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Estimation of production function for mines in Iran

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Mines as an important sector of Iran's economy have a principal role on supply chain of the most of the economical sectors. The determination of relationship between major production function (PF) factors in mines is one of the necessary activities for efficient management of mine sector. In this paper, the best mine production functions were estimated using information of selected minerals. For this purpose, by defining efficient criteria the active mines of coal, ferrous, lead and zinc, copper, barite, kaolin and decorative stones were chosen as samples for analysis. All required information for these minerals was gathered through 1996 - 2005. Then, different forms of production functions were evaluated by employing of econometric methods and finally 4 models were chosen, these models were evaluated by using the information of all the operating mines in Iran and outcomes are compared with actual data. The results showed that Cobb-Douglass model is the most compatible production function for Iran's mines with regards to the parameters of capital, labor number, research and development costs and investment efficiency ratio. The model showed that research costs and investments on machinery and development have positive effects on mines' value added earning. In addition, it was shown that time has no positive effects on technological growth in Iran's mines.

Key words: Mine, production function, Cobb-Douglas, CES.

INTRODUCTION

Mine sector is an essential part of the economy and has significant role in supplying raw materials for industries. Progress of any society would be at stake with lack of access to mineral resources. Mineral development can create new communities and bring wealth to those already in existence. Development of mines and optimum exploitation of mineral reserves will provide considerable production capacities in other sectors such as construction and mineral industries. A report of world bank (2002) on mining activities around the world suggests that in a global scale, the US $ spent by a company on a mine generates another 2.80 US $ elsewhere in the economy.

Iran's mineral deposits with diversity of 68 minerals including 37 billion tones of proved reserves as well as 20 billion tones of probable reserves have a good potential for development. The most important mines include iron, coal, lead and zinc, copper and decorative stones with a high degree of variety and unique quality. Iran is the largest producer of lead and zinc in the Middle East, the 17^{th} producer of copper ore and the 15^{th} producer of cement in the world.

Based on the reports of the Iran Ministry of mines and industries (2008), 3419 mines with production of 217 million tones of crude ore are active in Iran. Share of mines production value added on Iran's GDP (Gross Domestic Product) is about 1%. This value is increased to 6% by concluding of the mineral industries value added. The growth rate of mine value added in 2007 was about 17.7%.

Based on the plan of the Iran ministry of mines and industries (2008), national mineral industry map has been designed to produce 42 million tpy of steel, 110 million tpy of cement, 1 million tpy of copper anion and 1 million tpy of primary aluminum till 2011. Therefore, the development of mine sector and promotion of the value added are of the major policies of Iran's government.

These policies require high capital and labor forces as the main production factors. In this regard, enhancement

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of efficient production factors such as skilled working forces and modern technology will lead to the acceleration in the growth of value added. In this paper we present a new PF for Iran's mines in order to estimate the production factors to perform designed objectives.

Production function

Production is defined simply as the conversion of inputs into outputs. It is an economic process that utilizes inputs to create a product as an exchangeable output. A PF is a function that specifies the output of a firm, an industry, or an economy for all combinations of inputs. A PF indicates the mathematical relationship between inputs and outputs and can be defined as:

i.) Technologically possible maximum output from a given set of inputs
ii.) Specification of the minimum input requirements to produce designed quantities of output with a given available technology.

The output of any firm with a given input factors having defined cost and technology is determined by the PF. PF has been used as an important tool for economic analysis in the neoclassical tradition. Economists use PF in analysis of engineering and managerial problems associated inherently with a particular production process.

The different production functions

In general, the mathematical form of neoclassical PF can be expressed as

$$Q = f(x_1, x_2, ..., x_n) \quad (1)$$

Where Q and x_i (I = 1, 2, …, n) are quantity of output and inputs (such as capital, labor or land) respectively. In macroeconomics, the output Q is replaced by GDP. PF has several forms whose majors have been listed in Table 1. These equations can be estimated using OLS (Ordinary Least Square) method. Q is the total production output which can be calculated based on products value or value added (Oraee, 2000).

Literature review

Up to now, some attempts have been made to estimate the PF of mines in Iran and other countries

i.) Lotfalipour (1990) with estimation of 41 states of PF for Iran's mines suggested that the Cobb-Douglas model in terms of labor number and capital is the best fitting to Iran's mines.
ii.) Khaksar (2001) used Cobb-Douglas to estimate the productivity of aluminum industries of Iran.
iii.) Molaie (2005) by using Cobb-Douglas model estimated the productivity in the 9 industrial sectors of Iran.
iv.) Agheli (2006) based on information of Iran provinces in 1996 - 2002 period estimated Cobb-Douglas PF with increasing returns to scale by use of PLS(Pooled Least Squares) and GLS (Generalized Least Squares) method.
v.) Oraee (2000) used Cobb-Douglas PF based on labor number and capital to estimate the productivity of mines sector in Iran.
vi.) Jones et al (1986) based on data from 20 coal mines in USA estimated Cobb-Douglas PF with capital, labor and energy production factors.

Based on the literature review and some other studies, it can be concluded that Cobb-Douglass and CES functions are suitably PF for Iran's mines. However, they solely used the capital and labor number as the input factors and they did not used other parameters such as labor qualitative parameters, time effect and R and D costs in mines.

Data

In order to estimate PF of Iran's mine, we need historical data of production factors such as labor force, capital etc. However, currently continuous and valid detailed data of production factors are available just for 1996 - 2005 periods (except 2004). About mine capital, the oldest data belongs to 2000, therefore this value should be estimated for past years. Because of lack of valid data for estimation of PF with econometric method, we decided to use the data from selected minerals. These data were used as a sample for estimation of PF. The criteria for selection of minerals includes.

i.) The highest product value added.
ii.) The highest labor force number.
iii.) Collection of valid data from mines.
iv.) Wide range of minerals such as different metallic, non-metallic and construction minerals.

Based on these criteria, 81 data points for active mines of coal, ferrous, lead and zinc, copper, barite, kaolin and decorative stones (within 1996 - 2005) whose product value comprises 95% of total, were selected for analysis.

Parameters

To estimate the mine PF, the following parameters were defined.

Capital: To estimate capital value of each year, equation (2) has been used.

$$K_t = K_{t-1} + I_t - \alpha^* K_{t-1} \quad (2)$$

Where K_t and I_t are capital value and net investment in

Table1. Properties of main production functions [Saunders H, 2008; Greene, W.H, 1997

Name	Initial Form	Logarithmic Form	Variables	Specification
Generalized Cobb-Douglas	$Q = A\prod x_i^{\alpha_i}$	$\ln(Q) = \ln(A) + \alpha_i \sum x_i$	x_i :Quantities of each input i α_i :Demand elasticity of each input i	Homogeneous with $\sum \alpha_i$ degree Constant returns to scale Ability of using more than two factors
CES (Constant elasticity of substitution)	$Q = A\left[\lambda x_1^{-\rho} + (1-\lambda)x_2^{-\rho}\right]^{-\nu/\rho}$	$\ln(Q) = \ln(A)$ $+\nu*\lambda*\ln K + \nu*(1-\rho)\ln L$ $-0.5*\nu*\rho*\lambda*(1-\lambda)$ $*(\ln(K)-\ln(L))^2$	λ : Share parameter ρ : Degree of substitutability of the inputs. x1, x2 : Production factors. A :Productivity factor	Constant elasticity of substitution
Translog	$Q = A x_1^{\alpha 1} x_2^{\alpha 2} e^{(\gamma/2)(\ln x_1)(\ln x_2)}$	$\ln Q = \ln A + \alpha 1 \ln x_1 +$ $\alpha 2 \ln x_2 + \frac{1}{2}*\gamma*\ln x_1*\ln x_2$	x1, x2 : Production factors. A: productivity factor	Has both the linear and quadratic terms Ability of using more than two factors Applicable in the cost estimation of products

year t, respectively and α is depreciation index.

Labor force number: Labor force quantity is another important production factor. To measure it, the numbers of mine labor forces for each mineral were collected.

Labor force quality: Labor force properties such as experience, skill, education, and training are effective on productivity. In general, labor force quality parameter is sum of following terms.

i.) Total skill level which is sum of skill index and training indexes of productive labor force.
ii.) Total knowledge level which is sum of education indexes of productive labor force and researchers.
iii.) Experience index which is the average experience of productive labor force.
iv.) To achieve each index, weighted average of labor force levels (skill, training, workforce education, and researchers' education) is calculated based on importance of each level.

Labor wage: Labor wage include direct and indirect annual payments to labor forces that affect the labor productivity in a direct way.

Research and development costs: Research and development costs include spending on qualitative and quantitative improvements in production based on the science and technology. These activities are necessary due to continuous change in technology and market states.
Investment efficiency ratio: Investment efficiency ratio (IER) was defined to show the effects of proper investment on the creation of value added. This index was calculated based on equation (3) by using the annual investments on machinery, infrastructure, development, and exploration in the previous year.

$$IER_t = \frac{IM_{t-1} + ID_{t-1}}{IF_{t-1}} \quad (3)$$

Where IM_{t-1}, is annual investment on machinery, ID_{t-1} is annual investment on mine development and exploration and IF_{t-1} is annual investment on infrastructures in the previous year. With increasing of this index, the effects of annual investment on technology promotion and value added creation in mines will be improved.

Time: is a parameter that shows the effects of technological changes on model in each year. Time effect on technology has been written by some researchers such as Solow (1957).

Whole of costs unit was measured based on 1 million rials that equals about 100 $ (Sept. 10, 2008 price) and was converted to 1997 constant prices (based year set by Iran central bank). These parameters were calculated per mineral at each year. The data was entered as a panel data in Eviews software package.

Model: After running the model in reviews software, the different forms of PF with combination of above mentioned parameters were evaluated. Table 2 shows estimated models which is provided by using of reviews software based on selected mineral data. A complexity of models often comes from high correlation between production factors. Therefore for estimation of coefficients, the logarithmic form of parameters had been used. The main steps for the selection of the best model are as follows:

i.) Based on literature review studies and related discussion, preliminary assumption is that a Cobb-Douglas is a suitable PF in terms of capital and labor number. However, In order to select the best property of labor force in function, evaluation of combinational forms of the capital with either of labor force wage and labor force number parameters based on Cobb-Douglass PF was done (model 1 and 2 in Table 2). After evaluation of coefficients of both models based on t values, the coefficients of model 1 were recognized to be acceptable and consequently capital and labor number are main production factors.

ii.) After specification of main production factors at step 1, Translog PF (model 3) was evaluated based on t values. However, this model was rejected.

iii.) In the next step, we evaluated CES model on capital and labor number factors. The coefficients of this model are acceptable.

iv.) In model 5 we added time (T) as a technology parameter in Cobb-Douglass model. Based on coefficients, no considerable effects of time on technological changes in Iran mines were observed. Also the result of time adding to CES model was negative.

v.) Research and development cost logarithm (RDC) as another effective parameter on PF was added to the model (model 6). Results appeared to be acceptable.

vi.) In the next step, labor quality index logarithm and Investment Efficiency ratio logarithm (IER) were added to the model (model 7 and model 8). Evaluation of these model coefficients based on t values, shows that model 8 is acceptable while model 7 has been rejected.

Based on results of steps 1 to 4, the Cobb-Douglas and CES functions are appropriate PFs while Cobb-Douglas form bears more validity. These models appear to be so simple and we need to estimate model with more parameters in order to increase precision and ability of final model. In the next step, the combination of different parameters has been applied. The model 6 can estimate the PF with R and D costs effects. In model 8, the effects of annual investment components besides R and D costs were added. Finally after evaluation of different models, estimated equation about model 6 and 8 were selected as Cobb-Douglass acceptable function.

To select the best equation, we used real data of whole Iran's mines in confirmed equations (model 6 and 8). Those in agreement with real data will set to be the final equation. Table 3 shows the real input and output data of mines in Iran (Iran's Statistics center, 1996 - 2005 ; Central Bank of Iran, 1996 - 2005).

Then squares of differences between real data and calculated values for models at each year were calculated. Table 4 shows the difference between calculated values for value added logarithms (Q).

Based on sum of differences squares, adjusted R-squared and Durbin Watson value for models, model 8 is the best model and has the minimum values of differences with real data.

DISCUSSION

After evaluation of different models, Equation (4) based on model 8 represents to be the final appropriate PF equation.

$$q_t = 4.524 * \mathrm{IER}_t^{0.055} * k_t^{0.224} * l_t^{0.773} * rdc_t^{0.18}$$

$$(3.1) \quad (3.50) \quad (5.13) \quad (10.75) \quad (6.67) \tag{4}$$

$$\bar{R}^2 = 0.874 \qquad D.W = 1.16 \qquad F = 132.03$$

Where

q_t: is the mine value added at year t with constant values of 1995 (one million rial of Iran =209 US$).
k_t: is the mine capital value at the end of year t with constant values of 1995 (million rial).
l_t: is the labor numbers at year t (person).
RDC_t: is the mine research and development costs at year t with constant values of 1995 (million rial).
IER_t : is investment efficiency ratio at year t.

Based on equation (4), labor force number and capital have more effect on learning in Iran's mines. But applying of RDC and IER variables to PF equation led to increase in the reliability and accuracy of model.

Model 4 shows CES PF form of Iran's mines. Based on capital and labor number parameters. The major parameters of estimated CES function are given in the Table 2.

Conclusion

In this paper, after estimation of simple form of PF based on capital and labor number, the effects of applying different parameters such as wage, labor quality index, R and D costs and time on PF were evaluated. It was shown that application of more variables to estimate the proper PF for mines results in increasing of reliability and accuracy of models as a decision support system. This

Table 2. Different estimates of mine production function.

Durbin Watson index	Adjusted R-squared	t-statistic	Coefficient		Parameters	Production function form	
0.615	0.594	7.628	0.517	K	Log of capital	Cobb-Douglass	1
		4.243	0.313	L	Log of labor number		
		3.844	20.558	A	technology coefficient		
0.593	0.847	6.251	0.290	K	Log of capital	Cobb-Douglass	2
		13.078	0.785	LW	Log of labor wage		
		0.236	1.139	A	technology coefficient		
0.556	0.592	0.133	0.083	K	Log of capital	Translog	3
		-0.294	-0.226	L	Log of labor number		
		0.705	0.051	KL	K * L		
		1.166	1924.715	A	technology coefficient		
0.269	0.676	9.400	0.747	K	Log of capital	CES	4
		4.897	0.323	L	Log of labor number		
		-4.469	-0.056	(K-L)^2	(log (capital / labor))^2		
		2.05	3.144	A	technology coefficient		
0.614	0.589	7.391	0.518	K	Log of capital	Cobb-Douglass	5
		4.195	0.313	L	Log of labor number		
		-0.042	-0.002	T	time		
		3.813	20.603	A	technology coefficient		
0.767	0.854	4.459	0.227	K	Log of capital	Cobb-Douglass	6
		9.810	0.757	L	Log of labor number		
		7.783	0.212	RDC	Log of R&D cost		
		3.796	6.857	A	technology coefficient		
0.765	0.853	4.339	0.227	K	Log of capital	Cobb-Douglass	7
		9.702	0.757	L	Log of labor number		
		6.261	0.211	RDC	Log of R&D cost		
		0.049	0.011	LQ	Log of Labor quality		
		3.024	6.733	A	technology coefficient		
1.163	0.874	5.130	0.244	K	Log of capital	Cobb-Douglass	8
		10.753	0.773	L	Log of labor number		
		6.673	0.180	RDC	Log of R and D cost		
		3.500	0.055	IER	Log of Efficiency investment ratio		
		3.104	4.524	A	Technology coefficient		

Table 3. Input and output data of Iran's mines.

Year	Q	K	L	RDC	IER
1996	14.333	15.027	10.879	8.857	2.904
1997	14.282	15.058	10.942	8.025	3.966
1998	14.318	14.995	10.873	7.532	2.96
1999	14.444	14.952	10.925	7.611	3.169
2000	14.419	14.892	10.976	7.699	2.749
2001	14.588	14.966	10.972	8.64	3.029
2002	14.610	15.260	10.955	8.939	3.683
2003	14.704	15.376	10.943	8.924	3.538
2005	15.335	15.928	10.912	9.204	3.478

kind of models can be used by policy makers to implement national policies and plans to create value added by optimization of production factors.

The results show that Cobb-Douglass and CES functional forms could be used for estimation of PF for Iran's mines. Here, the Cobb-Douglass model is the best one considering the capital, labor number, R&D costs and investment efficiency ratio (IER) variables. This model is more reliable than previous models. It can be concluded that machinery and development investment affect the mine value added. This parameter plus research and development could be recognized as a technology indexes. In addition, it was found that the technological changes based on time do not have positive effect on Iran's mines.

Table 4. comparison of calculated value for selected models.

Year	Q Real	Calculated values	
		Q model 6	**Q model 8**
1996	14.333	15.457	15.349
1997	14.282	15.335	15.314
1998	14.318	15.164	15.101
1999	14.444	15.210	15.157
2000	14.419	15.254	15.174
2001	14.588	15.467	15.374
2002	14.610	15.585	15.522
2003	14.704	15.599	15.531
2005	15.335	15.761	15.689
Sum of differences squares between real data and calculated values		7.077	6.052

REFERENCES

Agheli L (2006). Estimation of Iran mines production function. Econ. Res. J. (in Persian) pp. 33-50.

Central Bank of Iran (2005). Annual reviews, Iran's Economic Research and Policy Department, Central bank of Iran, Tehran, Iran

Greene WH (1997). Econometrics Analysis. New York, Prentice, Hall Inc. 3rd Edition

Jones DW, Edward LH, Russell L, Cheryl BF (1986). Production functions and tract rents in Western U.S. surface coal Mining. Resources and Energy 8(1): 35-61.

Iran's Statistics center (2005). Operating mines statistics, Tehran, Iran (annual reports)

Khaksar Gh (2001). Measurement of productivity in Iran aluminium industry. Econ. Res. J (in Persian) pp. 106-137

Lotfalipour M (1990). Estimation of Iran mine sector production functions. Tarbiat modaress university, Master of science thesis, Department of economics (in Persian)

Ministry of mines and industries (2008). Industry & Mines of Iran in 2007. Tehran, Iran (in Persian)

Ministry of mines and industries (2008). Iran mineral industry plan. Tehran, Iran, (in Persian)

Molaie M (2005). Analysis of productivity in Iran Industries. Iranian Econ. Res. J. (in Persian) (22): 157-176

Oraee A, Khodaverdi A (2000). The economics of mineral resources. Ferdowsi university press, Iran, (in Persian) pp. 54-56 &175-185

Saunders HD (2008). Fuel conserving using production functions. Energy Economics 30: 2184–2235.

Solow R, (1956). A contribution to the theory of economic growth. The Quarterly Journal of Economics 70: 65–94.

World Bank (2002). Breaking new ground. International Institute for Environment and Development and World Business Council for Sustainable Development, the Report of the Mining, Minerals and Sustainable Development (MMSD) Project; Chapter 8, Minerals and Economic Development, pp. 4-5.