Technical Efficiency of the Manufacturing Industry in Turkey: 2003-2008*

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Abstract

This study estimates a stochastic frontier production function for the manufacturing industry in Turkey, at the NACE Rev.1.1 four-digit level, for the period 2003-2008, and scrutinizes the determinants of technical efficiency. The motivation is that the most recent estimation does not go beyond 2001, making it difficult to draw inferences about technical efficiency of the manufacturing industry in Turkey within the past decade. The estimation results suggest that the manufacturing industry in Turkey exhibits increasing returns to scale, and that technical efficiency, which varies with time, is positively affected by the average firm size, and by the share of industry output in total manufacturing output.

Keywords: Stochastic Frontier Analysis; Technical Efficiency; Translog Production Function; Manufacturing Industry; Turkey

JEL Classification: D24, L60, O14

1. Introduction

This study estimates a stochastic frontier production function for the manufacturing industry in Turkey, at the four-digit level, for the period 2003-2008, and scrutinizes the determinants of technical efficiency. The estimation results suggest that there are increasing returns to scale in the manufacturing industry in Turkey, and that technical efficiency, which varies with time, is positively affected by average firm size and the share of industry output in total manufacturing industry output.

The motivation of this study is clear. The manufacturing industry plays a crucial role in Turkey's exports and economic growth, especially since the Planned Development period. Following the export-oriented policies and economic liberalization in the late 1980s, the manufacturing industry's share in Turkey's total exports has increased steadily. It is therefore important to measure technical efficiency of the manufacturing industry, and to determine what causes inefficiency in order to take measures to preserve and increase the

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manufacturing industry's competitiveness in Turkey. That said, the most recent estimation of technical efficiency of the manufacturing industry in Turkey does not go beyond 2001, making it difficult to draw inferences, especially for the last decade. To progress on this, I use the recent, publicly available, manufacturing industry data that is at the four-digit level - according to the NACE Rev.1.1 classification - and is provided by the Turkish Statistical Institute (TurkStat).

The rest of the paper is organized as follows. Section 2 gives a brief overview of the literature on the measurement of technical efficiency using frontier functions. Sections 3 and 4 introduce the econometric model, and the data and variables, respectively. Section 5 presents the estimation results, and Section 6 concludes.

2. Measuring technical efficiency: frontier functions

In the received literature on the measurement of technical efficiency, there are two different methods that are commonly used to estimate frontiers: the non-parametric mathematical programming (the data envelopment analysis) and the econometric modeling. In the data envelopment analysis (DEA), data is exploited so as to construct a non-parametric frontier. According to Greene (2008), the DEA produces a piecewise linear, quasi-convex hull around the data points in the input space. The observed best practice, thus, becomes a production frontier. As technical efficiency requires production on the frontier, the DEA calculates efficiency by comparing each producer with the best practicing producer. [1]

In the econometric modeling, either deterministic or stochastic frontier models are used. In deterministic frontier models, all deviations from the production frontier are treated as inefficiency (Aigner and Chu, 1968; Afriat, 1972; and Richmond, 1974). Consider, for example, the Cobb-Douglas production function, given by equation (1),

$$Y_i = AX_{1i}^{\beta_1} X_{2i}^{\beta_2} U_i \ , \tag{1}$$

where $U_i \in [0, 1]$ is a random disturbance term, corresponding to technical efficiency. I can use equation (1), and write technical efficiency as the ratio of the observed output over the maximum feasible output such that

$$U_i = \frac{Y_i}{AX_{1i}^{\beta_1} X_{2i}^{\beta_2}} \ . \tag{2}$$

Taking the logarithm of equation (1) gives

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \varepsilon_i \ , \tag{3a}$$

where $y_i = ln[Y]$, $\beta_0 = ln[A]$, $x_{ki} = ln[X_{ki}]$, $k = \{1, 2\}$, and $\varepsilon_i = ln[U_i]$. Alternatively, ε_i can be replaced by the technical efficiency term $(-u_i)$ such that

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} - u_i \ . \tag{3b}$$

1 For discussions of the DEA, see Coelli et al. (2005: 161-206), and Thanassoulis et al. (2008).

This is a deterministic approach because the RHS of equation (3b) is comprised of the frontier (non-stochastic) and the inefficiency term (stochastic). In stochastic frontier models, however, deviations around the frontier caused by some other factors, which cannot be controlled by firms, are considered. As is independently proposed by Aigner et al. (1977), and Meeusen and van den Broeck (1977), in a basic stochastic production frontier model, the logarithm of output is specified as a function of a non-negative random error (u_i), which accounts for technical inefficiency, and of a symmetric random error (v_i), which represents statistical noise. Considering, again, a Cobb-Douglas production function, the stochastic frontier model can be written as

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + v_i - u_i \; . \qquad (4)$$

Following Battese and Corra (1977), stochastic frontier models have been used vastly, especially for the efficiency analysis of many different sectors (e.g., agriculture, banking, and hospitals). Although earlier stochastic frontier models were designed for and applied to cross-section data, Pitt and Lee (1981), Cornwell et al. (1990), Kumbhakar (1990), and Kumbhakar et al. (1991) developed and applied models that are compatible with panel data. In particular, using panel data improves degrees of freedom, and makes it possible to scrutinize the changes in technical efficiency over time (Coelli et al., 2005: 275).

It is equally crucial to delineate the factors affecting technical inefficiency, which is not an easy task. Pitt and Lee (1981), and Kalirajan (1981) are the two pioneering studies estimating inefficiency effects. There are different approaches to estimating the factors affecting inefficiency. By using cross-sectional data at the firm level, Reifschneider and Stevenson (1991), Kumbhakar et al. (1991), and Huang and Liu (1994) estimate stochastic frontier models and the factors affecting inefficiency, simultaneously, under appropriate distributional assumptions. In contrast, Battese and Coelli (1995) estimate a stochastic frontier production function by using firm-level panel data where non-negative inefficiency effects have a truncated normal distribution with constant variance.

Taymaz and Saatci (1997) is the first study looking at technical efficiency of a number of manufacturing industries in Turkey. They use Battese and Coelli's (1995) model, and estimate a stochastic production frontier for textile, cement and motor vehicle industries for the period 1987-1992. The estimation results suggest there are increasing returns to scale in all three industries. Not only do they find significant sectoral differences in terms of the factors affecting inefficiency, but also they pin the technical progress down, especially in textile and motor vehicles industries. By using firm-level data for 1987-1999, Taymaz (2001) shows that the highest rate of technological progress has been generated by the manufacture of fabricated metal products, machinery and equipment industry at the ISIC Rev.2 two-digit level. Also he finds that private enterprises and foreign-owned ones have higher technical efficiency levels than public enterprises and domestically-owned ones. Saygılı and Taymaz (2001), however, show in a stochastic production frontier model that privatization and ownership has no significant effect on technical efficiency, especially in the cement industry. They find that demand growth, the exports/sales ratio, the firm's share in regional sales, and the firm's location in the West have significant negative impact on efficiency, whereas firm size, the technology age, and the firm's location in the East have significant positive effect.

By using a translog production function and a stochastic frontier model with inefficiency effects, O¨ nder et al. (2003) study technical efficiency of the manufacturing industry in 18 provinces of Turkey for 1990-1998. Except for some years, they find a decrease in technical efficiency for the overall period. Also they find a positive relationship between average firm size and technical efficiency, and show that average technical efficiency is higher in the private sector than in the public sector. Not surprisingly, they show that Istanbul is the province with the highest technical efficiency in both private and public manufacturing industries. Similarly, Kok and Ye¸silyurt (2006) use a stochastic frontier model to study technical efficiency of the top 500 manufacturing industry enterprises in Turkey for 1993- 2000, and find a positive correlation between concentration ratios and technical efficiency of the subsectors. They observe divergence between the technical efficiency levels of the subsectors. Also they show that the private sector is more efficient than the public sector. Using cross-section 1998 data, and comparing public and private sugar plants in Turkey, Balcılar and C¸ okgezen (2003), however, find no significant technical efficiency difference.

3. The model

I use a panel of four-digit manufacturing industries in Turkey for 2003-2008, and use Battese and Coelli's (1995) model to estimate technical efficiency and the factors affecting inefficiency. The translog production frontier that is used in the estimation is given by equation (5) such that

$$ln[Y_{it}] = \beta_0 + \beta_1 ln[L_{it}] + \beta_2 ln[K_{it}] + \frac{1}{2}\left[\beta_{11}\left(ln[L_{it}]\right)^2 + \beta_{22}\left(ln[K_{it}]\right)^2\right] + \beta_{12} ln[L_{it}] ln[K_{it}] + v_{it} - u_{it}, \quad (5)$$

where v_{it} is the random error term. v_{it} is assumed to be independent and identically distributed (i.i.d.) according to a normal distribution function, $N(0, \sigma_v^2)$, and is assumed to be independent of u_{it}, the technical inefficiency term. Also the non-negative random variable, u_{it}, is distributed, independently, according to a truncated normal distribution $N(z_{it}\delta, \sigma_u^2)$ such that

$$u_{it} = z_{it}\delta + w_{it}, \quad (6)$$

Where w_{it} is a random variable that has a truncated normal distribution with zero mean, and variance σ^2. That is, the truncation point is $(-z_{it}\delta)$ (Battese and Coelli, 1995).

To estimate the factors affecting technical inefficiency, I use the following model:

$$u_{it} = \delta_0 + \delta_1 ln[AFS_{it}] + \delta_2 SIO_{it} + \delta_3 2004_{it} + \delta_4 2005_{it} + \delta_5 2006_{it} + \delta_6 2007_{it} + \delta_7 2008_{it} + w_{it}, \quad (7)$$

where AFS and SIO stand for the average firm size, and the share of industry output in total manufacturing output, respectively. Therefore technical efficiency in production for the i^{th} industry and for the t^{th} observation is given by equation (8) such that

$$\begin{aligned} TE_{it} &= exp(-u_{it}) \\ &= exp(-z_{it}\delta - w_{it}). \quad (8) \end{aligned}$$

As is clear from equation (7), when estimating the factors affecting technical inefficiency, I include year dummies so as to look at the time-varying effects.

4. Data and variables

I extract the data from the Annual Industry and Service Statistics provided by the Turk- Stat. It is a balanced panel data of 120 industries for 2003-2008. [2] I include two inputs,

[2] Although there are 234 industries operating under the Manufacturing Section (Section D) of the NACE Rev. 1.1 classification, in Turkey, data for the 114 industries are either partially or fully considered as confidential according to the Statistics Law of Turkey (Act Nr.5429).

labor (L) and capital (K), in the estimation of the stochastic production frontier. The description of the variables is as follows.

Output (Y) : Output values of 120 industries, measured at constant 2003 prices.
Labor (L) : The number of hours worked by employees.
Capital (K) : The capital stock of the selected industries for 2003-2008, measured at constant 2003 prices.

In Turkey, there is no publicly available capital stock data, nor is there depreciation data which could be used as a proxy for the capital stock. [3] Thereby I use the perpetual inventory method to estimate the capital stock, the main challenge of which is to determine the initial capital stock. Once the initial capital stock has been computed, it is straightforward to obtain the actual capital stock: add investments to the initial value, and subtract depreciation from that. Following Yılmaz (2007), I compute the initial capital stock as is given by equation (9):

$$K_0 = \bar{I}_n \times \frac{1-(1-\delta)^n}{\delta}, \qquad (9)$$

where δ and $\bar{I}_n$ are the depreciation rate of capital, and average investments for n years, respectively. I use gross investment in machinery and equipment to calculate the capital stock, and use a depreciation rate of 10% for machinery and equipment as is commonly assumed in the received literature.

5. Estimation results

I use the programme, FRONTIER 4.1, written by Coelli (1996), to obtain maximum likelihood estimates of the stochastic frontier model. In particular, FRONTIER 4.1 is capable of estimating various types of stochastic frontier models. Table 1 presents the estimation results, which suggest that γ, the estimated variance parameter, is highly significant: inefficiency effects have a significant impact on industry output.

The estimates of the coefficients in the stochastic frontier model have the expected sign. Most of the parameters are statistically significant. In particular, the estimates of the coefficients of labor and capital are highly significant which leads to

Proposition 1 Manufacturing industry in Turkey exhibits increasing returns to scale.

The estimated coefficients of AF S and SI O (see equation (7)) are statistically significant, and have a negative sign, which is expected, especially given Proposition 1, leading to

The TurkStat has not released the depreciation data since 2001. Also other alternative proxy variables, such as the total horsepower of the installed equipment, the number of machines installed, and the book value of fixed assets, have all been excluded from surveys since 2002.

Table 1 Parameter estimates for stochastic frontier production function

Variable	Parameter	Coefficient	t-value
Constant	β_0	-14.192*	-6.795
lnL	β_1	2.542*	9.269
lnK	β_2	0.904*	3.402
$(lnL)^2$	β_3	-0.023	-0.570
$(lnK)^2$	β_4	0.055	1.591
$lnL \times lnK$	β_5	-0.094*	-2.639
Inefficiency Effects			
Constant	δ_0	2.315*	28.756
ln(AFS)	δ_1	-0.079*	-5.023
SIO	δ_2	-45.996*	-25.792
2004	δ_3	-0.120*	-2.613
2005	δ_4	-0.171*	-3.671
2006	δ_5	-0.236*	-5.239
2007	δ_6	-0.234*	-6.201
2008	δ_7	-0.224*	-5.123
Variance Parameters			
${\sigma_s}^2$		0.107*	19.567
γ		0.920*	49.606
Log-likelihood		-171.223	

Variance parameters: ${\sigma_s}^2 = {\sigma_v}^2 + {\sigma_u}^2$; $\gamma = {\sigma_u}^2 / {\sigma_s}^2$.
(*): Statistically significant at the 5 per cent level.

Proposition 2 Technical inefficiency decreases as the average firm size increases, and industries with a bigger share of output in total manufacturing output are more efficient.

Also the estimated coefficients of the year dummies (see equation (7)) are all statistically significant, and have a negative sign, revealing the time-varying structure of technical efficiency of the manufacturing industry in Turkey.

For the robustness check, I carry out some hypothesis tests, especially for the estimation of the stochastic production frontier, and present the estimation results in Table 2. In particular, following Battese and Coelli (1995), I use the generalized likelihood-ratio test.
The likelihood-ratio test statistic is

$$LR = -2\left[lnL(H_0) - lnL(H_1)\right] \quad . \tag{10}$$

I first test whether there are inefficiency effects (the first null hypothesis in Table 2). The test result suggests that there are inefficiency effects, indeed, because it rejects the null hypothesis. This confirms that I can use the stochastic frontier method for the estimation of technical efficiency. [4]

Table 2 Hypothesis tests

Null hypothesis	Test statistic	Critical value*	Decision
No inefficiency effect			
$H_0 : \gamma = \delta_0 = ... = \delta_7 = 0$**	387.73	16.27	Reject H_0
Cobb-Douglas Production Function			
$H_0 : \beta_3 = \beta_4 = \beta_5 = 0$	147.07	11.07	Reject H_0
Time-invariant inefficiency			
$H_0 : \delta_3 = ... = \delta_7 = 0$	95.89	11.07	Reject H_0
Inefficiency effects are not a linear function of the selected variables			
$H_0 : \delta_1 = ... = \delta_7 = 0$	388.07	15.51	Reject H_0

* The critical value is for the 5 per cent significance level.
** The test statistic has a mixture of χ^2 distributions (Kodde and Palm, 1986).

In the second null hypothesis, I test whether the appropriate specification for the production function is Cobb-Douglas. In the third and the fourth null hypotheses, I look at whether the inefficiency effects are time-invariant, or whether they are a linear function of AF S, SI O, and of the year dummies. The test results reject all these hypotheses, and confirm that the method used to estimate the translog stochastic production frontier, which also includes inefficiency effects, is appropriate, and the results are robust.

6. Concluding remarks

In this study I have estimated a translog stochastic frontier production function for the manufacturing industry in Turkey, at the NACE Rev.1.1 four-digit level, for 2003-2008, and scrutinized the inefficiency effects. The main contribution of this study is that the most recent estimation does not go beyond 2001, making it difficult to draw inferences about technical efficiency of the manufacturing industry in Turkey. The estimation results have suggested that the manufacturing industry in Turkey exhibits increasing returns to scale, and that technical efficiency, which varies with time, is positively affected by the average firm size, and by the share of industry output in total manufacturing output.

[4] The test result also rejects $\gamma = 0$. If γ, the variance parameter, was equal to zero, then the model, given by equation (7), could have been considered as the traditional mean-response production function of AF S, SI O, and the year dummies, implying that the least-squares estimation would have been possible (Battese and Coelli, 1995; Coelli, 1995).

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