RESEARCH, INNOVATION AND PRODUCTIVITY: AN ECONOMETRIC ANALYSIS AT THE MANUFACTURING SECTOR IN TURKEY

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ABSTRACT

There are three determinants of labor productivity. First one is human capital, the second is technological change, the third one is economies of scale that reduce manufacturing costs. In this study, the second factor, technological change, innovation will be tested. The number of domestic patents in Turkey is significantly lower than the number of foreign patents. Therefore, innovative products are few. However, as the number of patents increases, innovative sales will increase and this will increase labor productivity. New innovation and discoveries inspire the emergence of new products, which in turn increases labor productivity. The paper used CDM model to investigate the links between productivity, innovation and research at the manufacturing sector in Turkey. For this purpose number of patents per employee, turnover per personnel employed in the R&D unit, value added per employee are used. The data obtained from the Turkish Statistical Institute and Turkish Patent and Trademark Office. Since the latest published data belongs to 2015, 2009-2015 have been used in the study. According to the model predicted using panel data, increase in the number of patents leads to increase in the innovative sales and innovative sales increase the labor productivity.

Key Words: CDM Model, Innovation, Labor Productivity.

Araştırma, Yenilik ve Verimlilik: Türkiye İmalat Sanayi Üzerine Bir Uygulama

Özet

İşgücü verimliliğinin üç belirleyicisi vardır. Birincisi insan sermayesi, ikincisi teknolojik değişim, üçüncüsü ise imalat maliyetlerini azaltan ölçek ekonomisidir. Bu çalışmada, ikinci faktör, teknolojik değişim, yenilik test edilecektir. Türkiye'deki yerli patentlerin sayısı, yabancı patent sayısından önemli ölçüde daha düşüktür. Bu nedenle, yenilikçi ürünler azdır. Ancak, patent sayısı arttıkça, yenilikçi satışlar artacak ve bu da işgücü verimliliğini artıracaktır. Yeni inovasyon ve keşifler, yeni ürünlerin ortaya çıkmasına ilham kaynağı olur ve bu da emek verimliliğini artırır. Bu çalışmada Türkiye'de imalat sektöründe verimlilik, yenilik ve araştırma arasındaki bağlantıyı araştırmak için CDM modeli kullanılmıştır. Bu amaçla, Türkiye İstatistik Kurumu ve Türk Patent ve Marka Ofisi’nden elde edilen; çalışan başına düşen patent sayısı, Ar-Ge biriminde istihdam edilen personel başına ciro, çalışan başına katma değer kullanılmaktadır. En son yayınlanan veriler 2015'e ait olduğundan, 2009-2015 yıllarına ait veriler kullanımıştır. Panel verileri kullanılarak tahmin edilen modele göre, patent sayısındaki artış yenilikçi satışların artmasına ve yenilikçi satışların artması da işgücü verimliliğinin artmasına neden olmaktadır.

Anahtar Kelimeler: CDM Modeli, Yenilik, İşgücü Verimliliği.

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INTRODUCTION

There are three determinants of labor productivity. First one is human capital. The training given by the firms is known as human capital. Human capital represents the increase in education and specialization, talent and expertise in the economic process. The second factor is technological change. Changes in technological are a factor that permanently increases labor productivity. Learning new techniques can increase labor productivity. New inventions and innovations inspire the development of new products and services, which, in turn, increase the productivity. The third one is economies of scale that reduce manufacturing costs (Korkmaz and Korkmaz, 2017: 71). Economies of scale provide cost advantages because of the size of firms.

When economic growth is desired to be analyzed, the production function is taken into account. The production function reflects the production process in which inputs such as labor, capital, raw materials are transformed into products.

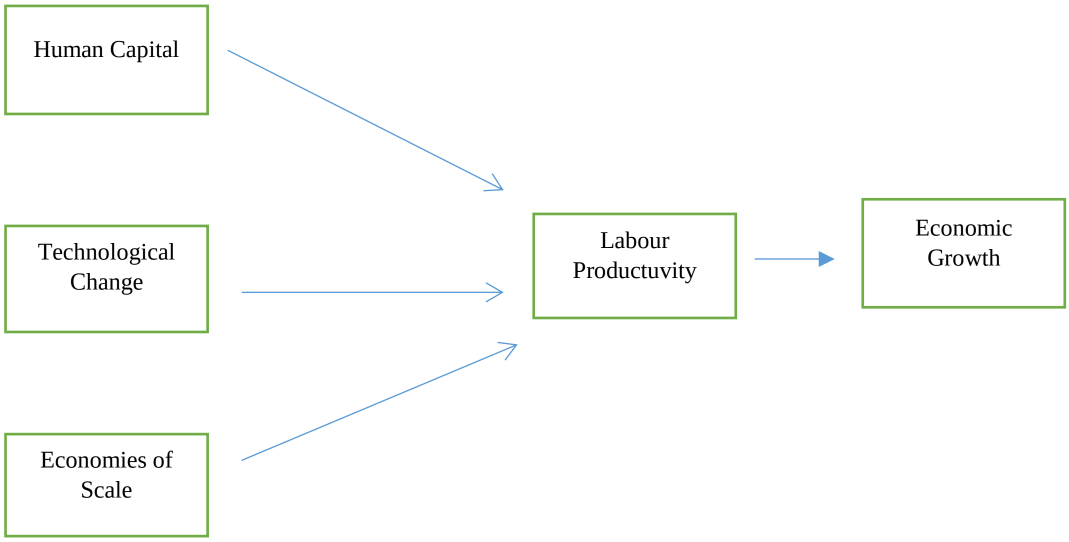


Figure 1. Labor Productivity and Economic Growth

It can be considered that technological change has brought new products and production processes to the economy. The emergence of new production processes and new products allows the community to enjoy higher levels of output by keeping constant inputs such as labor and capital. Hence the productivity will be increased. R&D expenditures is widely used to measure technological change, but patent numbers are also used to measure technological change (Globerman, 2000: 5-7).

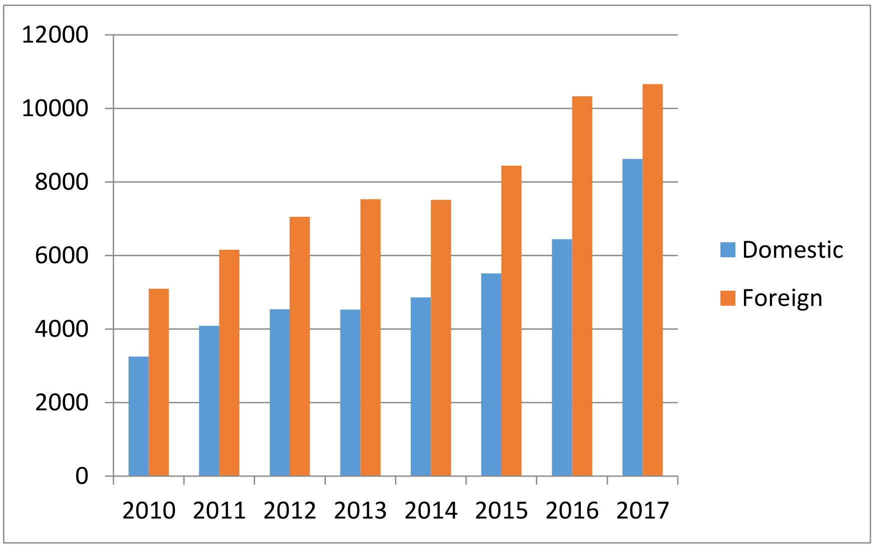
The relationship between innovation and productivity has long been the focus of research. Innovation represents the emergence of original outputs such as new goods, better quality goods, a new production method, a new market, a new organizational structure. It is accepted that innovation is the main source of competitive advantage. Innovation capacity is the most important determinant of firm performance. Labor productivity, defined as value added per employment, is an important measure of performance and competitiveness. Labor productivity is often seen as equivalent to the innovation performance of the firm, because successful product innovations are expected to increase the value added of the firm (Preenen vd., 2017: 273). In order for developing countries to level up per capita income levels similar to those of the richest economies productivity is vital. And consequently innovation is essential for increasing productivity (Crespi and Zuniga, 2012: 273). The association between innovation and productivity has been analysed for a large number of countries. Because innovation is a key factor of economic growth (Mohnen and Hall, 2013: 47). It affects the economy in various ways such as economic growth, global competition, financial system, quality of life, infrastructure development, employment, trade liberty (Maradana et al., 2017: 2). Technological innovation arises through the use of human capital and knowledge stock in the R & D sectors. It is then used in the production of final goods and leads to permanent increase in the growth (Ulku, 2004: 4).

The number of domestic patents in Turkey is significantly lower than the number of foreign patents. Therefore, innovative products are few.

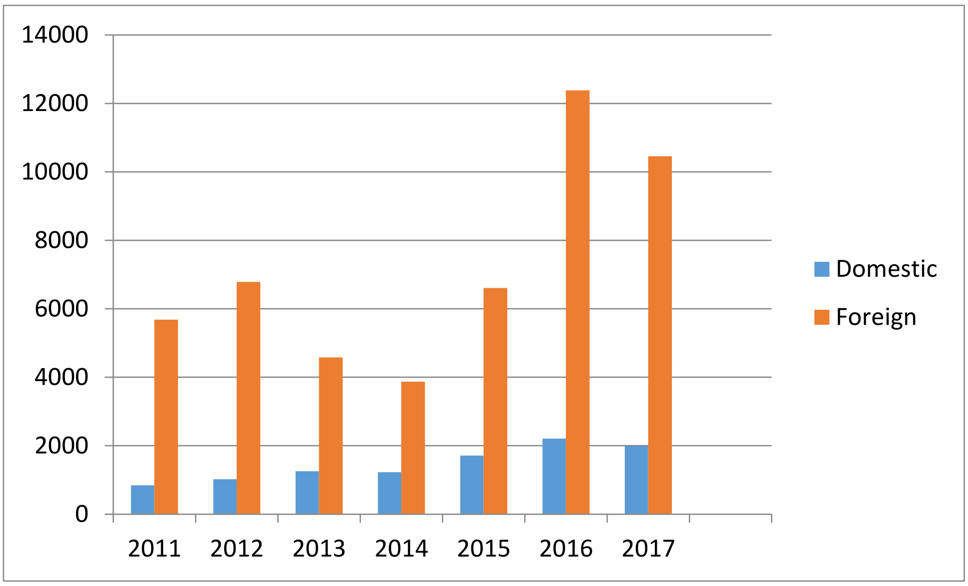
Table 1. Number of Patent Application and Patent Registration of Turkey, 2010-2017.

		2010	2011	2012	2013	2014	2015	2016	2017
Number of Patent Application	Domestic	3250	4087	4543	4528	4861	5512	6445	8625
	Foreign	5093	6154	7056	7527	7514	8446	10333	10658
Number of Patent Registration	Domestic	641	846	1022	1255	1231	1718	2213	1991
	Foreign	4868	5684	6790	4581	3877	6608	12384	10461

Source: Turkish Patent And Trademark Office



Graphic 1. Number of Patent Application



Graphic 2. Number of Patent Registration

As shown in Table 1, Graphic 1, Graphic 2, the number of domestic patent application in Turkey, 2017, is 8625, and the number of foreign patent application is 10650. The registered ones are domestic 1991, foreign 10461. As the number of patents increases, innovative sales will increase and this will increase labor productivity.

The paper uses the empirical research started by Crepón, Duguet, Mairesse (1998), CDM model, about the links between productivity, innovation and research at the manufacturing sector that has become increasingly popular in the last few years. CDM model studies four interrelated stages of the innovation chain: the choice of a firm whether or not to engage in innovative activities; number of patents per employee it decides to invest in R&D; the effects of these R&D investments on innovation output; the impacts of innovation output on the productivity of the sector (Crepón et al., 1998).

In this study, the effect of technological change on labor productivity is analyzed in the following loop.

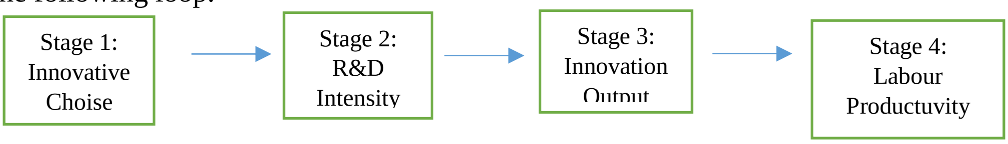


Figure 2. CDM Model

The CDM model can be used to analyze the firm’s decision to innovate, its innovative effort, the production of innovation as output, and the impact of such innovation on firm productivity (García-Pozo et al., 2018: 1050). García-Pozo et al. (2018), found that reducing the environmental impact has a statistically significant and positive effect on the probability of engaging in R&D activities in companies and on R&D intensity; on the likelihood of firms making innovations; on service company productivity. Baumann and Kritikos (2016) found that R&D intensity is larger smaller firms. And the link between R&D, innovation, productivity in micro firms does not largely differ from their larger conterparts. Griffith, Huergo, Mairesse, Peters (2006) compared that the role innovation plays in productivity across four European countries, France, Germany, Spain and UK, using firm level data. They found that overall the systems driving innovation and productivity are remarkably similar across thes four countires. Chudnovsky, López, Pupato (2006) estimated that the determinants of innovative inputs and outputs and their impacts on manufacturing firms' productivity in developing countries. The econometric results shown that R&D and technology acquisition expenditures have positive payoffs in terms of enhanced probability of introducing new products and/or processes to the market. Apergis, Economidou and Filippidis (2008) have investigated the relationship between labor productivity, innovation and technology externalities. The results show that there is a long-term single equilibrium relationship between labor productivity, innovation and technology transfer. In addition, R & D, trade and human capital, both directly and through innovation, indirectly improve technology diffusion and have significant impacts on labor productivity. Masso and Vahter (2008) applied a structural model that involves a system of equations on innovation expenditure, innovation outcome and productivity. They found that during 1998–2000 only product innovation increased productivity, while in 2002– 2004 only process innovation had a positive effect on productivity.

Hall, Francesca, Mairesse (2013) found that R&D and ICT are both strongly associated with innovation and productivity, with R&D being more important for innovation, and ICT investment being more important for productivity.

Hall and Sena (2017) found that that firms that innovate and rate formal methods for the protection of intellectual property highly are more productive than other firms, but that the same does not hold in the case of informal methods of protection, except possibly for large firms as opposed to SMEs. They also found that this result is strongest for firms in the services, trade, and utility sectors, and negative in the manufacturing sector. Howell (2017) shown that in the early stages of innovation, Chinese firms fail to incorporate learning spillovers into their innovation effort, even when considering their absorptive capacity. Conversely, the study finds that, in the later stages of innovation, learning spillovers positively increase firms' innovation output as well as their performance, especially for firms with high absorptive capacity. Fu, Mohnen and Zanello (2018) conducted an innovation survey on 501 manufacturing factories in Ghana. Using the CDM model, innovation has been found to have a positive effect on labor productivity. Peters, Riley, Siedschlag, Wahter, McQuinn (2018) have shown innovation in the service sector leads to higher productivity. Kijek and Kijek (2018) have shown that innovation is a positive influence on labor productivity in firms.

The paper is based on a model which takes into account the wholo process of innovation that includes number of patents per employee, turnover per employee and value added per employee, the results of these efforts and their impact on productivity. And explanatory variables are herfindahl index, employment, R&D expenditures, number of enterprises, number of R&D employments. In this paper, we study a developing country case: Turkey. We have data about innovation, R&D and production activities during period 2009-2015. We have followed the steps of

Crepón et al. (1998) by excluding firs step. Because data we used includes only the sectors which invest in R&D. Also, the data is about manufacturing sector. We carry out an econometric analysis of CDM model by using sector level panel data set provided by Turkish Statistical Institute and Turkish Patent and Trademark Office.

The organization of our paper is as follows. The definition of variables and the econometric specification of the model and explained and the results of the estimation discussed in section 2 and concluding remarks given in section 3.

MODEL AND DATA

The database used in this study was obtained from the Turkish Statistical Institute and Turkish Patent and Trademark Office. The codes of the sectors used in the study shown in Appendix. Codes are based on Nace Rev 2.

We did not attach production of tobacco products to the model. Because, manufacture of tobacco products does not invest in R&D. The objective of this study is to apply CDM model. First, firms decide whether they shoul do innovative activities. If the firm decides to do innovative activity, it determines the amount that should be invested in the research and development expenditures. The innovative inputs lead to innovative output. The innovative output leads to increase labor productuvity of the firm. To analyze this process, patent equation, innovative sales equation and productivity equation will be used.

In this study, dynamic panel data analysis was used. The dynamic panel data model incorporates the past version of the dependent variable into the model and measures the effect of the previous period dependent variable on the current period dependent variable (Güngör and Yerdelen Kaygın, 2015: 155, Zeren and Ergun, 2010: 76). In other words, dynamic data models are models with delayed variable or variables, in contrast to static models (Yerdelen Tatoğlu, 2012: 65). Since an economic event occurring over a certain period of time is largely affected by an economic event occurring in the past period, it is important that the lagged values of the variables are included in the explanatory variables when analyzing economic relations. There are a number of tests for measuring the validity and reliability of tests performed for dynamic panel data analysis.

The first one is the Wald test, which examines whether the independent variables of the predicted dynamic model are sufficient to explain the dependent variable. The basic hypothesis of this test (H_0) is that "independent variables do not have the power to explain the dependent variable", while the alternative hypothesis (H_1) is that "independent variables have the power to explain the dependent variable". In this context, the fact that Wald statistics is less than 5% means rejection of H_0 hypothesis.

The second is the Arellano-Bond (AB) autocorrelation test, which examines the autocorrelation in the predicted dynamic model. In this test, there are two statistics including first order autocorrelation AR (1) and second order autocorrelation AR (2). While the basic hypothesis (H_0) in this test is "there is no autocorrelation in the model", the alternative hypothesis (H_1) is "there is autocorrelation in the model". Acceptance of the H_0 hypothesis means that the model is not autocorrelated (Yerdelen Tatoğlu, 2018: 149).

Stage 1: The Patent Equation

The patent equation is,

$$PE= \gamma_1 FS + \beta_1 R\&D \quad (1)$$

where PE is the number of patents per employee in logarithm. This data was obtained from the Turkish Patent and Trademark Office. FS is the firm specific characteristics (e.g. size, number of employees etc.). R&D is the R&D expenditures in logarithm. FS and R&D was obtained from the Turkish Statistical Institute.

Stage 2: The Innovative Output Equation

The innovative output equation is,

$$IO= \gamma_2 FS + \beta_2 R\&D \quad (2)$$

where IO is the turnover per personnel empoyed in the R&D unit in logarithm. This data was obtained form the Turkish Statistical Institute.

Stage 3: The Productivity Equation

The productivity equation is,

$$PrE= \gamma_3 FS + \beta_3 IO \quad (3)$$

where PrE is the value added per employee in logarithm. IO is the innovative ouput. Explanatory variables and firm specific characteristics used in the study are,

- Number of enterprises
- Number of persons employed
- Number of persons employed in the R&D unit
- Herfindahl index

By solving the above equations, the following results are obtained.

The patent eqaution analysis;

Table 2: Regression Results- Equation (1) Dependet Variable: Number of Patents per Employee

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Number of patents per employee (-1)	0.7476	0.00346	215.82	0.000***
Number of persons employed	-0.0057	0.00017	-32.56	0.000***

Herfindahl Index	0.0004	0.00010	4.03	0.000***
Number of enterprises	0.0012	0.00005	23.52	0.000***
Number of persons employed in the R&D unit	0.0020	0.00023	10.78	0.000***
R&D expenditures	-0.0007	0.00014	-5.40	0.000***
C	0.0543	0.01040	38.69	0.000***
Assumptions of the model				
Wald	2120000***			
AR(1) AR(2)	-1.716 (0.086) -0.311 (0.755)			

Note: *** states that the variables are significant at 1% significance level.

The innovation process of firms depends on the interaction of firm specific character, e.g. R&D intensity, firm size, environmental factors such as using external resources, market structures, indutrial technology level etc (Becker and Dietz, 2004: 210).

The result of the estimation of the patent equation is presented in Table 2. According to model results number of patents per employee (-1), number of enterprises, number of persons employed in the R&D unit, Herfindahl Index are positive and significant 1% level in the regression. Number of persons employed and R&D expenditures are also negative and significant 1% level in the regression. Industries with high concentrations are more eager to do R&D acticities. And thus the number of patent is also increasing. Less concentrated (competitive) sectors have not a greater eager to engage in R&D activities. More competition can encourage innovation and growth. The competition can increase profits due to innovation. Schumpeter estimated relationships and found negative relationship between competition and innovation (Aghion et al., 2005: 702-703). Not number of persons employed but number of persons employed in the R&D unit also increase the number of patents. Also, the greater the sales of a firm, the more the firm invetsts in patentable activities (Scherer, 1965: 1100). Scherer (1967) showed a positive relationship between patenting activity and firm size. The Wald test was used to test whether the independent variables were statistically significant in explaining dependent variables. According to Wald test;

H_o= The independent variables have no power to explain dependent variables.

H_1= The independent variables have the power to explain the dependent variables.

The H_0 hypothesis was rejected ($p<0,05$). In other words, dependent variables have the power to explain the independent variables and the models are statistically significant. Autocorrelation in the model was controlled by Arellano-Bond (AB) test.

H_o= There is no autocorrelation.

H_1= There is autocorrelation.

According to the Arellano-Bond test results, H_0 hypothesis was accepted because it was AR (2) ($p> 0.05$). Accordingly, the model does not have an autocorrelation problem.

The innovative output equation analysis;

Table 3. Regression Results- Equation (2) Dependent Variable: Turnover per Personnel Employed in the R&D Unit

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Turnover per personnel employes in the R&D Unit (-1)	0.7159	0.0667	10.73	0.000***
Number of persons employed	0.2899	0.1479	1.96	0.0500**
Herfindahl Index	-0.0078	0.0204	-0.38	0.702
Number of enterprises	-0.0156	0.0260	-0.60	0.547
Number of persons employed in the R&D unit	-0.0399	0.0352	-1.13	0.257
R&D expenditures	0.0164	0.0285	0.58	0.565
Number of patents per employee	0.0610	0.01217	5.01	0.000***
C	3.370	0.4221	7.98	0.000***
Assumptions of the model				
Wald	121733.18***			
AR(1) AR(2)	-2.93(0.003) 1.7222 (0.085)			

Note: *** states that the variables are significant at 1% significance level.
** states that the variables are significant at 5% significance level.

According to model, turnover per personnel employes in the R&D unit (-1), number of persons employed, number of patents per employee are positive and significant. Herfindahl Index, number of enterprises, number of persons employed in the R&D unit, R&D expenditures are not statistically significant.

The H_0 hypothesis was rejected for the Wald test ($p < 0.05$). In other words, dependent variables have the power to explain the independent variables and the models are statistically significant. Similarly, there is no autocorrelation problem in the model ($p>0,05$). The productivity equation analysis;

Table 4. Regression Results- Equation (3) Dependent Variable: Value Added per Employee

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Value added per employee (-1)	0.072127	0. 25243	0.29	0.775
Herfindahl Index	-0.000023	4.60e-06	-5.08	0.000***
Turnover per personnel empoyed in the R&D unit	0.0000246	7.11e-06	3.46	0.001***
Number of persons employed	5.71e-07	6.01e-07	0.95	0.341
Number of enterprises	-5.78e-06	4.62e-06	-1.25	0.211
Number of persons employed in the R&D unit	8.79e-07	1.60e-06	0.55	0.446
Number of patents per employee	-1.05e-07	1.58e-06	-0.07	0.947
C	0.000344	0. 000079	4.31	0.000***
Assumptions of the model				
Wald	237.65***			
AR(1) AR(2)	-0.345 (0.7300) 0.462 (0.6435)			

Note: *** states that the variables are significant at 1% significance level.

Turnover per personnel empoyed in the R&D unit is positive and significant 1% level in the regression. Herfindahl index is negative and significant 1% level in the regression. This suggests a negative relationship between herfindahl index and labor productivity. All other variables were statistically insignificant. The H_0 hypothesis was rejected for the Wald test ($p < 0.05$). In other words, dependent variables have the power to explain the independent variables and the models are statistically significant. Similarly, there is no autocorrelation problem in the model ($p > 0,05$).

In developed countries economic growth depends on the size of technological innovation. In order to catch up these countries, developing countries should increase the dimension of technological innovation. Productivity is an important variable that raises the standard of living of a country, should increase to catch up high-income countries (Masso and Vahter, 2008: 241). The technological innovation is always the best factor to increase productuvity. If the labour force is required when combining new products in the production process innovation affects the labour productivity. The aim of innovation is to reduce the production cost per unit and thus increase labor productivity (Neri et al., 2013: 44).

CONCLUSIONS

The relationship between innovation and productivity has already attracted researches attention for a long time. In order for developing countries to level up per capita income levels similar to those of the richest economies productivity is vital. And consequently innovation is essential for increasing productivity. The association between innovation and productivity has been analysed for a large number of countries. Because innovation is a key factor of economic growth.

The paper is based on a model which takes into account the wholo process of innovation that includes number of patents per employee, turnover per employee and value added per employee, the results of these efforts and their impact on productivity. And explanatory variables are herfindahl index, employment, R&D expenditures, number of enterprises, number of R&D employments. In this paper, we study a developing country case: Turkey. We have data about innovation, R&D and production activities during period 2009-2015. We have followed the steps of Crepón et al. (1998) by excluding firs step. Because data we used includes only the sectors which invest in R&D. Also, the data is about manufacturing sector. We carry out an econometric analysis of CDM model by using sector level panel data set provided by Turkish Statistical Institute.

Consequently, the number of enterprises, R&D expenditures, the number of persons employed in the R&D unit and the lack of competition (when the herfindahl index is high) lead to increase number of patents per employee. Increase in the number of patents leads to innovative sales and this sales lead to labor productivity. High labor productivity means lower cost per unit and competitive power in the global markets. Number of patents, the first step in labor productivity is very low in Turkey. However as the number of patents increases, innovative sales will increase and this will increase labor productivity.

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APPENDIX

Codes and Definition of Manufacturing Industry Sectors

Code	Definiton
10+11	Manufacture of food products and Manufacture of beverages
12	Manufacture of tobacco products (not spend R&D expenditures)
13	Manufacture of textile products
14	Manufacture of clothing articles
15	Manufacture of leather and related products
16	Manufacture of wood, wood and cork products (except furniture); Manufacture of articles made from reeds, straw and similar materials
17	Manufacture of paper and paper products
18	Printing and duplication of recorded media
19+20	Manufacture of Coke Coal and Refined Petroleum Products, Chemicals and Chemical Products
21	Manufacture of basic pharmaceutical products and materials for pharmacy
22	Manufacture of rubber and plastic products
23	Manufacture of other non-metallic mineral products
24	Basic metal industry
25	Manufacture of fabricated metal products (except machinery and equipment)
26	Manufacture of computers, electronic and optical products
27	Manufacture of electrical equipment
28	Manufacture of machinery and equipment not elsewhere classified
29	Manufacture of motor vehicles, trailers and semi-trailers
30	Manufacture of other transport vehicles
31+32	Manufacture of furniture; manufacture of other products
33	Installation and repairment of machinery and equipment

Source: Turkish Statistical Institute.