Technological Change and its Relationship with Total Factor Productivity in Iran's Petroleum Refineries

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ABSTRACT

Nowadays, using appropriate technologies in order to increase productivity of production factors can be resulted in optimal factors employment and production enhancement in factories. Technological change is considered as one of the main sources of productivity growth. The purpose of this paper is to analyze the various aspects of technological change and their relationship with total factor productivity in Iran's petroleum refineries.
In order to achieve this goal, we used the econometric method to estimate the cost function. This method seems useful to estimate the structure of factors demand, considering changes in factors prices and technology status. We estimated a translog cost function as well as equations system of cost share, using Seemingly Unrelated Regressions (SUR) approach from 1982 to 2012.
The results show that the average rate of technological change was -0.482 percent over the study period. It means that over time, the cost growth rate of production units was decreased mainly due to technological change. Furthermore, the results indicate that technological change was biased towards the use of more labor and material, while it saved more capital and energy. Also, based on the estimation results, we decomposed total factor productivity growth rate into the contributions of technological change and economies of scale. Decomposition results show that the share of technological change in the productivity growth is greater than that of scale economies.

1. Introduction

Petroleum Refineries are considered as one of the most important parts of the oil industry value chain. This sector operates as an important tool for linking between the upstream production and consumer market.

Iran is a major producer of oil, but the country is relatively weak on petroleum refining capacity. Although the number of oil refineries was increased but for many reasons including low technology, resources were not been used efficiently and as a result many potential capacities of the refineries have not been utilized.

Big picture review on the volume of production and number of oil refineries in Iran shows that the problem is not the fewer number of the refineries, but the problems are low factor productivity, old production methods, inappropriate applications of modern technology, management weakness, etc. Thus it seems necessary to conduct researches on technological change analysis in order to enhance productivity in oil refineries and consequently optimize utilization of resources. Several studies on different sections of economy revealed that the effect of technological change to improve productivity are significant. After Second World War, the

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studies on technical change were expanded in economics. Some of the well-known studies are Solow (1957, 1962), Salter (1960), Intriligator (1965), McCarthy (1965), Drandakis and Phelps (1966) Jorgenson (1966), Nordhaus (1969), Atkinson and Stiglitz (1969), Diewert (1971), Binswanger (1974), Stevenson (1980), Romer (1990), Kant and Nautiyal (1997), Peretto (1999), Rasmussen (2000), Napasintuwong and Emerson (2002,2003), Datta and Christoffersen (2004), Grebel (2009), Krysiak (2011), Mattalia (2013), Hart (2013), Roshef (2013), Schafer (2014), and Chen and Wemy (2015) among others.

Tendency toward such researches have two main reasons: Firstly, supply increase of industrial products versus their demand caused decreasing trend in their prices and consequently in industrial section's revenue. This attracted many economists to discover the reasons of the growth, and they found that one of the main reasons for such growth is technical change. Secondly, there was a shortage of industrial materials in developing countries. Therefore, according to the aforesaid studies, technical change was considered as a major reason of productivity growth (Hayami and Godo, 2005).

Technological change in petroleum refineries is also one of the main elements of productivity growth. Thus, it is necessary to enhance our understandings on the technology of petroleum refineries, bias and rate of growth in order to modify and improve the industry condition. Considering above, the main purpose of this study is to analyze different aspects of technological change in Iran's petroleum refineries during the years 1982-2012.

2. Methodology

In production process literature, production technology is defined as the relation between inputs and output, which can be illustrated by production function (Chambers, 1988). The production structure and technological change can be surveyed by production function or dual cost function. Direct estimation of production function will be appropriate if amount of output is determined endogenously, while for exogenous amount of output cost function is preferred (Kant and Nautiyal, 1997).

For this study we chose translog functional form as the most appropriate functional form among all functional forms, because it is widely used in similar researches and also is flexible enough. Furthermore, it has several theoretical and statistical characteristics advantages such as the flexibility of avoiding pre-specification of any particular relationships, and the imposition of minimum restrictions on the parameters. Moreover, factor demand functions can be derived from Shepherd's lemma (Bhattacharyya, 2011).

General form of cost function considering time trend (T) variable is as follow (Rasmussen, 2000):

$$C = f\,(P_l, P_k, P_e, P_m, Q, T) \tag{1}$$

In which Pl, Pk, Pe and Pm are prices of labor, capital, energy and material respectively. Q is value of product and C is cost. So, translog cost function is written as follow:

$$\begin{aligned} LnC &= v + \sum_i a_i LnP_i + a_q \ln Q + \frac{1}{2}\sum_i\sum_j b_{ij} LnP_i LnP_j \\ &+ \sum_i b_{iq}\, LnQ \ln P_i + \frac{1}{2} b_q (\ln Q)^2 + b_t T + \frac{1}{2} b_{tt} (T)^2 \\ &+ \sum_i b_{ti} (\ln P_i) T + b_{qt} (\ln Q) T \end{aligned} \tag{2}$$

$$i, j = k, l, e, m$$

Factor cost shares can be obtained by partial derivation of translog function with respect to i-th input price, thus:

$$\frac{\partial \ln C}{\partial \ln P_i} = \frac{\partial C}{\partial P_i}\frac{P_i}{C} = \frac{x_i P_i}{C} = S_i \tag{3}$$

$$S_i = a_i + \sum_j b_{ij} \ln P_j + b_{iq} \ln Q + b_{ti} T \tag{4}$$

In which, $C = \sum P_i X_i$, Si is cost share of i-th input and X refers to amount of factor.

In order to ensure that the underlying cost function is well-behaved, the cost function must be homogeneous of degree one in input prices, given output. Then, liner homogeneity in factor prices and symmetry imposes the following restrictions:

$$\sum_j a_i = 1 \qquad \sum_j b_{ij} = 0 \qquad \sum b_{iq} = 0 \qquad b_{ij} = b_{ji} \tag{5}$$

Rate of technological change can be obtained by derivation of cost function with respect to time (Datta and Christoffersen, 2004 and Kant and Nautiyal, 1997):

$$\mathring{C} = \frac{\partial \ln C}{\partial T} = b_t + b_{tt} T + \sum b_{ti} \ln P_i + b_{qt} \ln Q \tag{6}$$

It shows that technological change can be divided into three elements:

1- pure technical change (bt+btt T)

2- non-neutral technical change ($\Sigma b_{ti} \ln P_i$)

3- scale-augmenting technical change (bqt lnQ)

The first element – pure technical change- has no relation with inputs, amount of output and factor prices. It is a fixed part of function and its change causes cost function moving towards up or down. If it is negative, cost function goes down and it indicates positive technological change.

Interaction of factors over time is in second element. In other words, it shows the effects of technological change on factors during the time. It shows any substitution or saving factors. Changing this element results slope changing of cost curve.

Third element is the effect of technological change on the capacity of institute. Clearly scale-augmenting technological change causes Economies of scale, due to increasing in production. It also decreases cost and leads to cost function shift.In cost function, return to scale (scale elasticity) is determined as follow:

$$E=\left[\frac{\partial \ln C}{\partial \ln Q}\right]^{-1}=\left(a_q+b_q\ln Q+\sum_i b_{iq}\ln P_i+b_{qt}T\right)^{-1} \quad (7)$$

Return to scale refers to changes in output subsequent to a proportional change in all inputs (where all inputs increase by a constant factor). If output increases by that same proportional change then there are constant returns to scale (CRS). If output increases by less than that proportional change, there are decreasing returns to scale (DRS). If output increases by more than that proportion, there are increasing returns to scale (IRS).

Stevenson (1980) believes that technological change may have bias to factor and scale characteristics of production. In case of technical progress, factor bias is as follow:

$$I_{bi}=\frac{\partial S_i}{\partial T} \quad (8)$$

If I_{bi}<0, technological change results to use input i more. If I_{bi}<0, technological change saves input i. If I_{bi}=0 then it has no effect on using input i. Scale bias is calculated by derivation of the phrase in bracket:

$$SE_i=\frac{\partial^2 \ln C}{\partial \ln P_i\cdot\partial \ln Q}=\frac{\partial S_i}{\partial \ln Q} \quad (9)$$

If SEi>0, increasing of production scale, leads to use input i more. If SEi<0, it leads to use input i less. If SEi=0 it has no effect on using input i.

Cost function system can be estimated if data and information is available. Although parameters of basic cost function are being estimated by Ordinary Least Squares (OLS) method, but it does not include cost share equations. A suitable method to estimate such systems is Seemingly Unrelated Regression (SUR). Since value shares sum to using, the sum of the disturbances across any three equations is zero at all observations (Baltagi, 2005). Hence, to avoid singularity of the covariance matrix any one of the four share equations can be dropped, i.e., three can be estimated and the forth is automatically determined (Kant and Nautiyal, 1997). We drop energy share equation. Eventually, according to the methodology, technological change is being analyzed.

3. Technological change and total factor productivity

There are different ways to calculate the total factor productivity. In this research this criterion calculated through econometric method and estimation of parameters. In this way, by estimating cost elasticity of the relevant production and replacing it in the following formula, total factor productivity growth can be estimated (Baltagi and Griffin, 1988):

$$\overset{\circ}{TFP}=-\overset{\circ}{T}+(1-\varepsilon_{CQ})\overset{\circ}{Q} \quad (10)$$

In this regard, $\overset{\circ}{T}$ indicates the technological change,is ε_{CQ} elasticity of the cost related to product, $\overset{\circ}{Q}$ is the per cent of production growth.

4. Sources of Data and Structure of Variables

The data were collected from various editions of the Iranian reports on industrial enterprises and different volume of the Wholesale Price Index in Iran. We have adopted 2004 as base year to converting nominal data to real data. Output is the value of aggregate output produced during the year. This implies that no change in the stock of output has taken place. The capital expenditure is computed as the user cost of capital multiplied by the capital stock. In order to calculate the user cost of capital, we used Puk=(r+P) Pi, where r is the long run interest rate, P is the depreciated rate of capital assumed to be 5.5 % by year and Pi is the investment deflator.

Total cost is the sum of the cost of labor, capital, material and energy. For labor input, the number of persons employed and the wage calculated for emoluments per person employed have been used for model estimation. The price of labor is obtained as the ratio of total compensation to labor divided by the number of workers. Fuel cost is the cost of all types of fuel used for production. We add fuel cost to electricity cost to obtain energy cost. The price of fuel is obtained by taking a weighted average of all types of fuel prices. The price of energy is obtained by taking a weighted average of fuel and electricity price. The cost share of labor, capital, material and energy are obtained by dividing the corresponding cost by the total cost.

5. Test of Stationarity

To use time series data in estimation of model, we need to examine the series for stationarity. If a time series is stationary, its mean, variance, and autocovariance (at various lags) remain the same no matter at what point we measure them; that is, they are time invariant. If series are nonstationary, F and t statistics are not valid and estimated model is not reliable (Gujarati, 2004). A commonly used test that is valid in large samples is the Augmented Dickey–Fuller test.

Results of the Augmented Dickey-Fuller (ADF) test showed that all variables have unit root and after first difference ADF statistics were greater than Mackinnon Critical Values and thus we can reject the null hypothesis of a unit root at all common significance levels which means they become stationary (Table 1). Also the test shows stationarity of residuals (table 2). Thus, spurious regression is rejected and the results of estimation are reliable.

Table 1: Results of Augmented Dickey-Fuller Unit Root Test on Variables

Variable*	ADF statistics	Mackinnon Critical Values		
		10%	5%	1%
D(LC)	-5.325	-2.623	-2.968	-3.679
D(LPL)	-5.081	-2.625	-2.972	-3.689
D(LPK)	-3.853	-2.623	-2.968	-3.679
D(LPE)	-4.674	-2.623	-2.968	-3.679
D(KPM)	-4.003	-2.623	-2.968	-3.679
D(SL)	-6.425	-2.636	-2.992	-3.738
D(SK)	-8.155	-2.623	-2.968	-3.679
D(SE)	-7.257	-2.623	-2.968	-3.679
D(SM)	-6.446	-2.623	-2.968	-3.679
D(LQ)	-6.124	-2.623	-2.968	-3.679

* Ln of variables in equations no. 1 & 3

Table 2: Results of Augmented Dickey-Fuller Unit Root Test on Residuals

Variable*	ADF statistics	Mackinnon Critical Values		
		10%	5%	1%
RESID 1	-6.306	-2.622	-2.967	-3.679
RESID 2	-3.938	-2.621	-2.963	-3.670
RESID 3	-5.334	-2.621	-2.963	-3.670
RESID 4	-4.408	-2.632	-2.986	-3.724

6. Empirical Results

6.1 Parameter estimates of the translog cost function

The parameter estimates of the translog cost function along with the associated cost share equations are presented in Table 3. Many significant variables and high value of R2 are signs of good estimation. Durbin Watson (D.W) statistic shows that there is no autocorrelation in the estimated model.

6.2 Rate of Technological Change

The study of technological change over the study years clarified that by the passage of time, technological progress in petrochemical industry decreased the rate of cost change. According to the equation 6, rate of technological change since 1982 to 2012 was -0.482. It means that average rate of decrease in cost of production was 0.482 % each year. As Table 4 portrays, although this rate changes over time, but negative sign means decreasing in cost rate during the time. Thus, our estimations confirm that technological progress decreased rate of cost change of the petroleum refineries.

Table 3: Results of Parameters Estimates

Parameter	Coefficient	t- Statistic	Parameter	Coefficient	t- Statistic
v	-104.131	-4.480	bkm	-0.028	-1.384
al	0.929	1.838	bem	0.037	3.101
ae	-0.339	-2.883	blq	0.041	2.463
am	0.057	0.103	bkq	-0.397	-10.114
ak	0.354	3.428	beq	-0.004	-1.370
aq	8.477	4.465	bmq	0.068	4.162
bll	0.044	1.272	bq	0.020	0.283
bkk	0.046	10.750	bt	-2.434	-4.393
bee	0.003	0.299	btt	-0.022	-3.145
bmm	-0.071	-1.446	blt	0.001	0.205
blk	-0.014	-0.747	bkt	-0.020	-1.857
ble	-0.012	-2.696	bet	-0.002	-1.850
blm	0.002	0.068	bmt	0.002	0.419
	0.011	3.081	bqt	0.113	5.704

Statistics of Cost Equation $R^2=0.99$ $\bar{R}^2=0.94$ D.W=2.17

Statistics of Equation of Labor share $R^2=0.68$ $\bar{R}^2=0.60$ D.W=1.82

Statistics of Equation of energy share $R^2=0.78$ $\bar{R}^2=0.73$ D.W=1.86

Statistics of Equation of material share $R^2=0.75$ $\bar{R}^2=0.69$ D.W=1.91

6.3 Return to Scale

Return to scale indicates that it was increased during the study years with the average of 1.26 (Table 5). Thus, capacity expansion of production units leads to Economies of scale.

6.4 Factor and Scale Bias

The results of factor and scale bias (equations 8 & 9) are presented in Table 6. Positive signs of bias of labor and material factors show that labor and material use was increased during the study time. It means that if the prices of other factors remain constant, the cost shares of labor and material will increase during the time. On the other hand, negative sign of bias of energy, indicates that using modern technologies causes less use of energy in production units. Finally, negative sign of capital shows that using advanced machineries leads to capital saving.

According to scale bias figures, increase in production scale will lead labor and material to be used increasingly. It means that expansion in size of production units increases tendency to use more labor and material. Meanwhile, capital and energy factors were used decreasingly.

6.5 Total factor productivity growth and technological change

Given that technological change is one of the main sources of change of total factor productivity in manufacturing plants, therefore, improvement of technological change can contribute to the growth of total factor productivity.

Accordingly, by estimating the cost function parameters and using equation (10), the growth of total factor productivity was measured and divided into technological change and economies of scale. The results are shown in Table 7.

Through econometric approach, we also found that the annual average of total factor productivity was 0.529 percent over the study period. In general, this growth originated from two factors, the changes in technology and production unit size (production scale). In addition to the mentioned factors, there were some other factors which affected productivity of this sector like diversify oil and gas production and safety systems of production, transportation and consumption. There are other factors that had a negative impact on the efficiency of the petroleum refineries such as as aging refineries, depreciation facilities and the absence in the global market. However, productivity growth in this sector was positive during the study period.

As Table 6 shows, improved total factor productivity was significantly affected by changes in technology. Due to the negative rate of technology change, it is characterized that the use of appropriate technology over time causes de-

Table 4: Rete of Technological Change

year	Rate of technological change(percent)	year	Rate of technological change(percent)
1982	-0.348	1998	-0.392
1983	-0.376	1999	-0.374
1984	-0.406	2000	-0.365
1985	-0.449	2001	-0.384
1986	-0.544	2002	-0.400
1987	-0.524	2003	-0.418
1988	-0.630	2004	-0.414
1989	-0.565	2005	-0.427
1990	-0.601	2006	-0.461
1991	-0.660	2007	-0.496
1992	-0.616	2008	-0.476
1993	-0.602	2009	-0.479
1994	-0.639	2010	-0.340
1995	-0.508	2011	-0.356
1996	-0.649	2012	-0.375
1997	-0.642	-	-
Average of period = -0.482			

Table 5: Return to Scale

year	Return to Scale	year	Return to Scale
1982	2.239	1998	1.436
1983	2.128	1999	1.421
1984	2.415	2000	1.328
1985	2.063	2001	1.407
1986	1.624	2002	1.367
1987	1.244	2003	1.426
1988	1.201	2004	1.341
1989	1.324	2005	1.414
1990	1.193	2006	1.385
1991	1.672	2007	1.336
1992	1.725	2008	1.349
1993	1.563	2009	1.278
1994	1.162	2010	1.254
1995	1.627	2011	1.291
1996	1.583	2012	1.263
1997	1.427	-	-
Average of the period = 1.267			

Table 6: Factor and Scale Bias

Input	Factor Bias	Scale Bias
Labor	0.001	0.041
Capital	-0.020	-0.397
Energy	-0.002	-0.004
Material	0.002	0.068

cline in the rate of change in the cost of production. Thus, the unit production is achievable by lower expending. On the other side, the increasing size of the production unit may lead to improved total factor productivity. Therefore, the result of improvement in technology and production scale is observed through growth of total factor productivity in petroleum refineries industry.

7. Conclusions

Estimation of translog cost function and cost share equations by SUR method in Iran's petroleum refineries seems appropriate because many of coefficients are significant and R2 is relatively high. The sign of the rate of technological change show that over time, rate of change in the cost of production units was decreased. According to the results of our estimations, we realized that using new and advanced technology led to better cost change during the study period. Thus, it is expected to have more economic production in petroleum refineries through right technologies.

Moreover, our analyses, scale elasticity statistic indicates increasing return to scale in Iran's petroleum refineries i.e. production increases were more than the proportional change in all inputs, which in turn decreased per unit cost. And as a result Economies of scale was appeared in production process.

Over the study period, the results of our model on factor and scale biases in petroleum refineries also revealed that the factor bias and scale bias of labor and material were positive while we observed high cost shares of these inputs out of total cost of inputs in production units. Consequently, we recommend that managers should be encouraged to enhance the productivity of the mentioned inputs in order to decrease production cost. Moreover, this type of technological change diminishes dependence on capital and energy and related costs.

Finally, based on the estimation results of the above mentioned models, we decomposed total factor productivity growth rate into the contributions of technological change

Table 7: Total Factor Productivity Growth and Technological Change

year	Growth of total factor productivity	Technological change	Economies of scale
1982	-	-0.348	-
1983	0.853	-0.377	0.476
1984	0.458	-0.406	0.052
1985	0.530	-0.449	0.081
1986	0.631	-0.544	0.087
1987	0.472	-0.525	-0.053
1988	0.603	-0.631	-0.027
1989	0.550	-0.566	-0.016
1990	0.597	-0.601	-0.004
1991	0.665	-0.661	0.004
1992	0.590	-0.616	-0.026
1993	0.775	-0.603	0.172
1994	0.631	-0.640	-0.008
1995	0.469	-0.508	-0.040
1996	0.586	-0.649	-0.064
1997	0.601	-0.642	-0.042
1998	0.495	-0.392	0.103
1999	0.620	-0.375	0.245
2000	0.504	-0.366	0.139
2001	0.399	-0.384	0.015
2002	0.418	-0.401	0.017
2003	0.432	-0.418	0.014
2004	0.436	-0.414	0.021
2005	0.436	-0.428	0.008
2006	0.459	-0.461	-0.002
2007	0.494	-0.497	-0.003
2008	0.520	-0.477	0.044
2009	0.504	-0.479	0.025
2010	0.399	-0.341	0.058
2011	0.357	-0.356	0.001
2012	0.380	-0.375	0.005
Average	0.529	-0.482	0.043

and economies of scale. The results showed that the share of technological change in the productivity growth is greater than that of scale economies which confirms the vital role of technological improvement in petroleum refining industry.

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