Stochastic Frontier Approach (SFA) to Measure Inefficiency in Food Industries of Iran

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Abstract: The food industries in Iran is widely recognized as a 'sunrise industry', with a huge potential for uplifting the agricultural economy, creating large scale processed food manufacturing and food chain facilities and resulting in the generation of employment and export earnings. Due to the importance of Food Industries in Iran this paper estimated and investigated the efficiency in this industry. The stochastic frontier approach is applied. The result showed that the measure of the average technical inefficiency of the Iranian food industries was 26%. In other words, the food industries of Iran are only 74% technically efficient. The important factors that affect on efficiency in food industries of Iran are Education (ED), skilled (SK), specialization (SP) and workers insurance (IN). All the factors have the expected significance values and are consistent with theory.
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1. Introduction

Food processing plays an important role in economic development. It can provide new outlets for agricultural output, raising the income of farmers, who tend to be poorer than non-farmers. The sector is sometimes involved in providing credit, seed, and technical assistance to producers in order to obtain higher-value crops. Furthermore, food processing generates employment, more so than many other manufacturing sectors because it is relatively labor-intensive. Since food processing plants are often located in rural areas, they create jobs for rural households, where poverty is often concentrated. Finally, the food processing sector can play a role in improving nutrition through fortification and the supply of foods with longer shelf-life. As a result, this industry is one of the largest industries in Iran. Based on the 2010 reports by the Statistical Centre of Iran (SCI), the sector is ranked first in terms of employment (18.9 percent). Moreover, in terms of value-added, it is ranked third (19 percent). In addition, the development of these industries would increase the demand for agricultural products in food processing and reduce the level of waste**.** The importance equally lies in identifying the strength and the weakness of the food industry in presenting scientific solutions to researchers. It will also assist economic policymakers to reach their program goals quickly. Briefly, the importance of food industries is due to three important factors; 1) Priority of the Non-oil Exports in Foreign Trade, 2) Respond to Nutrition of population, 3) Prevention of Wastage. Over the last two decades the government has encouraged the expansion of agro-industries and food industries. The increment of productivity and efficiency are the best ways that can increase the firms' profit in this sector. However the author have been studied related to determinants of productivity (Afrooz, et al. 2011) but unfortunately, there weren't a robust research regarding to efficiency and it's determinant in this sector. Therefore this paper estimated the technical efficiency by using the stochastic frontier approach (SFA).

2. Literature review

There are two approaches that can be used to estimate efficiency, i.e. parametric and nonparametric. The parametric approach involves estimation of a SFA models, whereas the non-parametric approach uses a linear programming method i.e. DAE approach. Parametric approach is preferred over the non-parametric approach because of its ability to relax the constant returns to scale assumption imposed under the latter approach, and application of mathematical forms as opposed to the linear programming of the nonparametric approach. In the usual stochastic frontier model it is acknowledged that the estimation of production or cost functions must respect the fact that actual production cannot exceed maximum possible production given input quantities, (Aigner, Lovell and Schmidt 1977, and Meeusen and Broeck 1977). Kumbhakar, Ghosh and McGuckin (1991) and Battese and Coelli (1995) were the first to suggest that determining the factors responsible for inefficiency is an essential component of efficiency analysis. The important task is to relate inefficiency to a number of factors that are likely to be determinants, and measure the extent to which they contribute to the presence of inefficiency. Kumbhakar, Ghosh and McGukin (1991) and Battese and Coelli (1995) suggested that under the assumption of truncated normal one-sided error term, the mean of the truncated normal distribution could be expressed as a function of certain covariates, a closed form likelihood function can be derived, and the method of maximum likelihood may be used to obtain parameter estimates, and provide inefficiency measures. Stochastic frontier approach has found wide acceptance within the agricultural economics literature and industrial settings (Battese and Coelli, 1992; Coelli and Battese, 1996), because of their consistency with theory, versatility and relative ease of estimation. A number of studies examined the technical efficiency of manufacturing industries in developing countries (Nishimizu and Page, 1982; Abdulkhadiri and Pickles, 1990; and Chuang, 1996; Harris, 1993; Sheehan, 1997) and steel production (Wu, 1996). Some literature focused on stochastic frontier model with distributional assumptions by which efficiency effects can be separated from stochastic element in the model and for this reason a distributional assumption has to be made (Bauer, 1990). Among others, an exponential distribution (Meeusen and Broeck, 1977); a normal distribution truncated at zero (Aigner, Lovell and Schmidt 1977); a half-normal distribution truncated at zero (Jondrow, *et al.* 1982) and a two-parameter Gamma or Normal distribution (Greene, 1990). However, these are computationally more complex, there are no priori reasons for choosing one distributional form over the other, and all have advantages and disadvantages (Coelli, Rao and Battese 1998). Ritter and Simar (1997) found that the requirement for the estimation of two parameters in the distribution may result in identification problems and several hundreds of observations would be required before such parameters could be determined. Further a maximum of the log-likelihood function may not exist under some circumstances. In general there are two types of panel data that can be adopted in measuring efficiency: time-invariant and time-variant. The former type of panel data model is specified in a way that the TE does not change over time (i.e. constant) but varies across firms, while the latter type of models allow the TE to vary across firms and through time for each firm. A number of studies have also attempted to estimate time-varying inefficiency. Cornwell, Schmidt and Sickles (1990) replaced the firm effect by a squared function of time with parameters that vary over time. Kumbhakar (1990) allowed a time-varying inefficiency measure assuming that it was the product of the specific firm inefficiency effect and an exponential function of time. This allows flexibility in inefficiency changes over time, although no empirical applications have been developed using this approach (Coelli, Rao and Battese, 1998). ML estimates of stochastic frontier functions for panel data with time varying efficiencies was estimated by Battese and Coelli (1995). More specifically, Battese and Coelli (1995) propose a stochastic frontier function for panel data in which inefficiencies are expressed as specific functions of explanatory variables. The model assumes firm effects to be distributed as truncated normal random variables, which are also permitted. In this analysis we use parametric approach, specifically SFA model to estimate the TE associated with the FI in Iran.

3. Methodology

We used a time-varying inefficiency effects measure assuming truncated at zero of normal distribution by Battese and Coelli (1995) in this paper. Stochastic estimations impose

$$y_{it} = f(x_{it}, \beta) e^{v_{it} - u_{it}} \quad (1)$$

For time t = 1, 2, ..., T, y_{it} output, x_{it} is a (1 × k) vector of inputs and β is a (k × 1) vector of parameters to be estimated. The error term v_{it} is assumed to be independently and identically distributed as N $(0,\sigma^2_v)$ and captures random variation in outputs due to factors beyond the control of firms. The error term u captures INEF in production. Coelli *et al.* (2005), assumed that: The error term $\varepsilon = (vi - u_i)$ and u_i is a non-negative random error which is assumed to account for errors and other factors under the control of a firm. vi is the asymmetric random error which is assumed to be normally distributed as $N(0, \sigma^2_v)$ and accounts for measurement of errors and other factors beyond the control of the firm and also vi is a two-sided random errors while ui is a one-sided EF component. The parameters of v_i and the parameters of u_i are assumed to be independent of each other. The error term u_{it} captures INEF in production, specified by:

$$u_{it} = z_{it}\delta + w_{it} \quad (2)$$

Where z_{it} a (1 × m) is the vector of explanatory variables, δ a (m × 1) is the vector of unknown coefficients and w_{it} a random variable such that u_{it} is obtained by a non-negative truncation of the parent distribution N $(z_{it}\delta,\sigma^2_u)$. The condition u_{it} in the equation (2) guarantees that all observations lie on or beneath the stochastic production frontier. Following Battese and Coelli (1995; 2005), the variance terms are parameterized by replacing σ^2_v and σ^2_u with $\sigma^2=\sigma^2_v+ \sigma^2_u$ and $\lambda= \sigma^2_u/ (\sigma^2 v+ \sigma^2_u)$. The value of λ=0 when there are no deviations in output due to INEF and λ = 1 implies that there is no deviations in output result from stochastic variations in the production possibility frontier. The firm or sub-sector

EF of the i-th firm or sub-sector in the t-th period for the basic case can be defined as:

$$TE_{it} = \frac{E(y_{it} | u_{it}, x_{it})}{E(y_{it} | u_{it} = 0, x_{it})} = e^{-u_{it}} = \exp(-\delta z_{it} - w_{it}) \quad (3)$$

The EF measured must have a value between 0 and 1. The empirical stochastic frontier model is usually specified in (natural) logs, so in INEF term, u_{it} can be interpreted as the percentage deviation of observed performance, y_{it} from the firm's own frontier. This model is estimated using Maximum Likelihood Estimation (MLE).

4. Data sources

Annual data on output, value added, capital a, labor and factors that affect efficiency such as education of workers(ED), skilled of workers(SK) and specialty of workers (SP)for the food industries were compiled in the periods 1995–2006 from the *Annual Survey of Manufacturing Industries* published by the Statistical Centre of Iran. The variables were deflated by using price index of each group on the base year 1997 that was published by the Central Bank of Iran.

Table 1. Tests of hypothesis for coefficient of the TEF

Null hypothesis	Log-likelihood value	Test Statistic λ	Critical Value $\chi^2_{0.95}$	Decision
H_0: $\gamma = \delta_0 = ... = \delta_8 = 0$ (No technical INEF exists)	68.5	82.8	18.3	rejectH_0

5. Empirical results

In this study, the equation (1&2) is utilized simultaneously in the program FRONTIER4.1 (Coeli ,1966) to measure INEF and determinants of INEF in total FI of Iran. The empirical equation can be defined as:

$$\ln Y_{it} = \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln L_{it} + v_{it} - u_{it} \quad (4)$$

i= (1, 2, 3……22) sub-sector .t= (1995….2006)

Where; Y, K and L are output, capital stock and labour respectively. v_{it} is error term and u_{it} is measure of inefficiency that for the 22 sub-sector of food industries of Iran over 12 years (panel data sets) are defined by equation (5):

$$u_{it} = \delta_0 + \delta_1 SK_{it} + \delta_2 SP_{it} + \delta_3 ED_{it} + \delta_4 CN_{it} + \delta_5 PW_{it} + \delta_6 FS_{it} + \delta_7 NC_{it} + \delta_8 IN_{it} + w_{it} \quad (5)$$

i = (1, 2, 3……22) sub-sector, t= (1995….2006)

Where: SK is ratio of skilled workers to total workers, *SP* is specialization or ratio of engineers to total workers, ED is ratio of educated workers to total workers , PW is ratio of product workers to non-product workers, IN is insurances per worker in each sub-sector, NC is nutrition cost per worker and FS is firm size. A formal hypothesis test was conducted in order to determine the random variables associated with the TINEF and the residual error term of the data sets. Table 1 shows the value of the test statistic λ over the critical value, meaning that the null hypothesis (H_0) indicates that TINEF does not exists in the FI ($\gamma = \delta_0 = ... = \delta_8 = 0$) is strongly rejected, indicating that TINEF effects are present.

Table 2. MLE of the production frontier and determinants of TINEF of FI

Variable	Expected sign	Coefficient
Stochastic Frontier Model		
Constant	n	1.53***
Log-labor	+	0.73***
Log-capital	+	0.24***
INEF effects		
Constant	n	1.005***
ED	_	-0.57***
SP	_	-1.13***
SK	_	-0.51***
PW	_	0.0003
IN	_	-0.18**
NC	_	-0.089***
FS	_	-0.055***
Variance parameters		
σ_u^2		0.13***
γ		0.78***
Mean Technical EF		0.74

*, **, *** denote statistical significance at the 10%, 5% and 1%, respectively

The estimation of TINEF for 22 sub-sector of FI is presented in Table (2) The results of the stochastic frontier model are presented in the first section of the table which shows the correlation between the total FI production value and the factors of production (i.e. labor and capital). Meanwhile, the results of the INEF effects model are presented in the second section of the tables showing the impact of Z_i variables on the TINEF.

The estimated value of the variance λ (0.78) indicates that the INEF effects are likely to be highly significant in the analysis. The estimated average

TINEF is 26%. In other words, the Iranian FI of is only 74% technically efficient. The estimated coefficients in the TINEF model for the Education (ED), skill (SK), specialization (SP), workers insurance (IN), worker nutrition (NC) and firm size (FS), have the expected values and significance, meaning that an increase in ED, SK, SP, IN, NC and FS lead to increased production EF. The most striking result to emerge from the data is that fact that the values of all parameters were as expected. Specialization (SP), Education (ED) and skills (SK) were important determinants of the EF in the FI of Iran. In the other word, increasing human capital cusses decreasing inefficiency in FI of Iran. The specialization coefficient is -1.13 this means if the specialist worker increase one percent inefficiency in FI will be decrease 1.13 percent. After specialization the educations level of workers and skilled of workers have more effect on efficiency than other factors. The educated workers (ED) coefficient and SK coefficient are -0.57 and -0.51 respectively that they are close together. The results, as shown in Table 2 indicate that the other factors that affect TINEF are IN, NC, FS and PW. The results show that there are significant relationships between TINEF and them except PW. The coefficients of the factors are -0.18, -0.089 and -0.055 for IN, NC and FS respectively. Among these factors IN has more effect on TINEF. That means increase in social insurance and health insurance increases the efficiency of the workers. The NC coefficient indicates that a weakly significant relationship was found between the nutrition of workers and TINEF. The average EF of the 22 sub-sectors of FI illustrated that the highest average of EF among all sub-sectors is related to sub-sector1514 (Vegetable and animal oils and fats), while the lowest average of EF is for subsector 1517(Cleansing, sorting and packaging of dates), i.e. 0.94 and 0.53 respectively. One of the main reasons for the high INEF in sub-sector 1517 is that the "Cleansing, sorting and packaging of dates" was a seasonal industry and manufacturers could not use production factors to their full capacity.

6.Conclusion

As aforementioned, TINEF was estimated and the average TINEF of the Iranian FI measured was 26%. In simpler words, the FI of Iran was technically and only 74% efficient. The important factors affecting the efficiency of FI are the estimated coefficients in the TINEF model for the Education (ED), skilled (SK), specialization (SP), workers' insurance (IN), workers' nutrition (NC) and firm size (FS). All the factors have the expected significance values and are consistent with the theory. Specialization (SP), Education (ED) and skills (SK) were shown to be the important determinants of the EF in the FI of Iran. They particularly illustrate that increasing human capital will cause inefficiency in FI of Iran to decrease. The highest average of EF among all the sub-sectors was indicated for sub-sector 1514 (namely, vegetables and animal oils and fat), while the lowest average of EF was for sub-sector 1517 (namely, cleaning, sorting and packing of dates), with 0.94 and 0.53, respectively.

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