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Evaluating the Total Factor Productivity Growth in Manufacturing Industries of Iran (Data Envelopment Analysis Approach)

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Abstract
This paper examines the total factor productivity changes for 23 main manufacturing industries (2-digit ISIC group) and country's provinces using data envelopment analysis during 2005 to 2007. The results show 2.3% increase in the productivity of the whole sector (average over the studied period), while the productivity of the country's provinces decreases by 7.3%, in the same period. We find Food and Beverage products and Khuzestan province having the highest productivity growth. Non-optimal allocation of resources and using of old equipments are the most important drawbacks of productivity growth for 23 main ISIC groups and provinces. Finally estimation of the regression models by panel data method reveals the privatization and increasing of labor’s available capital having a significant effect on productivity growth.
Keywords: total factor productivity, Malmquist index, panel data, manufacturing industries, data envelopment analysis

Introduction

An evaluation of the industrial sector of Iran

Manufacturing sector plays a key role in Iran economics. In the 2005 to 2007 period, this sector had approximately 13% in the GDP. Analysis of the value added in manufacturing industries showed that this sector produced about 338159 billion rials in 2007, so 15878 active firms created 21.3 billion rials on average. Large scale manufacturing plays a vital role in the industrial sector. A significant part of the added value is produced by these firms.

Assessments of firms labor force revealed that around 1102856 peoples worked in these firms in 2007. The number of employees differed according to the type of activities and their facilities. Industries like Food and Beverage, none-ferrous metals and transport equipments had the highest number of employees. Data showed that 14% of the productive employees were engineers and technicians, 41% of them were simple employees and the number of skilled employees was 44%.

In 2007, industrial firms paid 37000 billion rials to their employees and 34 million rials on average to each employee. Investment in the industrial sector was 58971 billion rials. In 2007, the ratio of investment to value added was 17.4%. Food and Beverage, chemical products, transport equipments, basic metals and none- ferrous metals had the highest investment.

Industrial firms totally exported 10 billion $ to other countries in 2007. Evaluation of industrial activities exports exhibited that chemical products, basic metals, food and beverage products, coal coke and refineries had 85% of the total industrial exports in this year. Industrial exports of these firms were respectively 55.4, 18, 6 and 5.6 percent of the total industrial exports. This shows a dramatically difference among the various industrial activities. Export share of total sales was 10%, which grow with 4% compared to 2005. This index shows the comparative advantage and market condition for the industrial activities. Data showed chemical products, leather products and basic metals exported 35, 28 and respectively 10% of their productions. The chemical industries didn't have only significant shares of the total exports, but also noticeable portion of the industry productions exported. One of the significant points was the high share of exports from total productions in leather industry. Although, the share of this activity from total industrial productions was negligible, the ability of exporting to other countries was higher than the other industrial activities (Statistical Center of Iran, 2007).

Table no. 1. Main indexes of manufacturing industries (2007)

Industry	No. of firms	No. of employees	Invest-ment	Value added
Food & Beverage products	2768	170591	5076	25138
Tobacco	2	6847	2	1175
Textiles	1337	93313	2633	9475
Wearing Apparel	165	7003	40	562
Leather Products	246	8778	86	852
Wood Products	137	7402	106	1135
Paper Products	318	18513	391	2743
Printing & Publishing	304	12724	70	1347
Coal Coke & Refinery	137	17467	1485	36107
Chemical Products	983	79879	17213	60917
Plastic Products	1055	52277	2222	8526
None – Ferrous Metal	3342	158455	6566	30006
Basic Metals	597	79128	6997	65297
Fabricated Metal Products	1285	72208	1756	14571
Machinery & Non-Classified Equipments	1081	82310	1378	15309
Official & Calculating Machines	32	2678	39	372
Electric Machinery	465	49164	735	9524
Radio & TV Products	73	8151	96	1650
Optical & Medical Equipments	163	12238	165	1461
Transport Equipments	750	127399	11204	47271
Other Transport Equipments	178	17906	521	2870
Furniture	448	18148	186	1821
Recycling	12	276	4	28

Literature review

Productivity growth and technical efficiency has been estimated in a lot of studies at sectoral level for different types of industries, using both, parametric and non-parametric methodology. In the parametric methodology, stochastic frontier analysis is performed while in non-parametric methodology, the Data envelopment analysis is used.

The Malmquist index approach has been used in a variety of studies related to the financial sector, to measure productivity change. In particular, this approach has been applied in studies such as in those of Fare, Grosskopf and Lee (1995) who made an analysis of the productivity in four Taiwanese manufacturing industries during 1978-1989, by decomposing the Malmquist productivity change index into technical change and technical efficiency change. Further was also compared to traditional and parametric approaches. The results of this study suggested that TFP growth in long run was totally because of technical change. Further results suggested that technical efficiency and technical progress may not move together and technical change was positively related whit R&D.

Fare, Grasskopf and Margaritis (2001) analyzed the relative trend in total factor productivity in Australia and New Zealand for the manufacturing sector, during 1986-1996. Malmquist productivity index was used to calculate the total factor productivity. The results showed that New Zealand performed better than Australia in terms of total factor productivity for the manufacturing sector. The lower TFP in Australia was due to low capital intensity in the production process. Further, the major source of TFP growth in New Zealand was technical change, rather than efficiency change.

Jajri (2007) analyzed the total factor productivity growth in Malaysia during 1971-2004, in order to discuss factors that determine the TFP growth. Data envelopment analysis was used to estimate the changes in the production frontiers. Empirical results suggested that the economy needs an enhancement of their productivity based catching-up capability, specifically the effective use of human capital in the labor market; increase the number of skilled workers to operate a more sophisticated technology and the adoption of the new technology. The results of TFP growth model showed that openness to foreign companies and world economy, restructuring of the economy through the shift of resources between sectors, and the presence of foreign companies in Malaysia, is believed to be major contributor to the TFP growth.

Raheman et al (2008) analyzed the total factor productivity of major manufacturing industries of Pakistan with Malmquist productivity index during 1998 to 2007. The results showed a mixed trend for all manufacturing sub sectors/industries in terms of TFP, technical efficiency change and technological change. Cement, oil and gas sectors depicted stable position. Most of the manufacturing industries had gained in terms of technical efficiency, but the technical change had a negative effect on productivity growth except few industries.

Vahid and Sowlati (2008) evaluated productivity changes of the manufacturing industries in the U.S from 1997 to 2002 with Malmquist productivity index. The results showed 5% increase in the average productivity of the whole sector over the studied period, while the productivity of the wood product manufacturing decreased by 1% over the same period. The efficiency decline of the industry was the main contributor to the decline of its productivity.

Senturk (2010) analyzed the total factor productivity growth of public and private manufacturing industries in Turkey over the period 1985 to 2001 using the linear programming technique. The empirical results indicated that TFP increased 56% for the entire manufacturing industry, 51% for the public sectors and 60% for private sectors.

Methodology

The Malmquist Productivity Index

Data envelopment analysis is a non-parametric linear programming methodology to measure the relative efficiency of a homogeneous set of decision making units (DMUs) on the basis of multiple inputs and multiple outputs (Charnes et al., 1978).

The concept of the Malmquist productivity index was originally introduced by Malmquist as a quantity for analyzing the consumption of inputs. Afterwards, Färe et al. (1992) constructed a Malmquist productivity index directly from input and output data using DEA. Specifically, the DEA-based Malmquist productivity index, hereafter referred to as DEA-MI, relies on firstly constructing an efficiency frontier over the whole sample realized by DEA and then computing the distance of individual observations from the frontier. In practice, this DEA-MI has proven to be a good tool for measuring the productivity change of DMUs over time and has been successfully applied in many fields.

To describe the method, we consider a set of n DMUs, or the 23 industrial activities in which each consuming m different inputs to produce s different outputs. x_{ij}^t, y_{ij}^t denote the ith input and rth output respectively of jth DMU at any given point in time t. The DEA-MI calculation requires two single-period and two mixed-period measures. The two single-period measures are obtained by solving the basic DEA model. An adjusted output- oriented DEA model is proposed as follows:

$$D_0^t(x_0^t, y_0^t) = \min \theta$$

$$\text{s.t. } \sum_{j=1}^{n} x_{ij}^t \lambda_j \geq x_{io}^t, i = 1,....,m \tag{1}$$

$$\sum_{j=1}^{n} y_{rj}^t \lambda_j \leq \theta y_{ro}^t, r = 1,....,m$$

$$\lambda_j \geq 0, j = 1,....,n$$

This linear program is computed separately for each DMU, and the subscript, o, refers to the DMU whose efficiency is to be evaluated. $\theta(0\langle\theta \leq 1)$ is the uniform proportional reduction in the DMU_0's outputs. It's minimum amount is known as the DEA efficiency score for DMU_0, which also equals to the distance function of DMU_0 in year t, i.e., $D_0^t(x_0^t, y_0^t)$. As a result, if the value of θ equals to one, then the DMU is efficient and its input-output combination lies on the efficiency frontier. In the case that $\theta\langle 1$, the DMU is inefficient and it lies inside the frontier. In a similar way, using t+1 instead of t for the above model, we obtain the efficiency score of DMU_0 in the time period t+1, denoted as $D_0^{t+1}(x_0^{t+1}, y_0^{t+1})$.

For the mixed-period measures, the first one is defined as $D_0^t(x_0^{t+1}, y_0^{t+1})$ for DMU_0, which is computed as the optimal value resulting from the following linear programming problem:

$$D_0^t(x_0^t, y_0^t) = \min \theta$$

$$\sum_{j=1}^{n} x_{ij}^t \lambda_j \geq x_{io}^{t+1}, i = 1,....,m$$

$$\sum_{j=1}^{n} y_{rj}^t \lambda_j \leq \theta y_{ro}^{t+1}, r = 1,....,s \tag{2}$$

$$\lambda_j \geq 0, j = 1,....,n$$

This model compares (x_0^{t+1}, y_0^{t+1}) to the frontier at time t. Similarly, we can obtain the other mixed-period measure $D_0^{t+1}(x_0^t, y_0^t)$, which compares (x_0^t, y_0^t) to the frontier at time t+1.

The (output-oriented) DEA-MI, which measures the productivity change of a particular DMU_0 at time t+1 and t, can be expressed as:

$$MI_0 = \left[\frac{D_0^t(x_0^{t+1}, y_0^{t+1})}{D_0^t(x_0^t, y_0^t)} \frac{D_0^{t+1}(x_0^{t+1}, y_0^{t+1})}{D_0^{t+1}(x_0^t, y_0^t)} \right]^{1/2} \quad (3)$$

$MI_0>1$ indicates progress in the total factor productivity of DMU_0 from the period t to t+1, while $MI_0=1$ and $MI_0<1$ means respectively the status quo and decay in productivity.

Moreover, in contrast to conventional production functions or other index approaches, the DEA-MI can be further decomposed into two components, one measuring the change in efficiency and the other measuring the change in the frontier technology. Mathematically, these two components can be measured by the following modification of MI in (4):

$$MI_0 = \frac{D_0^{t+1}(x_0^{t+1}, y_0^{t+1})}{D_0^t(x_0^t, y_0^t)} \left[\frac{D_0^t(x_0^{t+1}, y_0^{t+1})}{D_0^{t+1}(x_0^{t+1}, y_0^{t+1})} \frac{D_0^t(x_0^t, y_0^t)}{D_0^{t+1}(x_0^t, y_0^t)} \right]^{1/2} \quad (4)$$

The first term, i.e., $EFFCH = D_0^{t+1}(x_0^{t+1}, y_0^{t+1}) / D_0^t(x_0^t, y_0^t)$ indicates the magnitude of the efficiency change from period t to t+1, which also reflects the capability of an industry in catching up with those efficient ones. The second one, i.e.,

$$TECHCH = \left[\frac{D_0^t(x_0^{t+1}, y_0^{t+1})}{D_0^{t+1}(x_0^{t+1}, y_0^{t+1})} \frac{D_0^t(x_0^t, y_0^t)}{D_0^{t+1}(x_0^t, y_0^t)} \right]^{1/2}$$

measures the shift in the technology frontier between two time periods.

In this study we will use the output oriented analysis because most of the firms have their objective to maximize output in the form of revenue or profits. It is also assumed that there are constant returns to scale (CRS) technology to estimate distance function for calculating Malmquist productivity index (Shen et al., 2010).

Table no. 2. Definition of variable

Output Variables	Input Variables
Value Added of manufacturing industries (million rials)	Number of employees Capital formation (million rials) Raw materials employed by manufacturing industries (million rials) Fuel employed by manufacturing industries (million rials)

To analyze the productivity of industrial firms, at first the total factor productivity of 23 main industrial activities based on ISIC (two-digit codes) and then the productivity of industrial sector of the provinces, during the 2005-2007 period, were investigated.

Empirical results

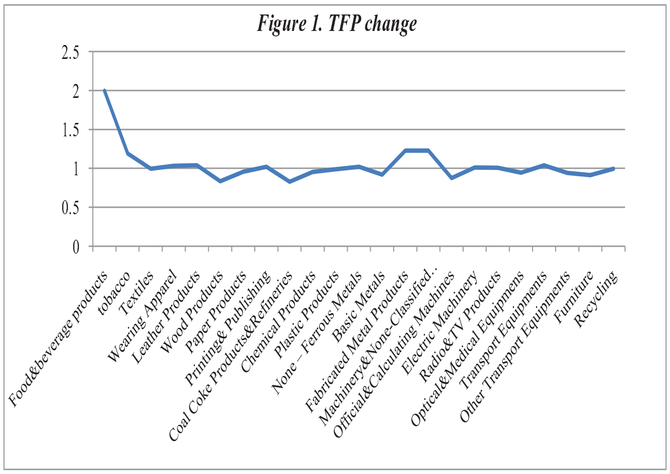
Total Factor Productivity Growth in the Industrial Sector (2-digit ISIC groups)

Table no. 3 shows that manufacturing industries experienced overall positive TFP growth (2.3%) during the 2005-2007 periods. The examination of industries reveals that 11 industries had positive TFP growth. The overall TFP is positive due to improvement in technology (5.2%). Technical inefficiency is the most important factor having negative effect on the total factor productivity growth. The overall technical efficiency in 14 industrial activities is less than 1. Technical efficiency change is a result of pure technical efficiency change and scale efficiency change. Pure technical efficiency change is one or less than one in the most industries. In the case of scale efficiency, the results are the same as the pure technical efficiency change; therefore, both scale efficiency and pure technical efficiency had the negative effect on improvement TFP growth.

The comparison of total factor productivity change in different industrial activities shows that Food and Beverage industry had the highest growth in TFP (99.65) on average during 2005-2007. The worst performance is related to the Coal Coke and refinery products. Total factor productivity of this activity decreased in average by 16.6%.

Table no. 3. Malmquist Productivity index (Means), 2005-2007

Industry	TFP change	TE change	Tech change	PE change	SE change
Food & Beverage	1.996	1.507	1.324	1.216	1.240
Tobacco	1.191	1	1.191	1	1
Textiles	0.994	0.9	1.104	0.888	1.014
Wearing Apparel	1.033	0.958	1.079	0.959	0.998
Leather Products	1.039	1.004	1.036	0.982	1.022
Wood Products	0.834	0.801	1.041	0.801	1
Paper Products	0.957	0.872	1.097	0.873	0.999
Printing & Publishing	1.019	0.905	1.126	0.938	0.965
Coal Coke Products & Refineries	0.828	1	0.828	1	1
Chemical Products	0.953	0.888	1.073	1	0.888
Plastic Products	0.987	0.940	1.050	0.958	0.982
None – Ferrous Metals	1.021	0.925	1.105	0.995	0.930
Basic Metals	0.920	0.855	1.076	1	0.855
Fabricated Metal Products	1.227	1.229	0.999	1.195	1.028
Machinery & None-Classified Equipments	1.229	1.232	0.997	1.185	1.039
Official & Calculating Machines	0.875	0.984	0.889	1	0.984
Electric Machinery	1.012	1	1.011	1.037	0.964
Radio & TV Products	1.008	1	1.008	1	1
Optical & Medical Equipments	0.944	0.889	1.063	0.915	0.971
Transport Equipments	1.038	1	1.038	1	1
Other Transport Equipments	0.941	0.951	0.989	1	0.951
Furniture	0.913	0.870	1.049	0.877	0.993
Recycling	0.994	0.892	1.114	1	0.892
MEAN	1.023	0.973	1.052	0.988	0.985



Total Factor Productivity Growth in the Industrial Sector (Regional Analysis)

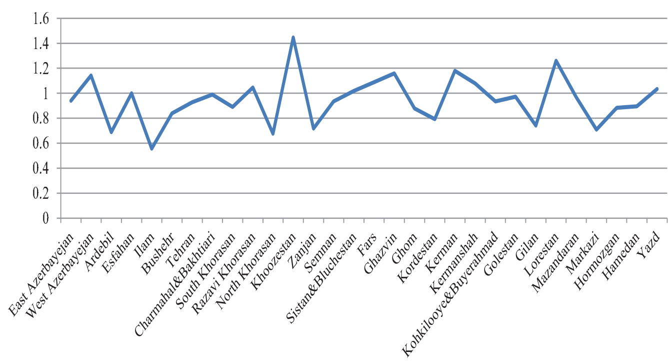
Table no. 4 shows that total factor productivity growth among industrial sector of the provinces decreased with 7.3%, during 2005 to 2007. Only 10 out of 30 provinces experienced positive productivity growth. Among the provinces with positive productivity growth, Khuzestan had the highest growth in TFP (44.7%). Technological inefficiency is the most important factor of negative productivity growth among provinces, 29 out of 30 provinces had technological inefficiency, and only Khuzestan province experienced the positive growth in technological efficiency (17%). Technical efficiency changes are 1 or higher than 1 in the total provinces.

Table no. 4. Malmquist Productivity index (Means), 2005-2007.

Provinces	TFP change	TE change	Tech change	PE change	SE change
East Azerbayejan	0.940	1.392	0.676	1.031	1.350
West Azerbayejan	1.141	1.626	0.702	1.455	1.117
Ardebil	0.689	1.050	0.656	1.032	1.017
Esfahan	1	1.341	0.746	1	1.341
Ilam	0.557	0.810	0.687	1	0.810
Bushehr	0.838	1	0.838	1	1
Tehran	0.927	1.417	0.654	1	1.417

Provinces	TFP change	TE change	Tech change	PE change	SE change
Charmahal & Bakhtiari	0.990	1.448	0.684	1.494	0.970
South Khorasan	0.890	1.054	0.844	1.072	0.983
Razavi Khorasan	1.045	1.643	0.636	1.059	1.552
North Khorasan	0.677	1	0.677	1	1
Khuzestan	1.447	1.237	1.170	1	1.237
Zanjan	0.717	1.098	0.653	0.995	1.103
Semnan	0.934	1.350	0.692	1.189	1.136
Sistan & Bluchestan	1.018	1.377	0.739	1.354	1.017
Fars	1.088	1.480	0.735	1.170	1.265
Ghazvin	1.158	1.669	0.694	1.198	1.392
Ghom	0.878	1.414	0.621	1.335	1.060
Kordestan	0.792	1.064	0.745	1.055	1.009
Kerman	1.180	1.350	0.874	1.190	1.134
Kermanshah	1.078	1.624	0.664	1.487	1.092
Kohkilooye Buyerahmad	0.934	1.315	0.710	1	1.315
Golestan	0.972	1.496	0.650	1.522	0.983
Gilan	0.742	1.175	0.631	1.091	1.077
Lorestan	1.259	1.428	0.882	1.419	1.006
Mazandaran	0.968	1.523	0.636	1.190	1.279
Markazi	0.708	1.021	0.693	0.868	1.176
Hormozgan	0.883	1	0.883	1	1
Hamedan	0.895	1.322	0.677	1.311	1.008
Yazd	1.034	1.425	0.726	1.186	1.202
MEAN	0.927	1.284	0.722	1.143	1.123

Figure 2. TFP change



Evaluation of Effective Factors on Productivity Growth in Industrial Sector among Provinces (Regression Analysis)

To determine more precisely the effective factors on productivity growth, the regression model with panel data method was estimated.

In this study, independent variables are share of wages in value added; ratio of private to public ownership, ratio of capital to labor and R&D costs and the dependent variable are the total factor productivity changes estimated with the DEA method.

$$\Delta TFP = (PP, WV, CL, RD)$$

PP: Ratio of Private to Public Ownership
WV: Share of Wages in Value added
CL: Ratio of Capital to Labor
RD: R&D costs

The model is estimated with pooled and fixed effect. Based on F test finally the pooled model is accepted for analyzing. R&D costs variable deleted due to statistically insignificant.

Table no. 5. The regression model of effective factors upon the total factor productivity growth

Variables	Coefficients	t	Standard Deviation
Intercept	1.0384	86.9	0.012
WV	0.0002	0.87	0.0002
pp	0.1834	3.31	0.0554
CL	0.0003	37.38	0.0098
R^2	0.97		
Adjusted R^2	0.97		
F	913.56		
DW	2.16		

The results show that coefficients of private to public ownership and capital to labor are positive and statistically significant, and privatization had noticeable effect on productivity growth.

Concluding remarks

The evaluation of total factor productivity changes for 23 main industries (2- digit ISIC groups) showed that firms had positive productivity growth during 2005 to 2007, while regional analysis depicted negative productivity growth in provinces.

More assessments of effective factors on productivity growth for 23 main industries (2-digit ISIC groups) revealed disability in optimal allocation of resources and acting in optimal scale were the most important factors for firms to promote their productivities.

The analyzing of productivity changes for provinces exhibited that the most drawback for productivity growth was the investment shortage for modern equipments. Regression analysis showed that privatization had noticeable effect on productivity growth. Continuing the privatization trend, we hope productions and export revenues of industrial firms will increase in future years.

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