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Efficiency Analysis on Iran's Industries

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Abstract:

In Iran's 4th five-year economic development plan it has been assessed that the productivity contribution in economic growth to be 2.5 percent and it can be materialized through increases in efficiency. Therefore, this study seeks to answer this question whether industrial efficiency, as an engine of economic growth, has had any growth during the 4th five-year economic development plan of Iran. In this study the stochastic frontier production function is estimated to determine efficiency in Iran's industry as a whole. For purposes of comparison, also, Iran's industry is categorized into three different sizes of firms, and two different types of ownership. The results show that efficiency level is the highest for the small firms group at 68.1 percent and the lowest for large firms group at 52.5 percent. Average efficiency level was approximately constant for small firms, rising for medium sized firms and decreasing for large sized firms over the time period. The efficiency level is higher for the private firms group at 86.8 than for public firms group at 46.1 percent. The average efficiency level is rising for both private and public firms during the time period. The efficiency was 41 percent in 2009 for Iran's industry as a whole and it has grown from 36 percent in 2003 to 45 percent in 2008. It shows efficiency has roughly increased 1.5 percent annually and also Iran's industry is becoming more efficient and competitive. In spite of efficiency growth, the level of efficiency is still low at 41 percent. The results show that the industries are not competitive enough.

JEL classification**: D24, C23**

Keywords: *Stochastic frontier production, efficiency, Iran's industries*

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1. Introduction

Iran's Five-year Economic Development Plan was initiated since the end of Iran-Iraq war in 1988. High rates of economic growth for a decade is a strategic approach as well as an outstanding issue in the 4th five-year development plan of Iran (March 2005-2010). It is estimated that close to 2.5 percent of the domestic economic growth is generated through productivity increases. To achieve this scope, industry has an important role. The industry's share in Iran economy has been assessed to rise from 14 percent to 16.2 percent and the value of industrial exports is set to be augmented from 7 percent to 14.8 percent in total Iran's exports (Central Bank of Iran, 2008). Iran's industrial sector, in practice, could not be able to achieve these targets. Also based on Iran's development plan, the industry should be able to achieve 14.8 percent of Iran's export during 2003-2008. However, it has been able to achieve a rate of only 9.1 percent during this period. This is perceived inefficient use of economic resources. Achieving the development plan`s targets hinges on more efficient use of resources.

On the other hand, since 1995 Iran's government has intended to join the World Trade Organization (WTO). However, the presence of inefficiency in Iran's industry enlarges production cost which affected price, sales and revenue. Therefore, inefficiency leads to industries being unable to compete effectively in the global market. As a result, joining WTO is challenging for Iran's industry since it have to compete in the global market. Hence, it is essential to answer a fundamental question, that is, whether industrial sector is competitive enough to face global challenges. The ability to compete of the sector over time could be measured by efficiency and productivity analyses.

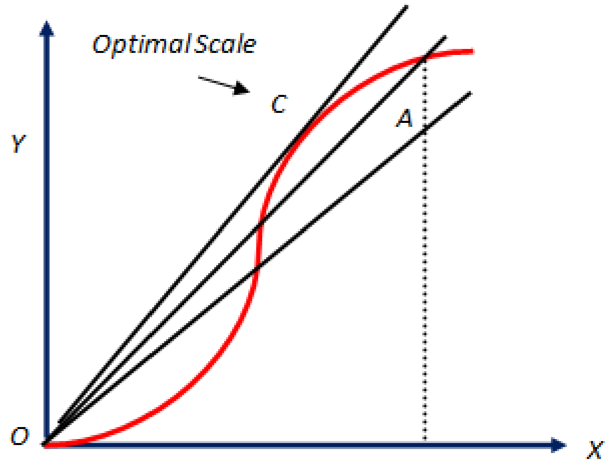
In the next section theoretical and empirical literature review are presented. Section five introduces the variables and sources of data. The empirical model and results are assessed in sections six and seven. The final section summarizes the results and presents the recommendations drawn from the study.

2. Theoretical Framework and Literature Review

Examining efficiency from an economic viewpoint seeks to answer this fundamental question whether inputs are used efficiently in production processes. Could output grow when input use is constant? Results of previous studies show that some of the producers are able to utilize inputs at minimum level to achieve some given levels of their outputs using their current technology. These producers are technically efficient and otherwise are technically inefficient. Determining the degree of inefficiency between industries or producers makes some useful information which may be used to decrease inefficiency by the firms or industries.

Unfortunately, the terms of productivity and efficiency are used interchangeably; however, they are not exactly the same. To show the difference between productivity and efficiency we use figure 1. In this figure a line is drawn through the origin to a particular point on the frontier. The slope of this point is *y/x* and it measures the average productivity. The higher slope represents the higher productivity. Point *C* shows maximum productivity due to the line from the origin is tangent to the production frontier. Point *C* also shows (technically) optimal scale. Other points on the production frontier indicate lower productivity. Hence, we can conclude that a firm may be technically efficient while it can also increase its productivity.

Figure 1: Productivity and technical efficiency



2.1. Efficiency

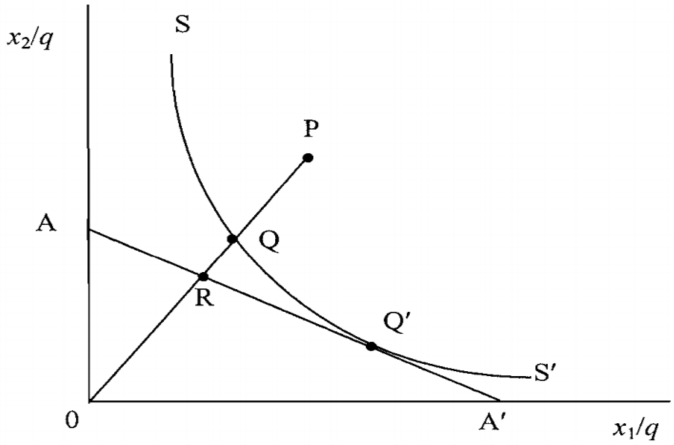
The definition of efficiency encompassed two components: technical and allocative efficiency (Farrell, 1957).

- Technical efficiency arises when a firm can obtain maximum output from available set of inputs. (Coelli and et al., 2005)
- Allocative efficiency occurs while a firm uses production factors at the optimal proportions (Coelli and et al., 2005).

Combination of these two measurements leads to a measure of economic efficiency. By using input-oriented technical efficiency measures, one can answer this question that is "whether inputs can be decreased without changing in output?" Figure 2 allows to measure efficiency by labor (X_1/Q) and capital (X_2/Q) per unit of output. The isoquant is shown by *SS'* which shows a fully efficient firm. If a representative firm operates at point *P*, the technical inefficiency may be measured by the ratio *QP*/*OP*, *proportionately*. Technical efficiency for this firm also can be represented by *OQ*/*OP*.

Technical efficiency = 1- technical inefficiency = 1- QP/OP = OQ/OP

Figure 2: Technical and allocative efficiencies



This proportion, if valued as unity, implies that the firm is technically efficient. Point *Q* is a fully technically efficient.

If the prices of inputs are available, one can obtain the cost efficiency (economic efficiency). *w* and *x* are vectors of input prices and input used corresponding to point *P*, respectively. The cost efficiency is measured as follows

CE = *OR* / *OP = w'x* / w'x*

Where *x** and *x* are input vectors corresponding to points *P* and *Q*'. Input price ratios are usually shown by the slope of the isocost line, AA'. It is concluded that the cost efficiency may be obtained by multiplying technical and allocative efficiencies as follows:

TE = *OQ* / *OP*

AE = *OR* / *OQ*

CE = (*OR* / *OQ*) * (*OQ* / *OP*) = *OR* / *OP*

1. Analysis of Efficiency

There are three approaches to analyze of efficiency

- Data Envelopment Analysis (DEA),
- Stochastic Production Frontier (SPF)

Each of these approaches has an extensive literature and our aim here is to provide an overview with associated references for stochastic frontier which used in this study.

2.2. Stochastic Frontier Model

The stochastic production frontier model was introduced by Aigner, Lovell, and Schmidt (1977), which has an error term with two components (u) and (v) shown as follows:

$$Y_i = f(X_i, \beta) e^{\varepsilon_i} \quad (1)$$

$$\varepsilon_i = v_i - u_i \quad (2)$$

Where Y_i is the output vector for i^{th} firm, X_i is a vector of inputs, β is a vector of parameters and ε_i is an error term. The statistical noise (v) is assumed to have a normal distribution v_{it} and the half normal or the exponential distribution is considered for the technical inefficiency (u) as $u_{i\sim}$ $[N(0, \sigma^2_u)]$, $u_i > 0$. It is assumed that they are distributed independently and there is no correlation among them and production factors in the production function. Statistical noise (v) is assumed to have the normal distribution such as equation (1). It is assumed inefficiency component (u) has the half normal or the exponential distribution as in equations (4) and (5), respectively. The half normal distribution has one parameter, σ_u .

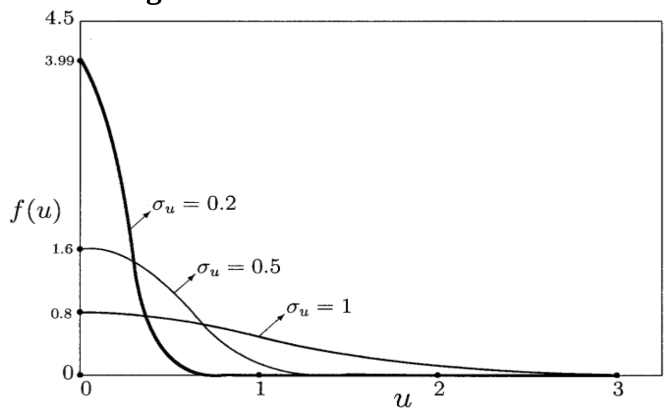
$$f(v) = \frac{1}{\sqrt{2\pi}\sigma_v} \exp(-\frac{v^2}{2\sigma_v{}^2}) \qquad \text{(normal)} \qquad (3)$$

$$f(u) = \frac{2}{\sqrt{2\pi}\sigma_u} \exp(-\frac{u^2}{2\sigma_u{}^2}), \quad u \geq 0 \quad \text{(half normal)} \qquad (4)$$

$$f(u) = \frac{1}{\sigma_u} \exp(-\frac{u}{\sigma_u}), \quad u \geq 0 \qquad \text{(exponential)} \qquad (5)$$

Figure 3 shows three half normal distributions corresponding to three $\sigma_u s$ (0.2, 0.5, 1).

Figure 3: Half Normal Distribution



Let σ^2 be the summation of variances of '*U*' and '*V*',

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \tag{6}$$

Then, the technical inefficiencies' variance ratio can be shown as:

$$\gamma = \sigma_u^2 / \sigma^2 \tag{7}$$

By using Maximum Likelihood method to estimate a stochastic frontier production function one can obtain the value of σ^2 and γ.

Jondrow et al. (1982) calculated a conditional mean of *u* in given ε as follows:

$$E(u_i|\varepsilon_i) = \frac{\sigma_u \sigma_v}{\sigma}\left[\frac{f(\varepsilon_i \gamma \sigma)}{1-f(\varepsilon_i \gamma \sigma)} - \frac{\varepsilon_i \gamma}{\sigma}\right] \tag{8}$$

Where *f* is the standard normal density which is evaluated at $\frac{\varepsilon_i \gamma}{\sigma}$. The technical efficiency of production for the i^th firm is defined here by

$$TE = \exp(-u_i), \quad 0 < TE < 1 \tag{9}$$

3. Empirical Literature Review

Efficiency analysis involves answering an essential question of whether inputs are used efficiently in the process of production. May output be increased while levels of inputs are constant? Farrel (1957) is the first to attempt to measure efficiency. Others who studied efficiency measures include Aigner, Lovell and Schmidt (1977), Bauer (1990), Battese and Coelli's (1995), Soderbom and Teal (2001), Vu (2003), Movshuk (2004), Alias et al. (2008), Ghafarzade and Haji Rahimi (2008), Helvoigt and Adams (2009) and Chang et al. (2009).

Choosing the suitable method in measuring efficiency will influence the quality of efficiency estimates. Some previous studies used SPF to measure efficiencies in diverse industries including mining, power generation, and manufacturing. Also some researchers have used SPF on the agriculture sector. Recent examples include: Mathijs and Swinnen (2001), Coelli, Sanzidur, and Thirtle (2003), and Latruffe, Balcombe, Davidona, and Zawalinska (2004) among others. Some manufacturing sector studies include: Brada, King, and Ma (1997), Margono and Sharma (2003), Alias et al. (2008), Ghafarzade and Haji Rahimi (2008), Helvoigt and Adams (2009) and Chang et al. (2009) utilized SPF to estimate efficiency in the underground mining industry.

The Data Envelopment Analysis (DEA) method was introduced by Farrell (1957) and Koopmans (1951). DEA is a mathematical programming method to measure inefficiency of a firm. Some previous studies used DEA to measure efficiencies in diverse industries. Others include Banker et al. (1986), Charnes et al. (1978), Banker et al. (2005) and Chang et al. (2009).

4. Data and Variables

In most studies a researcher is interested to measure efficiency for the whole sector like industry or agriculture or the whole of economy. The problem is choosing a suitable measure for output. In many cases value added are used (Battese and Coelli, 1995).

The present study is conducted involving Iran’s industries. The study seeks to calculate technical efficiency in Iran’s industries as a whole and also to investigate the effects of firms’ characteristics such as size and ownership over efficiency. Hence technical efficiency is estimated in terms of the different sizes and ownership status separately and then the results are compared. A panel data set of Iranian industries is used for the estimation of a stochastic frontier production function. Panel data on 13 industries for 6 years 2003 to 2008 are obtained from the databases of the Ministry of Industries of Iran and Central Bank.

The Output is measured by net value added which is adjusted to constant units by deflation with the wholesale price index for industries at 2003 base. The Capital input is measured by the sum of interest payments and repair and replacement costs of machinery. Capital is also converted to constant figure using WPI deflator. Labor input is defined as the number of total employee in each industry. Data regarding firms' characteristics include information of firms' size and ownership situation also are under consideration. The number of labor in the firm has been taken as the indicator of its size. Firms having labor equal to or less than 49, between 50 and 199 and above 199 have been defined as small, medium and large respectively. Regarding ownership, all firms are divided into two parts of public and private owes.

5. Empirical Model

In this study a stochastic production function model (Battese and Coelli, 1995) have been used to analyze the trend of industry level efficiency of Iranian industries and identify factors which have important influence on the efficiency of the industries. The stochastic production function has been defined as:

$$lnY_{it} = \beta_0 + \beta_2 lnL_{it} + \beta_3 lnK_{it} + V_{it} - U_i \qquad (10)$$

It is assumed v_{it} has a normal distribution and inefficiency term u_i has half normal distribution.

Y = output (value added)

L = number of labor

K = capital (cost of capital)

All variables are in natural logarithm form. A technological possibilities characterized by Cobb Douglas production functions have been considered.

Regarding the distribution of inefficiency term u_i , Meeusen and van den Broeck used an exponential distribution, Battese and Corra applied a half normal distribution, and Aigner, Lovell, and Schmidt considered both. Later, Stevenson (1980) proposed a Gamma and truncated normal, and Greene (1990) assigned a two-parameter Gamma distribution. For the stochastic frontier production function $y_i = f(x_i, \beta) + \varepsilon_i$, if we assume that the two error terms u_i and v_i are independent of input variables x_i and also independent of each other, then we can apply one of the above distributions, defined as the likelihood function, and compute the maximum likelihood estimates.

In this, study we adopted Battese and Coelli (1995). Hence, the maximum likelihood method is used to estimate of the parameters of the model for the technical inefficiency effects. Previous studies show that the result of maximum likelihood method for stochastic frontier model is more significant than the OLS results. Hence, in this study the model is estimated using maximum likelihood method by Limdep 7.0 software.

6. Estimation of Stochastic Frontier Production Function

The coefficients of stochastic production model for the industry as a whole and the different sizes are tabulated in table (1). As shown, almost all coefficients (elasticity) are significant at 1% level and have an expected sign. But the elasticity of *K* is not significant for small industry sub-group and *L* does not have expected sign for large sized firms. Computed λ shows the relevance of stochastic production function. If the null hypothesis is accepted, this would indicate that σ^2_u is zero and hence the *u* term should be removed from the model, leaving a specification with parameters that can be consistently estimated using ordinary least square. Table (1) shows that the value of λ has a star and as such we reject the null hypothesis at 1% level of significance.

$H_0: \lambda = 0,$

$H_1: \lambda \neq 0$

The same conclusion is derived for different groups as in table (1). So this validates the use of stochastic production function.

Table 1: The results

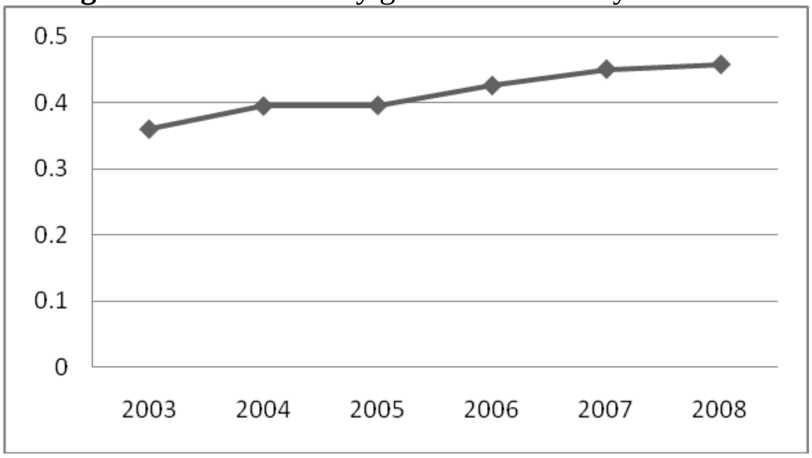
Coefficient			Variance Parameters		Average	
Intercept	L	K	σ	λ	Efficiency	Inefficiency
Whole Industry						
5.43	0.	0.	0.3	0.6	0.41	0.585
Small						
2.46	0.	0.	2.7	6.8	0.68	0.319
Medium						
4.08	0.	0.	7.8	6.4	0.66	0.338
Large						
14.9	-	0.	0.4	0.8	0.52	0.535

Source: obtained from Limdep 7.0

In this study, it is hypothesized that as size increases, efficiency level of the firm will increase as larger firms were expected to have better marketing network and may have easier access to critical inputs etc. Table (1) includes, also, some information regarding the mean efficiency of firms for the whole industry and for different sizes of firms. It shows efficiency level is the highest for the small firms group at 68.1% and the lowest for large firms group at 52.5%. This result contradicts our *a priori* expectation. This result is justified as almost all small-sized firms have private ownership in Iran which as expected have better management, plan, marketing and motivations that lead to higher efficiency level. The efficiency for medium group and the whole industry are 66.2% and 41%, respectively.

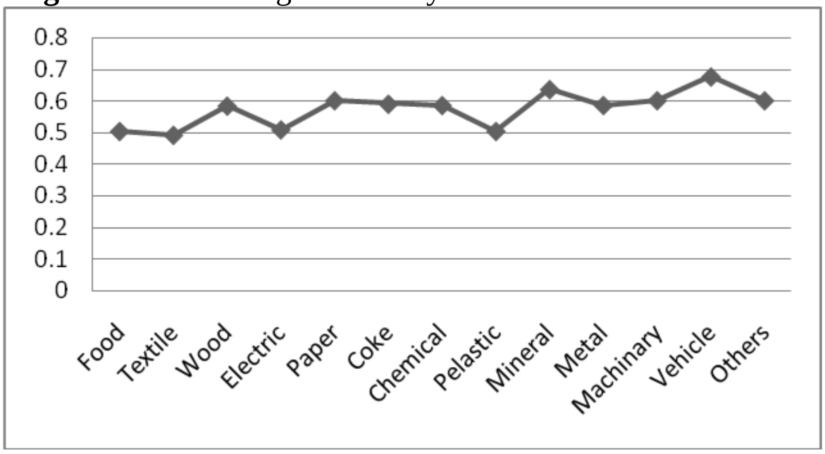
The efficiency growth for the industry as a whole has been shown in figure (4). As shown the efficiency level increases from 36% in 2003 to 45% in 2008. It shows efficiency has roughly increased 1.5% annually and also Iran’s industry is becoming more efficient and competitive. Despite the efficiency growth, the level of efficiency is low at 45%.

Figure 4: The efficiency growth for industry as a whole



The advantage of using panel data to estimate stochastic frontier is that the researcher is able to compare efficiency level among the different industries in terms of their output at the same time. Hence, we show the average of efficiency for each industry during these six years. Figure (5) shows, among these industries, vehicle industry is the most efficient one compared with others.

Figure 5: The average efficiency level for different industries



Figures 6 to 8 show average efficiency growth for different sizes of firms during the 2003-2008. As shown, the average efficiency level has approximately been constant for small firms, rising for medium sized firms and decreasing for large sized firms during the 2003-2008. Highest efficiency level is attributed to small firms, 81%, in 2006.

Figure 6: The efficiency growth for small firms

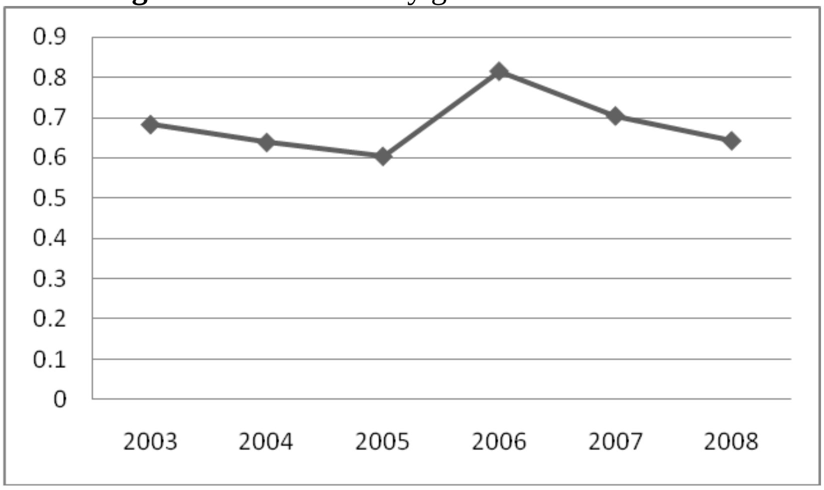


Figure 7: The efficiency growth for medium firms

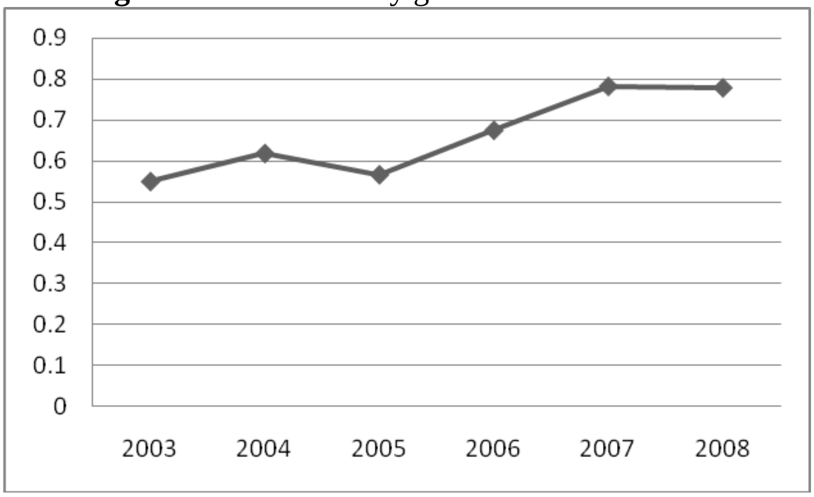
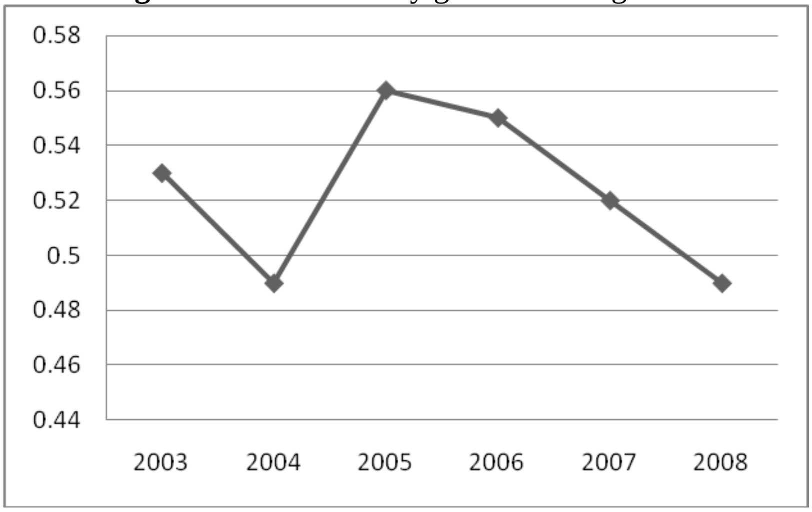


Figure 8: The efficiency growth for large firms



Stochastic frontier production function is estimated for public and private firms separately. It is hypothesized that efficiency level of the firms under private ownership is higher than firms under public ownership. Table (2) includes information regarding the mean efficiency level of different ownerships of firms and the coefficients of the model. All coefficients are significant at 1% level except the capital coefficient for private firms. It shows the efficiency level is higher for private firms group at 86.8% and lower for public firms group at 46.1%. These results are theoretically expected that private firms have more motivation to use factors efficiently, while public firms suffer from weak management and have less motivation to use factors efficiently. In other words, public firms are financially assisted by the government and that they have annual budget which is allocated by the government.

Table 2: The results

Coefficients			Variance	Parameters	Average	
Int	L	K	σ	λ	Efficiency	Inefficiency
Private						
4.55*	0.914*	-0.66	0.122*	0.295*	0.868	0.132
Public						
13.48*	0.47*	0.13*	1.75*	1.94**	0.461	0.539

Source: obtained from Limdep 7.0

Figures 9 and 10 show the average efficiency growth for different firms in terms of ownership status during the study period. As shown, the average efficiency level is rising for private and public firms during the 2003-2008. Highest efficiency level is attributed to private firms, i.e. at 88%, in 2008.

Figure 9: The efficiency growth for private firms

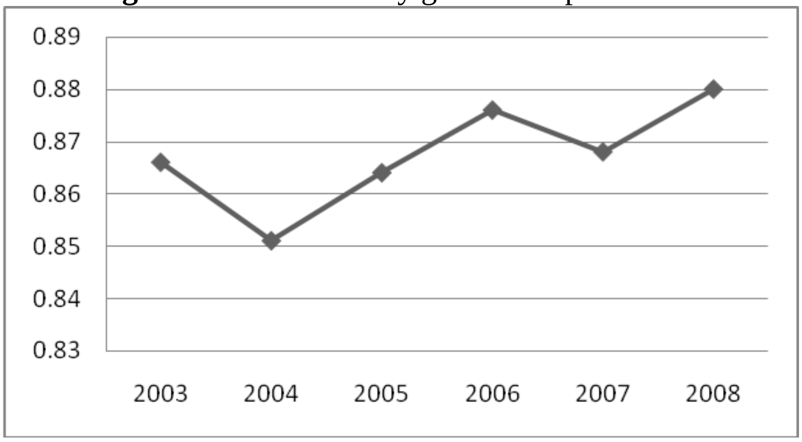
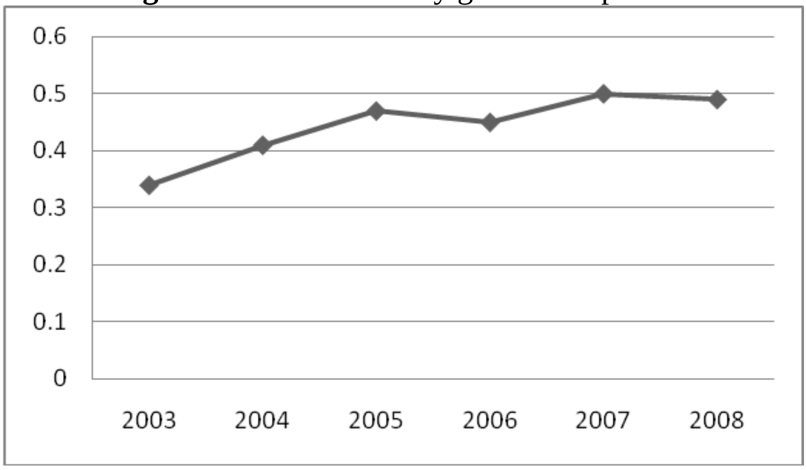


Figure 10: The efficiency growth for public firms



7. Conclusion and Recommendations

In this study the stochastic frontier production function is estimated to determine efficiency in Iran's industry as a whole. For purposes of comparison, also, Iran's industry is categorized into three different sizes of firms, and two different types of ownership.

A six-year time series data for 13 major components of Iran's industries are used as panel data to estimate the model. A Cobb-Douglas model has been used as the functional form in this study.

Results show that the value of λ is significant for all categories and stochastic frontier is appropriate to show inefficiency in Iran's industry. They also show that the efficiency level is highest for the small firms group at 68.1% and lowest for large firms group at 52.5%. However, this result contradicts our expectation. But, it is justified as almost all small sized firms are privately owned which has better management, plan, marketing and motivations that lead to higher efficiency level. According to the 4^{th} five-year plan, the price of energy must be determined by market forces and subsidies should be lifted. Hence, it seems that the small sized firms can continue their operation, and large sized firms may leave the markets. It is also recommended that policymakers encourage investors in establishing small and medium sized firms to achieve the goals of the development plan.

The level of efficiency for large-sized firms is the lowest due to the fact that they have publicly owned. In Iran, public firms suffer from poor management and they have no motivation to use factors efficiently. In other words, public firms are financially assisted by the government. Hence, the government must decrease its support gradually and encourage private sector to invest in large sized firms. Also, the government must pursue privatization of large sized firms to achieve the goals of the plan since theoretically, privatization leads to greater efficiency. It is recommended that withdrawing subsidies is done gradually so that the firms are provided with enough time to adjust to become competitive.

The average efficiency level is approximately constant for small firms, rising for medium sized firms and decreasing for large sized firms over the time period. Highest efficiency level is attributed to small firms at 81 percent, in 2006.

The efficiency for Iran's industry as a whole has grown from 36 percent in 2003 to 45 percent in 2008. It shows that efficiency has roughly increased by 1.5 percent annually and that Iran's industry is becoming more efficient and competitive. Despite efficiency growth, the level of efficiency is still low at 41 percent. As mentioned, Iran has attempted to join WTO since 1995. However, the results show that the industries are not competitive enough. Thus, firms should be assisted to enhance their technical skills and management, particularly in encouraging innovation and making economic value from technology. Existing training programs should be directed towards improving entrepreneurial skills, business planning, marketing and financial management. The success and growth of the industries will significantly contribute to overall national economic growth.

The efficiency level is the higher for the private firms group at 86.8 percent than for public firms group at 46.1 percent. Private firms have more motivation to use factors efficiently while public firms have low management skills and they are less motivated to use factors efficiently.

To continue efficiency growth, efficiency must be improved trough improving the quality of labor by training and education. Iran’s industries must develop necessary skills through investment in human capital.

Reference:

Aigner, D., Lovell C.A.K. & P. Schmidt. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. Journal of Econometrics 6: 21-37.
Alias, R., A. Mimiliana & A. Amin Mahir. (2008). Technical Efficiency of Small and Medium Enterprise in Malaysia: a Stochastic Frontier Production Model. International Journal of Economics and Management 2(2): 395-408.
Banker, R. D., H. Chang & R. Natarajan. (2005). Productivity Change, Technical Progress and Relative Efficiency Change in the Public Accounting Industry. Management Science 2005, 51:291–304.
Banker, RD, A. Charnes & WW. Cooper. (1986). Some Models for Estimating Technical and Scale Efficiency in Data Envelopment Analysis. Management Science, 30:1078–92.
Battese, G. & T. Coelli. (1992). Frontier Production Function, Technical Efficiency and Panel Data: with Application to Paddy Farmer in India. Journal of Productivity Analysis 3: 153-169.
Bauer, P. (1990). Recent Developments in the Econometric Estimation of Frontier. Journal of Econometrics, 46(1-2): 39-56.
Brada, J. C., A.E. King & C. L. Ma. (1997). Industrial Economics of the Transition: Determinants of Enterprise Efficiency in Czechoslovakia and Hungary. Oxford Economics Papers, 49(4): 104-127.
Central Bank of Iran, Indicators of Economic, Various Years.
Charnes, A., W.W. Cooper & E. Rhodes. (1978). Measurement the Efficiency of Decision Making Units. Europian Journal of Operations Research 2: 429-444.
Coelli, T. J., R. Sandizur & C. Thirtle. (2003). A Stochastic Frontier Approach to Total Factor Productivity Measurement in Bangladesh Crop Agriculture. Journal of International Development. 15(3): 321-333.
Coelli, T.J., D.S.P. Rao, C.J. O'Donnell & G.E. Battese. (2005). An Introduction to Efficiency and Productivity Analysis. Second Edition, Springer, America.
Farrell, M. (1957), The Measurement of Productive Efficiency, Journal of the Royal Statistics Society A CXX(3): 253-290.
Ghaderzadeh, H. & M. Haji Rahimi. (2008). Estimation of Technical Efficiency of Wheat Farms: A Case Study in Kurdistan Province, Iran. American-Eurasian Journal Agriculture & Environment Science, 4 (1): 104-109.
Green, W. H. (1990). A Gamma-distribution Stochastic Frontier Model. Journal of Econometrics 46: 141-163.
Helvoigt, T. L. & D. M. Adams. (2009). A Stochastic Frontier Analysis of Technical Progress, Efficiency Change and Productivity Growth in The Pacific Northwest Sawmill Industry. Forest Policy and Economics, 11: 280-287.

Jondrow, J. C. A. K. Lovell, I. S. Materov, & P. Schmidt. (1982). On the Estimation of Technical Inefficiency in the Stochastic Frontier Production function model. Journal of Econometrics, 19(2-3): 233-238.
Koopmans, T. (1951). An Analysis of Production as an Efficient Combination of Activities. John Wiley, New York.
Margono, H. & S. C. Sharma. (2003). Technical Efficiency and Productivity in Indonesian Provincial Economies. Southern Illinois University Carbondale Working Paper.
Mathijs, E. & J. F. Swinnen, (2001). Production Organization and Efficiency During Transition: an Empirical Analysis of East German Agriculture. The Review of Economics and Statistics 83(1): 100-107.
Meeusen, W. & J. V. D. Broeck, (1977). Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. International Economic Review 8: 435-444.
Ministry of Industries and Mines. Industrial Statistics. Several Years.
Movshuk, O. (2004). Restructuring, Productivity and Technical Efficiency in China’s Iron and Steel Industry, 1988–2000. Journal of Asian Economics 15: 135–151.
Moghtadaee, A., M. Zarra Nezhad & E. Ansari. (2006). The Role of Small Industries in Employment Generation and Economic Development in Maharashta and Khuzestan. Quarterly Journal of Economics Review (Quantitative Economics), 3(3): 3-23.
Soderbom, M. & F. Teal. (2001). Are Arican Mnufacturing Frms Rally Iefficient? Evidence from Frm-level Pnel Data. Working Papers Series 2001-14, Centre for the Study of African Economies, University of Oxford.
Stevenson, R. E. (1980). Likelihood Functions for Generalized Stochastic Frontier Estimations. Journal of Econometrics 13: 57-66.
Vu, N. Q. (2003). Technical Efficiency of Industrial State-owned Enterprises in Vietnam. Asian Economic Journal, 17(1): 87-101.