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# The Determinants of Technical Efficiency of Manufacturing Firms in Ghana\*

Hasan A. Faruq and David T. Yi

## Abstract

This paper uses the Data Envelopment Analysis (DEA) technique to estimate the technical efficiency of firms in Ghana across six manufacturing industries during 1991-2002. We observe that manufacturing firms in Ghana are significantly less efficient than their counterparts in other countries. In addition, we find that firm characteristics such as size, age, foreign ownership, and the mix of labor and capital used during the production process have positive effects on firm efficiency. These results have implications for Ghana's import-substitution industrialization and foreign investment policies.

**KEYWORDS:** Ghana, technical efficiency, Data Envelopment Analysis, import-substitution, FDI

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## 1. INTRODUCTION

Many economists consider Ghana an emerging success story in Africa. It has one of the highest GDP per capita in the region and is expected to reach “middle-income-country” status by 2015 (Clemens et al. 2008). While Ghana’s economy is mainly driven by agriculture, its manufacturing base is also relatively advanced compared to other African countries, consisting of industries ranging from food processing to light manufacturing and textiles. Many of these industrial activities resulted from Ghana’s import-substitution industrialization policies since its independence in 1957, which increased the manufacturing sector's share of GDP from 10 percent in 1960 to 14 percent in 1970. Unfortunately, these import-substitution industrialization policies also led to the creation of excess industrial capacity and low capacity utilization (Clark 1994). In addition, manufacturing efficiency in Ghana has remained stagnant despite increases in its manufacturing output (Teal 1999).

Numerous industrial activities in Ghana also resulted from the economic reform programs it introduced during the 1990s. Following policy recommendations by the World Bank and International Monetary Fund, Ghana implemented policies such as privatization of public enterprises and relaxation of government controls, which helped create a more attractive environment for foreign investors. As a result, foreign direct investment (FDI) inflows to Ghana grew between 4 percent and 8 percent annually during the 1990s. Between 1994 and 2002, 1,309 FDI projects were registered with the Ghana Investment Promotion Centre. 368 of these FDI projects were in the manufacturing sector (Abdulai 2005). Despite the increase in FDI related activities in Ghana, the total volume of its FDI inflows has been very low at approximately 2 percent of its GDP.<sup>1</sup>

Ghana’s economic experience thus raises several questions. For example, how efficient are manufacturing firms in Ghana across different industries? What are the determinants of Ghana’s manufacturing efficiency? How did Ghana’s import substitution and foreign investment policies affect the efficiency of its manufacturing firms? This paper attempts to shed some light into these questions. For the first time in the literature, we estimate the technical efficiency of a sample of manufacturing firms in Ghana during 1991-2002 using the non-parametric *Data Envelopment Analysis* (DEA) technique. After estimating efficiency, we attempt to identify some factors which may affect efficiency, including those that may be associated with Ghana’s import substitution industrialization policies and foreign investment policies.

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<sup>1</sup> Source: World Data Bank (2010) <http://databank.worldbank.org/ddp/home.do>.

This paper thus follows a growing literature on the estimation of technical efficiency of manufacturing firms in developing countries. For example, Lundvall and Battese (2000) examine the effect of firm size and age on the technical efficiency of Kenyan manufacturing firms. Similarly, Oczkowski and Sharma (2005) investigate the effect of firm size and other firm characteristics on the technical efficiency of manufacturing firms in Nepal. One difference between our work and these studies lies in methodology. We estimate technical efficiency using the non-parametric DEA technique, while these studies employ parametric techniques such as *Stochastic Frontier Analysis*. While each method has its advantages and disadvantages, we use the DEA technique mainly because it does not require us to specify the functional form of the production function or make any assumptions about the probability distribution for the errors. Our work is closely related to Alvarez and Crespi (2003), who also use the DEA technique to analyze the determinants of efficiency among small manufacturing firms in Chile. To the best of our knowledge, no study has previously examined the technical efficiency of manufacturing firms in Ghana using the DEA technique. Our work thus extends this literature. In addition, our work contributes to the literature on Ghana's import substitution and foreign investment policies. We are not aware of many studies which have empirically examined the direct and/or indirect effects of these policies on the performance of Ghana's firms.<sup>2</sup> While we do not examine the direct effects of these policies in this paper, we find some evidence consistent with the idea that these policies affected the efficiency of Ghana's manufacturing firms.

The rest of this paper is organized as follows. In section 2, we outline the likely determinants of technical efficiency in Ghana based on our survey of the literature. In sections 3 and 4, we discuss the empirical methodology, data and results respectively. In section 5, we make some concluding remarks and discuss the policy implications of our findings.

## **2. THE DETERMINANTS OF EFFICIENCY**

The literature has previously examined various determinants of technical efficiency, including firm-specific characteristics such as age, size, labor-capital mix and foreign ownership status (i.e. whether or not the firm is owned by a foreign entity). In what follows, we describe the expected effect of each of these variables on a firm's technical efficiency.

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<sup>2</sup> Some studies which have discussed the effects of import substitution and foreign investment policies on Ghana's economy include Steel (1972), Wangwe (1995), Abdulai (2005), Dupasquier and Osakwe (2005), and Bigsten and Söderbom (2010). These studies do not, however, provide empirical estimates of the effects of these policies on efficiency and other measures of firm performance in Ghana.

**(a) Firm size:** Some empirical papers find strong support for the hypothesis that there is a positive relationship between firm size and firm efficiency (Oczkowski and Sharma 2005, Lundvall and Battese 2000). Large firms are likely to be more efficient because of greater market power, better access to important resources and economies of scale effects. However, it can be argued that small firms can be efficient since they are more exposed to competition than larger firms and have a strong incentive to address their own weaknesses in order to survive. It is also possible that, for some firms, an increase in size may lead to temporary coordination problems within the firm, resulting in lower efficiency. Therefore, the relationship between firm size and firm efficiency is not necessarily straightforward. Previous studies have used a firm's labor input as a measure of its size (Badunenko and Stephan 2004). We use the same measure of firm size in this paper.

**(b) Firm age:** Empirical findings on the relationship between firm age and firm efficiency are mixed. Some studies conclude that the relationship is positive, since firms become more efficient as their stock of experience grows and they identify and reject previously used inefficient production methods (Malerba 1992). However, other studies raise the possibility that older firms may be less efficient if they fail to upgrade to new production technology and adapt to changing market conditions (Little, Mazumdar, and Page 1987). There are also empirical studies that suggest that the link between age and efficiency may depend on the nature of the industry; for example, Lundvall and Battese (2000) find a positive relationship between efficiency and age among Kenyan firms in the textile sector, but fail to identify any effect of firm age on efficiency in the food, wood, and metal sectors. Given the multitude of connections between age and efficiency, the net effect is therefore an empirical matter.

**(c) Labor-capital mix:** According to Oczkowski and Sharma (2005), developing countries may have a comparative advantage in labor-intensive products due to the availability of labor and the relative scarcity of available capital and infrastructure. As a developing country, it is therefore likely that Ghana has a comparative advantage in labor-intensive products. Consequently, firms in Ghana using a high labor-capital mix (i.e. a higher labor-capital ratio) are likely to be more efficient. Also, we expect that a more labor-intensive firm is more likely to be nimble. Consequently, in the comparatively volatile economies of developing countries, a firm with a high labor-capital mix is more likely to be operating close to its efficient level.

**(d) Foreign ownership:** Foreign owners can help improve the efficiency of domestic firms by giving them access to foreign technology, management talent,

and an established distribution network (Faruq 2008). On the other hand, foreign ownership may also be associated with lower efficiency due to co-ordination problems and high cost of learning about a different market (Bernard and Sjöholm 2003). Given all these possibilities, the relationship between foreign ownership and efficiency is in essence an empirical matter. We use an indicator variable to represent the foreign ownership of a domestic firm. The indicator variable takes the value of 1 if the firm is owned by a foreign entity and takes the value of 0 otherwise. Unfortunately, our dataset does not allow us to distinguish between different types of foreign investment (such as Greenfield operations versus purchased plants).

### **3. METHODOLOGY**

#### **Estimating Technical Efficiency**

Two efficiency measures are commonly used in the efficiency literature: *Stochastic Frontier Analysis* (SFA) and *Data Envelopment Analysis* (DEA). SFA is a parametric estimation technique in which the production function contains a two-sided normally distributed random error term and a one-sided error term which may take different distributional forms (Aigner et al. 1977, Meeusen and Van den Broeck 1977). This one-sided error term is specific to each firm and measures the shortfall of actual output from potential frontier output. Technical efficiency is estimated from this one-sided error term. On the other hand, DEA is a non-parametric estimation method which uses linear programming techniques to measure the technical efficiency of firms for a given set of output and a corresponding set of inputs (Charnes et al. 1978, Lovell and Schmidt 1988). More specifically, DEA measures the efficiency of a firm relative to other firms in a comparable environment (i.e. within the same industry and/or country). As a result, the DEA efficiency scores range from 0 to 1. Firms with efficiency scores close to 1 are considered to be more efficient than those on the other end of the scale.

As mentioned earlier, we adopt the DEA method to estimate technical efficiency in this paper. Since DEA is a non-parametric technique, it has the advantage that the functional form of the production function does not need to be specified. Another benefit of using the DEA approach is that it does not make any *a-priori* distinction between the relative importance of output and inputs in a firm's decision making process. Finally, the DEA method has the advantage that the efficiency measurements are similar regardless of whether the efficiency estimates are 'input-oriented' (i.e. whether firms can reduce their input usage to

produce a given level of output) or ‘output-oriented’ (i.e. whether firms can increase their output level for a given set of inputs).<sup>3</sup>

DEA also has several limitations. For example, DEA estimates can be highly sensitive to measurement errors in outputs and inputs since production functions are estimated using a small number of the most efficient firms. In addition, using a high number of inputs can cause all or most of the firms to be rated as efficient (Leibenstein and Maital 1992). To minimize potential measurement errors in output, we use sales as an output variable, which typically has less measurement errors in surveys. To minimize potential measurement errors in inputs and to avoid the problem of using a high number of inputs, we only include two inputs: labor and capital.

The DEA approach is illustrated in Figure 1. Here,  $X$  is an index of inputs and  $Y$  is an index of output(s). The straight line  $OF$  and the concave line  $ABCDE$  represent the deterministic production frontier under *constant returns to scale* (CRS) and *variable returns to scale* (VRS) respectively. Suppose a firm produces at point  $H$  with output  $G$  and a given amount of input  $K$ . Under the DEA method, efficiency can be defined in four different ways: (1)  $E_1 = (GI/GH)$  measures input-oriented efficiency under CRS, (2)  $E_2 = (GJ/GH)$  measures input-oriented efficiency under VRS, (3)  $E_3 = (KH/KF)$  measures output-oriented efficiency under CRS, and (4)  $E_4 = (KH/KL)$  measures output-oriented efficiency under VRS.

In this paper, we only focus on the efficiency estimates under VRS, although both CRS and VRS have been previously used in the literature. Zheng et al. (1998) suggests that when the CRS and VRS efficiency estimates are significantly different, the latter is preferred. Results from  $F$ -tests suggest that our efficiency estimates under CRS are statistically different from those under VRS at the 5 percent level of statistical significance. Therefore, we focus on input-oriented ( $E_2$ ) and output-oriented ( $E_4$ ) efficiency estimates under VRS production technology.

There are two reasons why we consider both  $E_2$  and  $E_4$  as measures of efficiency. First, results from  $t$ -tests indicate that although strongly correlated, they are statistically different.<sup>4</sup> Second, it is not clear *a priori* which measure may be more relevant for firms in Ghana. On one hand, if firms in these countries operate at a less-than-optimal scale due to excessive use of inputs, the use of the input-oriented efficiency  $E_2$  may be more relevant. On the other hand, if firms deliberately choose to maintain excess capacity (for example, to meet unexpected

<sup>3</sup> This is true in our data as well. We find that the correlation between the efficiency estimates under input-oriented approach and output-oriented approach is 0.92.

<sup>4</sup> Two separate  $t$ -tests were performed. The first  $t$ -test performed a paired test of the hypothesis that  $(E_2 - E_4)$  has a mean of zero. The second  $t$ -test performed a two-sample  $t$ -test of the hypothesis that the mean of  $E_2$  equals mean of  $E_4$ .

surge in demand), the use of the output-oriented efficiency  $E_4$  may be more appropriate. In the standard DEA literature, both input-oriented and output-oriented efficiency measures have been used.

We calculate both input-oriented and output-oriented efficiency using information on three inputs: labor, capital, and materials. We restrict the number of inputs to these three variables to decrease the likelihood of overstating firm efficiency. As discussed by Leibenstein and Maital (1992), using a high number of inputs can cause all or most of the firms to be rated as efficient. Furthermore, since our data may not be comparable across time or industry, we construct a cross-sectional frontier for each industry for each year in the sample and pool the efficiency scores together. This is consistent with other studies in the literature (Zheng et al. 1998).<sup>5</sup>

### Determinants of Technical Efficiency

We now proceed to identify the determinants of technical efficiency for manufacturing firms in Ghana. The estimating equation is as follows:

$$\begin{aligned} \text{efficiency}_{it} = & \alpha_0 + \alpha_1 \ln \text{age}_{it} + \alpha_2 \ln \text{age}_{it}^2 + \alpha_3 \ln \text{size}_{it} + \alpha_4 \ln \text{size}_{it}^2 \\ & + \alpha_5 \ln(\text{labor} / \text{capital})_{it} + \alpha_6 \text{ownership}_{it} + \varepsilon_{it} \end{aligned} \quad (1)$$

The dependent variable  $\text{efficiency}_{it}$  measures firm  $i$ 's technical efficiency in year  $t$ . It is estimated using the DEA technique and has a value between 0 and 1. The variable  $\ln \text{age}_{it}$  is the natural log value of firm  $i$ 's age measured in years. The variable  $\ln \text{size}_{it}$  is the natural log value of firm  $i$ 's size measured in terms of the number of its employees. The variable  $\ln(\text{labor} / \text{capital})_{it}$  measures the ratio between labor and capital. Finally, the variable  $\text{ownership}_{it}$  takes the value of 0 for domestically owned firms and takes the value of 1 for foreign owned firms. We also include square terms for firm's age and size to control any non-linearity in the age-efficiency and size-efficiency relationships. In addition, we include dummy variables for industry and year in all regressions to control any unobserved industry-specific or time-specific shocks.<sup>6</sup> We estimate equation (1)

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<sup>5</sup> For a discussion of various method regarding applications of DEA using panel data, see Tulkens and Vanden Eeckaut (1995).

<sup>6</sup> See Zheng, Liu and Bigsten (1998) for similar treatment. Potential differences in FDI regulations across industries and regions can be a concern. However, we do not have specific information on FDI regulations in different manufacturing industries and regions in Ghana (according to a 2005 OECD report, this information is not publicly available). So, we do not know whether there are industry and regional differences in FDI regulations. In order to control for potential industry



primarily using Ordinary Least Squares (OLS) methods. Since the efficiency estimates are bounded between 0 and 1, we also use the Tobit Maximum Likelihood Estimation method to check the robustness of our results.

The firm-level data used in this paper comes from the Center for the Study of African Economics at the University of Oxford. It contains information on firm characteristics such as output, capital and materials (both measured in real U.S. dollar terms, deflated using producer price series) as well as other information such as the number of employees and the firm's age (in years). The data covers six industries within the manufacturing sector – textiles, garment, machinery and chemical, food, furniture, and wood – and spans the period between 1991 and 2002. The data includes 48 observations from the textile industry, 355 observations from the garment industry, 153 observations from the wood industry, 363 observations from the furniture industry, 401 observations from the food industry and 417 observations from the machinery industry. Hence, there are 1,737 observations in the sample data, out of which 338 observations represent foreign owned firms (24 percent of the data). On average, a firm's age is approximately 18 years and its size is approximately 72 employees. Table 2 presents the summary statistics.

## 4. RESULTS

### Technical Efficiency Estimates

In this section, we present the DEA efficiency estimates and discuss their rankings along several dimensions, such as industry, year, ownership, firm age and firm size. Table 4(a) presents mean efficiency measured by six industries in Ghana. Overall mean efficiency for manufacturing firms in Ghana is 55 percent under VRS input-oriented measurement ( $E_2$ ) and 54 percent under VRS output-oriented measurement ( $E_4$ ). These efficiency figures are significantly lower than those reported in other comparable studies which examine the efficiency of firms in different countries using the DEA method. This can be seen from Table 3, which lists the mean efficiency estimates for firms in Chile (65.0 percent, manufacturing), China (82.5 percent, manufacturing), and several other countries.

Table 4(a) also shows that among the six industries, the textile and garment industries seem to be relatively more efficient, while the furniture industry appears to be relatively less efficient. Results from  $F$ -test confirm that there is a substantial variation in technical efficiency across different industries. For example, firms in the textile industry have an average input-oriented

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differences, we use industry dummies in our regression analysis. However, we cannot control for regional differences due to lack of regional information in our dataset.

efficiency of 84 percent whereas firms in the furniture industry have an average input-oriented efficiency of 49 percent.

Table 4(b) presents the efficiency scores over time. Results from *F*-tests suggest that neither input-oriented efficiency nor output-oriented efficiency changed significantly over time. This may suggest a stagnation of the technical efficiency in Ghana's manufacturing sector during the period. According to Teal (1999), while real value-added in Ghana's manufacturing sector grew by 21 percent between 1991 and 1995, there was no improvement in productivity during this period. This suggests that the country's economic growth may have had little impact on the efficiency of individual firms.

Table 4(c) reports the efficiency scores for firms under foreign and domestic ownership. *F*-tests show no statistical difference in input-oriented efficiency under domestic and foreign ownership among firms in Ghana ( $p > F = 0.15$ ). However, foreign owned firms appear to be relatively more efficient when output-oriented efficiency is used. This may imply that there is an efficiency gap between domestically owned firms and foreign owned firms when the efficiency measures focus on production possibilities rather than excessive input usage.

Table 4(d) presents efficiency rankings over firm age. The results show that there is a positive relationship between the output-oriented efficiency and age of firms in Ghana, implying that older firms, on average, produce closer to their production frontier than younger firms for a given level of inputs. However, the relationship between input-oriented efficiency and age appears to be statistically insignificant for Ghana. This suggests that the relationship between firm age and efficiency may be somewhat dependent upon whether we use input-oriented efficiency or output-oriented efficiency.

Finally, Table 4(e) and 4(f) present efficiency rankings by firm size across six industries. Results from the *F*-tests indicate that technical efficiency varies with firm size. In particular, the results show that the relationship between firm size and efficiency may be nonlinear. Mean efficiency rankings show that smaller and larger firms appear to be relatively more efficient than medium size firms across all six industries.

### **Determinants of Efficiency: Econometric Findings**

We now discuss the regression results obtained by estimating equation (1). Note that all estimations are performed with heteroskedasticity-robust standard errors. As mentioned before, we include industry and year dummies in the regressions, but do not report them here due to space limitations.

First, we observe that the relationship between firm size and efficiency is statistically significant and non-linear. This can be seen from Table 5, which

reports the OLS results when all firms across the six industries are pooled together and measures of input-oriented efficiency and output-oriented efficiency are used as dependent variables respectively. In both cases, the coefficients on firm size are negative and statistically significant, while the coefficients on the square of firm size are positive and statistically significant. This implies that technical efficiency initially decreases with firm size, but increases beyond a threshold size. Based on the estimated parameters and predicted values of efficiency, we notice that input-oriented efficiency decreases with size for firms that employ less than 100 employees and output-oriented efficiency decreases with size for firms that employ less than 30 employees. Beyond these threshold limits, efficiency increases with firm size, but at a decreasing rate. We observe the same relationship between size and efficiency within each industry as well. As shown in Tables 6(a) and 6(b), efficiency decreases with size for relatively smaller firms, but increases afterwards for larger firms, regardless of the nature of the industry. It is not quite clear to us why relatively smaller firms fail to become more efficient with an expansion in size, but we observe this pattern consistently in our data. It seems that smaller firms may need to reach a certain critical size before they can experience the benefits of expansion (such as greater market power, access to better resources, and scale economies).

Second, we find that the relationship between a firm's age and its efficiency is somewhat tenuous. When tested using pooled data across all six industries (as shown in Table 5), only the coefficient on the square of firm age appears to be positive and statistically significant. This indicates that experience has an impact on efficiency only for very experienced firms. Given the estimated parameters and predicted value of efficiency, we notice that input-oriented efficiency is 7 percent higher for firms with 30 years of experience and output-oriented efficiency is 10 percent higher for firms with 30 years of experience compared to a new firm. When the relationship between efficiency and firm age is examined at the industry level (as shown in Tables 6a-6b), the coefficient on firm age appears to be statistically significant only for the textile and food industries. This mixed result is similar to that of Lundvall and Battese (2000) and suggests that the relationship between firm age and efficiency is industry specific in nature.<sup>7</sup> This result also provides some support to the idea that government policies should be tailored for each industry.

Third, we discover that firms in Ghana which use a greater mix of labor and capital (i.e. a higher labor-capital ratio) during the production process are more efficient. This can be seen from the results in Table 5, which are obtained by

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<sup>7</sup> Lundvall and Battese (2000) employ the SFA technique rather than DEA. They examine the relationship between firm age and efficiency for Kenyan manufacturing firms in four industries: food, textile, metal and wood. They find that firm age is statistically insignificant in all industries except textile.

combining data across all industries. The results in Tables 6(a) and 6(b) suggest that an increase in the labor-capital mix increases efficiency in all but the garment industry. This finding is consistent with Ghana's comparative advantage in labor-intensive production. From a policy perspective, this finding also implies that previous efforts to pursue import-substitution industrialization policies in Ghana may have adversely affected the efficiency of its manufacturing firms. As previous studies have shown, these industrialization policies may have encouraged some firms to over-invest in capital-intensive activities in the past and create excess capacity (Steel 1972). Thus, over-investment in capital-intensive activities may have led to lower efficiency among manufacturing firms which may actually have a comparative advantage in labor-intensive activities.

Fourth, we find that there is a positive relationship between foreign ownership and the efficiency of manufacturing firms in Ghana. The OLS results in Table 5 indicate that, on average, firms in Ghana under foreign ownership are approximately 5-7 percent more efficient depending on whether we are looking at output-oriented efficiency or input-oriented efficiency. When the effect of foreign ownership on firm efficiency is examined at the industry level, as shown in Tables 6(a) and 6(b), the coefficient on foreign ownership still seems to be positive and statistically significant in five out of six industries when input-oriented efficiency is used and in four out of six industries when output-oriented efficiency is used. These findings have implications for Ghana's efforts to liberalize its economy and attract FDI. As mentioned earlier, FDI inflows to Ghana grew significantly during the 1990s, largely due to major policy efforts to create a good environment for foreign investors. Our empirical results suggest that foreign ownership may have been beneficial for the efficiency of manufacturing firms in Ghana by giving local firms access to superior foreign technology, management talents and an established distribution network, etc.

Finally, to check the validity of our results, we estimate equation (1) using Tobit analysis since the values of technical efficiency are bounded between 0 and 1. The results for the full sample are reported in Table 7. These results are very similar to the OLS estimates reported in Table 5. Although not reported here, the Tobit results for each industry also resemble the industry-specific results in Tables 6(a) and 6(b) closely.

## **5. CONCLUSION**

This paper provides some insights on the technical efficiency of manufacturing firms in Ghana. Using the DEA technique, we observe that the overall mean efficiency of manufacturing firms in Ghana ranges between 54 and 55 percent. These figures are much lower than those reported in comparable studies on manufacturing efficiency in other countries. For example, Zheng et al. (1998)

estimate the mean efficiency of Chinese manufacturing firms to be around 82 percent, while Alvarez and Crespi (2003) estimate the mean efficiency of manufacturing firms in Chile to be around 65 percent. Our econometric analysis suggests that an increase in: (1) size, (2) foreign ownership and (3) labor-capital mix are associated with an improvement in the efficiency of manufacturing firms in Ghana. These results are similar across most industries in our sample and are robust under different scenarios.

One limitation of our results is that we cannot account for the possibility that some of the efficiency differences across different industries may be due to differences in transport costs (e.g. furniture) or trade barriers across those industries. According to *WTO Tariff Profiles* (2006), the tariff rates in Ghana vary quite a bit by industry. For example, average tariff rates were 86% in animal and dairy products (a subset of the food industry), 45% in textiles, 40% in wood, and 30% in machinery industry respectively. During this period, the average output and input oriented efficiency in Ghana was 0.54-0.56 in food, 0.82-0.84 in textiles, 0.53 in wood, and 0.50-0.52 in machinery (see Table 4a). These data points do not exhibit a clear relationship between industry efficiency and industry trade barriers, but we cannot rule out the existence of such a relationship based on only a few data points. Unfortunately, detailed information on tariff and transport barriers for Ghana's industries is not publicly available. So, with our existing dataset, it is not possible to empirically examine the effect of differences in trade and transport barriers in different industries on the efficiency of firms in those industries. We hope that future researchers can address this issue with the help of more detailed dataset.

Our results have several policy implications. First, policies designed to help small firms grow may help them become more efficient in the future. Second, government policies that attract foreign investors and foreign owners may help improve the efficiency of local firms by giving them access to superior foreign technology, management talents, etc. Third, import-substitution industrialization policies may not have the desired effects on firm efficiency. These policies may result in the injection of additional physical capital into industries which are labor-intensive in nature. These industries may not find the additional physical capital useful unless it is complemented by additional human capital. Policymakers in Ghana should therefore carefully evaluate their past experience with import-substitution industrialization policies before embarking on similar programs in the future.

While our analysis is by no means comprehensive (especially due to the limited nature of our dataset), our results provide an important first step in understanding the various factors which affect Ghana's manufacturing efficiency. These results also lend some support to the notion that manufacturing firms in developing countries like Ghana, on average, need to become more efficient. We

hope these findings will pave the way for future research on the efficiency of firms in Ghana and other developing countries in Sub-Saharan Africa.

**APPENDIX**

**Table 1: Growth in Real GDP and Manufacturing Value Added**

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Real GDP Growth (Percent)	4	5	3	4	5	4	5	4	4	4	4
Manufacturing Value Added (Percent of GDP)	17	25	25	24	24	26	25	25	25	25	25

Source: *World Development Indicators*, The World Bank

**Table 2: Summary Statistics**

	Mean	Std. Deviation
Real Output (in 1,000 US \$)	917.27	3,166.00
Real Capital (in 1,000 US \$)	986.95	4,186.24
Labor (no. of workers)	71.99	158.32
Firm Age (in years)	17.92	12.09
Foreign Ownership Dummy	0.19	0.40
Observation	1737	

**Table 3: Mean Technical Efficiency in Previous Studies**

Country	Industry	Mean Efficiency (Percentage)	Year	Methodology	Source
Australia	Dairy	82.1	2000	DEA, Bayesian, Classical	Balcombe et. al (2006)
Bangladesh	Farming	80.0	1997	DEA	Wadud (2003)
Chile	Manufacturing	65.0	1998	DEA	Alvarez and Crespi (2003)
China	Manufacturing	82.5	1986-1990	DEA	Zheng et. al (1998)

**Table 4(a): Mean Efficiency by Industry**

	Mean VRS Input- oriented ( $E_2$ )	Std. Dev.	$F$ -Test	Mean VRS Output- oriented ( $E_4$ )	Std. Dev.	$F$ -Test	Obs.
All Industries	0.55	0.25		0.52	0.25		1737
Textile	0.84	0.17	$F = 23.69$	0.82	0.19	$F = 23.68$	48
Garment	0.60	0.23	$p > F = 0.00$	0.58	0.23	$p > F = 0.00$	355
Wood	0.53	0.26		0.53	0.26		153
Furniture	0.49	0.25		0.44	0.25		363
Food	0.56	0.25		0.54	0.27		401
Machinery	0.52	0.23		0.50	0.23		417

**Table 4(b): Mean Efficiency by Year**

	Mean VRS Input- oriented ( $E_2$ )	Std. Dev.	$F$ -Test	Mean VRS Output- oriented ( $E_4$ )	Std. Dev.	$F$ -Test	Obs.
1991	0.54	0.26	$F = 0.90$	0.50	0.27	$F = 1.20$	156
1992	0.56	0.26	$p > F = 0.54$	0.53	0.26	$p > F = 0.28$	160
1993	0.55	0.24		0.53	0.24		150
1994	0.58	0.24		0.57	0.24		168
1995	0.57	0.24		0.54	0.24		168
1996	0.54	0.25		0.51	0.25		167
1997	0.52	0.25		0.49	0.24		167
1998	0.56	0.25		0.54	0.26		137
1999	0.57	0.26		0.53	0.27		136
2000	0.54	0.24		0.52	0.26		109
2001	0.54	0.25		0.52	0.26		109
2002	0.54	0.25		0.50	0.26		110

**Table 4(c): Mean Efficiency by Ownership**

	Mean VRS Input- oriented ( $E_2$ )	Std. Dev.	$F$ -test	Mean VRS Output- oriented ( $E_4$ )	Std. Dev.	$F$ -test	Obs.
GHANA							
0	0.55	0.24	$F = 2.04$	0.52	0.24	$F = 9.11$	1399
1	0.57	0.28	$p > F = 0.15$	0.56	0.28	$p > F = 0.00$	338

NOTE: 0 = Domestic ownership; 1 = Foreign ownership

**Table 4(d): Mean Efficiency by Firm Age**

	Mean VRS Input- oriented ( $E_2$ )	Std. Dev.	$F$ -test	Mean VRS Output- oriented ( $E_4$ )	Std. Dev.	$F$ -test	Obs.
GHANA							
1-5 yrs.	0.55	0.24	$F = 0.16$	0.50	0.25	$F = 3.21$	226
6-10 yrs.	0.54	0.23	$p > F = 0.92$	0.49	0.24	$p > F = 0.02$	298
11-20 yrs.	0.55	0.25		0.53	0.25		609
over 20 yrs.	0.55	0.26		0.54	0.26		604

**Table 4(e): Mean Efficiency by Industry and Firm Size  
(VRS Input-oriented:  $E_2$ )**

	Overall	Textile	Garment	Wood	Furniture	Food	Machinery
Micro (1-4)	0.81	1.00	0.80	1.00	0.89	0.79	0.83
Small (5-20)	0.56	0.95	0.57	0.86	0.58	0.54	0.52
Medium (21-100)	0.47	0.76	0.51	0.54	0.36	0.51	0.43
Large (101-500)	0.52	N/A	0.70	0.47	0.39	0.59	0.59
Super (over 500)	0.71	0.93	N/A	0.54	0.79	0.46	0.59
$F$	79.76	5.45	30.22	7.61	38.24	10.52	32.00
$p > F$	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Observations	1737	48	355	153	363	401	417



**Table 4(f): Mean Efficiency by Industry and Firm Size  
(VRS Output-oriented:  $E_4$ )**

	Overall	Textile	Garment	Wood	Furniture	Food	Machinery
Micro (1-4)	0.66	1.00	0.67	1.00	0.58	0.59	0.70
Small (5-20)	0.50	0.84	0.54	0.80	0.47	0.50	0.47
Medium (21-100)	0.49	0.75	0.58	0.52	0.39	0.53	0.44
Large (101-500)	0.54	N/A	0.75	0.49	0.40	0.63	0.62
Super (over 500)	0.73	0.93	N/A	0.58	0.79	0.49	0.60
$F$	23.93	3.64	7.54	5.08	8.42	3.72	16.13
$p > F$	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Observations	1737	48	355	153	363	401	417

**Table 5: Determinants of Efficiency: OLS Regression**

	Input Oriented Efficiency	Output Oriented Efficiency
Age	-0.03 (0.03)	-0.03 (0.03)
Age-squared	0.01 <sup>b</sup> (0.01)	0.01 <sup>c</sup> (0.01)
Size	-0.27 <sup>a</sup> (0.02)	-0.13 <sup>a</sup> (0.02)
Size-squared	0.03 <sup>a</sup> (0.00)	0.02 <sup>a</sup> (0.00)
Labor-capital mix	0.03 <sup>a</sup> (0.00)	0.04 <sup>a</sup> (0.00)
Foreign Ownership	0.07 <sup>a</sup> (0.02)	0.05 <sup>a</sup> (0.02)
Constant	1.51 <sup>a</sup> (0.05)	1.22 <sup>a</sup> (0.03)
$R$ -squared	0.28	0.19
Observations	1,737	1,737

NOTES: Table 5 reports the results of estimating equation (1) via OLS. Dependent variables are firm-level input-oriented and output-oriented efficiency respectively (under variable returns-to-scale production frontier). The notations  $a$ ,  $b$ , and  $c$  represent statistical significance at 1 percent, 5 percent, and 10 percent respectively. Heteroskedasticity-robust standard errors are in parenthesis. Industry and year dummies are included but not reported. All variables are expressed in natural logarithm, except the indicator variable for foreign ownership.

**Table 6(a): Determinants of Input-Oriented Efficiency by Industry**

	Textile	Garment	Wood	Furniture	Food	Machinery
Age	- 3.15 <sup>c</sup> (1.61)	0.03 (0.05)	- 0.13 (0.27)	- 0.01 (0.04)	- 0.05 (0.07)	- 0.05 (0.05)
Age-squared	0.56 <sup>b</sup> (0.27)	- 0.01 (0.01)	0.02 (0.04)	0.01 (0.01)	0.02 <sup>c</sup> (0.01)	0.03 (0.01)
Size	- 0.33 <sup>a</sup> (0.09)	- 0.47 <sup>a</sup> (0.04)	- 0.34 <sup>a</sup> (0.07)	- 0.53 <sup>a</sup> (0.03)	- 0.25 <sup>a</sup> (0.04)	- 0.21 <sup>a</sup> (0.04)
Size-squared	0.02 <sup>a</sup> (0.01)	0.08 <sup>a</sup> (0.01)	0.03 <sup>a</sup> (0.01)	0.07 <sup>a</sup> (0.00)	0.04 <sup>a</sup> (0.01)	0.03 <sup>a</sup> (0.01)
Labor-capital mix	0.03 <sup>b</sup> (0.01)	- 0.01 (0.01)	0.64 <sup>a</sup> (0.01)	0.04 <sup>a</sup> (0.01)	0.04 <sup>a</sup> (0.01)	0.06 <sup>a</sup> (0.01)
Foreign Ownership	0.11 (0.07)	- 0.11 <sup>a</sup> (0.04)	0.10 <sup>b</sup> (0.04)	- 0.07 <sup>c</sup> (0.03)	0.10 <sup>a</sup> (0.03)	0.14 <sup>a</sup> (0.03)
Constant	5.28 <sup>b</sup> (2.38)	1.12 <sup>a</sup> (0.09)	2.13 <sup>a</sup> (0.47)	1.64 <sup>a</sup> (0.09)	1.13 <sup>a</sup> (0.12)	1.46 <sup>a</sup> (0.08)
R-squared	0.71	0.31	0.44	0.47	0.28	0.42
Observations	48	355	153	363	401	417

NOTES: Table 6(a) reports the results of estimating equation (1) via OLS for each industry. Dependent variable is firm-level input-oriented efficiency under variable returns-to-scale production frontier. The notations *a*, *b*, and *c* represent statistical significance at 1 percent, 5 percent, and 10 percent respectively. Heteroskedasticity-robust standard errors are in parenthesis. Year dummies are included but not reported. All variables are expressed in natural logarithm, except the indicator variable for foreign ownership.

**Table 6(b): Determinants of Output-Oriented Efficiency by Industry**

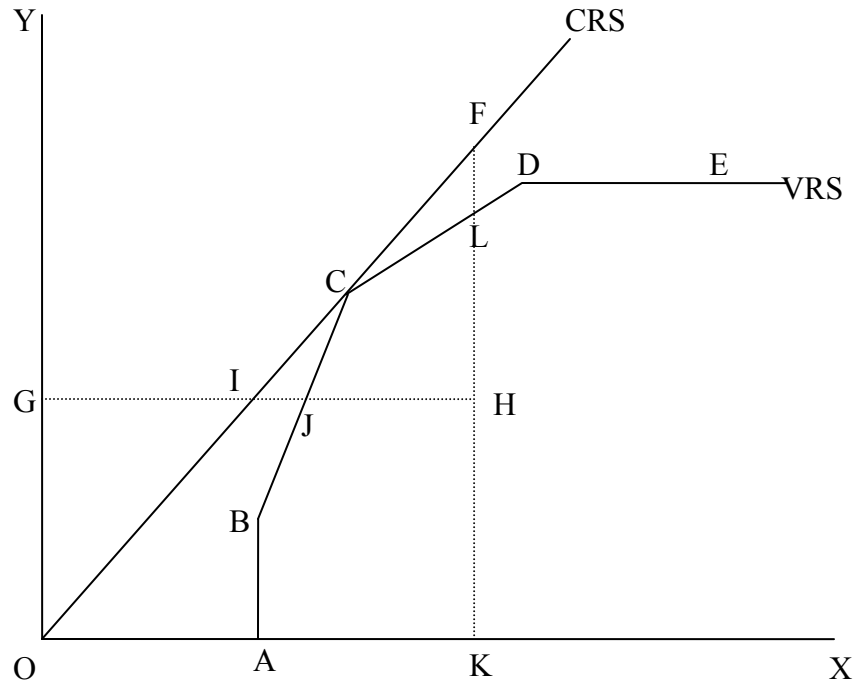
	Textile	Garment	Wood	Furniture	Food	Machinery
Age	-4.28 <sup>a</sup> (1.41)	-0.01 (0.06)	-0.14 (0.27)	0.04 (0.06)	-0.10 (0.07)	-0.07 (0.05)
Age-squared	0.75 <sup>a</sup> (0.24)	0.01 (0.01)	0.03 (0.04)	-0.00 (0.01)	0.03 <sup>b</sup> (0.01)	0.01 (0.01)
Size	-0.36 <sup>a</sup> (0.08)	-0.34 <sup>a</sup> (0.05)	-0.34 <sup>a</sup> (0.08)	-0.24 <sup>a</sup> (0.05)	-0.08 (0.05)	-0.09 <sup>c</sup> (0.04)
Size-squared	0.03 <sup>a</sup> (0.01)	0.06 <sup>a</sup> (0.00)	0.04 <sup>a</sup> (0.01)	0.04 <sup>a</sup> (0.01)	0.02 <sup>a</sup> (0.01)	0.02 <sup>b</sup> (0.01)
Labor-capital mix	0.06 <sup>a</sup> (0.02)	-0.00 (0.00)	0.08 <sup>a</sup> (0.02)	0.05 <sup>a</sup> (0.01)	0.06 <sup>a</sup> (0.01)	0.07 <sup>a</sup> (0.01)
Foreign Ownership	0.19 <sup>a</sup> (0.06)	-0.05 (0.05)	0.11 <sup>b</sup> (0.05)	-0.09 <sup>b</sup> (0.04)	0.04 (0.03)	0.15 <sup>a</sup> (0.03)
Constant	6.91 <sup>a</sup> (2.12)	0.91 <sup>a</sup> (0.11)	2.14 <sup>a</sup> (0.49)	0.97 <sup>a</sup> (0.13)	0.97 <sup>a</sup> (0.13)	1.29 <sup>a</sup> (0.08)
R-squared	0.79	0.17	0.41	0.21	0.28	0.37
Observations	48	355	153	363	401	417

NOTES: Table 6(b) reports the results of estimating equation (1) via OLS for each industry. Dependent variable is firm-level output-oriented efficiency under variable returns-to-scale production frontier. The notations *a*, *b*, and *c* represent statistical significance at 1 percent, 5 percent, and 10 percent respectively. Heteroskedasticity-robust standard errors are in parenthesis. Year dummies are included but not reported. All variables are expressed in natural logarithm, except the indicator variable for foreign ownership.

**Table 7: Determinants of Efficiency: Tobit Regression**

	Input Oriented Efficiency	Output Oriented Efficiency
Age	-0.04 (0.03)	-0.04 (0.03)
Age-squared	0.01 <sup>b</sup> (0.01)	0.01 <sup>b</sup> (0.01)
Size	-0.31 <sup>a</sup> (0.02)	-0.15 <sup>a</sup> (0.02)
Size-squared	0.04 <sup>a</sup> (0.00)	0.02 <sup>a</sup> (0.00)
Labor-capital mix	0.03 <sup>a</sup> (0.00)	0.04 <sup>a</sup> (0.00)
Foreign Ownership	0.07 <sup>a</sup> (0.02)	0.06 <sup>a</sup> (0.02)
Constant	1.64 <sup>a</sup> (0.03)	1.32 <sup>a</sup> (0.03)
Pseudo <i>R</i> -squared	0.76	0.45
Observations	1,737	1,737

NOTES: Table 7 reports the results of estimating equation (1) via Tobit since the value of the dependent variable is bounded between 0 and 1. Dependent variables are firm-level input-oriented and output-oriented efficiency respectively (under variable returns-to-scale production frontier). The notations *a*, *b*, and *c* represent statistical significance at 1 percent, 5 percent, and 10 percent respectively. Heteroskedasticity-robust standard errors are in parenthesis. Industry and year dummies are included but not reported. All variables are expressed in natural logarithm, except the indicator variable for foreign ownership.



**Figure 1: Illustration of Efficiency Measure**

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