Iran. Econ. Rev. Vol. 23, No. 4, 2019. pp. 795-818

Research and Development Investment and Productivity Growth in Firms with Different Levels of Technology

Leili Soltanisehat*[1], Reza Alizadeh[2], Nader Mehregan[3]

Received: 2018, July 24 Accepted: 2018, October 10

Abstract

In the modern competitive world, Research and Development (R&D) and its overflowing technologies are the main basis of innovation, which in turn, can be determined as an important source of economic growth. Investing in research activities can help firms with different technological levels, especially high-tech industries to improve their productivity. This paper aims to analyze the role of R&D expenditures in total factor productivity (TFP) growth in Iran's industry sector. For this purpose, data from industries with different levels of technology (high, medium and low) over the period 1994-2010 is used. Results show that R&D expenditures in high-tech and then in medium/high-tech industries have the most positive and significant effect on TFP growth. In addition, among high-tech industries, R&D expenditures have the greatest impact on the productivity growth in drug and chemical industries related to medicine (Code 2423) which has experienced significant progress in recent years.

Keywords: Total Factor Productivity, Research and Development, High-Tech Industry, Panel Data Econometrics.

JEL Classification: O10, O30, O40, B23.

1. Introduction

As the world comes into a new era of development, the manufacturing-based economy is changing to a knowledge-based economy. Knowledge and information play a fundamental role in the economic growth and value creation in developed countries and lead them to-

---

1 . Department of Engineering Management and Systems Engineering, Old Dominion University, VA, USA (Corresponding Author: lsolt001@odu.edu).

2 . Systems Realization Laboratory @OU, School of Industrial and Systems Engineering, University of Oklahoma, OK, USA (reza.alizadeh@ou.edu).

3 . Faculty of Economics and Social Sciences, Bu-Ali Sina University, Hamedan, Iran (mehregannader@basu.ac.ir).

wards more development (Godin, 2006). Based on the theory of endogenous growth, total factor productivity (TFP) depends on the capital accumulation of domestic R&D, since internal R&D activities lead to the production of tradable goods and services, more efficient use of existing resources and absorption of advanced foreign technology. This fact, not only leads to the creation of technology to make new products but also establishes some new ways to utilize the production components or raw materials, beneficially (Braconier & Sjöholm, 1998). In another word, R&D expenditures and technology improvement lead firms to reduce their total production costs, increase productivity and promote export level. Thus, by creating new demand, growth and prosperity of the national economy will be ensured. In addition, both basic and applied research and development in high-tech industries are the main requisites for entering to the international markets for industries.

Industries are the engines of economic development of each country and play an important role in TFP growth. At the micro level, the productivity of an economic agency is considered as the main base for competition in the market. In this regard, high-tech industries will not only motivate economic growth but also cause the enterprise survival in the global competitive market. Many developed countries are trying to achieve a high level of economic growth by promoting local production technology and international market share through exporting high-tech products.

The aim of this study is to analyze the impact of R&D expenditures on productivity growth using data from various industries over the period 1994-2010. The results will clarify, in which level of technology; R&D costs have the highest impact on productivity growth among different industries. In the following section, theoretical foundation and a review of previous studies on the topic of productivity and R&D is presented. Description of data from different industrial activities in three technological levels are presented in the third section. In addition, research method and the results of the models are presented in this section. In the fourth section, results obtained from the estimation of each panel data model are analyzed and conclusions and recommendations are summarized.

2. Research Method

2.1 Theoretical Foundations

In the knowledge-based economy, economic prosperity would be obtained by innovation and sustained technological progress. Even though in traditional theory, the main reason for economic growth was an accumulation of production factors, newer theories consider productivity as an important source of sustainable economic growth. In neoclassical growth models, such as Solow (1956) model, economic growth through the accumulation of production factors is not stable due to diminishing returns; therefore, productivity has a significant role in long-term growth. In fact, economic growth is attributed to physical capital accumulation and endogenous technical progress, which in the lower population rates and higher technology level, increases short-term growth rate. Therefore, to achieve long-term growth, technical progress as an exogenous variable should be considered into the model. (Aydin, Alrajhi, & Jouini, 2018; Inekwe, 2015)

In the past two decades, Romer (1990), Grossman and Helpman (1991) and Aghion and Howitt (1990) proposed patterns of growth, which consider fixed physical capital and labor could be an indicator of economic growth. The main feature of these models, knowing as endogenous growth models, is that they remove downward returns. Theoretically, endogenous growth model considers R&D and technological progress as an endogenous factor in economic growth theoretically. According to Romer (1990), endogenous technological change is one kind of two-part economic growth model, which is based on three theoretical rationales: (a) technological changes that means improved methods for applying materials is the core factor of economic growth; (b) Most of the technological changes which are formed by voluntary actions of people and economic agents are endogenous. They are mostly based on market and profit motivators; and (c) Training and knowledge are fundamentally different from other economic goods because the new set of training has own inherent costs while in this case, training can be reused for free of charge.

According to Romer's theory (1990), the same incentives that encourage firms to accumulate physical capital would lead them to perform R&D activities, and scientific progress and in this way, technology would become endogenous. In this kind of models, the role of technology would be specified by a variety of features such as personal characteristics, accumulated knowledge, R&D expenses and exhaustible and inexhaustible resources. Therefore, with the fixed capital, technological progress raises the improvement of production. Productivity growth is determined in the model instead of being assumed constant, and one of its determinants is the investment in research. This model assumes that labor, capital, and technology are combined to improve technology and then to allocate more resources to R&D leader companies to increase innovation and productivity. In addition, technology and R&D costs would reduce total production costs and increase productivity and export growth.

2.2 Literature Review

Study of the relationship between productivity and R&D expenditures began about 60 years ago. Since then, this area of research has seen a lot of theoretical work and empirical studies (Table 1). R&D activities and R&D spillovers affect TFP growth positively. In addition, both international technology spillovers and local efforts are important factors, which influence the industries' performance. Level of technology in each industry can affect the power and willingness to absorb new foreign technologies or invest in domestic research and development. High-tech industries adapt to new technologies faster or invest more on innovations. On the other hand, Low-tech sectors such as textile industry do little R&D however they are important for employment, economic growth and knowledge formation in the economy. Also, scientific research and development is a requirement of the entrance to the international market and development of modern industries in each country. The efficiency of enterprises will not increase by the company itself, whereas, the diffusion of technological knowledge of upstream and downstream companies is an important factor impact on productivity.

Although many research investigated the role of R&D in TFP growth, few research has been done to clarify how much R&D will change the productivity in various industries with different levels of technology in their product and processes. The basis of categorizing industries in four technological groups is the number of R&D activities that they have. This general index is defined by OECD[1] (2011) for countries all over the world, however, it can differ from one country to another country. This paper concentrates on the case Iran as a developing country. The results not only can justify the hypothesis of the research but also helps policymakers to develop development strategies for each specific industry. These development strategies can defer regard to the country economic and political situation.

Table 1: Summary of the key literature on relationship between R&D and TFP

Research	Aim	Results
(X. Liu & Buck, 2007)	Studied performance of innovation and the channels of overflowing international technology in Chinese high-tech industries, using panel data technique	Learning based on imports and exports leads industries to promote innovation in Chinese high-tech industries. In addition, both international technology spillovers and local efforts are important factors, which influence the industries' performance.
(Nagano, 2006)	Compared the productivity of economic enterprises in the electronics industry in Taiwan and Korea	When the external effect of promoting and expanding of R&D activities is high, the increase in productivity and efficiency, reduction in the costs and therefore increase in market share and competitiveness is further.
(Parham, 2009)	Examined the impact of domestic and foreign investment on R&D on TFP in Australia. R&D is considered as an investment, not a cost, and the capability of considering R&D cost as an investment is examined.	There is a positive relationship between R&D investment and productivity growth, but the obtained coefficients are sensitive to the different methods of R&D evaluation. In addition, R&D impact on TFP can differ from one industry to the other industry.
(Vaez, Tayyebi, & Ghanbari, 2007)	Analyzed the impact of R&D expenditures on value-added of high-tech industries in Iran, over the period 1988-2006	Cost of R&D plays an important role in increasing the value-added of high-tech industries.
(López-Pueyo, Barcenilla-Visús, & Sanaú, 2008)	Analyzed the long-term impact of foreign and domestic technological capital on production TFP in Finland, France, Italy, America, Canada and Spain, considering ten industrial sectors in these countries	Although domestic technology has a significant impact on one sector's TFP, external R&D spillovers have a more effective impact on most sectors' TFP, in the same sector or other sectors.

1. Organization for Economic Co-operation and Development

Research	Aim	Results
(Sterlacchini & Venturini, 2014)	Performed a dynamic panel estimation of the long-run elasticity of TFP for R&D capital, on twelve manufacturing industries in Italy and Spain, over the period 1980-2006.	High-tech industries in Spain have experienced a similar or slightly higher R&D elasticity than their Italian counterparts
(Mehregan, Dehghanpour, & Dehmobad, 2011)	Estimated the behavior of the developed and developing countries to identify factors, which have an impact on exports, based on higher technology	R&D variables, FDI, real effective exchange rate, economic openness and experiences resulting from trade, have a significant and positive impact on high-tech industries, in both kinds of countries.
(Mehregan & Soltanisehat, 2014)	Identified the impact of different factors on TFP growth in Iran's Industry	R&D, training, educated and skillful labor has a highly positive impact on the productivity growth in the industry in Iran. This affect although is different for various industries based on their need for innovation and technology.
(Crespi & Zuniga, 2012)	Investigated the relationship between firm-level productivity and innovation in six countries across Latin America	There is a significant relationship between innovation internals and externalities. In all countries, firms investing in knowledge are more able to introduce new technological advances. Firms that innovate, have greater labor productivity than the others.
(Shahnazi, 2012)	Analyzed the impact of basic variables such as ICT (Information and communications technology), R&D expenditures, and training, on high-tech industries in 48 countries	Technology, IT and R&D expenditures has Significant and positive effects on TFP and also education has positive impact with less level of confidence in high-tech industries
(T.-K. Liu, Chen, Huang, & Yang, 2013)	Analyzed the simultaneous impact of e-commerce and R&D on productivity growth of Taiwanese manufacturing firms, over the period 1999-2002	(1)Both the e-commerce and R&D activities have a positive effect on productivity, (2) E-Commerce and R&D have a supplementary effect on productivity growth (3) Among the different spillovers of e-commerce and R&D, network technology trade's outcomes have the greatest effect on productivity growth
Alizadeh et al. (2016a, 2016b) (Reza Alizadeh, 2016; 2015; Reza Alizadeh, Maknoon, Majidpour, & Salimi, 2015))	Studied the impact of R&D in both energy industries and environment protection projects like carbon capture and storage (CCS)	Technology transfer in high-tech energy technologies is not possible without public and private partnership in R&D expenditures.

Research	Aim	Results
(Abolghasemi & Alizadeh, 2014; Beynaghi et al., 2016; Kaleibari, Beiragh, Alizadeh, & Solimanpur, 2016)	Studied the impact of R&D on manufacturing process when there are huge difficulties for FDI.	In sanction situation and when there are huge difficulties for FDI, firms are encouraged to spend more on R&D which in turn helps to improve their manufacturing productivity

3. Model Specification

This study aims to analyze the impact of R&D on the industries' productivity growth in Iran's industries over the period 1994-2010. Data is obtained from all large manufacturing cooperatives (with more than 10 workforces) by Iran's statistic center. According to Iran's statistic center manufacturing cooperatives, take action in various areas of industry according to the field of activity mentioned in their statutes through making use of their capitals, manpower, and expertise. These statistics are available from the year 1994 is classified into four different categories based on industry's level of technology.

3.1 Industries with Different Technological Level

According to Lall (2000), characteristics of industries with different levels of technologies are summarized as follow:

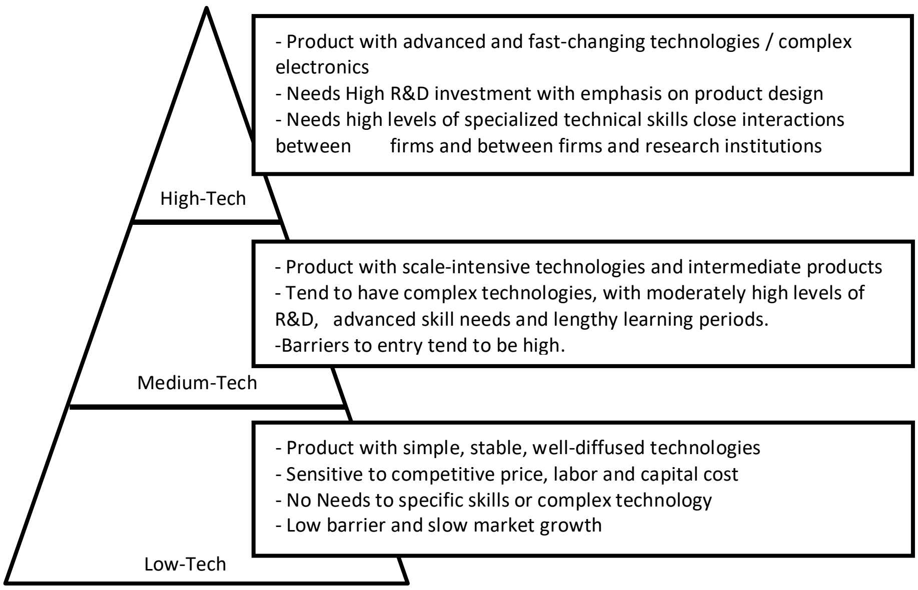

Figure 1: Characteristic of Industries with Different Technological Level

According to the classification performed by the Organization for Economic Cooperation and Development in 2011 (OECD, 2011), all industries are divided into four groups of high-tech industries, medium/high-tech industries, medium/low-tech industries and low-tech industries. This classification is based on the technological level of each industry (which is estimated by the ratio of the intensity of R&D costs comes from value added) and based on the technology, which is used in raw materials and intermediate products in the industry's production line. This classification is given in Table 2. It should be noted that some industries of two-digit codes category are not completely classified in a same technological level. For example, drugs and chemicals used in herbal medicinal products recognized by the code 2423, a

Table 2: Classification of Industries Based on Technology Intensity Proposed by the OECD*

High-technology industries	ISIC	Medium/high-technology industries	ISIC
Aircraft and spacecraft	353	Electrical machinery and apparatus	31
Pharmaceuticals	2423	Motor vehicles, trailers, and semi-trailers	34
Office, accounting, and computing machinery	30	Chemicals excluding pharmaceuticals	24
Radio, TV and communications equipment	32	Railroad and transport equipment	352
Medical, precision and optical instruments	33	Machinery and equipment	29
Medium-low-technology industries	**ISIC**	**Low-technology industries**	**ISIC**
Building and repairing of ships and boats	351	Manufacturing, Recycling	36-37
Rubber and plastics products	25	Wood, pulp, paper, paper products, printing, and publishing	20-22
Coke, refined petroleum products and nuclear	23	Food products, beverages	15
Other non-metallic mineral products	26	Tobacco	16
Basic metals and fabricated metal products	27-28	Textiles, textile products,	17-18
Uncategorized vehicle	354	leather and footwear	19

*__Source__: obtained from www.oecd.org

subdivision of Chemical industry recognized by code 24, is only categorized in high-tech industries while other subdivisions of the code 24 are classified in high/medium-tech industries. For code 35, there is the same situation. In this study, all industries are categorized into four groups due to their technological level, and after calculating the productivity value of each industrial code, the impact of R&D investment on the productivity growth is estimated and analyzed.

The division of manufacturing industries into four technological level (high technology, medium/high-technology, medium/low-technology and low technology) groups was made after ranking the industries according to their average direct and indirect R&D intensities and R&D embodied in intermediate and investment goods proposed in (Hatzichronoglou, 1997). In OECD classification, R&D intensity defined as direct R&D expenditures as a percentage of production (gross output), calculated after converting countries' R&D expenditures and production using GDP PPPs.

3.2 Model Estimation and Results Analysis

One conventional method of estimating total factor productivity is using production function. The production function is a purely physical concept and indicates the relationship between outputs and inputs. This function is the maximum yield that can be achieved from different combinations of inputs. In this study, a Cobb-Douglas (1976) production function in logarithmic form is used. Eq.1 shows the general form of the Cobb – Douglas function in which Q is the value of products and A is total productivity parameter. L(labor) and K (capital) are two factors of production respectively, and α and β are the partial elasticity coefficients of capital and labor factors. (Jones et al., 1998)

$$Q = AK^{\alpha}L^{\beta} \quad (1)$$

To estimate the production function, value-added (VA) is used instead of production’s value. Generally, in economical computations and specifically in productivity estimation, using value-added is advantageous compared with using values of production. Because, in production values, the value of one or more product could be repeated whereas in value-added it is not possible. Thus, in this study, value added of industrial sectors is considered as a function of labor and physical capital. Then using logarithm form of the production function TFP can be calculated. (Armagan & Ozden, 2007; Hajkova & Hurnik, 2007).

$$\mathrm{VA} = \mathrm{f(K, L)} \quad => \quad \mathrm{VA} = \mathrm{A}K^{\alpha}L^{\beta} \tag{2}$$

$$\mathrm{Log(VA)} = \mathrm{Log(A)} + \alpha \times \mathrm{Log(K)} + \beta \times \mathrm{Log(L)} \tag{3}$$

Total factor productivity (TFP) growth in the manufacturing sector is equal to the remainder of value-added growth after deducting some part of value-added that is produced by labor and physical capital inputs. Eq5 shows the anti-log of the fixed component (intercept) represents the total productivity factors of production.

$$Log(TFP) = Log(A) = Log(VA) - \alpha \times \mathrm{Log(K)} - \beta \times \mathrm{Log(L)} \tag{4}$$

$$TFP = A = AntiLogarithm(Log(A)) \tag{5}$$

After estimation of TFP, the productivity growth is considered as a function of R&D expenditures. In this function, some part of TFP's growth that comes from changes in the research investment is estimated. Based on the economic theory, along with efforts to improve the organization's performance and value-added, investment in research enhances the productivity of the organization. Thus, according to the following logarithmic formula, the impact of the endogenous variable of R&D investment on productivity growth is estimated (impact model):

$$\mathrm{Log(TFP)} = \alpha + \beta \mathrm{Log(RD)} + \varepsilon \tag{6}$$

Depending on the data in this study, productivity would be estimated using panel data approach. A panel data is a model used for integrating cross-sectional and time series data. Traditional econometrics, time series, and cross-sectional data usually do not take into account the heterogeneity of the cross sections, so their results of estimation have some levels of bias, but panel data method would eliminate or reduces the estimation bias by considering the heterogeneity of individual effects. On the other hand, high volume observations would somewhat resolve multi-collinearity in econometric estimations. The general regression model, in the form of a panel data, is as Equation 7.

$$\mathrm{Y}_{it} = \alpha + \beta \mathrm{X}_{it} + \mathrm{u}_{it} + \mathrm{e}_{it}, \varepsilon_{it} = \mathrm{u}_i + \mathrm{e}_{it} \quad (7)$$

In the above equation, Y_{it} is the dependent variable vector and X_{it} is independent variable vector at time t. ε_{it} is the error term in regression, which has zero mean and constant variance. u_{it} shows fixed effects and indicates individual differences among cross sections and e_{it} is disruption component.

The first step in estimating panel data models is to ensure that all variables used in the estimation are stationary. Unit root test is one of the most common tests for diagnosing the stationary state of a time series. A random process is called stationary when it is average, and variance is constant over the time and the covariance between two-time periods depends only on the distance or interval between two periods and has not any dependence to the time of covariance calculation. Unit root test is based on the logic that if a process is first-order autoregressive, then the series is nonstationary. To determine the stationary state in panel data models, unit root test which is proposed by Qwah (1992 and 1994) and Britton (1994) and extended by Levin, Lin, and Chu (2002) and Im, Pesaran, and Shin (2003) is used. These tests include Levin, Lin, and Chow (LLC), Bertong test, Hadri test, Im test, Pesaran and Shin (IPS), Fisher's extended Dickey-Fuller (ADF) and Fischer-Phelps Perron (PP). (Zaranejad & Anvari, 2005)

In the next step, the heterogeneity of the units should be determined, and then by using diagnostic tests for pooled, fixed effects or random effects (Random) model, the best method of estimation should be chosen and applied. The most common diagnostic tests include F-limer and Hausman tests. F-limer test checks preferable of using a fixed effects model versus pooled model and Hausman test determines the feasibility of using fixed effects versus the random effects model.

F-limer test assumptions and statistic test are as follow:

$$assumptions: \begin{cases} H_0: u_1 = u_2 = \cdots = u_n = 0 \\ H_1: atleastoneu_i \mathrm{isnon-zero} \end{cases} \quad (8)$$

$$F_{((N-1)(NT-N-K))} = \frac{(RSS_R - RSS_u)/(N-1)}{RSS_u/NT-N-K} \quad (9)$$

where RSS_r is the square error of constrained or pooled model and RSS_u is the square error of the unrestricted model. If the calculated F is greater than F-static from the standard table with degrees of freedom (N-1) and (NT-N-K), the null hypothesis is rejected, and thus the model should be estimated using panel data (fixed or random effects). Otherwise, the model should be estimated using OLS (Hsiao, 1981).

After confirming the heterogeneity, the Hausman test (Gujarati & Porter, 1999) is used to choose between fixed and random effect method. W is the parameter of the Hausman test and is calculated as follow:

$$W = (b_s \beta_s)'(M_1 - M_0)^{-1}(b_s - \beta_s) \approx x^2(r) \quad (10)$$

In the above equation, r is the number of parameters and W has x^2 distributions with r degrees of freedom. M_1 is covariance matrix for the coefficients of the fixed effects model (b_s) and M_0 is covariance matrix for the coefficients of the random effects model (b_s). If M_1 and M_0 are correlated, b_s and β_s can vary significantly, and this issue is reflected in the test. In Hausman test, the null hypothesis suggests the random method and the opposite hypothesis chooses fixed-effect the method. Therefore, if the null hypothesis is rejected, fixed effect method is acceptable (Baltagi, 2008).

To estimate the model using panel data method, the presence or absence of a unit root in the model's variables should be examined. It helps to get reliable estimation results. Based on Levin Lin unit root test for productivity model, value-added growth (log(va)), Physical capital growth (log(k)) and human capital growth (log(l)) are stationary. Also, results of F-limer test to evaluate heterogeneity of the variables, and Hausman test to select between random effects or fixed effects model is shown in Table3. Based on the result, that fixed effects model should be applied to productivity estimation.

Table 3: Results of Diagnostic Tests for Productivity Model

Test F-statistic	Limer		Hausman	
	Critical value	**Results**	**Critical value**	**Results**
Estimated F	26.000 (0.000)	Fixed effect	8.145 (0.047)	Fixed effect

Source: Article calculations

Results of fixed effect regression are shown in table 4. The estimation results indicate that the physical capital and human resources growth have a significant positive impact on value-added growth, while the impact of human capital is higher. The $R^2 = 0.99$ indicates a high explanatory power of the model, and since the model is estimated by GLS method, there is no concern about the heteroscedasticity. Now, using equation 5 and estimated coefficients for value-added and exogenous variables, total factor productivity (TFP) of various industries in each period can be calculated and put in the impact model.

Table 4: Productivity Model Estimation Results Using Panel Data

Variable	Coefficient	t-statistic	Probability
C	0.347347	3.434381	0.000
Log(k)	0.057356	3.853522	0.001
Log(l)	0.973938	64.10469	0.000
	Estimation index		
R^2	0.991086	**F**	1704.867(0.000)

Source: Article calculations

In the estimation of the impact model, the presence or absence of a unit root in the variables should be examined first. According to Levin Lin test results, variables TFP and R&D are stationary. Also according to diagnostic tests, which their results are given in Table 5, using the fixed effects model is the best method to estimate the impact model.

Table 5: Unit Root Test Results for Model Variables in the Level of 95%

Test F-statistic	Limer		Hausman	
	Critical value	results	Critical value	results
Estimated F	12.438 (0.000)	Fixed effect	81.442 (0.000)	Fixed effect

Source: Article calculations

Table 6 shows the results of the fixed effects estimation. According to the results, the average value of R&D coefficients for high-tech industries with a value of 0.3 is higher than other industries. However, some of the coefficients in high-tech industries are not meaningful because of lower investments in manufacturing and research. The most differential amount of R&D coefficient belongs to the manufacturing chemicals, pharmaceuticals and the related medical products (Code 2423), with a value of 0.5. This industry is considered among the high-tech industries, is based on laboratory research in recent decades, and has experienced remarkable progress in recent years in Iran.

Table 6: The Impact Model Results Using Fixed-Effect Method

Technology level	code ISIC	Estimated equation	t-statistic (probability)
High tech	2423	Log(TFP)=-2.011599+0.502531Log(RD)+ε	5.747046(0 .000)
	30	Log(TFP)=0.399793-0.153851Log(RD)+ε	-1.09147 (0.276)
	32	Log(TFP)=-0.178771+0.055823Log(RD)+ε	1.638495(0.102)
	33	Log(TFP)=-0.669093+0.199943Log(RD)+ε	7.63171(0.000)
	353	Log(TFP)=-0.82765+0.476362Log(RD)+ε	3.808806(0.000)
Medium/ high tech	24 (-2423)	Log(TFP)=-1.265342+0.302776Log(RD)+ε	2.868732(0.004)
	29	Log(TFP)=-0.988382+0.251796Log(RD)+ε	1.936139(0.053)
	31	Log(TFP)=-1.061185+0.289731Log(RD)+ε	8.069821(0.000)
	34	Log(TFP)=-1.680475+0.383684Log(RD)+ε	5.966846 (0.000)
	352	Log(TFP)=0.31138-0.111406Log(RD)+ε	-1.945142(0.000)
Medium/ low tech	23	Log(TFP)=-0.5636564+0.16476Log(RD)+ε	5.196047(0.000)
	25	Log(TFP)=-0.225616+0.064248Log(RD)+ε	0.563358(0.573)
	26	Log(TFP)=-1.429818+0.367884Log(RD)+ε	2.178465(0.051)
	27	Log(TFP)=-0.376167+0.089722Log(RD)+ε	0.947329(0.344)
	28	Log(TFP)=-1.554685+0.439538Log(RD)+ε	3.534184(0.000)

Technology level	code ISIC	Estimated equation	t-statistic (probability)
	351+352	Log(TFP)=0.31138-0.111406Log(RD)+ε	-1.94514(0.0525)
Low tech	15	Log(TFP)=-1.934355+0.474055Log(RD)+ε	8.968573(0.000)
	16	Log(TFP)=0.061772-0.035814Log(RD)+ε	-1.344342 (0.179)
	17	Log(TFP)=-0.079959+0.025319Log(RD)+ε	0.740024(0.459)
	18	Log(TFP)=0.038218-0.022462Log(RD)+ε	-0.193753(0.846)
	19	Log(TFP)=-0.062211+0.031279Log(RD)+ε	0.454511(0.649)
	20	Log(TFP)=0.04916-0.020907Log(RD)+ε	-0.600444(0.548)
	21	Log(TFP)=-0.190541+0.06779Log(RD)+ε	1.364119(0.173)
	22	Log(TFP)=0.046762-0.022725Log(RD)+ε	-0.715742(0.475)
	36	Log(TFP)=-0.470069+0.170328Log(RD)+ε	3.80453(0.065)
	37	Log(TFP)=0.162600-0.202282Log(RD)+ε	-1.67638(0.0945)

Source: Article calculations

The next significant coefficient belongs to the air transport industry with a value of 0.47. Even though Iran has still strong competitors in this industry, it seems that the cost of researches spent in the field of repair and maintenance has had a significant impact on productivity in recent years. Thus, expanding the R&D investment can enhance value-added and productivity in this industry directly and in upstream and downstream industries indirectly. Another high-tech industry, which its R&D expenditures have a positive and significant impact on productivity is the industry of production of medical instruments and devices. Although foreign products largely fill the market of this industry and Iranian manufacturers are active in the high-competitive market, R&D costs could explain some part of the productivity growth in this industry. It is expected that by investing in R&D in producing high-quality products, local industries could increase their productivity in this competitive market.

Among the high/medium-tech industries, R&D has a significant effect on the productivity level, such as chemical products manufacturing (except for manufacturing drugs that is one part of the high-tech industries), production of motor equipment and electricity production and transmission equipment in some industries. The generators and power transmission industry have had an acceptable relative development during the study's period. This development is because many firms in the field of advanced electric equipment production have performed huge investments on R&D and have transferred technology to the domestic industries. According to the world rankings, Iran is ranked fifth in the production of advanced electrical equipment and is ranked 12th in electrical power generation. This fact shows growth and development in this industry in recent years.

The coefficient of R&D investment in the transportation industry is positive and significant at a very high level. However, the transportation industry is semi-governmental; most of the R&D costs are spent in downstream industries, which belong to the private sector. Therefore, to retain and maintain market share in a competitive environment, R&D investment can play a significant role. Subordinate industries such as manufacturing of vehicles and mechanical parts seem to need research activities for development due to the type of their products, especially in mechanical and application design. Thus, it can be said that R&D investment in advanced design and production of distinctive cars is one the most influential factor for prosperity in this industry. Given all this analysis and considering that Iran is placed among the developing countries which have a far distance from developed nations in the advanced and high technology industries, nonsense coefficients in some high-tech and medium high-tech industries are expected.

Among the lower medium-tech industries, in the basic and Fabricated Metal Products except for Machinery and Equipment, R&D variable is positive and significant. Although one part of the petroleum refinery products industry, including coke production, does not need a high R&D investment, the positive coefficient can be attributed to significant research activities in the field of petroleum production and refining, as well as the sheer volume of its production. The magnitude of this industry makes its return on R&D costs affordable. On the other hand, a major portion of the industry of fabricated metal products, except machinery and equipment production is related to the production of custom specific machinery and equipment that needs a major research effort. Having this in mind, investment in research is an important factor affecting the development of this industry.

Among the low-tech industries in Iran, Food & Beverage industry is significantly influenced by the research activities. Although this sector is classified as low-tech industries, it seems that R&D investments have a positive impact on productivity via applying new and innovative modern methods of food processing, diversification, and packaging (which is one important issue in the nowadays-competitive market). This fact is more critical in Iran, which can create more diversity in crops and food related to environmental and climatic diversity.

4. Conclusions and Recommendations

This paper examines the impact of R&D investment on the productivity growth of different industries dealt with different technology levels. Increasing the R&D activities could enhance TFP via two ways of improving invention and using with high-educated experts (to expand the R&D activities). Government is proposed to promote long-term and short-term economic benefits of R&D activities by improving the trade condition, motivating R&D activities, cooperating with universities and research institutes, creating intellectual property and copyrights for researchers, research institutions and leading high-tech companies, beside spending more financial and non-financial investment on improvement of graduate education and academic research.

Models' results indicate that the average amount of R&D coefficients in high-tech industries in Iran is higher than the average amount in other industries. Therefore, it can be stated that the research investment in high technology industries can significantly improve total factor productivity in the industrial sector. Among high-tech industries, manufacturing of pharmaceutical products has the highest R&D coefficient. The pharmaceutical industry is one of most important industry, which is formed based on research to develop new medicine and drugs. Since the cost of developing an approved medicine is high during R&D process, there should be other mechanisms to increase the profit of the industry. Therefore, studies of the productivity of the pharmaceutical industry and its contributions to social welfare have long been of substantial interest to drug developers, drug regulators, and policymakers (DiMasi, Grabowski, & Hansen, 2016). Iran's policies toward having self-sufficiency and non-reliance pharmaceutical industries cause the creation of many national and multinational pharmaceutical companies. Subsidizing API (active pharmaceutical ingredient) and machinery purchase, regulating drug market (production, importation, and distribution), generic-based medicine policy, promotion of local production of medicines, price control, formulation-based national industry and promoting local production of medicines aims to improve availability and affordability of medicine all over the country. However, some challenges still affect the efficiency and productivity of pharmaceutical industry in Iran. Lack of privatization of the industry is one of the major problems, which affects the growth of the industry inside a competitive market.

Governmental regulation and decisions have a substantial influence on pharmaceutical market growth, which affects the performance of the companies. Sanctions are the second important hindrance in front of the pharmaceutical industry. Under sanction situation, companies have profound difficulties in machinery procurement, investing in R&D activities, importing technology and even finished products and API. After signing the agreement between Iran and the P5+1 (i.e., China, France, Germany, Russia, the United Kingdom and the United States) in November 2013, it is expected that pharmaceutical industry increases its share of economic growth as well as its market share in the region. Because Iran has one of the largest capacity of production of generic medicines in the Middle East and North Africa region. This situation will be true for other high-tech industries, which depend on R&D investment according to Table 6, such as industry medical, precision and optical instrument, and the industry of aircraft and spacecraft (Cheraghali, 2017).

Due to all the above-mentioned facts, this paper gives some recommendation to boost the productivity and prosperity of the high-tech industry (Cheraghali, 2017):

1. Increase the speed of privatization of high-tech industries according to article.44 of the Iranian Constitution. This will lead companies toward more investment on R&D inside a competitive market;
2. Having a predictive and comprehensive national plan for the different situation in order to boost the market-based economy of the country (including sanction era or post-sanction era);
3. Supporting the local high-tech industry growth by imposing high tariffs on imported medicines, medical and optical instrument

and other high-tech products which are being produced inside the country;

4. Establishing encouraging policies toward having effective R&D activities and marketing strategies to expand the markets in neighborhood countries such as Iraq, Afghanistan, and CIS countries;
5. Encouraging international investment into Iran local market in order to import the knowledge and technology and boost R&D activities;
6. Providing comprehensive intellectual property rights (IPR) law in order to support innovators and research institutes in the high-tech industrial sector.

In the estimated model, R&D coefficients are meaningfully positive and close to high-tech industries' coefficients in most of high/medium-tech industries. The most significant coefficient belongs to the industry of motor vehicles followed by industry of electrical machinery and apparatus. Iran's automotive industry is the second biggest industry after oil and gas industry accounting for about 10% of GDP and employing about 4% of the labor force. Paying more attention to R&D activities in these industries would have a significant effect on total factor productivity and economic growth more than scale. Severe economic sanctions in recent years were the big setback for Iran's automotive industry.

The sanctions made the automobile industry's policymakers to localize the industry, by increasing the local market share via increasing the automobile import tariffs. After the agreement between P5+1 and Iran, the economic pressure is ameliorated. Although localization helped to stability and sustainability of this industry (Barazandeh & Rafieisakhaei, 2016), as one of the biggest sources of GDP growth in Iran economy, automotive industry should move along with global markets. With increasing global interest in new green products such as hybrid electric and fully electric cars makes Iran's automobile industry invest more to on R&D for the acquisition of competitive privileges (Vafaei, Shakeri, & Owlia, 2011).

There most important step after measuring the impact of R&D investment on TFP growth in each industry is developing applicable strategies in order to boost this positive impact. Due to various critical uncertainties in Iran's economic situation, strategic planning methods can be developed for each industry. Methods such as developing a scenario-building framework can help to develop resilient conservation policies when faced with unpredictable and external uncertainties. Government is proposed to promote long-term and short-term economic benefits of R&D activities by improving the trade condition, motivating R&D activities, cooperating with universities and research institutes, creating intellectual property and copyrights for researchers, research institutions and leading high-tech companies, beside spending more financial and non-financial investment on improvement of graduate education and academic researches.

References

Abolghasemi, M., & Alizadeh, R. (2014). A Bayesian Framework for Strategic Management in The Energy Industry. *International Journal of Scientific Engineering and Technology, 3*(11), 1360-1366.

Aghion, P., & Howitt, P. (1990). A Model of Growth through Creative Destruction. Retrieved from https://www.nber.org/papers/w3223.pdf.

Alizadeh, R. (2016). A Combined Model of Scenario Planning and Assumption-Based Planning for Futurology, and Robust Decision Making in the Energy Sector. *Quarterly Journal of Energy Policy and Planning Research, 2*(2), 7-32.

Alizadeh, R., Lund, P. D., Beynaghi, A., Abolghasemi, M., & Maknoon, R. (2016). An Integrated Scenario-based Robust Planning Approach for Foresight and Strategic Management with Application to Energy Industry. *Technological Forecasting and Social Change, 104*, 162-171.

Alizadeh, R., Majidpour, M., Maknoon, R., & Kaleibari, S. S. (2016). Clean Development Mechanism in Iran: Does it Need a Revival? *International Journal of Global Warming, 10*(1-3), 196-215.

Alizadeh, R., Majidpour, M., Maknoon, R., & Salimi, J. (2015). Iranian Energy and Climate Policies Adaptation to the Kyoto Protocol. *International Journal of Environmental Research, 9*(3), 853-864.

Alizadeh, R., Maknoon, R., Majidpour, M., & Salimi, J. (2015). Energy Policy in Iran and International Commitments for GHG Emission Reduction. *Journal of Environmental Science and Technology, 17*(1), 183-198.

Armagan, G., & Ozden, A. (2007). Determinations of Total Factor Productivity with Cobb-Douglas Production Function in Agriculture: The case of Aydin-Turkey. *Journal of Applied Science, 7*(4), 499-502.

Aydin, N., Alrajhi, A. N., & Jouini, J. H. (2018). Estimating The Impact Of R&D Spending On Total Factor Productivity For OECD Countries: Pooled Mean Group Approach. *The Journal of Developing Areas, 52*(2), 159-168.

Baltagi, B. (2008). *Econometric Analysis of Panel Data.* New Jersey: John Wiley & Sons.

Barazandeh, B., & Rafieisakhaei, M. (2016). Effect of Localization on the Sustainable Development in Iran's Car Industry. *EEE Conference on Technologies for Sustainability (SusTech)*, Retrieved from https://ieeexplore.ieee.org/abstract/document/7897170.

Beynaghi, A., Moztarzadeh, F., Shahmardan, A., Alizadeh, R., Salimi, J., & Mozafari, M. (2016). Makespan Minimization for Batching Work and Rework Process on a Single Facility with an Aging Effect: a Hybrid Meta-heuristic Algorithm for Sustainable Production Management. *Journal of Intelligent Manufacturing, 30*(1), 1-13.

Braconier, H., & Sjöholm, F. (1998). National and International Spillovers from R&D: Comparing a Neoclassical and an Endogenous Growth Approach. *Weltwirtschaftliches Archiv, 134*(4), 638-663.

Cheraghali, A. M. (2017). Trends in Iran Pharmaceutical Market. *Iranian Journal of Pharmaceutical Research (IJPR)*, Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5423229/.

Crespi, G., & Zuniga, P. (2012). Innovation and Productivity: Evidence from Six Latin American Countries. *World Development, 40*(2), 273-290.

DiMasi, J. A., Grabowski, H. G., & Hansen, R. W. (2016). Innovation in the Pharmaceutical Industry: New Estimates of R&D Costs. *Journal of Health Economics, 47*, 20-33.

Douglas, P. H. (1976). The Cobb-Douglas Production Function once Again: Its History, Its Testing, and Some New Empirical Values. *Journal of Political Economy, 84*(5), 903-915.

Godin, B. (2006). The Knowledge-based Economy: Conceptual Framework or Buzzword? *The Journal of Technology Transfer, 31*(1), 17-30.

Grossman, G., & Helpman, E. (1991). *Innovation and Growth in the Global Economy*. Cambridge: Massachusett and London Publication.

Gujarati, D. N., & Porter, D. C. (1999). *Essentials of Econometrics* (Trans. H. Abrishami). Tehran: University of Tehran Publication.

Hajkova, D., & Hurnik, J. (2007). Cobb-Douglas Production Function: The Case of a Converging Economy. *Czech Journal of Economics and Finance (Finance a uver), 57*(9-10), 465-476.

Hatzichronoglou, T. (1997). Revision of the High-technology Sector and Product Classification. Retrieved from https://www.oecd-ilibrary.org/docserver/050148678127.pdf?expires=1569048623&id=id&accname=guest&checksum=043F182C6B97D501CDFCD88C8B7E3E5F.

Hsiao, C. (1981). Autoregressive Modelling and Money-income Causality Detection. *Journal of Monetary Economics, 7*(1), 85-106.

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for Unit Roots in Heterogeneous Panels. *Journal of Econometrics, 115*(1), 53-74.

Inekwe, J. N. (2015). The Contribution of R&D Expenditure to Economic Growth in Developing Economies. *Social Indicators Research, 124*(3), 727-745.

Jones, C., Takesm, M. S., & Spence, M. (1998). Introduction to Economic Growth (2^{nd} Ed.). *Science, 334*, 906-912.

Kaleibari, S. S., Beiragh, R. G., Alizadeh, R., & Solimanpur, M. (2016). A Framework for Performance Evaluation of Energy Supply Chain by a Compatible Network Data Envelopment Analysis Model. *Scientia Iranica, Transaction, Industrial Engineering, 23*(4), 1904-1917.

Lall, S. (2000). The Technological Structure and Performance of Developing Country Manufactured Exports, 1985-1998. *Oxford Development Studies, 28*(3), 337-369.

Levin, A., Lin, C. F., & Chu, C. S. J. (2002). Unit Root Tests in Panel Data: Asymptotic and Finite-sample Properties. *Journal of Econometrics, 108*(1), 1-24.

Liu, T. K., Chen, J. R., Huang, C. C., & Yang, C. H. (2013). E-commerce, R&D, and Productivity: Firm-level Evidence from Taiwan. *Information Economics and Policy, 25*(4), 272-283.

Liu, X., & Buck, T. (2007). Innovation Performance and Channels for International Technology Spillovers: Evidence from Chinese High-tech Industries. *Research Policy, 36*(3), 355-366.

López-Pueyo, C., Barcenilla-Visús, S., & Sanaú, J. (2008). International R&D Spillovers and Manufacturing Productivity: A Panel Data Analysis. *Structural Change and Economic Dynamics, 19*(2), 152-172.

Mehregan, N., Dehghanpour, M. R., & Dehmobad, B. (2011). Industrial Exports Based on High Technology and Its Deterministic Factors. *Journal of Science and Technology, 3*(4), 69-83.

Mehregan, N., & Soltanisehat, L. (2014). Identified the Impact of Different Factors on TFP Growth in Iran's Industry. *Journal of The Macro and Srategic Policies, 2*(5), 1-24.

Nagano, M. (2006). R&D Investment and the Government's R&D Policies of Electronics Industries in Korea and Taiwan. *Journal of Asian Economics, 17*(4), 653-666.

OECD. (2011). Technology Intensity Definition, Classification of Manufacturing Industries into Cat-egories Based on R&D Intensities. Retrieved from http://www.oecd.org/sti/ind/48350231.pdf.

Parham, D. (2009). Empirical Analysis of the Effects of R&D on Productivity. *Productivity Measurement and Analysis*, Retrieved from https://www.oecd-ilibrary.org/docserver/9789264044616-17-en.pdf?expires=1569048340&id=id&accname=guest&checksum=877CF0F5457D0BFEAEAFD6488421E9A7.

Romer, P. M. (1990). Endogenous Technological Change. *Journal of Political Economy, 98*(5), S71-S102.

Shahnazi, R. (2012). Deterministic Factors Impact on High-tech Industries' Production in the Knowledge-based Economy; Panel Data GLS Method. *Journal of Science and Technology Parks & Incubators, 9*(33), 2-12.

Solow, R. M. (1956). A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics, 70*(1), 65-94.

Sterlacchini, A., & Venturini, F. (2014). R&D and Productivity in High-tech Manufacturing: A Comparison between Italy and Spain. *Industry and Innovation, 21*(5), 359-379.

Vaez, M., Tayyebi, S. K., & Ghanbari, A. (2007). The Impacts of R&D Costs on High-Tech Industries' Value Added. *Journal of Quantitative Economics, 4*(4), 53-73.

Vafaei, M., Shakeri, F., & Owlia, M. S. (2011). Study of Innovativeness Factors in the Iranian Automotive Industry. *International Conference of Industrial Engineering and Operation Managements*, Retrieved from http://www.iieom.org/ieom2011/pdfs/IEOM189.pdf.

Zaranejad, M., & Anvari, E. (2005). The Implication of Panel Data in Econometrics. *Journal of Quantitative Economics, 2*(4), 21-52.