Economic Modelling 50 (2015) 179–192

Contents lists available at ScienceDirect

Economic Modelling

journal homepage: www.elsevier.com/locate/ecmod

A "true" random effects stochastic frontier analysis for technical efficiency and heterogeneity: Evidence from manufacturing firms in Ethiopia

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ARTICLE INFO

Article history:
Accepted 23 June 2015
Available online xxxx

Keywords:
Stochastic frontier analysis
"True" random effects
Unobserved heterogeneity
Technical efficiency
Ethiopian manufacturing sector

ABSTRACT

This study examines the technical efficiency of the Ethiopian manufacturing sector using establishment-level census panel data over the period of 2000 to 2009. The "true" random effects stochastic frontier model (Greene, 2005a,b), which can disentangle time-varying technical inefficiency from time-invariant unobserved heterogeneity, and the conventional fixed and random effects models are used to estimate efficiency for the aggregated and individual industry groups. The results indicate that efficiency estimates are sensitive to model specifications of firm-specific unobserved heterogeneity. We find a significant gap in efficiency estimates between the "true" random effects model and the fixed and random effects models, which would imply considerable heterogeneity of manufacturing firms in Ethiopia. Our results suggest that firm-specific heterogeneity would be particularly significant in the food and beverages, non-metals, and furniture industries. We also show that the production of the Ethiopian manufacturing sector is largely responsive to changes in intermediate inputs compared to labor and capital inputs. The estimated technical efficiency considerably varies across firms within an industry suggesting a significant potential for improving efficiency in the sector. We discuss that the major problem for the variation in efficiency is the inability of firms to operate at their full production capacity, which was mainly caused by shortage of raw material supply. Generally, it is important to differentiate between inefficiency and unobserved heterogeneity in a stochastic frontier framework when firms operate under diverse social, industrial and environmental conditions.

1. Introduction

Given the importance of technical efficiency as a firm's performance indicator, many scholars have attempted to measure efficiency and identify the factors that cause efficiency variations among manufacturing firms. Some of the empirical studies on the question of efficiency in African manufacturing industries include Soderbom and Teal (2004) for Ghana's manufacturing, Aggrey et al. (2010) for Kenyan, Tanzanian and Ugandan manufacturing industries, and Ngui-Muchai and Muniu (2012) for Kenyan manufacturing. Soderbom and Teal (2004) argued that manufacturing firms in Africa are less efficient compared to their counterparts in the developed world.

Despite the widely believed view of the central role of the manufacturing sector in economic transformation of nations, the Ethiopian manufacturing sector may not have performed up to its expectation. Its share of GDP remains stagnant at about 14% (African Development Bank, 2010). The sector is dominated by simple agro-processing activities and production of basic consumer goods. Most manufacturing exports are agriculture-based, which include clothing, semi-processed hides, footwear, beverages and others. However, Dinh et al. (2012) discussed that Ethiopia may take advantage of its low-cost labor, particularly in light manufacturing including textile, wood products, leather products and apparel industries. By comparing the cost of labor of the leather industry in China and the leather shoe industry in Ethiopia, Sonobe et al. (2009) suggested that potentially Ethiopia has a comparative advantage in the shoe industry.

The main objectives of this study are twofold: (1) to determine the effect of firm-specific unobserved heterogeneity in measuring technical efficiency under different specifications of stochastic frontier models and (2) to investigate the technical efficiency performance of the Ethiopian manufacturing sector using unbalanced panel data (census data) over the period of 2000 to 2009. Thus far, there have been only limited attempts to study the efficiency performance of the manufacturing sector in Ethiopia (Abegaz, 2013; Bekele and Belay, 2007; Gebeyehu, 2003; Kinda et al., 2009; Kuma, 2002). Most, if not all, of these studies use stochastic frontier models of the type by Battese and Coelli (1992, 1995). However, the inherent problem of these models is that firm-specific unobserved heterogeneity is not treated explicitly in the analyses. This generates a misspecification bias in the presence of time-invariant unobservable factors (e.g., firm-specific innate ability). The effect of these factors, unrelated to the production process but affecting the output, may

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http://dx.doi.org/10.1016/j.econmod.2015.06.015
0264-9993/

be captured by the inefficiency term, thereby producing biased results. To address this problem, the present study applies a recently proposed stochastic frontier model called the "true" random effects (TRE) model (Greene, 2005a,b). This approach enables us to disentangle time-varying inefficiency from firm-specific time-invariant unobserved heterogeneity. This is particularly useful for the analysis of diverse and heterogeneous manufacturing firms in Ethiopia.[1] We also use the conventional fixed effects (FE) and random effects (RE) stochastic frontier models to examine how the specification of the unobserved heterogeneity affects the estimation results.

This study contributes to the existing literature of stochastic frontier analysis (SFA) in the following way. To the best of the authors' knowledge, this is the first large-scale panel SFA to address the problem of unobserved heterogeneity in measuring technical efficiency for nationwide manufacturing firms. Focusing on the Ethiopian manufacturing sector, we examine to what extent the technical efficiency estimates are affected by the different econometric specifications of the unobserved heterogeneity. Previous studies on efficiency performance in the Ethiopian manufacturing sector are scarce, and their scope is limited to specific industries giving only partial view of the sector, which may not be representative of the whole manufacturing. We thus fill this gap by providing evidence on the efficiency performance based on comprehensive and more recent dataset covering the entire Ethiopian manufacturing sector. It will provide policy implications on possible areas for further improvement in the manufacturing sector.

Our results indicate that efficiency estimates are sensitive to model specifications of the firm-specific unobserved heterogeneity. We find a significant gap in efficiency estimates between the TRE model and the FE and RE models, which would imply considerable heterogeneity of manufacturing firms in Ethiopia. The conventional FE and RE models seem to underestimate the efficiency estimates since the firm-specific unobserved heterogeneity is confounded with the inefficiency term. Our results suggest that the firm-specific unobserved heterogeneity would be particularly significant in the food and beverages, non-metals, and furniture industries due to the more heterogeneous mix of firms in these industries. We also find that the production of the Ethiopian manufacturing sector is largely responsive to changes in intermediate inputs compared with labor and capital inputs. With regard to efficiency estimates, we find that the technical efficiency considerably varies across firms within an industry. Efficiency estimates across industries in the TRE model range from 68.4 in the fabricated metal industry to 88.2% in the textile industry, and the overall mean efficiency for the whole manufacturing sector is estimated to be 74%. We also find that the sector has experienced a positive trend of technological change, which may imply that firms have been involved in some innovative activities.

The rest of the paper is organized as follows. Section 2 summarizes literature review and the current status of the Ethiopian manufacturing sector. After describing the data and methodology used in the paper in Section 3, we proceed to present our empirical results in Section 4. Section 5 discusses the efficiency variations in the context of Ethiopian industries. Section 6 concludes the paper.

2. The Ethiopian manufacturing sector

2.1. Literature review on Ethiopian manufacturing

There is a large body of technical efficiency studies in the literature for manufacturing industries in developed countries. However, studies that use large census data for developing countries are scarce mainly due to limited availability of such data. In the case of Ethiopia, technical efficiency in the manufacturing sector is generally under-researched. Gebeyehu (2003) estimated technical efficiency differential among firms in the leather industry using SFA. The author found a general decline of the technical efficiency in the industry during 1996 to 1999. Bekele and Belay (2007) studied the technical efficiency of grain mill products in Ethiopian manufacturing for 1999. Kuma (2002) showed the widespread inefficiency in the manufacturing sector in Ethiopia for the period 1984–1999. Furthermore, Kinda et al. (2009) compared the labor productivity, total productivity and technical efficiency of the manufacturing sector of 22 countries using World Bank data for 2002. They examined only 5 industries (textile, leather, garment, agro-processing, and wood and furniture) for Ethiopia. Ethiopia is ranked 20th indicating the low performance of the sector in terms of technical efficiency. More recently, Abegaz (2013) studied the technical efficiency for Ethiopian manufacturing industries that employ 10 or more people for the period 1996–2009. The mean efficiency estimates for the overall sector was about 56%.

While the above studies help us understand the condition of the manufacturing sector in the country, they have some deficiencies that are addressed in this study. The data used in most of the studies appear to be rather old with the exception of Abegaz (2013). Studies such as Bekele and Belay (2007) and Kinda et al. (2009) were based on cross-sectional data. Most previous studies were limited to specific industries, not representative of the entire manufacturing sector, thus giving only a partial view of the sector. In contrast, our study uses panel data of recent 10 years and covers the entire manufacturing firms in Ethiopia. The richer set of information in the panel data allows a more realistic characterization of the inefficiencies. Moreover, the use of census data helps us obviate any bias that could arise from sampling variability.

Furthermore, the methodological approach that the previous studies employed raises issues of concern that directly affect the estimation procedure of the technical efficiency in the sector. Most of these studies used stochastic frontier models similar to Battese and Coelli (1992, 1995) to estimate technical efficiency. However, the inherent problem of these models is that firm-specific unobserved heterogeneity is not treated explicitly in the analysis. This generates a misspecification bias in the presence of time-invariant unobservable factors (e.g., firm-specific innate ability). The effect of these factors may be captured by the inefficiency term, thereby producing biased results. Kumbhakar et al. (2014) noted that the models of Battese and Coelli (1992, 1995) are restrictive and mix unobserved heterogeneity with the inefficiency term. This underestimates efficiency scores in the sector. For example, Abegaz (2013) applied Battese and Coelli's (1992) model with the assumption of time-invariant efficiency. However, this assumption seems to be unrealistic, particularly with relatively long unbalanced panel data of 14 years. To address this problem, the present study applies a recently proposed stochastic frontier model called the "true" random effects (TRE) model (Greene, 2005a,b) as discussed in the Introduction section. This approach enables us to disentangle time-varying inefficiency from firm-specific time-invariant unobserved heterogeneity.

2.2. Current status of the sector

In developing countries, the manufacturing sector plays a pivotal role in economic growth by its potential to create jobs for both skilled and unskilled laborers. For example, Page (2012) notes that the development of the manufacturing sector in East Asian countries has been of paramount importance for their economic growth. It is also argued that East Asian countries were able to rapidly and successfully retrain their farmers as manufacturing workers. However, it seems that Africa has failed thus far to bring about the structural change that has recently been seen in East Asian countries. The manufacturing industry is dominated by simple agro-processing activities and production of basic consumer goods. Industries that help to create technological capabilities and dynamism such as chemical, electrical and electronics, metal-processing and other engineering industries have not yet been developed. Most manufacturing exports are agriculture-based, which

[1] See, for example, Drine and Nabi (2010), Berta et al. (2010), and Abid and Drine (2011) for further discussion of the application of Greene's approach to various other fields.