Iran. Econ. Rev. Vol. 24, No. 4, 2020. pp. 935-957

Energy-saving Effect of Technological Progress in Iranian Economic Sectors: A Growth Accounting Application

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Received: 2018, December 13   Accepted: 2019, March 18

Abstract

Energy as an input of production is one of the main production factors in Iranian economic growth. Unfortunately, this growth leads to the high energy intensity in economic sectors in which its management is essential for policymakers and planners in Iran. One of the main issues in energy management is the impact of technological progress on saving energy. Respectively, this study is to analyze the relation of energy intensity and technological progress by Cob-Douglas production function between 1979 and 2015 for the Iranian agriculture, industry, and service sector with using panel data analysis and growth accounting model. The results indicate that technological progress will reduce the growth rate of energy intensity in the industry sector by 6.1%, in the agriculture sector by 8.9%, and in the service sector by 7.2%. Also, unlike the agriculture and service sector, the impact of technological progress on energy saving in the industry sector explains only 64% of total variations. The rest of changing in the energy intensity of the industrial sector is about 36% due to a decline in labor employment during the study period.

Keywords: Energy Intensity, Technological Progress, Energy Saving, Cobb-Douglas Function, Growth Accounting Model.

JEL Classification: C23, D24, O14, O33, O47, Q43.

1. Introduction

Energy is one of the most important inputs for production in the economy. Supplying sufficient diverse forms of energy in different sectors of the economy has a vital role in the improvement of the living standards of the people. Employing energy resources for

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achieving sustainable development in any society, and optimal management of energy consumption is one of the most important issues in all countries of the world. Accordingly, energy efficiency optimization with the focus on raising the level of technology and applying leverage to increase efficiency in production and achievement of higher energy efficiency is inevitable.

Since the more economic output needs more energy consumption, if we consider the labor, capital, and energy as primary factors of production, then increasing each of these inputs leads to increased production. In other words, the economic growth accompanies by increasing pressure on energy resources (Mohammadi et al., 2013).

However, along with other factors of production, there is another input of production as technological progress that can lead to improved utilization and decreasing energy intensity or increased pressure on energy resources to achieve economic growth. Respectively, technological progress affects energy consumption according to the two channels. On the one hand, technological progress will make lots of new tools and new types of machinery to decrease energy consumption. On the other hand, technological progress will increase economic growth which will then cause more energy consumption. So it is very difficult to explain the relationship between technological progress and energy consumption.

However, Ma, and Stern (2016) indicated that technological progress must be such that manufacturers would be able to reduce their energy consumption to reduce their energy intensity. In other words, the purpose of policymakers is mainly to introduce capabilities and pathways of technology for producing more productive employment of labor, capital, and energy.

Energy as the main factor of production in many developing countries is considered to be the engine of economic growth and increased production. In the meantime, Iran with high energy consumption needs to manage energy consumption with the mentioned new technological tools and techniques.

Iranian Energy Balance Sheet (2016) indicates that the energy intensity in Iran in 2015 was about 1591.216 and in the last 10 years, it grew by an average of 4.87%. On the other hand, energy consumption in Iran after the implementation of the targeted subsidy plan for energy carriers in different sectors of the economy has an important place in macroeconomic policies and therefore, the energy consumption efficiency, finally, reduction of energy intensity is one of the most important responsibilities of policymakers in economic sectors. On the other hand, based on theoretical foundations of production theories and economic growth, changes in the production of goods and services at the level of the economic sectors is due to the shift in technology and its effects on the other production factors as labor and capital. The effect of this technological progress on the rate of employment of the other production factors, especially on improving energy intensity, is another important issue that is especially important for economic policymakers.

The purpose of this study is to measure the impact of technological progress on energy saving of economic sectors based on the Cobb-Douglas production function and employing the growth accounting model. In this study, the Cobb-Douglas production function estimates the level of agriculture, industry, and service sector by using panel data analysis. This methodology includes more information based on the three main economic sectors simultaneously in the unique estimated production function and less multicollinearity among independent variables. In this regard, along with the effect of reducing the variance of estimation, results are more efficient and reliable than previous studies which are never considered by the researchers in Iran heretofore.

In the following, this study is organized into several sections. After the first part as an introduction, the second section reviews the empirical studies related to theoretical foundations of research. In the third section, the Cobb-Douglas production function and the growth accounting model are presented in the framework of the research purpose. In the fourth section, we analyze the statistical database in the three sectors of Iran's economy and analyze the results. Finally, the fifth section is presented the conclusion and policy recommendations based on the Iranian economy realities.

2. Theoretical Foundations and Literature Review

The literature on economic growth theories includes three main streams that are historically and methodologically different. The first stream is the classical economic growth of literature, whose pioneers are David

Hume (1711-1776) and Adam Smith (1723–1790). This classic approach was formed in the eighteenth century and ended with John Stuart Mill (1806-1873) and Karl Marx (1811-1883) in the middle of the nineteenth century. The second stream was the neoclassical approach of economic growth with the new statistical database that creates after World War II. Neoclassical ideas consider technological progress as an exogenous production factor and capital accumulation as an endogenous production factor in economic growth. The influential and enduring works in this mainstream approach are owned by Robert Solow (1924), Simon Kuznets (1901-1985), Moses Abramovitz (1912-2000), Hollis Burnley Chenery (1918-1994), and Edward Fulton Denison (1915-1992). The third stream is the endogenous growth theory in which the term of endogenous growth in the various sets of theoretical and empirical studies emerged in the 1980s. Endogenous growth distinguishes from neoclassical growth, with the emphasis on the fact that economic growth is the consequence of an economic system, not the result of endogenous forces. This approach focuses on technological-driven and tradable activities as the main engine for economic growth. The main participants of this theory are Kenneth Joseph Arrow (1921), Robert Emerson Lucas (1937), Gene Michael Grossman (1955) Elhanan Helpman (1946), Paul Romer (1986), and Pajooyan and Faghih Nasiri (2009).

However, Technological progress is the turning point of the concept of technology change in neoclassical economics, which is started by Robert Solow with publishing the article "A Contribution to the Theory of Economic Growth" in 1956. The conclusion Solow reached then was that technology advanced at a rate of 1.5 percent per year from 1909 to 1949. More than half the growth in real output could be attributed to the technical change rather than the growth in the physical quantity of production factors. More recent evidence has tended to confirm Solow's conclusions about the relative importance of technical change[1] (Nicholson and Synder, 2012).

1. This theory with publishing the article "The Economic Welfare and Allocation of Resources for Invention" by Kenneth Arrow in 1962 was followed. The theory of endogenous growth by two papers of Paul M. Romer in 1986 and 1990 has expanded according to the "Increasing Returns and Long-Run Growth" and " Endogenous Technological Change ". This approach eventually led to the Nobel Prize in Economics in 2018. Paul M. Romer won this prize for integrating technological innovations into long-run macroeconomic analysis.

Solow's empirical results were examined with similar studies in the economies of the OECD member states, and the results show that a shift in total factor productivity can be explained by technological progress. Since the attention of economic planners has been focused on the role of technology and is considered as a special role for technology development. Solow's studies in the two articles entitled "Technical Change and the Aggregate Production Function" and "Investment and Technical Progress" are the basis for the development of growth accounting theory. "…Growth accounting divides the growth in output of a firm or a country into two parts. The first part is the growth in output that can be attributed to growth in all factor inputs, holding technology constant. The second part is the growth that is solely due to an increase or decrease in technology… "(Huggett, 2018: 2).

Until the late 1970s, the national energy production function was not considered as an input of production. With oil price shock in 1973 and 1979 which was accompanied by the economic recession in the developed economies, the important role of energy as one of the drivers of economic growth recognized by researchers and policymakers (Mehrara and Zareei, 2012). However, in the new empirical studies of economic growth, the energy factor has also entered the production function, the methodology of considering technical progress in different models is not the same.

In a biophysical model of growth, energy is the sole primary factor and the most important growth factor, since according to the first principle of thermodynamics; energy in nature cannot be created or destroyed. Therefore, the goods and services produced in the economy, even with trained and non-specialized human resources, need large amounts of energy employed in production. Respectively, in a biophysical model expressed by ecological economists, energy is the main factor, and the only factor in production and labor and capital are intermediary factors that require energy to be employed. One of the most important studies of the biophysical models was done by Cleveland (1984), which assumes a close relationship between energy consumption and gross domestic product. Other neoclassical economists such as Brent (1980) and Denison (1979) have a different opinion than ecologists. Neoclassical economists believe that energy, through its impact on labor and capital, affect economic growth indirectly. Most neoclassical economists believe in the unique principle that energy has a small role in economic production and is an intermediary input so that the main factors of production are only labor, capital, and land. According to Stern (1993), these neoclassical results are strongly influenced by their maintenance of a priori assumptions that energy can have a direct impact on economic growth only in certain ways, and that these maintained hypotheses influenced the construction of their empirical studies. Of course, some other neoclassical economists such as Hamilton (1983), Barbridge, and Harrison (1984) believe that energy has a more fundamental role in economic growth, which is in line with the views of the biophysical models. Some studies have been focused on the role of technological progress in the employment of energy as a production factor alongside capital and labor for economic growth. Perez et al. (2004) analyze the hypothesis about the effectiveness of energy-saving technologies to reduce the trade-off between economic growth and energy preservation. In a general equilibrium vintage capital model with embodied energy-saving technical progress, they show that positive growth is only possible (Mehrara, Rezaee bargoshadi, & Hamedi, 2016) if the growth rate of the energy-saving technical progress exceeds the decreasing rate of the energy supply. Ma et al. (2008) indicated that China's primary energy consumption has exceeded domestic energy production since 1994 with its rapid economic growth. The results of this study based on the calculation of the Allen partial elasticity of factor and energy substitution, and the price elasticity of energy demand with using a two-stage translog cost function approach, suggests that energy is substitutable with both capital and labor. Coal is significantly substitutable with electricity and complementary with diesel while gasoline and electricity are substitutable with diesel. Yuan et al. (2009) analyze the relationship between energy intensity and technological progress in which energy, labor, capital, and technological progress are taken as independent variables. It proves that in the Chinese industry, the growth of output per capita and output per labor will increase energy intensity while technological progress will decrease energy intensity. De Cian et al. (2014) analyze energy intensity trends and drivers in 40 major economies using the WIOD database. They show that heterogeneity within each sector across countries is high. These general trends within the economic sectors are dominated by large economies such as the United States. Regarding changes in energy intensity at the country level, improvements between 1995 and 2007 are largely attributable to technological progress while structural change is less important in most countries. Notable exceptions are Japan, the United States, Australia, Taiwan, Mexico, and Brazil where a change in the industry mix was the main driver behind the observed energy intensity reduction. Zhang and Laher (2014) use the structural decomposition approach to uncover the regional disparities in energy consumption from 1987 to 2007 in China. They examine six possible key factors for the change in energy consumption by region. They find that final demand change outpaced efficiency improvements to drive up energy use in all regions. This study shows that Energy, directly or indirectly is flowing from Northwest, Central and North China to coastal regions. Regional- specific policies should be designed to promote production structure change and curb energy demand. Lin and Li (2017) adopts the growth-accounting method to investigate the effects of two types of technological progress, namely, the Hicks-neutral and the capital-embodied technological progress on the changes in energy productivity. The main results for 30 Chinese provinces from 1997 to 2012, show that the Hicks-neutral and the capital-embodied technological progress directly contributes to energy productivity, However, due to energy rebound effect, the energy-saving performance from the capital-embodied technological progress is poor. Abdoli and Varharami (2009) evaluated the relationship between energy consumption and technology improvement in two sectors of agriculture and industry separately in Iran using economic growth theory. The results indicate that improving technology will reduce the growth rate of energy consumption in the industrial sector more than agriculture. Azamzadeh Shurki et al. (2011) investigated the selection production function and estimate important coefficient of energy in Iran's agricultural sector. The results of this study showed that Cobb-Douglas function in comparison with other function is the proper function for estimation of production function of agricultural sector. Production elasticity of all inputs is between zero and one, which represent the optimum consumption of these inputs. Energy input coefficient statistically is significant, and has the importance effect on production of agricultural sector. Ramezanian and Mahdavi Adeli (2014) estimate the long-run energy elasticity of production in order to show how important energy use could be in the industrial production process in Iran. Empirical evidences of this study show a production elasticity of 0.48 for the energy input which is greater than the elasticity of production for capital and labor which is estimated to be 0.45 and 0.42 respectively. Eslamloueyan and Ostadzad (2016) estimate various production functions, with emphasis on energy and investment in R& D, in Iran over the period 1979-2010. According to their findings, a 10 percent increase in energy consumption, raises the output by 7.3 percent. However, a 10 percent increase in R&D expenditure only increases the output by 2.6 percent. Finally, the results show that the production function in Iran exhibits increasing return to scale after the end of Iran-Iraq war. Shahiki Tash et al. (2016) by employing a flexible cost function evaluate the technological change measure and total factor productivity and examine the impact of technology on the combination of input and scale of production in Iranian manufacturing industries. According to the results of this study, technological change has led to saving in raw materials and to an increase in the use of three inputs of labor, capital, and energy.

This study compared to the previous studies has these main features:

(1) evaluating the effect of technological progress on energy-savings in the three main Iranian economic sectors of agriculture, industry, and services will be made simultaneously, however, the literature review shows that this evaluation is only made for sectors such as agriculture and industry separately.

(2) The Cobb-Douglas production function for simple analysis and stability in equilibrium conditions can be adapted to the neoclassical growth theory as a turning point for the concept of technology change.

(3) This production function using panel data analysis will be estimated for the mentioned three sectors at the same time. Although this feature can reduce the estimator variance,

uncertainty and raise the reliance on estimation, it is not considered by researchers in previous studies.

(4) Respectively, the estimation of the production function and evaluating the effect of technological progress on the energy-saving of Iran's service sector is made in this study for the first time. In the next section, a Cobb-Douglas production function with technical progress assumption and growth accounting model with an emphasis on energy input growth was introduced for the analysis of the main hypothesis of this study.

3. Model: Growth Accounting Application

Regarding the literature review of economic growth, the elements of the production function for evaluating the impact of technological progress on energy saving in the level of economic sectors are capital, labor, energy, and technological progress. Hence, in our production function, we focus on five variables: output (Y), capital (K), labor (L), energy (E), and technological progress (T). Capital, labor, energy, and technological progress are combined to make output. The production function in a general form can be written as Eq. (1):

$$Y(t) = f(K(t), L(t), E(t), T(t)) \tag{1}$$

Technological progress is supposed to be exogenous and has a constant growth rate c, so the technological progress grows exponentially in the form Equation (2):

$$T(t) = Ae^{ct} \tag{2}$$

Considering the exact form of the production function depends to a large extent on the conditions of production and adaptation to the assumptions of the research. Economists, in addition to the research primary assumptions, employ the same experiences as criteria for selecting the form of the superior production function. In this regard, the Cobb-Douglas production function is a good approximation to actual production (Romer, 2001). Hence, the Cobb-Douglas production function regarding the energy input is shown as below:

$$Y(t) = Ae^{ct}K(t)^{\alpha}L(t)^{\beta}E(t)^{\gamma} \tag{3}$$

In Equation (3), α, β and γ are constant coefficients and show the elasticity of output concerning capital, the labor, the elasticity of output regarding the labor and the elasticity of output with respect to the energy, respectively. In this regard, the size of elasticities is:

$$0 < \gamma, \alpha, \beta < 1 \tag{4}$$

One of the features of this form of the production function assumed in this research is the constant returns to scale regardless of the level of production. So, the summation of elasticities can be written as below:

$$\alpha + \beta + \gamma = 1 \tag{5}$$

To estimate the effect of technological progress on energy savings, we will use the linear form of the Cobb-Douglas production function derived from the logarithm form of Equation (3):

$$LnY = LnA + ct + \alpha LnK + \beta LnL + \gamma LnE \tag{6}$$

Given the constant return to scale in the Cobb-Douglas production function, regarding to the Eq. (5), we have:

$$\beta = 1 - \alpha - \gamma \tag{7}$$

Regarding Eq. (6) and Eq. (7), the following linear regression model is estimated:

$$LnY - LnL = LnA + ct + \alpha(LnK - LnL) + \gamma(LnE - LnL) \tag{8}$$

To estimate the production function mentioned above (Eq. (8)), the necessary tests are performed to estimate the coefficients of the production function based on the energy input. Since the production function for the three economic sectors is simultaneously estimated, the panel data analysis is employed.

According to the linear form estimation of production function and constant returns to scale of production function as Eq. (5), for quantitative evaluation of the impact technological progress on energy saving, regarding Eq. (3), yields:

$$(\frac{E}{Y})^{\gamma} \times e^{ct} \times A = \frac{Y^{1-\gamma}}{K^{\alpha}L^{\beta}} \quad (9)$$

Since $\alpha + \beta + \gamma = 1$, the Eq. (9) can be rewritten as below:

$$(\frac{E}{Y})^{\gamma} \times e^{ct} \times A = (\frac{Y}{K})^{\alpha}(\frac{Y}{L})^{\beta} \quad (10)$$

Assume that $\varphi = \frac{E}{Y}$ which indicates energy intensity; $\frac{Y}{K} = y_k$ which indicates the output per capital and $\frac{Y}{L} = y_l$ which indicates output per labor. Then Eq. (10) is changed as Equation (11):

$$\varphi^{\gamma} \times e^{ct} \times A = y^{\alpha}{}_{k} y^{\beta}{}_{l} \quad (11)$$

With calculation the natural log of both sides of Eq. (11), and yields:

$$\gamma ln\varphi(t) + ct + lnA = \alpha lny_k(t) + \beta lny_l(t) \quad (12)$$

By using the partial derivatives subject to the time for two sides of Equation (12), (a dot over a variable denotes a derivative concerning time), we have:

$$\gamma \frac{\dot{\varphi}(t)}{\varphi(t)} = \alpha \frac{\dot{y}_k(t)}{y_k(t)} + \beta \frac{\dot{y}_l(t)}{y_l(t)} - c \quad (13)$$

On the left-hand side of Eq. (13), the $\frac{\dot{\varphi}(t)}{\varphi(t)}$ indicates the growth rate of energy intensity ($\varphi(t)$) and the right-hand side of Eq. (13), the $\frac{\dot{y}_k(t)}{y_k(t)}$ is the growth rate of $y_k(t)$ (output per capital) and the $\frac{\dot{y}_l(t)}{y_l(t)}$ is the growth rate of $y_l(t)$ (output per labor). c is the growth rate of technological progress.

Equation (13) denoted that with increasing the growth rate of $y_k(t)$ and growth rate of $y_l(t)$, energy intensity increases over time, however, technological progress has a decreasing impact on the growth rate of energy intensity over time. Therefore, with the estimation of the growth accounting coefficients, and according to the two-sided impact of technological progress through c (growth rate of technological progress) on energy savings, to determine whether technological progress has led to a reduction in energy consumption in the three sectors of agriculture, industry, and services in Iran. In the next section, we explain the database of the research and then analyze the results of the estimated production function and the growth accounting model.

4. Data

In this study, three main sectors of industry (including industry, mining, construction, and supply of water and electricity and gas), agriculture (including agriculture, hunting, forestry, and fisheries) and services (including wholesale and retail, transportation, home services, warehousing, communications, real estate, financial intermediation, and other services sectors), throughout 1979-2016 in Iran will be employed for estimation the production function. The services have the highest share of the two other sectors. According to the Statistical Center of Iran (2018), the share of value-added of the service sector in Iran is about 51% of GDP. The industry sector with 27% of GDP and agriculture with 10% of GDP has a lower share of the Iranian economy.

Respecting the Equation (3), output as $Y(t)$ indicates the value-added of each sector at a constant price of 2004 in terms of billion Rials. $L(t)$ presents the number of workers in each sector. These data are retrieved from the Statistical Center of Iran (2018). Also, $E(t)$ as energy consumption based on Iranian Energy Balance Sheet (2016) is employed in terms of million barrels of oil equivalent for each economic sector and capital as $K(t)$ indicates the capital stock in terms of billion rials at a constant price of 2004. The capital stock data is retrieved from the Central Bank of Iran (2016). In the following, a statistical description of data is presented in Table (1). Also, we use the per capita of each variable for production function estimation.

Table 1: Statistical Description of Data between 1979 and 2015

1979-2015		Energy Consumption (million barrels of oil equivalent)	Capital Stock (billon Rials)	Labor (person)	Value Added (billon Rials)
Agriculture	Average	32	158,721	3,457,205	90,614
	Maximum	51	327,424	4,554,433	145,540
	Minimum	12.7	82,077	3,041,852	41,397
Industry	Average	161	805,772	4,777,445	282,291
	Maximum	323	1,355,528	7,841,138	561,554
	Minimum	52.2	495,918	2,835,007	119,120
Services	Average	424	3,749,523	7,142,277	689,925
	Maximum	794	6,333,586	11,080,890	1,263,286
	Minimum	123	2,077,446	3,586,563	346,124

Source: Research Findings.

According to Table (1), the services have the largest amount of capital and labor force employed and energy consumption from 1979 to 2015 in Iran. This sector also has the highest added value among others. This reality reveals the high opportunity cost for economic agents to enter productive activities and the wasteful expansion of services as an anti-development factor.

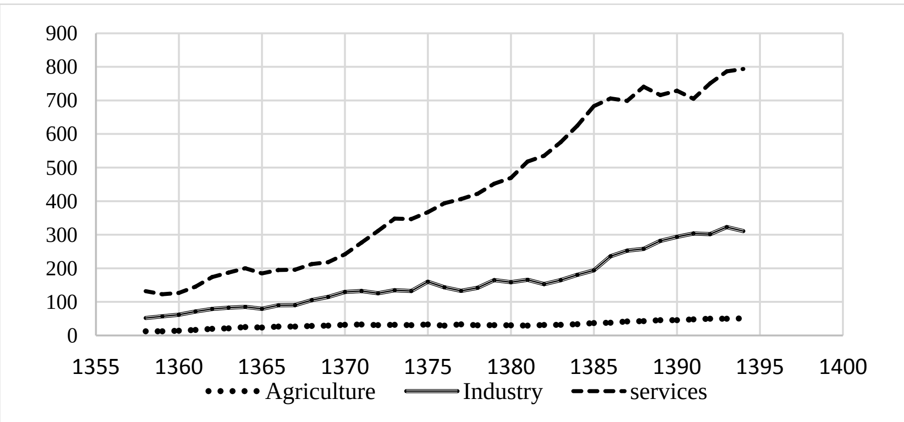

Figure 1: The Growth of Energy Consumption in Economic Sectors in Iran (1979-2015)

Source: Research Findings.

Also, energy consumption data based on fig (1) show that energy as an input of production has usually upward trend in all three sectors, but this trend in the service sector is very higher than the others. The industrial sector after the residential and transportation sectors is the third-largest energy consumer in Iran, which has faced high energy consumption in recent years. Iran’s industrial sector consumes not only 24% of the final energy consumption, but also plays a key role in determining the energy efficiency of its products. This is an important factor determining the energy consumption of other sectors of the economy because many of the commodities used are somehow the result of industrial activities. The agricultural sector has an almost minimal share of the final consumption of energy. Respectively, the study of the final consumption of agricultural energy in the years 1357-94 indicates that consumption of petroleum products has been decreasing trend, and on the contrary, natural gas and electricity have become the alternative in which it can reduce the energy consumption of petroleum products as the main fuel in this sector. In the service sector, final energy consumption due to some economic reasons such as increasing population and urbanization, the per capita GDP growth, development of transportation sector, and the absence of new technology of public transformation has a very highly upward trend than the other two mentioned sectors.

5. Empirical Results

In this section, at first, the Cobb-Douglas production function will be estimated based on the three sectors of agriculture, industry, and services, and then, using the growth accounting model, the impact of technical progress on energy saving will be investigated.

5.1 Estimation of Cobb-Douglas Production Function

For estimation of production function according to the Equation (8) throughout 1979-2015 for three main sectors, we employ the panel data analysis. Investigation of the panel unit root test is the first step for estimation. For this step, we employ the Levin, Lin, and Chu (LLC) unit root test. The summary result of the panel unit root test is represented in Table (2).

Table 2: Panel Unit Root Test*

Hypothesis	Null Hypothesis: Common Unit root			
Method	Levin, Lin, and Chu (LLC)			
	Level		First Difference	
	Statistic	P-Value	Statistic	P-Value
Value Added	-1.67169	0.0473	-	-
Capital Stock	1.83205	0.9665	-9.91260	0.0000
Energy Consumption	-3.66902	0.0001	-	-

Source: Research Findings based on Eviews 10.0
*the variables for estimation employ in terms of "Per Capita".

According to the 95% confidence level, based on the LLC panel unit root test, value-added and energy consumption don't have a unit root at the level and capital stock after the first difference is stationary.

Taking into account a long-run relationship, we examine the cointegration between the underlying variables. If the variables are integrated, short-run error terms are corrected in the long run. To examine the long-run relationship between the underlying variables, the Kao Residual Cointegration Test is employed. The results of Table (3) show that at the 95% confidence level, the null hypothesis based on the absence of cointegration is rejected. Respectively, we have a long-run relationship between underlying variables.

Table 3: Kao Residual Cointegration Test

Hypothesis	Null Hypothesis: No Cointegration	
Method	Levin, Lin, and Chu (LLC)	
	t-Statistic	P-Value
Kao Residual Cointegration Test	-1.723803	0.0424

Source: Research Findings based on Eviews 10.0

In the next step, to examine the type of panel or pooled estimation, we use the Redundant Fixed Effect Test. The result of the F-Limer Test in Table (4) shows that the null hypothesis for pooled estimation is rejected and the production function should be estimated with the panel method. For panel analysis, we should decide between fixed or random effect estimation according to the Hausman test, where the null hypothesis is that the preferred model is random effects or the alternative the fixed effects. If the number of cross-sections is less than the number of estimated coefficients in the model, then the fixed effects model is preferable as it is easier to compute. Hence, the final panel estimation is fixed effects (Baltagi, 2005).

Table 4: F-Limer Test Result

Hypothesis	Null Hypothesis: Pooled Estimation	
	F-Statistic	**P-Value**
F-Limer Test	3.6694	0.0288

Source: Research Findings based on Eviews 10.0.

Finally, the result of production function estimation for three economic sectors shown in Table (5) indicates that the p-value for all estimated parameters is equal to zero at the 95% confidence level. The results show that capital stock, energy consumption, and technological progress impact on value-added of each sector is significantly positive.

Table 5: Estimation of Cobb-Douglas Production Function for Three Sectors

	Variable	Coefficient	Std. Error	t-statistic	P-Value
Agriculture	*K(t)*	0.241587	6.73E-15	3.59E+13	0.0000
	E(t)	0.173723	1.07E-14	1.62E+13	0.0000
	T	0.018895	3.54E-16	5.33E+13	0.0000
Industry	*K(t)*	0.386891	4.06E-15	9.54E+13	0.0000
	E(t)	0.392664	1.79E-15	2.19E+14	0.0000
	T	0.016519	2.10E-18	7.87E+15	0.0000
Services	*K(t)*	0.274611	7.19E-16	3.82E+14	0.0000
	E(t)	0.382393	9.07E-16	4.22E+14	0.0000
	T	0.029432	3.00E-17	9.80E+14	0.0000

Source: Research Findings based on Eviews 10.0

Investigating the parameters in the agriculture sector shows that capital stock has the most impact on the value-added of the agriculture sector and in the industry and services, the energy consumption has the most impact on the value-added of the two mentioned sectors.

Meanwhile, technological progress has a significantly positive impact on value-added of all three sectors, but the parameters of the service sector which is equal to 0.029432 have the most significant positive impact on value-added services than the other economic sectors. Also, the results of the estimation indicate that the agriculture sector is capital intensive for its production, while the industry and services are energy-intensive. Also, the technology progress has the most impact on the service sector value added while the other two mentioned sectors are in the next orders.

5.2 Growth Accounting Estimation

Regarding estimating the parameters of production function, we can rewrite the Equation (3) for each economic sector, according to Equations (8) and (9), as below:

The cobb-Douglas production function for the agriculture sector:

$$Y(t) = 0.803\, e^{0.018t} L(t)^{0.586} E(t)^{0.173} K(t)^{0.241} \quad (14)$$

Equation (14) shows the Cob-Douglas function with emphasis on technological progress and energy input for the agriculture sector. Equations (15) and (16) are presented in the following.

The Cobb-Douglas production function for the industry sector:

$$Y(t) = 0.755 e^{0.016t} L(t)^{0.778} E(t)^{0.392} K(t)^{0.386} \quad (15)$$

The Cobb-Douglas production function for the service sector:

$$Y(t) = 0.92 e^{0.029t} L(t)^{0.344} E(t)^{0.382} K(t)^{0.274} \quad (16)$$

And, according to Equations (12) and (13), the growth accounting estimation for each sector can be shown as below:

Growth equation for agriculture sector:

$$0.173 \frac{x^{\cdot}}{x} = 0.241 \frac{Y_k}{Y} + 0.586 \frac{Y_l}{Y} - 0.018 \quad (17)$$

In Equation (17), the growth rate of technological progress is 0.018. The technology growth rate for the industry and services is about 0.016 and 0.029 respectively. The growth equation is presented in Eq. (18) and (19) in the following.

Growth equation for industry sector:

$$0.392\frac{x^{\cdot}}{x} = 0.386\frac{Y_k}{Y} + 0.778\frac{Y_l}{Y} - 0.016 \quad (18)$$

Growth equation for service sector:

$$0.382\frac{x^{\cdot}}{x} = 0.274\frac{Y_k}{Y} + 0.344\frac{Y_l}{Y} - 0.029 \quad (19)$$

Technological progress growth in the industrial, agricultural, and service sectors will lead to an increase in the output and marginal production of capital, labor, and energy. Hence, employing more labor, capital, or energy by employers ultimately depends on the growth rate of technological progress. In other words, the growth rate of technological progress potentially can save the other inputs for output growth. Accordingly, for measuring the impact of the technological progress growth rate on energy consumption, we use the actual growth rate of labor and capital per capita in three main sectors. Regarding the authors' calculation, the growth rate of labor and capital stock per capita in the period of 1979-2015 for the agriculture sector is about 0.4 % and 0.16% respectively. Concerning Equation (17) and recalculation of Equation (17), the growth rate of energy per capita yields:

$$0.173\frac{x^{\cdot}}{x} = 0.241(0.0016) + 0.586(0.004) - 0.018 \quad (20)$$

In which the growth rate of energy per capita is equal to:

$$\frac{x^{\cdot}}{x} = -8.9\ \%$$

The growth rate of energy input during the period of 1979-2015 for the agriculture sector is about-8.9%. This negative amount of growth rate for energy input shows that although the positive growth rate of capital and labor, technological progress leads to employing lower energy input as a production factor. Indeed, the technological progress in this period can save energy employment for production in Iran's agriculture sector. This positive impact is due to substituting electricity with alternative fuels especially gasoline. Since agriculture production using modern mechanical machines and instruments in recent years, the amount of energy saving in this sector is more than in the industry and service sector as expected.

For the industry sector, the growth rate of labor and capital stock per capita in the period of 1979-2015 is about -0.117 % and 0.07% respectively. Regarding Eq. (18) and recalculation of the Eq. (18), the growth rate of energy per capita yields:

$$0.392\frac{x^{\cdot}}{x} = 0.386(0.0007) + 0.778(-0.0117\ ) - 0.016 \qquad (21)$$

In which the growth rate of energy per capita is equal to:

$$\frac{x^{\cdot}}{x} = -6.1\ \%$$

This negative amount of growth rate for energy input shows that the technological progress in this period could save energy employment for production in Iran's industry sector but all amount of this impact is not due to technological progress. The other cause of saving in energy employment is the negative growth rate of the labor force in the mentioned period. As a matter of fact, against the result for the agriculture sector, the share of technological progress on energy saving in the industry sector is about only 64%; however, 36% is related to the decreasing of labor employment. Because of this impact, the technological progress in the industry sector comparing with two other sectors has a lower growth rate.

This procedure can be repeated for the service sector. Regarding the authors' calculation, the growth rate of labor and capital stock per capita in the period of 1979-2015 is about 0.43 % and -0.03% respectively. Concerning Eq. (19) and the growth rate of labor and capital stock per capita, we can measure the energy-saving or intensity for the service sector as Eq. (22):

$$0.382\frac{x^{\cdot}}{x} = 0.274(-0.0003) + 0.344(0.0043) - 0.029 \qquad (22)$$

In which the growth rate of energy per capita is equal to:

$$\frac{x^{\cdot}}{x} = -7.2\%$$

Similar to the industry, technological progress in this period can only explain part of changing in energy saving in Iran's service sector. Respectively, the other part of energy-saving causes of the service sector is related to the negative growth rate of capital stock but its impact on energy saving of production can be ignored (less than 1%). In this sector, the technological progress is due to the prevalence of software's and smart applications in recent years, so as expected, employing other traditional inputs such as labor and capital will decrease and energy as another input of production in this sector is less employed.

6. Conclusion and Policy Recommendation

In this study, we measure the impact of technological progress on energy saving of output in Iranian agriculture, industry, and service sector over the period 1979-2015. The empirical results of this study based on growth accounting applications show that in all three mentioned sector, the technological progress would decrease the energy consumption as input according to the Cob-Douglas production function. However, energy-saving changes in the agriculture and service sector completely due to the result of technological progress, this variation in the industry sector only explain 64% of energy saving. The rest of the energy-saving changes is about 36% due to decreasing the employment of labor during the study period.

The results of this study show that policymakers should be paid attention to technological progress impacts on all economic sectors' output. For instance, in the service sector, the enterprisers can be used smart applications to sell their services and increase its output without more energy consumption, but applying these smart services need special infrastructures for mobilizing data regarding the population growth and their needs which it needs to the government or private sector financial aids. In the industry and agriculture sector, the type of fuels that are consumed in machines and instruments for production is very important for achieving energy saving in production. Maintaining this condition, according to the dependency of industry and agriculture sector on imported modern machines is very difficult for the Iranian government especially during the economic sanctions.

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