dressing, and wearing apparel. These are the categories which largely dominate the manufacturing sector of Ethiopia by employment, production, and value added. In the 2009/10 survey, for instance, the value added of these groups was about 90 percent of the total value added of the sector.

The variables *y* and *x* in the production function specified above are defined as vector of outputs and inputs, respectively. Based on the data, the appropriate value which could represent *y* is either the gross value of production or value added (gross value of production net of raw materials and energy used in production). In this respect TFP can be calculated based on gross-output (gross-output based TFP) or value added (value added based TFP). Diewert (2000) noted that for comparing TFP growth at the industry level, it is best to use value added output rather than gross output as the latter includes the purchase of intermediate inputs which may vary greatly among industries (cited in Mahadevan 2002).

The TFP analysis based on value added assumes that technological progress improves productivity of primary inputs. However, it is difficult to find empirical evidence to support the assumption. Value added based TFP may provide overstated results because of the omission of intermediate inputs such as materials and energy. Aldaz (1998) (cited in Aldaz and Millan 2000) analyzed TFP in the food industry in Spain and found that TFP mean rates following the value added approach are about three times those obtained through the production approach. Taking into account the availability of data on raw materials and

[1] International Standard for Industrial Classification.

energy, and importance of intermediate inputs in the production process, this study employed output based TFP analysis.

Accordingly, while the dependent variable in the production function (*y*) is the gross value of production (sales revenue), the vector of inputs includes labor (given by total wages and salaries), capital, costs of raw materials, and energy expenditure. Data on fixed capital are presented in the survey by including value of fixed assets at the beginning of the survey year, new capital expenditures, capital sold and disposed during the year, depreciation, and the book value at the end of the year. Thus, capital is measured by the net value of fixed assets at the end of the survey year. The other two inputs are raw materials and energy. Raw materials include expenditure on imported and domestic intermediate goods. Similarly, energy input includes expenditure on fuel, electricity, and wood and charcoal used for production.

## 4. Empirical results and discussion

### 4.1. Descriptive results: Partial Productivity Analysis

The two important partial productivity measures are labor productivity and capital productivity. Labor productivity measures the ratio of value added to different measures of labor input. Labor can be measured by total labor hours of work, total number of employees, or the total wage bill. In the discussion below, I used total wage bill as a measure of labor because of lack of data on hours worked and number of temporal employees. Value added and total wages and salaries paid by the manufacturing sector are deflated by implicit sectoral GDP deflator and CPI, respectively. Thus, the productivity of labor, ratio of value added to total wages and salaries, indicate the real productivity of a Birr (in real terms) paid by the sector. On the other hand, productivity of capital is measured by the ratio of value added to the total fixed capital. Fixed capital is deflated using implicit capital formation deflator from the World Bank's Africa Development Indicator (ADI). ADI has data on gross capital formation at current local currency and gross capital formation at constant local currency (using year 2000 prices as a base) which I use to calculate the capital deflator by dividing the former to the latter.

**Table 4.1. Total manufacturing sector's partial productivity and factor intensity**

| Year | VA/W | Growth of VA/W | VA/K | Growth of VA/K | K/W | Growth of K/W |
|---|---|---|---|---|---|---|
| 1995/96 | 4.03 | 2.99 | 0.80 | -5.30 | 5.06 | 8.76 |
| 1996/97 | 3.13 | -22.46 | 0.55 | -31.24 | 5.70 | 12.76 |
| 1997/98 | 2.75 | -12.17 | 0.43 | -21.41 | 6.37 | 11.75 |
| 1998/99 | 3.74 | 36.29 | 0.47 | 10.04 | 7.89 | 23.86 |
| 1999/00 | 3.79 | 1.14 | 0.44 | -7.47 | 8.62 | 9.31 |
| 2000/01 | 3.36 | -11.38 | 0.38 | -13.03 | 8.79 | 1.89 |
| 2001/02 | 2.77 | -17.53 | 0.36 | -6.43 | 7.75 | -11.86 |
| 2002/03 | 3.00 | 8.32 | 0.38 | 7.30 | 7.82 | 0.95 |
| 2003/04 | 3.23 | 7.60 | 0.46 | 19.78 | 7.02 | -10.17 |
| 2004/05 | 3.58 | 10.91 | 0.55 | 19.83 | 6.50 | -7.44 |
| 2005/06 | 3.89 | 8.85 | 0.65 | 18.10 | 5.99 | -7.83 |
| 2006/07 | 4.31 | 10.57 | 0.67 | 2.82 | 6.44 | 7.54 |
| 2007/08 | 4.21 | -2.19 | 0.75 | 12.21 | 5.62 | -12.83 |
| 2008/09 | 5.79 | 37.49 | 0.83 | 10.63 | 6.98 | 24.28 |

Source: Own calculations using CSA's annual manufacturing sector survey reports.
Note: * VA, W, and K stand for Value Added, Wages and Salaries, and Value of Fixed Capital respectively.

The figure for the ratio of value added to wage shows some declining trends in the earlier periods. However, the trend has shown an improvement after 2002/03. The average of the ratio for the period 1995/06–2001/02 was 3.36 showing an average annual decrement at the rate of 3.3 percent. Unlike this period, for the period 2002/03–2008/09 the average productivity of a Birr paid to an employee was 4.00 showing an average annual increment at a rate of 11.65 percent. A productivity (value added per wage bill) of four implies that for every Birr the worker is paid he added value roughly amounting to four Birr. The productivity of capital has also showed the same trend as the productivity of labor. Average productivity of capital for the periods 1995/06–2001/02 and 2002/03–2008/09 was 0.49 and 0.61 with an average annual rate of growth of negative 10.7 percent and (positive) 12.95 percent, respectively. The productivity of capital (value added per unit of fixed productive capital) is very small compared to that of productivity of labor.

The factor intensity (capital intensity), ratio of value of fixed capital to the wage bill, has shown a reverse trend opposite to the productivity trends. It had been rising steadily for the period 1995/96–2001/02 with the exception of 2001/02. It grew at an average annual rate of 8.07 percent. The opposite is true for the period 2002/03–2008/09 where the factor intensity fell at annual average rate of 0.97 percent. Negative growth of capital intensity signifies increasing labor employment (wage bills) more than the growth in capital employment.

**Table 4.2. Partial productivity by industrial groups for periods 1995/06–2001/02 and 2002/03–2008/09**

| Industrial Group | | Labor Productivity | | Capital Productivity | | Capital Intensity | |
|---|---|---|---|---|---|---|---|
| | | Average VA/W | Average annual growth | Average VA/K | Average annual growth | Average K/W | %change of K/W between the two periods |
| Food products and Beverages | 1995/96–2001/02 | 4.57 | -0.02 | 0.69 | -16.39 | 7.59 | |
| | 2002/03–2008/09 | 4.55 | 8.09 | 0.66 | 13.49 | 6.97 | -8.15 |
| Textiles | 1995/96–2001/02 | 1.23 | -9.01 | 0.21 | -11.23 | 6.46 | |
| | 2002/03–2008/09 | 1.53 | 42.23 | 0.30 | 33.83 | 5.12 | -20.65 |
| Wearing apparel | 1995/96–2001/02 | 0.88 | 1.86 | 0.29 | -2.80 | 3.41 | |
| | 2002/03–2008/09 | 1.17 | 13.59 | 0.37 | -2.25 | 4.41 | 29.48 |
| Tanning and dressing of leather | 1995/96–2001/02 | 2.54 | -4.43 | 0.58 | -10.94 | 5.88 | |
| | 2002/03–2008/09 | 2.62 | 8.80 | 0.34 | 8.78 | 7.87 | 33.73 |
| Paper, paper products and printing | 1995/96–2001/02 | 2.78 | -0.96 | 1.03 | -7.71 | 2.77 | |
| | 2002/03–2008/09 | 3.16 | 12.27 | 1.05 | 10.15 | 3.04 | 9.61 |
| Chemical and chemical products | 1995/96–2001/02 | 3.78 | 0.18 | 0.27 | -11.72 | 14.24 | |
| | 2002/03–2008/09 | 4.27 | 24.68 | 0.65 | 30.43 | 6.85 | -51.88 |
| Rubber and plastic products | 1995/96–2001/02 | 4.06 | 0.45 | 0.32 | 8.99 | 13.37 | |
| | 2002/03–2008/09 | 4.69 | 10.88 | 0.54 | 13.82 | 8.86 | -33.71 |
| Non-metallic mineral products | 1995/96–2001/02 | 4.36 | -7.45 | 0.45 | 3.60 | 9.94 | |
| | 2002/03–2008/09 | 6.54 | 17.91 | 0.73 | 18.74 | 10.40 | 4.57 |
| Fabricated metal except machinery and equipment | 1995/96–2001/02 | 2.24 | 0.07 | 0.22 | 1.68 | 10.18 | |
| | 2002/03–2008/09 | 3.94 | 25.66 | 0.64 | 35.59 | 6.46 | -36.52 |

Source: Own computation using CSA's annual manufacturing sector survey reports (1996–2009).

Labor productivity in 1995/96–2001/02 was high in sectors producing non-metallic mineral products, rubber and plastic products, and food and beverages. Higher productivity in such sectors could result from having better technologies, high competition, and high market demand. The fast growth of the economy, like the construction sector, creates a large demand for non-metallic mineral products (products such as glass, structural clay, and cement), rubber and plastic products, and even food and beverages, and it may encourage the producers to use better technology that improve labor productivity. In contrast, productivity of labor is low in sectors producing wearing apparel and textiles. Manufacturers of non-metallic minerals, fabricated metal, textile, and wearing apparel have achieved better increase in their labor productivity than others. Regarding productivity of capital, it is high in sectors producing paper products and printing, non-metallic minerals and food and beverages. Manufacturers of wearing apparels and textiles have low capital productivity similar to their labor productivity. This is possibly because of the large value of capital used in the production process compared to the wage bills.

To sum, the two productivity measures show that the Ethiopian manufacturing sector has low factor productivities; especially capital productivity is very small. The trend of both productivity measures, however, showed improvements in recent years as the average annual growth of both productivity measures were positive for most sectors in the period 2002/03–2008/09.

In the recent period, producers of non-metallic products, and rubber and plastic are seen to have higher capital intensity while producers of paper products and printing have lower capital intensity. With only these observations we can argue that producers with higher capital intensity will have higher labor productivity and producers with lower capital intensity will have better capital productivity. However, taking all manufacturing industries into consideration it will be difficult to make such conclusion. Given the results in Table 4.2 the correlation of labor productivity (column three) and capital intensity (column seven) is 0.51 and the correlation between capital productivity (column five) and capital intensity is -0.43. This is consistent with the theoretical negative relationship between factor intensity of a particular factor and its productivity.

## 4.2. Estimation results

### *4.2.1. Hypothesis tests and model estimation*

Industrial groups are categorized based on the two digits ISIC (International Standard for Industrial Classification) except for food and beverage for which I used a three digits ISIC. Separate maximum likelihood estimations for each industrial group are then obtained using Stata 12 program. Translog production functions with a logged output as a dependent variable and logged values of primary inputs (labor and capital) and intermediate inputs (material and energy) are initially estimated. Time is also included to capture technical change. Translog production function is a more general and less restrictive function than the Cobb Douglas function. For instance, while the Cobb Douglas function assumes a constant elasticity of substitution, translog function makes testing the assumption of constant elasticity of substitution possible.

The general translog frontier production function is written for four inputs—labor, capital, material, and energy—and time in the following form, which is the extended version of equation (6):

$$\begin{aligned}\ln Y_{it} &= \alpha_0 + \alpha_l \ln L_{it} + \alpha_k \ln K_{it} + \alpha_m \ln M_{it} + \alpha_e \ln E_{it} + \alpha_t t + \frac{1}{2}\beta_{ll}(\ln L_{it})^2 + \frac{1}{2}\beta_{kk}(\ln K_{it})^2 + \\ &\frac{1}{2}\beta_{mm}(\ln M_{it})^2 + \frac{1}{2}\beta_{ee}(\ln E_{it})^2 + \frac{1}{2}\beta_{tt}t^2 + \beta_{lk}(\ln L_{it})(\ln K_{it}) + \beta_{lm}(\ln L_{it})(\ln M_{it}) + \beta_{le}(\ln L_{it})(\ln E_{it}) \\ &+\beta_{km}(\ln K_{it})(\ln M_{it}) + \beta_{ke}(\ln K_{it})(\ln E_{it}) + \beta_{me}(\ln M_{it})(\ln E_{it}) + \beta_{lt}(\ln L_{it})t + \beta_{kt}(\ln K_{it})t \\ &+\beta_{mt}(\ln M_{it})t + \beta_{te}(\ln E_{it})t + (v_{it} - u_{it})\end{aligned}$$

where $Y_{it}$ is the gross value of output, $t$ is time, and $L$, $K$, $M$, and $E$ are the inputs for labor, capital, material and energy as measured by wages, fixed capital, cost of materials, and cost of energy, respectively. The values of the output and inputs are deflated by different deflators using 1999/2000 as a base year. Output is deflated by an implicit sectoral GDP deflator (implicit deflator for large and medium manufacturing industries), energy is deflated by an implicit GDP deflator for energy and water, capital is deflated by an implicit fixed capital formation deflator, and wages and materials are deflated by CPI. Implicit sectoral GDP deflators are from MoFED, CPI from CSA, and capital formation deflator from WB's ADI.

This general function allows to undertake different tests. The first test is to check separability of intermediate inputs from primary inputs. It is to test if the coefficients of the products of intermediate inputs with primary inputs and time ($\beta_{lm}$, $\beta_{le}$, $\beta_{ke}$, $\beta_{me}$, $\beta_{mt}$ and $\beta_{te}$) are all equal to zero. The main purpose of this test is to check which TFP measure, TFP based on gross output or TFP based on value added, is the appropriate one for the industrial group under consideration. However, in cases where separability is accepted I run a constrained gross output frontier function with restrictions made to the coefficients of the interaction terms of intermediate inputs with primary inputs and time. This is because there are many cases where the value added becomes negative, in which case the logarithm of value added cannot be computed. Whenever the value added turns negative the establishment will be excluded from the estimation. This reduces the sample size and makes convergence difficult.

The other tests are tests for Cobb-Douglas production function ($\beta_{ll} = \beta_{kk} = \beta_{mm} = \beta_{ee} = \beta_{tt} = \beta_{lk} = \beta_{lm} = \beta_{le} = \beta_{km} = \beta_{ke} = \beta_{me} = 0$), no technical change ($\alpha_t = \beta_{tt} = \beta_{lt} = \beta_{kt} = \beta_{mt} = \beta_{te} = 0$) and neutral technical change ($\beta_{lt} = \beta_{kt} = \beta_{mt} = \beta_{te} = 0$). As the model is based on the Battese and Coelli (1992) specification there are two addition important considerations. It is important to test the time trend and distribution of the inefficiency term. It is testable whether efficiency is time varying or not. It is done by constraining the parameter $\eta$ (in the formulation of time varying inefficiency, $u_{it} = \eta_i u_i = \exp[-\eta(t-T)]u_i$ (refer to the methodology section)), which measures the rate of change of technical efficiency, to zero. If the null is true, then efficiency is time invariant. With regard to distribution of the inefficiency term, $u_{it}$, the Battese and Coelli model assumes a non-negative truncation of the normal distribution $N(\mu, \sigma_u^2)$. An alternative distribution to the truncated normal distribution is a half-normal distribution. The test to choose one of the two competing distributional forms is to test a constrained model where the constraint is $\mu = 0$. Based on the log likelihood ratio test (LR), if the null is accepted then the model will follow a half-normal distribution.

Cleaning the data to minimize noise and produce a robust estimation is also one of the tasks that should be done with care. At first, observations with missing values in either the value of production or one of the inputs are cleared from the data. Outliers are also controlled in the estimation in two ways. First, given each year's data, observations with extreme low values for any of the variables are cleared as they may highly influence the inefficiency of a given sector [2]. These observations constitute about 2 percent of each year's data. Further, in some sectors extreme values far from the large concentrations are as well cleared (see Table 4.4). The final data used for estimation are unbalanced panel data from the years 1995/96–2008/09. A summary statistics of the final data is given in the table below.

[2] Extreme low values include wages less than 1000 Birr, energy less than 100 Birr, and capital less than 1000 Birr.

**Table 4.3. Summary statistics of observations and variables by industrial group**

| | | Food | Non-metallic minerals | Publishing and printing | Tanning and dressing | Fabricated metal products | Chemi-cals | Rubber and plastic | Textile | Beverage | Wearing apparel |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Total observations* | | *3144* | *1421* | *835* | *813* | *753* | *630* | *559* | *447* | *371* | *340* |
| Output | Mean [a] | 13.92 | 12.78 | 14.01 | 14.81 | 13.45 | 15.09 | 15.17 | 15.40 | 16.41 | 13.64 |
| | SD [b] | 1.98 | 1.82 | 1.61 | 1.89 | 1.96 | 1.87 | 1.54 | 2.28 | 2.09 | 1.62 |
| Wage | Mean | 11.09 | 10.43 | 12.03 | 11.99 | 11.27 | 12.36 | 12.40 | 13.23 | 13.74 | 11.94 |
| | SD | 1.73 | 1.86 | 1.42 | 1.75 | 1.62 | 1.62 | 1.30 | 2.25 | 1.81 | 1.68 |
| Capital | Mean | 12.95 | 11.53 | 13.24 | 14.58 | 12.61 | 14.18 | 14.85 | 14.49 | 15.54 | 12.72 |
| | SD | 2.31 | 2.25 | 1.66 | 1.90 | 2.28 | 2.05 | 1.45 | 2.74 | 2.18 | 2.30 |
| Material | Mean | 13.32 | 11.73 | 13.08 | 14.15 | 12.69 | 14.41 | 14.39 | 14.62 | 15.08 | 12.90 |
| | SD | 2.03 | 1.84 | 1.75 | 2.08 | 2.03 | 1.92 | 1.67 | 2.51 | 2.01 | 1.65 |
| Energy | Mean | 10.37 | 8.27 | 9.16 | 10.63 | 9.10 | 10.27 | 11.41 | 11.62 | 11.42 | 8.96 |
| | SD | 1.72 | 2.29 | 1.45 | 1.88 | 1.78 | 1.93 | 1.74 | 2.73 | 2.62 | 1.63 |

Source: Own computation based on the data from CSA's manufacturing survey.
Notes: a/ Mean is mean of log of deflated values of each variable.
b/ SD is standard deviation.
The above data consists of a total of 9313 firms/year observations.

Given the general translog production frontier a log likelihood ratio test has been made in each industrial group for the different hypotheses. Following the test statistics reported in Table 4.4 below, intermediate inputs are found to be not separable from primary inputs in all industrial groups except publishing and printing. This implies that measuring TFP or efficiency using gross output is better than using value added output. The tests for Cobb-Douglas production frontier and no technical change are as well rejected in all industrial groups. Thus, translog production functions with time included as a regressor to capture technical change are appropriate models in all industrial groups. The Hicks-neutrality of technical change is not rejected in groups such as publishing and printing, rubber and plastic, and textile. In the other sectors, technical change is found to be non-neutral with the different inputs used in the production process. The traditional production function without technical inefficiency effects is rejected in all sectors at 5 percent confidence level except for textile where it is rejected at 10 percent significance level.

Furthermore, as to the time varying or time invariant inefficiency the test statistics shows that industrial groups with the exception of two groups, beverage and tanning and dressing, are found to have a time invariant inefficiency. Accordingly, except for the two groups, the stochastic model for others is with a time invariant inefficiency term. Finally, a test is made regarding the distribution of the inefficiency term whether it follows the more general truncated normal or a half normal distribution.

**Table 4.4. Statistics for hypotheses testing using the log likelihood ratio test**

| | Log likelihood ratio | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Null Hypothesis | Food | Non-metallic minerals[a] | Publishing and printing | Tanning and dressing | Fabricated metal products[b] | chemicals | Rubber and plastic[a] | Textile[c] | Beverage | Wearing apparel [a] | Critical Value (5%) |
| Separability | 20.91 | 102.90 | 5.17 | 49.63 | 49.14 | 58.53 | 14.48 | 20.14 | 10.79 | ** | 12.59 |
| Cobb-Douglas | 314.81 | 413.92 | 46.33 | 153.02 | 120.58 | 155.57 | 39.49 | 75.51 | 49.47 | 32.88 | 19.68 |
| No technical change | 254.68 | 114.61 | 90.44 | 121.01 | 78.46 | 57.23 | 19.21 | 20.65 | 53.83 | 60.77 | 14.07 |
| Neutral technical change | 9.68 | 15.37 | 6.32 | 9.75 | 11.71 | 8.11* | 2.30 | 3.51 | 10.09 | ** | 9.49 |
| No inefficiency | 465.15 | 205.70 | 59.18 | 26.88 | 81.90 | 30.29 | 23.13 | 4.85* | 92.10 | 9.36 | 7.82 |
| Time invariant inefficiency | 2.37 | 2.66 | 0.82 | 8.77 | 1.05 | 0.45 | 0.46 | 1.23 | 6.41 | 2.10 | 3.84 |
| Half-normal distribution for $u_{it}$ | 325.11 | 58.21 | 7.60 | 2.30 | 37.65 | 0.52 | 4.90 | | 4.91 | 0.38 | 3.84 |

Source: Own computation based on estimation results.
Notes: a/Establishments observed for only a year are dropped so as to bring some balance in the data.
b/ Large extreme (lower and upper) values of production are observed and establishments with output at the top of 98% and bottom 2% are dropped so as to achieve convergence in estimations.
c/ Estimations using the general truncated normal distribution for $u_{it}$ are not convergent. As a second alternative I used the half normal distribution.
* Though it is unlikely to reject the null at 5% confidence interval, it is rejected at 10% confidence interval. Subsequently, the final estimation is based on a consideration that the null is rejected.
** The constrained model does not converge.

The test for the half normal distribution of the inefficiency term is not rejected for industrial groups of wearing apparel, chemical and chemical products, and tanning and dressing. The general model for textile industry with truncated normal distribution does not achieve convergence. Consequently, many attempts were made to fit an appropriate model and the second best option where results are found to be convergent is in the case of half normal distribution of the inefficiency term.

Following the hypotheses testing, specific models are then chosen for each industrial group. A translog production frontier is used for all estimations and also a time invariant efficiency model is used except for beverage, and tanning and dressing. While a Hicks-neutral technical change is used for publishing and printing, rubber and plastic, and textile, a half normal distribution for the inefficiency term is used for tanning and dressing, textile, chemical products and wearing apparel. For all other groups production functions with truncated normal distributed inefficiency term and non-neutral technical change are estimated. Furthermore, for publishing and printing the coefficients for the product of intermediate inputs with primary inputs and time are constrained to be zero and are excluded from the estimation. Based on the preferred models for each industrial group which passed the hypotheses tests, estimations are then made and the results of the estimations are given in the Table 4.5 below.

**Table 4.5. Maximum likelihood estimates for the translog Stochastic frontier model[a]**

| Variables (dependent var. is $\ln Y_{it}$) | Food | Non-metallic minerals | Publishing and Printing | Tanning and dressing | Fabricated metal products | Chemi-cals | Rubber and plastic | Textile | Beverage | Wearing apparel |
|---|---|---|---|---|---|---|---|---|---|---|
| ln L | 0.039 | 0.118 | 0.419** | 0.04 | 0.603*** | 0.620*** | 0.26 | 0.517** | 0.164 | -0.218 |
| ln K | -0.168*** | -0.088 | 0.026 | -0.120- | -0.027 | -0.107 | 0.046 | -0.112 | 0.162 | 0.021 |
| ln M | 0.455*** | 0.391*** | 0.228* | 0.646*** | 0.410*** | 0.487*** | 0.4 | 0.198 | 0.384 | 0.96*** |
| ln E | 0.093* | 0.308*** | -0.126 | 0.168 | 0.184 | -0.074 | 0.181 | 0.171 | 0.522*** | 0.59*** |
| *T* | -0.054*** | -0.062** | -0.043*** | -0.125*** | -0.056* | -0.055 | -0.04* | -0.073 | 0.048 | -0.063 |
| $0.5(\ln L)^2$ | 0.035*** | 0.024 | -0.023 | 0.096*** | 0.062** | 0.124*** | 0.039 | 0.053 | 0.002 | -0.054 |
| $0.5(\ln K)^2$ | -0.001 | 0.027*** | -0.009 | -0.004 | 0.015 | 0.033** | 0 | -0.004 | -0.012 | 0.004 |
| $0.5(\ln M)^2$ | 0.063*** | 0.154*** | 0.028* | 0.113*** | 0.159*** | 0.161*** | 0.144*** | 0.097*** | 0.066*** | 0.023 |
| 0.5(ln E)2 | 0.044*** | 0.074*** | 0.01 | 0.02* | 0.031* | 0.037** | 0.013 | 0.048** | 0.048*** | 0.021 |
| 0.5t2 | 0.012*** | 0.011*** | 0.01*** | 0.015*** | 0.014*** | 0.011*** | 0.008*** | 0.007*** | 0.014*** | 0.009*** |
| (lnL)(lnK) | -0.001 | 0.031*** | 0.008 | 0.009 | 0.023 | -0.032* | 0.045* | 0.011 | 0.009 | 0.006 |
| (lnL)(lnM) | -0.014** | -0.058*** | _ | -0.084*** | -0.103*** | -0.115*** | -0.087*** | -0.076*** | _ | 0.038 |
| (lnL)(lnE) | -0.009 | 0.014 | _ | 0.001 | -0.013 | 0.003 | 0.005 | -0.009 | _ | 0.024 |
| (lnK)(lnM) | 0.005 | -0.034*** | _ | -0.006 | -0.029*** | -0.012 | -0.033 | 0.016* | _ | -0.006 |
| (lnK)(lnE) | 0.012*** | -0.021*** | _ | 0.015* | -0.007 | 0.023** | -0.01 | -0.019 | _ | -0.011 |
| (lnM)(lnE) | -0.041*** | -0.059*** | 0.007 | -0.038*** | -0.011 | -0.038*** | -0.015 | -0.016 | -0.07*** | -0.067** |
| t(lnL) | -0.005*** | -0.001 | _ | 0.003 | 0.005 | 0.003 | _ | -0.001 | -0.003 | 0.027*** |
| t(lnK) | 0.002* | 0.007*** | _ | 0.006** | 0.007** | 0.006** | _ | 0.003 | -0.005 | 0.007* |
| t(lnM) | 0.002 | -0.004 * | _ | -0.006** | -0.01*** | -0.006* | _ | 0.003 | _ | -0.03*** |
| t(lnE) | 0 | -0.003 | _ | 0 | -0.003 | -0.004 | _ | -0.002 | _ | 0.001 |
| $\sigma^2 = \sigma_u^2 + \sigma_v^2$ | 0.161*** | 0.197*** | 0.138*** | 0.156 | 0.151*** | 0.181*** | 0.157*** | 0.191*** | 0.179*** | 0.141 |
| $\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$ | 0.302*** | 0.325*** | 0.201*** | 0.411 | 0.331*** | 0.366 | 0.143*** | 0.177** | 0.55 | 0.234* |
| $\mu$ | 2.345 | 1.452 | 0.609 | | 1.414 | _ | 0.691 | _ | 0.824*** | _ |
| $\eta$ | _ | _ | _ | -0.091** | _ | _ | _ | _ | -0.026 | _ |

Source: Estimation results.
Notes: a/ Extended form of this table with standard errors for the coefficients is presented in Annex Table A.1.
*, **, *** show the 10%, 5%, and 1% level of significance, respectively.

### *4.2.2. Technical efficiency*

The parameter gamma ( $\gamma$ )—which is the ratio of the variance parameter of the inefficiency term to the sum of variances of the two error terms ($v_{it}$ and $u_{it}$)—measures the proportion of total variability resulted from technical inefficiency. The value of this parameter ranges from 14.3 percent in the rubber and plastic industrial group to 55 percent in the beverage industrial group. This implies that large differences in output can be explained by technical inefficiencies. In addition to this large percentage of output variability that results from inefficiency, the inefficiency of most industries, except for groups of tanning and dressing and beverage, is found to be time invariant ( $\eta$ is found to be insignificant). Time invariant inefficiency implies that firms continue their production without considerations given to their technical inefficiency.

The mean technical efficiency reported in Table 4.6 below ranges from 88 percent in the tanning and dressing industry, which is a relatively efficient sector, to 10 percent in the food industrial group with lowest efficiency score. The absolute values of this efficiency measures may be affected by the different specifications of the production frontier, especially assumptions on the distribution of the inefficiency effect ($u_{it}$). However, the different distributional assumptions produce a relatively similar ranking of firms according to their efficiencies (Kumbhakar and Lovell 2000) and calculation of changes in efficiency of firms. Furthermore, the level of aggregation may also affect the mean efficiency of the industrial group. In groups whose production is very similar their efficiencies would be relatively greater than those groups with highly diversified type of products. This is true in the case of industries categorized as food producers which have a high variability in the type of products they produce and size of firms. The general observation, however, indicates that there is still a greater possibility of increasing firm's productivity by making them become more efficient.

**Table 4.6. Mean, minimum, and maximum technical efficiencies by industrial group[a]**

| Technical efficiency | Food | Non-metallic minerals | Publishing and printing | Tanning and dressing | Fabricated metal products | Chemicals | Rubber and Plastic | Textile | Beverage | Wearing apparel |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.10 | 0.25 | 0.56 | 0.88 | 0.25 | 0.83 | 0.51 | 0.86 | 0.53 | 0.87 |
| Minimum | 0.06 | 0.10 | 0.39 | 0.54 | 0.16 | 0.55 | 0.38 | 0.69 | 0.26 | 0.73 |
| Maximum | 0.60 | 0.58 | 0.82 | 0.99 | 0.52 | 0.95 | 0.67 | 0.94 | 0.91 | 0.96 |

Source: own computation from the estimation results.
Note: a/ efficiency of each firm is $\exp(-u_{it})$ and the mean is calculated using each firms output share as a weight.

### *4.2.3. Output elasticity, returns to scale, and direction of technical change*

Output elasticity of a given input is derived from the partial derivative of the logged value of output with respect to the logged value of the input. The monotonicity principle of production implies that increase in input must not result in deterioration of output and the elasticity must be positive. This is true in the Ethiopian manufacturing sector. An important issue related with output elasticity is the returns to scale which is the sum of output elasticity with respect to each input used in the production function.

**Table 4.7. Output elasticity and return to scale (RTS, as defined in equation (5)) (at mean output over the period)[a]**

| | | Food | Non-metallic minerals | Publishing and printing | Tanning and dressing | Fabricated metal products | Chemi-cals | Rubber and plastic | Textile | Beverage | Wearing apparel |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Output elasticity | Labor | 0.09*** | 0.148*** | 0.245*** | 0.165*** | 0.204*** | 0.091*** | 0.219*** | 0.166*** | 0.313*** | 0.115*** |
| | Capital | 0.026*** | 0.05*** | 0.003 | 0.05*** | 0.045*** | 0.067*** | 0.015 | 0.021 | 0.07*** | 0.021 |
| | Material | 0.799*** | 0.668*** | 0.659*** | 0.704*** | 0.705*** | 0.783*** | 0.748*** | 0.695*** | 0.622*** | 0.813*** |
| | Energy | 0.066*** | 0.123*** | 0.059*** | 0.067*** | 0.056*** | 0.077*** | 0.018 | 0.079*** | 0.077*** | 0.073** |
| RTS[b] | | 0.981 | 0.988 | 0.966 | 0.986 | 1.0113 | 1.018 | 0.999 | 0.961 | 1.081 | 1.022 |

Source: Own computation based on the estimation results.
Notes: a/ Each year's elasticity and RTS at annual mean output are given in Annex Table A.2.
b/ A test for constant returns to scale (at mean output over the study period) is made and it is accepted in industrial groups producing non-metallic minerals, tanning and dressing, fabricated metal products, chemical products, rubber and plastic, and wearing apparel.
*** and ** show level of significance at 1% and 5%, respectively.

Table 4.7 indicates that all Ethiopian manufacturing sectors have high and significant output elasticity with respect to material followed by a relatively lower but significant elasticity with respect to labor. A high output elasticity of intermediate inputs is not a good indicator. This may mean that the sector has lower value added and/or is heavily dependent on raw materials. The lower and in some cases insignificant output elasticity with respect to capital implies that the manufacturing sector is less responsive to changes in capital accumulation. This could arise from capital intensive technologies (use of large or more machineries and equipments) or use of older techniques of production.

The sum of the elasticities, returns to scale, is different among groups. A test is made whether the RTS is constant (sum of the elasticities is equal to one) (see Annex Table A.2 regarding the RTS in each year). The null that the RTS is not different from one (constant returns to scale, CRS) is accepted in industrial groups producing non-metallic minerals, tanning and dressing, fabricated metal products, chemical products, rubber and plastic, and wearing apparel. Exceptions to this general finding include rejection of the null in non-metallic mineral producers for the years 2006/07–2008/09, and tanning and dressing for 1995/96 and 1996/07, where RTS is decreasing, and wearing apparel for the years 2003/04–2005/06 in which the RTS is increasing . The food industry showed constant returns to scale for the period 1995/96–2000/01 and decreasing returns to scale (DRS) then after. Publishing and printing, and textile industries exhibited decreasing returns to scale except for 2004/05 and 2005/06 where publishing and printing exhibited CRS and 2008/09 where textile industry exhibited CRS. Finally, the beverage industry exhibited increasing returns to scale (IRS) except for the year 2007/08 where the RTS is found to be constant.

Another point about the output elasticity and RTS is the trend overtime which is given in Annex Table A.2. Output elasticity with regard to labor has been decreasing in industrial groups of food products, beverages, and non-metallic minerals. The elasticity with respect to capital has been increasing in most groups. The exceptions are beverage—where the elasticity was declining through time—and groups such as publishing and printing, rubber and plastic and textile—whose capital elasticity of output was steady with some fluctuations. Material elasticity of output has been steady with some fluctuation in most sectors except the decreasing trend in tanning and dressing (with a sharp decreasing trend), and textile and wearing apparel, and the increasing trend in the rubber and plastic group. The groups with a decreasing material elasticity of output are those with increasing trend in output elasticity with respect to labor and returns to scale. The return to scale has shown a decreasing trend in the food, beverage, and non-metallic minerals groups and it is steady in the other sectors. For food and non-metallic minerals, it turned from IRS to DRS but for beverage industry it is still IRS. Issues that matter in these observations are the decreasing trend in output elasticity with respect to labor and capital, the increasing trend in output elasticity of materials, and the decreasing trend in RTS while the opposite trends of these have positive implications. In this respect the industrial groups of tanning and dressing, and wearing apparel have achieved better results.

The test for Hicks neutral technical change is not accepted in all industrial groups except in publishing and printing, and rubber and plastic. Accordingly, the technical change is biased to the different type of inputs used in the production. The results from Table 4.5 indicate that the technological changes are capital using and the coefficients of ***t(lnK)*** are positive and significant except in the beverage industrial group where the coefficient is negative but insignificant. In contrast, the coefficients of ***t(lnM)*** are negative and significant implying that technical changes are material saving, the exceptions are in industries of food and wearing apparel where the coefficients are insignificantly positive. With regard to labor, technical change has an insignificant effect except in the food industry where technical change is found to be labor saving and in wearing apparel where it is found to be labor using. The coefficient of ***t(lnE)*** is insignificant in all industrial groups implying that technical change is neutral towards energy use. The interpretations of effect of technical change are in relative terms. Technical change will be input i-saving (input i-using) if the proportional savings on the $i^{th}$ input is greater than (less than) the average proportional savings overall inputs (Berndt 1990, cited in Mandal & Madheswaran 2009).

### *4.2.4. Decomposition of growth of TFP*

As indicated in the foregoing discussion, growth in total factor productivity can be achieved from the three components: technical change (change in production technology or shift in production frontier, it is also defined as technical progress), scale component, and technical efficiency change (change in technical efficiency of firms and industrial groups, i.e. movement towards the frontier). Technical efficiency of an industrial group at a given year is calculated by the average of each establishment's efficiency using their output share as a weight. Efficiency of a group is then calculated each year even though individual firms have a time invariant efficiency. The group's efficiency may change from year to year depending on the composition of firms. On the other hand, the scale effect exists only if the RTS is statistically different from one (CRS). In Table 4.8 a summary of the decomposition for each industrial group is presented by taking averages for two periods (1996/07–2001/02 and 2002/03–2008/09). Details of each year's decomposition are presented in Annex Table A.3.

**Table 4.8. TFP growth and the decomposition into the three components (based on equations (2)–(5))**

| | Technical Efficiency Change (%) | | Scale Efficiency Change (Scale Component of TFPG) (%) | | Technical Change (%) | | Total Factor Productivity Growth (%) | |
|---|---|---|---|---|---|---|---|---|
| Industrial Group | 1996/07–2002/03 | 2003/04–2008/09 | 1996/07–2002/03 | 2003/04–2008/09 | 1996/07–2002/03 | 2003/04–2008/09 | 1996/07–2002/03 | 2003/04–2008/09 |
| Food | 0.782 | -1.962 | -0.001 | -0.887 | -1.171 | 6.281 | -0.389 | 3.431 |
| Non-metallic minerals | -0.266 | 0.429 | 0.000 | -0.395 | -1.184 | 5.803 | -1.450 | 5.835 |
| Publishing and printing | 0.223 | -0.048 | -0.608 | -0.304 | -0.003 | 6.212 | -0.388 | 5.858 |
| Tanning and dressing | -0.228 | -0.818 | -0.402 | 0.000 | -1.886 | 7.815 | -2.517 | 6.997 |
| Fabricated metal products | -0.468 | 0.066 | 0.000 | 0.000 | -0.805 | 7.497 | -1.273 | 7.562 |
| Chemicals | 0.042 | -0.259 | 0.000 | 0.000 | -0.292 | 6.873 | -0.249 | 6.613 |
| Rubber and plastic | 0.608 | -0.531 | 0.000 | 0.000 | -0.366 | 4.887 | 0.242 | 4.355 |
| Textile | 0.082 | -0.016 | -0.037 | -0.011 | 0.277 | 4.890 | 0.322 | 4.863 |
| Beverage | -1.501 | -1.348 | 1.351 | 0.694 | -0.777 | 8.542 | -0.926 | 7.887 |
| Wearing apparel | -0.041 | 0.777 | 0.000 | 0.221 | 1.608 | 6.823 | 1.567 | 7.821 |

Source: Computed based on the estimation results.

There is a good progress regarding TFP growth. The trend of TFP growth proves the existence of a better and encouraging TFP growth in all industrial groups in the period 2002/03–2008/09 than in the period 1996/07–2001/02. The growth of TFP in the second period ranges from the lowest 3.43 percent in the food industry to the highest 7.89 percent in the beverage industry. The productivity difference between the periods is large in the tanning and dressing industry (9.51 percent) followed by the industrial groups of fabricated metal products (8.83 percent) and beverage (8.81 percent). As the main contributor of this increase in productivity, technical progress also shows similar trends. It shows a shift from an average negative growth in the first period to a significant positive growth in the second period. Thus, the largest share of the TFP growth comes from technical progress. For instance, of the 6.99 percent, 7.82 percent and 7.56 percent TFP growths in tanning and dressing, wearing apparel and fabricated metal products, 7.81 percent, 6.82 percent and 7.5 percent are the contributions of technical change, respectively. In some sectors the technical change is greater than the TFP growth referring to a negative contribution of the other two components. Access to information, competition, access to foreign markets, foreign direct investment (FDI), and improvements in knowledge and human capital may result in such progressive shifts in the manufacturing sector's production technology.

The share of technical efficiency change in TFP growth is small and negative in most of the industrial groups. While the effect of technical efficiency has deteriorated in most sectors, it has improved from negative to positive only in three sectors; it is in the non-metallic minerals, fabricated metal products, and wearing apparel. In the first period it varied from the lowest in the beverage industry (-1.5 percent) to the highest in the food industry (0.78 percent). In the second period it continued to have large variation from the lowest in the food industry (-1.9 percent), followed by the beverage industry (-1.35 percent), to the highest in wearing apparel producers (0.77 percent).

As it is indicated in the hypothesis testing, firms in most industrial groups have a time invariant technical efficiency, except those in tanning and dressing, and beverage industries whose technical efficiency is time varying and is found to have a negative trend (the parameter $\eta$ in the estimation being negative for both sectors but insignificant in beverage industrial group). The time invariant efficiency implies that firms are not improving their efficiencies and are continuing their old practices of business management and marketing and are not updating the technical knowledge of their employees to achieve the best practice production frontier.

The estimation results and decomposition of TFP growth, in general, provides a good insight into the Ethiopian manufacturing sector. The sector is found to have some improvements in its TFP, especially in recent years, the years after 2002/03. The main engine of the observed TFP growth has been technical change. Technical change (progress) refers to the change in production technology which allows industries to scale up their level of production and improve productivity of their inputs. The other components, technical efficiency and scale component, are found to have a negative, zero, or a small positive contribution to TFP growth. Output variation among firms is significant and at least 14 percent of it can be explained by variation in technical efficiencies. As a way to reduce the variations in output, improving technical efficiency is very important. This in turn will help to increase TFP.

With regard to the last component of TFP growth, the scale component, increasing returns to scale is found in industries of beverage and wearing apparel (only for 2003/04–2005/06), which increases TFP when input growths are positive. Thus, the scale component has a positive contribution to TFP growth for these two industrial groups. However, the scale component is negative in industrial groups of textile, publishing and printing, food (after 2000/01), and non-metallic minerals (2006/07–2008/09), whose returns to scale are decreasing. In the others, whose returns to scale are constant in most years, the scale component is zero or close to zero.

## 5. Conclusion and recommendation

This study has evaluated TFP growth and technical efficiency in the Ethiopian manufacturing sector. A Stochastic frontier model is used to evaluate technical efficiency and measure TFP growth and decompose it into its components. Translog production function with labor, capital, material, and energy as inputs in the production function is used to determine the production frontier and time is included in the function to trace any movements in production frontier through time. A descriptive analysis to measure partial factor productivity (labor and capital productivity) has also been done to give more explanation about the growth of productivity.

Results of the descriptive partial productivity indicate deterioration in the productivity of labor and capital in the period before 2002/03 and an improvement starting from the year 2002/03. This result is similar to the findings based on the frontier analysis. The frontier analysis has shown a negative TFP growth in most groups in the first period and a large increase in the second period. Estimation results of the frontier model have also shown existence of large inefficiencies in the manufacturing sector and existence of material saving and capital using technical progress. Decomposition of TFP growth indicated that a large share of the growth comes mostly from technical change. Factors such as FDI, technological advances, and import of technologies may have contributed largely to the progressive technical change. With regard to the other components, it is found that the effect of scale efficiency and technical efficiency are negative or slightly positive. Constant returns to scale and/or decreasing returns to scale and technical inefficiencies make the two components to have a limited role in improving TFP.

Achievements in TFP growth can further be strengthened by improving the technical efficiency and scale efficiency of manufacturers. Promoting efficiency by creating an environment which makes that employees advance their technical know-how, management skills, and entrepreneurial and innovative skills is very important. Increasing productivity is also possible by bringing, adopting, and imitating new technologies. Furthermore, making the market competitive and encouraging firms to export their products is important in order to get new technologies and move to the frontier of production and marketing.

We also find large output elasticity with respect to material as compared to the other inputs signifying that the availability of materials is an important factor that determines TFP growth and production in general. In the manufacturing survey producers claim that the lack of raw material is a major business constraint, as it is the main factor that hindered them in producing their full potential. Increasing availability of materials by creating different marketing and transportation channels or guiding firms to areas where supplies of raw materials are abundant is important to increase efficiency and productivity of firms.
Another issue is regarding the decreasing returns to scale observed in some of the industrial groups. The existence of decreasing returns to scale is an indication that firms are operating above their optimal scale (proportion of factors). In this case firms may need to improve their scale to the optimal one by decreasing their costs of production, improving efficiency, and adjusting the proportion of factors to bring more intensive utilization of the more productive inputs. Having labor or capital above the optimal proportion will bring productivity down though production increases with increase in inputs. Thus, firms need to understand that and improve their scale of operation by improving the proportion of their inputs.

Finally, further investigations and thorough researches should be undertaken to identify the determinants of technical efficiency, technical progress, and scale of operation and their changes. Such studies will help identify the causes of inefficiencies, sub-optimal or over-optimal scale operation, and changes in technology. Policies will then be developed to bring changes in the manufacturing sector and to significantly contribute to the economic growth.

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## Annex

### Annex Table A.1. Maximum likelihood estimates for the translog Stochastic frontier model (Extended version of Table 4.5)

| Variables (dependent var. is $lnY_{it}$) | Food | Non-metallic minerals | Publishing and printing | Tanning and dressing | Fabricated metal products | Chemicals | Rubber and plastic | Textile | Beverage | Wearing apparel |
|---|---|---|---|---|---|---|---|---|---|---|
| constant | 7.126 | 4.833 | 4.823 | 3.553*** | 1.849 | 1.812 | 2.936 | 3.688*** | 0.481 | -0.258 |
| | (18.845) | (17.340) | (1.165) | (0.719) | (23.671) | (1.114) | (9.519) | (1.125) | (2.062) | (1.401) |
| ln L | 0.039 | 0.118 | 0.419** | 0.040 | 0.603*** | 0.620*** | 0.260 | 0.517** | 0.164 | -0.218 |
| | (0.070) | (0.110) | (0.176) | (0.125) | (0.184) | (0.199) | (0.312) | (0.213) | (0.298) | (0.267) |
| ln K | -0.168*** | -0.088 | 0.026 | -0.120- | -0.027 | -0.107 | 0.046 | -0.112 | 0.162 | 0.021 |
| | (0.046) | (0.074) | (0.131) | (0.082) | (0.111) | (0.116) | (0.214) | (0.103) | (0.161) | (0.136) |
| Ln M | 0.455*** | 0.391*** | 0.228* | 0.646*** | 0.410*** | 0.487*** | 0.400 | 0.198 | 0.384 | 0.96*** |
| | (0.059) | (0.092) | (0.128 | (0.107) | (0.135) | (0.142) | (0.248) | (0.154) | (0.257) | (0.245) |
| ln E | 0.093* | 0.308*** | -0.126 | 0.168 | 0.184 | -0.074 | 0.181 | 0.171 | 0.522*** | 0.59*** |
| | (0.055) | (0.070) | (0.131) | (0.102) | (0.120) | (0.124) | (0.184) | (0.151) | (0.165) | (0.187) |
| *t* | -0.054*** | -0.062** | -0.043*** | -0.125*** | -0.056* | -0.055 | -0.04* | -0.073 | 0.048 | -0.063 |
| | (0.016) | (0.026) | (0.014) | (0.028) | (0.034) | (0.035) | (0.021) | (0.047) | (0.042) | (0.048) |
| $0.5(\ln L)^2$ | 0.035*** | 0.024 | -0.023 | 0.096*** | 0.062** | 0.124*** | 0.039 | 0.053 | 0.002 | -0.054 |
| | (0.012) | (0.016) | (0.023) | (0.016) | (0.030) | (0.042) | (0.049) | (0.042) | (0.033) | (0.041) |
| $0.5(\ln K)^2$ | -0.001 | 0.027*** | -0.009 | -0.004 | 0.015 | 0.033** | -0.000 | -0.004 | -0.012 | 0.004 |
| | (0.004) | (0.008) | (0.011) | (0.011) | (0.012) | (0.014) | (0.020) | (0.011) | (0.018) | (0.015) |
| $0.5(\ln M)^2$ | 0.063*** | 0.154*** | 0.028* | 0.113*** | 0.159*** | 0.161*** | 0.144*** | 0.097*** | 0.066*** | 0.023 |
| | (0.007) | (0.010) | (0.015) | (0.013) | (0.017) | (0.018) | (0.028) | (0.018) | (0.026) | (0.035) |
| $0.5(\ln E)^2$ | 0.044*** | 0.074*** | 0.010 | 0.02* | 0.031* | 0.037** | 0.013 | 0.048** | 0.048*** | 0.021 |
| | (0.007) | (0.010) | (0.013) | (0.010) | (0.018) | (0.015) | (0.019) | (0.022) | (0.015) | (0.029) |
| $0.5t^2$ | 0.012*** | 0.011*** | 0.01*** | 0.015*** | 0.014*** | 0.011*** | 0.008*** | 0.007*** | 0.014*** | 0.009*** |
| | (0.001) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.003) | (0.003) | (0.002) | (0.003) |
| (lnL)(lnK) | -0.001 | 0.031*** | 0.008 | 0.009 | 0.023 | -0.032* | 0.045* | 0.011 | 0.009 | 0.006 |
| | (0.005) | (0.009) | (0.014) | (0.011) | (0.014) | (0.017) | (0.025) | (0.017) | (0.021) | (0.017) |
| (lnL)(lnM) | -0.014** | -0.058*** | _ | -0.084*** | -0.103*** | -0.115*** | -0.087*** | -0.076*** | _ | 0.038 |
| | (0.007) | (0.010) | _ | (0.013) | (0.019) | (0.020) | (0.029) | (0.018) | _ | (0.030) |

_

| Variables (dependent var. is $\ln Y_{it}$) | Food | Non-metallic minerals | Publishing and printing | Tanning and dressing | Fabricated metal products | Chemicals | Rubber and plastic | Textile | Beverage | Wearing apparel |
|---|---|---|---|---|---|---|---|---|---|---|
| (lnL)(lnE) | -0.009 | 0.014 | _ | 0.001 | -0.013 | 0.003 | 0.005 | -0.009 | | 0.024 |
| | (0.007) | (0.010) | _ | (0.011) | (0.019) | (0.019) | (0.021) | (0.024) | _ | (0.037) |
| (lnK)(lnM) | 0.005 | -0.034*** | _ | -0.006 | -0.029*** | -0.012 | -0.033 | 0.016* | _ | -0.006 |
| | (0.004) | (0.007) | _ | (0.010) | (0.011) | (0.012) | (0.020) | (0.009) | _ | (0.014) |
| (lnK)(lnE) | 0.012*** | -0.021*** | _ | 0.015* | -0.007 | 0.023** | -0.010 | -0.019 | _ | -0.011 |
| | (0.004) | (0.006) | _ | (0.008) | (0.011) | (0.010) | (0.014) | (0.013) | _ | (0.017) |
| (lnM)(lnE) | -0.041*** | -0.059*** | 0.007 | -0.038*** | -0.011 | -0.038*** | -0.015 | -0.016 | -0.07*** | -0.067** |
| | (0.006) | (0.008) | (0.014) | (0.009) | (0.015) | (0.011) | (0.016) | (0.016) | (0.018) | (0.028) |
| t(lnL) | -0.005*** | -0.001 | _ | 0.003 | 0.005 | 0.003 | _ | -0.001 | -0.003 | 0.027*** |
| | (0.002) | (0.003) | _ | (0.003) | (0.005) | (0.005) | _ | (0.006) | (0.005) | (0.007) |
| t(lnK) | 0.002* | 0.007*** | _ | 0.006** | 0.007** | 0.006** | _ | 0.003 | -0.005 | 0.007* |
| | (0.001) | (0.002) | _ | (0.002) | (0.003) | (0.003) | _ | (0.004) | (0.004) | (0.004) |
| t(lnM) | 0.002 | -0.004 * | _ | -0.006** | -0.01*** | -0.006* | _ | 0.003 | _ | -0.03*** |
| | (0.002) | (0.002) | _ | (0.003) | (0.004) | (0.003) | _ | (0.005) | _ | (0.006) |
| t(lnE) | 0.000 | -0.003 | _ | -0.000 | -0.003 | -0.004 | _ | -0.002 | _ | 0.001 |
| | (0.002) | (0.002) | _ | (0.003) | (0.004) | (0.003) | _ | (0.002) | _ | (0.007) |
| $\sigma^2=\sigma_u^2+\sigma_v^2$ | 0.161*** | 0.197*** | 0.138*** | 0.156 | 0.151*** | 0.181*** | 0.157*** | 0.191*** | 0.179*** | 0.141 |
| | (0.005) | (0.009) | (0.008) | (0.020) | (0.010) | (0.022) | (0.010) | (0.022) | (0.031) | (0.021) |
| $\gamma=\frac{\sigma_u^2}{\sigma_u^2+\sigma_v^2}$ | 0.302*** | 0.325*** | 0.201*** | 0.411 | 0.331*** | 0.366 | 0.143*** | 0.177** | 0.550 | 0.234* |
| | (0.021) | (0.032) | (0.041) | (0.082) | (0.048) | (0.084) | (0.043) | (0.103) | (0.083) | (0.125) |
| $\mu$ | 2.345 | 1.452 | 0.609 | | 1.414 | _ | 0.691 | _ | 0.824*** | _ |
| | (18.839) | (17.328) | (0.674) | | (23.649) | _ | (9.323) | _ | (0.233) | _ |
| $\eta$ | _ | _ | _ | -0.091** | _ | _ | _ | _ | -0.026 | _ |
| | _ | _ | _ | (0.039) | _ | _ | _ | _ | (0.017) | _ |
| Log likelihood | -1371.41 | -751.678 | -318.054 | -223.48 | -291.83 | -248.590 | -263.109 | -234.570 | -106.64 | -116.38 |

Source: Estimation results.

Notes: Values in parenthesis are standard errors. *, **, *** show the 10%, 5%, and 1% level of significance, respectively.

## Annex Table A.2. Output elasticity and returns to scale (RTS), annual

| Industrial groups | | | 1995/96 | 1996/97 | 1997/98 | 1998/99 | 1999/00 | 2000/01 | 2001/02 | 2002/03 | 2003/04 | 2004/05 | 2005/06 | 2006/07 | 2007/08 | 2008/09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Food | Output elasticity of inputs | Labor | 0.13 | 0.13 | 0.12 | 0.12 | 0.11 | 0.11 | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.07 | 0.06 | 0.05 |
| | | Capital | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 |
| | | Material | 0.77 | 0.79 | 0.79 | 0.80 | 0.80 | 0.79 | 0.79 | 0.78 | 0.79 | 0.82 | 0.80 | 0.80 | 0.81 | 0.81 |
| | | Energy | 0.08 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.06 | 0.06 | 0.05 | 0.06 |
| | RTS | | 1.00[a] | 1.00[a] | 1.00[a] | 1.00[a] | 1.00[a] | 1.00[a] | 0.98[c] | 0.98[b] | 0.98[b] | 1.01[a] | 0.97[b] | 0.97[b] | 0.96[b] | 0.96[b] |
| Non-metallic minerals | Output elasticity of inputs | Labor | 0.18 | 0.18 | 0.17 | 0.18 | 0.17 | 0.16 | 0.16 | 0.16 | 0.15 | 0.17 | 0.15 | 0.13 | 0.12 | 0.13 |
| | | Capital | 0.00 | 0.02 | 0.01 | 0.02 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.05 | 0.06 | 0.07 | 0.07 | 0.08 |
| | | Material | 0.67 | 0.69 | 0.67 | 0.65 | 0.65 | 0.68 | 0.67 | 0.65 | 0.68 | 0.62 | 0.66 | 0.68 | 0.70 | 0.64 |
| | | Energy | 0.16 | 0.12 | 0.15 | 0.15 | 0.15 | 0.12 | 0.13 | 0.15 | 0.13 | 0.17 | 0.13 | 0.09 | 0.09 | 0.12 |
| | RTS | | 1.01[a] | 1.01[a] | 1.01[a] | 1.00[a] | 1.00[a] | 1.00[a] | 1.00[a] | 1.00[a] | 1.00[a] | 1.02[a] | 0.99[a] | 0.97[d] | 0.97[c] | 0.97[c] |
| Publishing and printing | Output elasticity of inputs | Labor | 0.25 | 0.24 | 0.25 | 0.25 | 0.25 | 0.25 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.25 |
| | | Capital | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | Material | 0.65 | 0.65 | 0.66 | 0.65 | 0.65 | 0.65 | 0.66 | 0.66 | 0.66 | 0.67 | 0.67 | 0.66 | 0.66 | 0.66 |
| | | Energy | 0.06 | 0.06 | 0.06 | 0.05 | 0.06 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| | RTS | | 0.96[b] | 0.96[b] | 0.96[b] | 0.95[b] | 0.96[b] | 0.95[b] | 0.96[c] | 0.97[c] | 0.96[c] | 0.98[a] | 0.98[a] | 0.97[c] | 0.97[d] | 0.97[c] |
| Tanning and dressing | Output elasticity of inputs | Labor | 0.13 | 0.13 | 0.13 | 0.15 | 0.16 | 0.15 | 0.17 | 0.16 | 0.16 | 0.18 | 0.19 | 0.17 | 0.19 | 0.21 |
| | | Capital | 0.00 | 0.00 | 0.01 | 0.03 | 0.03 | 0.04 | 0.05 | 0.05 | 0.06 | 0.07 | 0.08 | 0.08 | 0.09 | 0.09 |
| | | Material | 0.76 | 0.77 | 0.77 | 0.74 | 0.72 | 0.73 | 0.71 | 0.71 | 0.70 | 0.69 | 0.67 | 0.68 | 0.64 | 0.61 |
| | | Energy | 0.05 | 0.05 | 0.05 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.06 | 0.07 | 0.07 | 0.08 | 0.10 |
| | RTS | | 0.94[b] | 0.95[b] | 0.96[b] | 0.98[d] | 0.98[a] | 0.99[a] | 1.00[a] | 0.99[a] | 0.99[a] | 1.00[a] | 1.00[a] | 1.00[a] | 1.00[a] | 1.01[a] |
| Fabricated metal products | Output elasticity of inputs | Labor | 0.20 | 0.23 | 0.21 | 0.19 | 0.19 | 0.21 | 0.22 | 0.23 | 0.18 | 0.16 | 0.18 | 0.20 | 0.23 | 0.24 |
| | | Capital | 0.00 | 0.02 | 0.02 | 0.02 | 0.03 | 0.04 | 0.04 | 0.05 | 0.04 | 0.04 | 0.05 | 0.07 | 0.07 | 0.07 |
| | | Material | 0.73 | 0.70 | 0.71 | 0.73 | 0.73 | 0.70 | 0.69 | 0.67 | 0.74 | 0.77 | 0.73 | 0.70 | 0.67 | 0.66 |
| | | Energy | 0.09 | 0.08 | 0.09 | 0.08 | 0.07 | 0.06 | 0.06 | 0.06 | 0.06 | 0.05 | 0.05 | 0.04 | 0.04 | 0.03 |
| | RTS | | 1.02[a] | 1.02[a] | 1.02[a] | 1.02[a] | 1.02[a] | 1.01[a] | 1.01[a] | 1.01[a] | 1.01[a] | 1.01[a] | 1.01[a] | 1.00[a] | 1.00[a] | 1.01[a] |
| Chemicals | Output elasticity of inputs | Labor | 0.05 | 0.06 | 0.05 | 0.05 | 0.08 | 0.07 | 0.11 | 0.13 | 0.12 | 0.11 | 0.09 | 0.11 | 0.11 | 0.09 |
| | | Capital | 0.01 | 0.02 | 0.04 | 0.05 | 0.06 | 0.06 | 0.06 | 0.07 | 0.07 | 0.08 | 0.08 | 0.08 | 0.09 | 0.11 |
| | | Material | 0.87 | 0.85 | 0.84 | 0.84 | 0.78 | 0.80 | 0.75 | 0.73 | 0.74 | 0.75 | 0.77 | 0.76 | 0.76 | 0.76 |
| | | Energy | 0.08 | 0.08 | 0.08 | 0.08 | 0.10 | 0.08 | 0.09 | 0.09 | 0.09 | 0.08 | 0.07 | 0.06 | 0.05 | 0.06 |
| | RTS | | 1.01[a] | 1.01[a] | 1.02[a] | 1.02[a] | 1.02[a] | 1.02[a] | 1.02[a] | 1.02[a] | 1.02[a] | 1.02[a] | 1.02[a] | 1.01[a] | 1.01[a] | 1.02[a] |

| Industrial groups | | | 1995/96 | 1996/97 | 1997/98 | 1998/99 | 1999/00 | 2000/01 | 2001/02 | 2002/03 | 2003/04 | 2004/05 | 2005/06 | 2006/07 | 2007/08 | 2008/09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rubber and plastic | Output elasticity of inputs | Labor | 0.21 | 0.23 | 0.24 | 0.23 | 0.25 | 0.25 | 0.25 | 0.25 | 0.22 | 0.22 | 0.21 | 0.20 | 0.20 | 0.20 |
| | | Capital | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | Material | 0.74 | 0.73 | 0.72 | 0.73 | 0.70 | 0.71 | 0.70 | 0.71 | 0.76 | 0.75 | 0.76 | 0.78 | 0.78 | 0.77 |
| | | Energy | 0.03 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 |
| | RTS | | 1.00 [a] | 1.00 [a] | 1.00 [a] | 1.00 [a] | 1.00 [a] | 1.00 [a] | 1.00 [a] | 1.00 [a] | 1.00 [a] | 1.00 [a] | 1.00 [a] | 1.00 [a] | 1.00 [a] | 1.00 [a] |
| Textile | Output elasticity of inputs | Labor | 0.17 | 0.17 | 0.16 | 0.16 | 0.19 | 0.17 | 0.17 | 0.16 | 0.15 | 0.16 | 0.15 | 0.16 | 0.16 | 0.18 |
| | | Capital | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 | 0.04 | 0.03 | 0.04 |
| | | Material | 0.68 | 0.69 | 0.69 | 0.69 | 0.66 | 0.70 | 0.68 | 0.71 | 0.71 | 0.71 | 0.71 | 0.70 | 0.69 | 0.69 |
| | | Energy | 0.10 | 0.09 | 0.10 | 0.09 | 0.09 | 0.08 | 0.09 | 0.08 | 0.07 | 0.06 | 0.07 | 0.07 | 0.08 | 0.06 |
| | RTS | | 0.95 [b] | 0.95 [b] | 0.95 [b] | 0.96 [b] | 0.95 [b] | 0.96 [b] | 0.96 [b] | 0.97 [c] | 0.97 [d] | 0.97 [c] | 0.97 [d] | 0.97 [d] | 0.97 [d] | 0.97 [a] |
| Beverage | Output elasticity of inputs | Labor | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.32 | 0.32 | 0.32 | 0.31 | 0.31 | 0.30 | 0.30 | 0.29 | 0.29 |
| | | Capital | 0.11 | 0.10 | 0.10 | 0.09 | 0.08 | 0.08 | 0.07 | 0.07 | 0.07 | 0.06 | 0.06 | 0.05 | 0.05 | 0.04 |
| | | Material | 0.63 | 0.64 | 0.62 | 0.61 | 0.62 | 0.63 | 0.63 | 0.61 | 0.62 | 0.63 | 0.63 | 0.63 | 0.61 | 0.61 |
| | | Energy | 0.07 | 0.07 | 0.07 | 0.08 | 0.08 | 0.07 | 0.06 | 0.09 | 0.07 | 0.07 | 0.07 | 0.07 | 0.09 | 0.09 |
| | RTS | | 1.14 [b] | 1.14 [b] | 1.12 [b] | 1.11 [b] | 1.11 [b] | 1.10 [b] | 1.09 [b] | 1.08 [b] | 1.08 [b] | 1.07 [d] | 1.06 [c] | 1.05 [d] | 1.04 [a] | 1.03 [d] |
| Wearing apparel | Output elasticity of inputs | Labor | -0.05 | -0.05 | -0.02 | 0.01 | 0.03 | 0.06 | 0.09 | 0.12 | 0.15 | 0.16 | 0.19 | 0.24 | 0.28 | 0.29 |
| | | Capital | -0.03 | -0.01 | -0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.02 | 0.03 | 0.04 | 0.04 | 0.04 | 0.05 | 0.06 |
| | | Material | 1.01 | 1.00 | 0.95 | 0.93 | 0.91 | 0.87 | 0.83 | 0.81 | 0.79 | 0.76 | 0.74 | 0.68 | 0.64 | 0.59 |
| | | Energy | 0.04 | 0.07 | 0.08 | 0.07 | 0.06 | 0.07 | 0.08 | 0.09 | 0.08 | 0.08 | 0.08 | 0.06 | 0.05 | 0.10 |
| | RTS | | 0.98 [a] | 1.00 [a] | 1.00 [a] | 1.01 [a] | 1.01 [a] | 1.01 [a] | 1.01 [a] | 1.03 [a] | 1.05 [d] | 1.05 [c] | 1.05 [c] | 1.02 [a] | 1.02 [a] | 1.04 |

Source: Own computation based on estimation results.

Note: The superscripts in RTS refer to the decisions regarding the test statistics that it is not different from one (CRS):

a/ accept the null that the production function exhibits CRS

b/ reject the null at 1% significance level

c/ reject the null at 5% significance level

d/ reject the null at 10% significance level.

**Annex Table A.3. Decomposition of TFP growth, annual**

| Industrial groups | | 1996/97 | 1997/98 | 1998/99 | 1999/00 | 2000/01 | 2001/02 | 2002/03 | 2003/04 | 2004/05 | 2005/06 | 2006/07 | 2007/08 | 2008/09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Food | Technical progress | -4.05 | -2.85 | -1.71 | -0.54 | 0.54 | 1.58 | 2.73 | 3.93 | 5.14 | 6.26 | 7.45 | 8.62 | 9.84 |
| | Efficiency change | 4.34 | -3.02 | -3.67 | 2.08 | 5.68 | -0.71 | -0.79 | 0.51 | 1.70 | -8.33 | 5.69 | -4.05 | -8.46 |
| | Scale efficiency change | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.01 | -0.33 | -0.21 | 0.00 | -1.54 | 0.25 | -2.49 | -1.90 |
| | TFPG | 0.29 | -5.87 | -5.38 | 1.53 | 6.23 | 0.87 | 1.61 | 4.23 | 6.84 | -3.60 | 13.39 | 2.08 | -0.52 |
| Non-metallic minerals | Technical progress | -3.77 | -2.87 | -1.74 | -0.65 | 0.46 | 1.46 | 2.54 | 3.52 | 4.50 | 5.82 | 7.14 | 7.95 | 9.16 |
| | Efficiency change | -0.87 | -6.32 | -0.05 | 5.22 | -0.54 | 0.96 | 1.26 | -0.60 | -0.20 | 0.65 | 0.71 | 0.16 | 1.02 |
| | Scale efficiency change | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.22 | -1.24 | -1.30 |
| | TFPG | -4.64 | -9.19 | -1.79 | 4.57 | -0.07 | 2.42 | 3.80 | 2.92 | 4.30 | 6.47 | 7.62 | 6.86 | 8.87 |
| Publishing and printing | Technical progress | -2.39 | -1.44 | -0.48 | 0.48 | 1.43 | 2.39 | 3.34 | 4.30 | 5.26 | 6.21 | 7.17 | 8.12 | 9.08 |
| | Efficiency change | 1.49 | -1.06 | 0.15 | 1.06 | 1.64 | -1.93 | -1.17 | 1.17 | -2.70 | 1.34 | -1.25 | 0.73 | 1.53 |
| | Scale efficiency change | 0.63 | -0.89 | -0.63 | -1.16 | 1.58 | -3.18 | -0.10 | -0.96 | 0.00 | 0.00 | -0.13 | -1.34 | 0.39 |
| | TFPG | -0.28 | -3.38 | -0.97 | 0.38 | 4.65 | -2.73 | 2.08 | 4.51 | 2.56 | 7.55 | 5.79 | 7.52 | 11.00 |
| Tanning and dressing | Technical progress | -6.04 | -4.50 | -2.62 | -0.90 | 0.63 | 2.12 | 3.46 | 4.74 | 6.25 | 7.80 | 9.31 | 10.71 | 12.44 |
| | Efficiency change | 0.00 | -0.87 | 0.52 | -0.30 | -0.03 | -0.69 | -0.56 | -0.56 | -0.87 | -1.01 | -0.93 | -1.07 | -0.73 |
| | Scale efficiency change | 1.08 | -1.74 | -1.75 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | TFPG | -4.96 | -7.11 | -3.85 | -1.20 | 0.59 | 1.43 | 2.90 | 4.18 | 5.38 | 6.79 | 8.39 | 9.64 | 11.71 |
| Fabricated metal products | Technical progress | -3.94 | -2.81 | -1.60 | -0.26 | 1.26 | 2.51 | 3.96 | 4.58 | 5.84 | 7.36 | 8.94 | 10.20 | 11.59 |
| | Efficiency change | 2.15 | -0.42 | 0.27 | -0.90 | -1.88 | -2.02 | -2.27 | 0.71 | -1.26 | 1.02 | 1.59 | -1.30 | 1.97 |
| | Scale efficiency change | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | TFPG | -1.79 | -3.23 | -1.33 | -1.16 | -0.62 | 0.50 | 1.69 | 5.29 | 4.58 | 8.38 | 10.53 | 8.91 | 13.56 |
| chemicals | Technical progress | -3.23 | -2.04 | -0.75 | 0.30 | 1.31 | 2.66 | 3.72 | 4.70 | 5.74 | 6.79 | 7.99 | 9.02 | 10.14 |
| | Efficiency change | -0.98 | 2.41 | -1.03 | -0.04 | -0.67 | 0.58 | -0.05 | 1.78 | -3.49 | -0.50 | 0.17 | 0.28 | 0.00 |
| | Scale efficiency change | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | TFPG | -4.21 | 0.37 | -1.79 | 0.26 | 0.64 | 3.24 | 3.68 | 6.49 | 2.25 | 6.29 | 8.16 | 9.30 | 10.14 |
| Rubber and plastic | Technical progress | -2.39 | -1.58 | -0.77 | 0.04 | 0.85 | 1.65 | 2.46 | 3.27 | 4.08 | 4.89 | 5.70 | 6.50 | 7.31 |
| | Efficiency change | 1.89 | -0.34 | 1.93 | -0.80 | -0.67 | 1.64 | -0.53 | 0.73 | -0.68 | 0.51 | -3.55 | 1.41 | -1.60 |
| | Scale efficiency change | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | TFPG | -0.50 | -1.91 | 1.16 | -0.76 | 0.18 | 3.29 | 1.93 | 4.00 | 3.40 | 5.40 | 2.15 | 7.91 | 5.71 |

| Industrial groups | | 1996/97 | 1997/98 | 1998/99 | 1999/00 | 2000/01 | 2001/02 | 2002/03 | 2003/04 | 2004/05 | 2005/06 | 2006/07 | 2007/08 | 2008/09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Textile | Technical progress | -1.51 | -0.84 | -0.03 | 0.54 | 1.47 | 2.02 | 2.84 | 3.61 | 4.24 | 4.90 | 5.54 | 6.16 | 6.94 |
| | Efficiency change | -0.17 | 0.56 | -1.39 | 0.41 | 0.65 | 0.43 | -0.14 | -0.17 | -0.03 | 0.49 | -0.21 | -0.62 | 0.57 |
| | Scale efficiency change | 0.08 | 0.43 | 0.01 | 0.05 | -0.55 | -0.24 | -0.41 | -0.90 | 0.44 | -0.18 | -0.13 | 1.11 | 0.00 |
| | TFPG | -1.60 | 0.14 | -1.40 | 1.00 | 1.57 | 2.22 | 2.29 | 2.53 | 4.65 | 5.21 | 5.20 | 6.64 | 7.51 |
| Beverage | Technical progress | -4.13 | -2.83 | -1.41 | -0.20 | 1.30 | 2.62 | 3.92 | 5.57 | 7.14 | 8.52 | 9.97 | 11.54 | 13.14 |
| | Efficiency change | 0.32 | -1.63 | -1.18 | -1.90 | -2.96 | -1.66 | -0.38 | -1.75 | -1.33 | 0.45 | -1.55 | -1.42 | -3.45 |
| | Scale efficiency change | 1.22 | 1.51 | 0.18 | 1.75 | 1.47 | 1.98 | 0.33 | 0.65 | 1.98 | 0.35 | 0.72 | 0.00 | 0.84 |
| | TFPG | -2.60 | -2.95 | -2.41 | -0.36 | -0.19 | 2.94 | 3.87 | 4.46 | 7.78 | 9.32 | 9.13 | 10.11 | 10.53 |
| Wearing apparel | Technical progress | -0.88 | 0.49 | 0.92 | 2.30 | 3.19 | 3.63 | 3.93 | 4.01 | 5.81 | 6.69 | 7.74 | 8.92 | 10.65 |
| | Efficiency change | -2.82 | 1.59 | 1.67 | -2.03 | 3.10 | -1.75 | 2.34 | -0.36 | -2.14 | 2.13 | 3.67 | -3.39 | 3.19 |
| | Scale efficiency change | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.85 | -0.53 | 1.23 | 0.00 | 0.00 | 0.00 |
| | TFPG | -3.70 | 2.08 | 2.59 | 0.26 | 6.29 | 1.88 | 6.27 | 4.51 | 3.14 | 10.05 | 11.41 | 5.53 | 13.84 |

Source: Own computation based on estimation results.
Note: TFPG = Total Factor Productivity Growth.

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