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**Article**

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# Energy consumption and total factor productivity growth in Iranian agriculture



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## ABSTRACT

In this study we investigated the relation between energy consumption and growth of total factor productivity (TFP) of agriculture in Iran from 1974 to 2012 using Solow residual method. The results from estimated aggregate Cobb–Douglas production function showed that one percent change in the value of labor, capital and energy will lead to 4.07, 0.09 and 0.49 percent change in agriculture value added, respectively. Also in a long term, based on the Johansen cointegration test, there is a negative relation between TFP growth and energy consumption in Iranian agriculture which might be due to cheap and inefficient energy use in this sector. Gradual liberalization of energy price and use of so called green box support policies is recommended.

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## 1. Introduction

World development has been accelerated over the last decades. Energy, as the most important commercial commodity with the biggest share in world trade, has proved to have an ever more important role in economic growth of many countries (Deylami Nejad and Ostad Hosein, 2010). Some ecological economists believe that in the biophysical growth model, energy is the most important growth factor, while, labor and capital are mediating factors that require energy to be used (Stern, 1993). Iran, as a developing country and member of OPEC, is an example of oil-dominant economies that has provided cheap energy to different sectors, including agriculture, for decades. As a result, today energy plays a vital role in Iranian agriculture (Zare Mehrjerdi and Zia Abedi, 2010). Based on official data, energy use in Iranian agriculture has increased from 10.26 million barrels (oil equivalent) in 1974 to 32.3 million barrels in 1994.

Many studies have focused on energy use in agriculture. Karkacier et al. (2006), have reported a strong relationship between energy use and agricultural productivity in Turkey. Fuglie et al. (2007) examined total factor productivity of US agriculture. They believe that productivity has been the main driver of agricultural development in this country for the period 1948–2004 and more than two-thirds of the growth in this sector was due to productivity increase. Furthermore, innovation and modern technology played a critical role in productivity

enhancement of US agriculture which, in turn, resulted from governmental investment on research in agriculture. Chen et al. (2008) investigated total factor productivity growth in Chinese agriculture over the period 1990–2003. They conclude that the major source of productivity growth was technical progress and regional disparities in productivity growth has worsen over time.

The literature on energy use in Iranian agriculture and its impacts on real output of the sector is not so rich. Some studies have revealed the existence of long run relation between agricultural growth and energy use (Hojabr Kiani and Varedi, 2000; Zibaei and Tarazkar, 2004). Akbari and Ranjesh (2003) calculated the average TFP growth rate in Iranian agriculture at 4.33% for the period 1971–2007. Also Mehrabi Boshir Abadi and Esmaeili (2011) showed that energy efficiency in agriculture has decreased in the period of 1971–2007.

The main motivation of present study is lack of clear answer to the question that whether heavily subsidized energy has contributed to more efficient use of agricultural inputs. So this study aims to investigate the long term relation between energy consumption and total factor productivity growth in Iranian agriculture using Solow residual method (as suggested by Asian Productivity Organization) and cointegration analysis for the period 1974–2012.

## 2. Materials and methods

TFP can be calculated by using direct and indirect methods. Diewert (1992) First one relies on calculation of an aggregated index as representative of all inputs used in production. The ratio of output quantity to aggregated input index, provides an

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approximation of TFP. Second approach, requires an estimation of appropriate production function.

### 2.1. Direct methods

Kendrick's and Divisia's models are among the most frequently used direct methods.

#### 2.1.1. Kendrick's model

Kendrick's model (in a three input production process) relies on the weighted average of inputs. Kendrick used an implicit production function to estimate changes in productivity which is defined as follows:

$$TFP_t = \frac{VA_t}{\alpha K_t + \beta L_t + \gamma E_t}. \quad (1)$$

In which  $VA_t$  stands for real value added of the sector,  $K_t$  is real capital stock,  $L_t$  indicates labor force,  $E_t$  is energy,  $\alpha$ ,  $\beta$  and  $\gamma$  are the share of capital, labor and energy in value added, respectively.

#### 2.1.2. Divisia's model

Total factor productivity in this model is defined as follows:

$$TFP_t = \frac{VA_t}{K_t^\alpha L_t^\beta E_t^\gamma}. \quad (2)$$

In prefect competition in which each factor is rewarded equal to its marginal productivity,  $\alpha$  and  $\beta$  indicate productivity elasticities of capital and labor. So, when there is no data about shares of factors in production, we can use production elasticity of labor and capital to estimate total factor productivity.

### 2.2. Indirect methods

Two of the most popular indirect methods are:

#### 2.2.1. Solow residual model

This is expressed mathematically as follows:

$$\dot{TFP} = \dot{VA} - \hat{\alpha}\dot{K} - \hat{\beta}\dot{L} - \hat{\gamma}\dot{E}. \quad (3)$$

In other words, that part of production growth which cannot be explained by inputs growth, is assigned to growth in total factor productivity.

#### 2.2.2. Solow model

Here a production function like Cobb–Douglas is specified as follows:

$$VA_t = AK_t^\alpha L_t^\beta E_t^\gamma. \quad (4)$$

In which  $A$  is technology parameter. Considering the assumption of constant return to scale; namely:  $\alpha + \beta + \gamma = 1$ , production function will have only two parameter. Dividing both sides of (4) by  $L$  and after some mathematical operations, the following equation is achieved and by that  $\hat{A}$  can be calculated which is an approximation of total factor productivity growth.

$$\dot{P}_L = \hat{A} + \hat{\beta}\dot{K} + \hat{\gamma}\dot{E}. \quad (5)$$

In this equation,  $\dot{P}_L$  is labor productivity growth,  $\hat{A}$  is the total factor productivity growth and  $\dot{K}$  is growth of capital intensity. If both sides of (4) are divided by  $K$ , the following equation results:

$$\dot{P}_K = \hat{A} + (\hat{\beta} + \hat{\gamma} - 1)\dot{K}. \quad (6)$$

### 2.3. Data

In order to estimate Eq. (4) data on real agricultural value added (in billion Rials<sup>1</sup>), real net capital stock of agriculture (in billion Rials), agricultural labor force (in million person) and energy use in agriculture (in million barrels of crude oil) is gathered for the period 1974–2012 from the Central Bank and Statistical Center of Iran.

### 3. Results and discussion

Since time series data is used, it is necessary to check the stationarity of variables. Table 1 presents the results of three different unit root tests.

According to the Table 1, all series are integrated of order one. To calculate the total factor productivity growth by Solow residual model, Eq. (4) is estimated in logarithmic form. Table 2 reports the result.

Further examination of the regression residuals confirmed its stationarity. Hence, the results in Table 2 are reliable and can be interpreted. The results show that all variables have positive effects on agricultural growth; but the impact of capital stock is not statistically significant, which can be due to the low level of capital–labor ratio in Iran that is far away from its optimum status. As the Table 2 shows, labor force has the greatest effect on sector growth, while energy consumption, the variable of interest in this study, shows a moderate impact. In other words, one percent increase in agricultural energy use leads, in average, to 0.49% rise in agricultural growth. Meanwhile, a first order moving average term is added to solve the autocorrelation problem. Based on the obtained elasticities, total factor productivity growth is calculated based on Eq. (3). Table 3 portrays the results for whole period.

So Iranian agriculture has experienced 4%, in average, decrease in TFP growth in the period under study. At next step, the long-run relationship between total factor productivity growth ( $\dot{TFP}$ ) and energy consumption is examined by using the Johansen–Juselius cointegration test. The results are shown in Table 4.

According to the information provided in Table 4, there is a long-run relationship between the total factor productivity growth and energy consumption in the agriculture sector. The respective coefficient is estimated at  $-0.001$ .

$$\dot{TFP} = -0.001E. \quad (7)$$

Therefore, our estimation reveals the existence of a reverse (indirect) relation between energy use and TFP growth in Iranian agriculture. It seems that provision of cheap energy has encouraged farmers to use energy at levels much more than its optimum level which, in turn, has led to fall in TFP growth rate. For better interpretation, the elasticity of  $\dot{TFP}$  with respect to energy consumption is computed at  $-0.56$  (Eq. (8)).

$$E_{\dot{TFP},E} = \frac{d\dot{TFP}}{dE} \times \left| \frac{\bar{E}}{\bar{\dot{TFP}}} \right|. \quad (8)$$

In other words, if the energy consumption is increased by 1%, total factor productivity growth will decline by 0.56%.

### 4. Concluding remarks

In this study, total factor productivity growth in Iranian agriculture is calculated through estimation of the production function using Solow residual method. To estimate the production function, real value added of agriculture was regressed on labor,

<sup>1</sup> Iranian national currency, which nearly equals 0.00003 US Dollar.

**Table 1**

Unit root test results.

Source: Research findings.

Variable	KPSS		Phillips–Perron		Augmented Dickey Fuller	
	Level	First difference	Level	First difference	Level	First difference
LnVA	0.18 <sup>*</sup>	0.5	−3.37	−20.69 <sup>**</sup>	−3.43	−8.10 <sup>**</sup>
LnK	0.16 <sup>*</sup>	0.12	−1.32	−3.82 <sup>*</sup>	−0.61	−3.54 <sup>*</sup>
LnL	0.21 <sup>*</sup>	0.10	−3.93	−4.71 <sup>*</sup>	−4.77	−4.53 <sup>*</sup>
LnE	0.17 <sup>*</sup>	0.114	−4.10	−6.86 <sup>**</sup>	−4.025	−6.84 <sup>**</sup>

<sup>\*</sup> Denote statistically significance at 5% level.<sup>\*\*</sup> Denote statistically significance at 1% level.**Table 2**

Results of production function estimation.

Source: Research findings.

Variable	Symbol	Coefficient	Standard dev	t-statistic	Prob
Intercept	C	−53.32	9.35	−5.7	0.00
Capital stock	LnK	0.09	0.11	0.86	0.39
Labor	LnL	4.07	0.7	5.8	0.00
Energy consumption	LnE	0.49	0.07	6.99	0.00
Moving average	MA(1)	0.53	0.14	3.59	0.00
Agricultural value added (dependent variable)	LnVA	$R^2 = 0.979$	$\bar{R}^2 = 0.976$	$F = 404.46$	$D.W. = 1.55$

**Table 3**

Calculated total factor productivity growth of the agriculture (1974–2012).

Source: Research findings.

Year	TFP	Year	TFP	Year	TFP	Year	TFP
1974	–	1984	−0.06	1994	−0.15	2004	−0.03
1975	−0.03	1985	−0.09	1995	−0.01	2005	−0.04
1976	0	1986	0.04	1996	−0.02	2006	−0.06
1977	−0.09	1987	−0.04	1997	−0.01	2007	−0.05
1978	−0.02	1988	0.03	1998	−0.14	2008	−0.09
1979	−0.08	1989	−0.01	1999	0.01	2009	−0.06
1980	−0.01	1990	−0.05	2000	−0.06	2010	−0.05
1981	−0.04	1991	−0.04	2001	0	2011	0.02
1982	−0.13	1992	0.03	2002	−0.04	2012	−0.03
1983	−0.13	1993	0	2003	−0.07	<b>Average</b>	<b>−0.04</b>

**Table 4**

The results of Johansen–Juselius cointegration test.

Source: Research findings.

Null hypothesis	Alternative hypothesis	Trace statistic		Maximum eigenvalue statistic	
		Value	Critical value 5%	Value	Critical value 5%
$r = 0$ <sup>*</sup>	$r \geq 1$	20.58	15.49	14.55	14.26
$r = 1$	$r \geq 2$	4.02	6.02	3.02	3.84

<sup>\*</sup> Denotes rejection of null hypothesis at 5% level.

real net capital stock and energy consumption in this sector for the period 1974–2012. Results of the estimated production function show that labor and energy have direct relation with sector growth, though, the labor's effect is greatest. This finding is in line with Hojabr Kiani and Varedi (2000); Zibaei and Tarazkar (2004). Also, according to Johansen test, in long run, there is a negative relation between TFP growth and energy use in agriculture sector which may result from low energy prices in this sector that leads to overconsumption of energy.

More investment on training the employed labor force in agriculture and improvement of their capabilities, provision of required incentives (such as subsidized credits) to private sector in order to increase capital stock and finally gradual liberalization of energy price and use of so called green box support policies, are some recommendations which can be driven from obtained results.

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