THE KEY ACTORS OF KNOWLEDGE PRODUCTION FUNCTION IN TURKEY: 
THE ROLE OF UNIVERSITIES AS A KNOWLEDGE PRODUCER*

TÜRKİYE'DEKİ BİLGİ ÜRETİM FONKSİYONUNUN TEMEL AKTÖRLERİ: 
BİLGİ ÜRETİCİSİ OLARAK ÜNİVERSİTELERİN ROLÜ

Assoc. Prof. Dr. Selen IŞIK MADEN1
Assist. Prof. Dr. Aykut SEZGİN2
Assist. Prof. Dr. Aységül BAYKUL3
Sevim UNUTULMAZ4
Prof. Dr. Murat Ali DULUPÇU5

ABSTRACT

By taking the projects which are carried out in the universities in Turkey and are funded by the Scientific and 
Technological Research Council (TÜBİTAK) as an output, the paper tries to estimate the knowledge production 
function of Turkey. In the study, an OLS analysis is made with cross-section data by utilizing the datum of state 
universities operating in Turkey at the NUTS III level. The dependent variable of the knowledge production 
function that is developed by using Cobb-Douglas production function is the annual R&D fund transferred to 
universities by TÜBİTAK for the projects. Other variables in the analysis are the annual R&D expenditures of 
universities, the number of academic staff, number of postgraduate students and the existence of Technology 
Transfer Office and/or Technopolis. According to the analysis results there is a positive and significant relationship 
between R&D fund, and postgraduate students and technology transfer offices/technopolis. However, the 
relationship between R&D expenditures and the R&D funds transferred to the universities is found to be 
statistically insignificant. A negative and insignificant relationship is found when R&D funds and academic staff 
are estimated together, but in the models in which academic staff is decoupled, the results differ.

Keywords: Knowledge Production Function, Turkey, State Universities, Endogenous Growth.

JEL Classification Codes: O30, O31, O40.

ÖZ

Bu çalışmada Türkiye'deki üniversitelerde yürütülen ve Bilimsel ve Teknolojik Araştırma Kurumu (TÜBİTAK) 
tarafından finanse edilen projeler çıktı olarak ele alınarak, Türkiye'nin bilgi üretim işlevi tahmin edilmeye 
calışmıştır. Çalışmada, Türkiye'de faaliyet gösteren devlet üniversitelerinin NUTS III düzeyinde verileri

1 Süleyman Demirel University, Faculty of Economics and Administrative Sciences, Department of Economics, selenmaden@sdu.edu.tr
2 Süleyman Demirel University, Faculty of Economics and Administrative Sciences, Department of Economics, aytuzezgin@sdu.edu.tr
3 Süleyman Demirel University, Faculty of Economics and Administrative Sciences, Department of Economics, aysugulbaykul@sdu.edu.tr
4 Süleyman Demirel University, Graduate School of Social Sciences, Department of Economics, sevimenutulmaz@hotmail.com
5 Süleyman Demirel University, Faculty of Economics and Administrative Sciences, Department of Economics, muratumdulupcudue.edu.tr

* This paper was presented at the Regional Studies Association Annual Conference 2018, Lugano-Switzerland, 3–6 June 2018.
The knowledge production process should be well understood in order economic growth and innovation to be explained. The solid indicators of economic growth and one of the most crucial sources of it, namely innovation, are the high tech and high value-added products which are the by-product of knowledge. In the basis of all the growth and innovation theories developed in the last decades, the role of knowledge is emphasized both in the regional and national level (Sakalyte and Bartuseviciene 2013). Evolutionary economics also supports the idea that knowledge is a crucial factor in the technologic development and improvement via innovation (Freeman 1988; Lundvall 1988; Nelson 1993; Carlsson 1995; Edquist 1997; Nelson 2002).

The analysis of how knowledge is produced is actually regarded as “black box”. The transformation of inputs to outputs in the knowledge creation process, that is in fact the emergence of new knowledge, is seen as a subject that remains mysterious. The purpose of that is estimated to be those unforeseen variables such as knowledge externalities and spillovers (Charlot, Crescenzi, and Musolesi 2014).

The most accepted method to measure knowledge production is the use of Knowledge Production Function (KPF). In this way, the knowledge production process seen as a black box is tried to be explained with the use of function created. It may be claimed that the KPF approach is not sufficient on itself for the analysis of knowledge production process. However, as the patent and R&D datum are the easiest quantitative indicators that is usual

If those studies that utilise knowledge production function are examined, it attracts attention that previously there are many studies focusing on the industry. The literature on knowledge production function has developed in two distinct ways. The first group of studies have concentrated on micro-level studies that utilise survey datum (Acs et al. 2002; Fritsch 2002; Ranga et al. 2003; Conte and Vivarelli 2005; Czarnitzki et al. 2008; Ramani et al. 2008; Ponds et al. 2009), the second group have concentrated on regional level studies that analyse the relationship between regional inputs and local knowledge production (Jaffe 1989; Acs et al. 1992, 1994; Feldman and Florida 1994; Anselin et al. 1997, 2000; Egbo 2002; Riddel and Schwer 2003; Bilbao-Osorio and Rodriguez-Pose 2004).

At this point it is necessary to emphasize that the reflection of the knowledge that is produced by the firms is a subject that has typically been studied by the researches in recent years. Today it is also remarkable that the university emphasis in recent studies on the knowledge production in the regional level has significantly increased. It would not be wrong that the driving force of innovative knowledge in the regional level is the universities as universities recently play pioneering roles in the growth dynamics and regional development of national economies in the context of knowledge production (Lorber 2017).

The objective of the study is to examine the knowledge production of the universities in Turkey by utilising the knowledge production framework that was developed by Griliches (1979, 1985). At this point, it would be beneficial to examine the present situation of higher education sector in Turkey. If the higher education system in Turkey is evaluated it is seen that 60% of the R&D efforts has been executed by the universities. Thus, it may be said that the universities in Turkey have primary role in the knowledge production. The finance of the higher education is to a large extent get from public sources. The number of universities in Turkey has dramatically increased in the last decade. Since 2006, 100 new public universities have been established. As of 2018 there are...
201 universities, 129 of which are public while 72 of which are non-profit foundations. The higher education system in Turkey have a huge potential with 7 million students, 157 thousand academic staff and 70 thousand international students (COHE 2018).

2. LITERATURE REVIEW

In most of the KPF based studies that are aiming to measure the effects of knowledge production in the regional scale on both innovation capacity and economic development/growth the role of universities take an important place. The pioneering role of universities in obtaining patent, the procurement of innovative infrastructure, the supply of human resource, the enabling of cooperation with the industry are remarkable. The importance of universities that is increasing gradually reflects on the studies in the literature. In the micro-, macro- and reginal-level studies the factors that the universities possess (monetary, infrastructure, human resources etc.) take place among the input and/or output variables in the KPF.

If the literature on KPF is examined, it can be seen that the role of the universities are modelled in two different ways: directly or indirectly. While in those studies in which the effect is indirectly measured, the universities take place as an independent variable among all other variables that produce knowledge; in other studies in which the effect is directly measured, only the self-knowledge production process of universities is focused.

The first study that incorporated universities to KPF indirectly belongs to Anselin, Varga and Acs (1997). In the study, by using the quality and the ranking of the advanced technology centres of universities, total employment and total education expenditures and the advanced technology employment as independent variables the regional innovation capacity is tried to be measured. In the study utilizing the OLS method, it is determined that R&D activities and innovation activities have positive and significant direct and indirect effects on the private sector.

Fischer and Varga (2003) use advanced technology employment, R&D expenditures and the research expenditures of universities as the factors determining the corporate patents that is the output of university-industry cooperation. As the result of spatial lag modelling, it is determined that patent activities are robustly related to university research spillovers and industrial R&D. It is also mentioned that the significance of the relationship is more for advanced technological firms.

In their study, Buesa, Hejis, Pellitero and Baumert (2006) analyse the R&D system of Spain at the regional scale by utilising multivariate data analysis. They assessed regional innovation capacity with 4 different factors. These factors are public administration, environment, enterprises and university. An emphasis is laid on that special R&D policies for each region where innovative inequalities exist should be applied.

Abdih and Joutz (2006) incorporate the number of scientists and engineers who are employed in the R&D departments of the universities to the KPF model as an independent variable in their study. They determine that in order to increase total factor productivity and magnitude a policy that give weight to R&D supports is necessitated.

Chen and He (2014) realise a panel data application by utilising the data for eastern-western and central regions of China for the period 2000-2005. They reveal that the R&D staff and the R&D expenditures of universities have significant effect on patent activities.

Perret (2016) examines the knowledge production process, which he thinks as the key for national innovation system, for the USA and Russian Federation. Knowledge production is thought as an element that reveals the efficiency of innovation system. He proves that there is a nonlinear relationship between the input and outputs of knowledge. While examining the relationship he utilises the regional data such as the R&D expenditures and patents of universities. In both countries, small sized research systems exhibit more dynamic results. In the USA and Russian Federation KPF exhibits separate yields according to the size of the research system. The study derives policy recommendations for the USA and Russia.

The first pioneering research in which the universities are put in the centre of KPF is the paper published by Varga in 1997. Varga determines that the research expenditures of universities have positive effects on the innovation output of economics activities in metropolitan regions. As the reason of the effect he indicates that local academic knowledge transfers produce agglomeration effects in metropolitan regions.
In 2003, Andersson and Ejermo included the industrial R&D, university research and the index of geographical coincidence between university and industry research as independent variables into the model where patent is the dependent variable and realised a panel pooled OLD analysis with the 1993-99 data. Different from previous studies, the index of geographical coincidence is utilised in the study in order to decrease the effect of geographical discrepancies. They determined that university research has positive and significant effects on patent activities.

On the other hand, in their study in 2007 Ohuallachain and Leslie they found that R&D expenditures of universities have no effect on patents in the USA. They made a regression analysis for knowledge production in the regional scale in order to analyse the relationship between R&D and innovation by utilising the 2002-4 data. They determined a positive relationship between industrial R&D expenditures and institutional patents. However, they also revealed that human capital provides an advantage in the increase of knowledge flows and in taking patents.

In their study, Gurmu, Black and Stephan (2010) build a model on the patent activities of universities. In the study that encompasses the USA data for the period 1985-99, the R&D expenditures and the fields of study of the universities and the existence of TTOs in the universities are included as variables. The fields of study are divided into 5 distinct disciplines. Besides, the researchers in the universities are also categorised according to their departments, level of education and visa status of this level. A positive and significant relationship is determined between the patent output, and the stock of R&D expenditure and the existence of TTOs. Also, a positive and significant relationship is also determined between human resource and the number of patents. A positive and significant relationship also prevails between all researches and patents. It is also determined that all Ph.D. graduate students and Post-docs have equivalent contributions to obtain patents, but this may differ according to the visa status. At this point, it is seen that the field of study and visa status have distinct effects on patenting activities. The competition between the residents and immigrants is emphasized to be effective on this situation. It is confirmed whether there is a positive and significant relationship between resident Ph.D. students and the number of patents but a negative relationship between immigrant Ph.D. students and the number of patents. On the other hand, it is stated that among post-docs those who are immigrant have positive and significant effect on the number of patents.

Conti and Liu (2014) is a study that focuses on the knowledge produced by the graduate and post-doc students in the academic community. The knowledge performance in the Department of Biology, MIT is tested by using 1970-2000 data. It is revealed that previously produced knowledge, a stock variable, has crucial and significant contributions to the studies to be made and to the knowledge to be produced in the future. Therefore, it is a crucial study in terms of the measurement of the contributions of universities to knowledge production.

Chatterjee, Dinor and Gonzalez-Rivera made a regression analysis in 2016 on the University of California by using 2007-2013 data. In the KPF model the variables of full-time equivalent extension positions, expenditures on salaries per unit FTE and expenditures on infrastructure per unit FTE were used. As a result, it is determined that all these variables have positive and significant effects on knowledge production.

After the 1980s, the KPF literature has turned into a topic that exhibits a development with an interaction with the disciplines of economic growth, development and economic geography. Assessed in this context, the literature has developed in two distinct branches: micro and regional level analyses. The studies from both branches, regardless of their level of analysis, draw attention to the important role of universities in the KPF. Therefore, in this study, although the distinction between these two branches is accepted, the literature is assessed by focusing on the role of universities. In the study, the KPF method is utilised, as used in Varga (1997), Andersson and Ejermo (2003), Ohuallachain and Leslie (2007), Gurmu, Black and Stephan (2010), Conti and Liu (2014), Chatterjee, Dinor and Gonzalez-Rivera (2016), in order to analyse the KP process of universities among Turkish universities.

3. METHOD
KPF identifies the relationship between the knowledge inputs and knowledge outputs like the traditional production functions identifying the relationship between input and output. As knowledge can be subsidised and as it has no maximum theoretically similar to the production factors, the knowledge production function may be assessed as a substitutional production function.
The concept of knowledge production function was brought to the literature by Griliches (1979) based on the aggregate production function. This function is based on Cobb-Douglas production function that actually reflects a traditional production function; 

\[ Y = F(K, L, A) \]  

(1)

\( Y \) represents the input related outputs; \( K, L \) and \( A \) represent capital, labour and the level of technological knowledge, respectively. In the function the relationship between the level of technological knowledge and knowledge production is correlated with R&D investments. Like the total production function, Griliches also bases the relationship between the knowledge and R&D investments while generating the knowledge production function;

\[ \dot{A} = R \]  

(2)

In the function above \( \dot{A} \) represents the new knowledge output and \( R \) represents the knowledge attained as a consequence of R&D expenditures. According to Griliches cumulative R&D expenditures constitute the knowledge stocks. The stock variables determined in this context are shown in the following equation:

\[ A_t = \sum_{i=-\infty}^{t} \dot{A}_i = \sum_{i=-\infty}^{t} R_i \]  

(3)

While attaining knowledge stocks from knowledge production function, it is probable knowledge depreciations to occur. As a result of knowledge to lose its currency in due course, previous R&D expenditures contribute less to the knowledge stocks compared to current R&D expenditures. At this stage, Griliches identifies technological knowledge stocks as a function of R&D expenditure flows.

\[ A_t = G(W(B)R, v) \]  

(4)

Although the above equation is named as knowledge function, in fact it defines the knowledge accumulation. While \( A \) represents the technological knowledge accumulation in the equation, \( W(B)R \) is the indicator of current and lagged R&D expenditures. The \( G(W(B)R) \) function can be redefined as follows:

\[ A_t = R_t + (1-\gamma) A_{t-1} \]  

(5)

In the above equation Perpetual Inventory Method (PIM) is utilised for the measurement of stock variables. In the PIM equation calculated for the current knowledge stocks \( R_t \) represents the total of current period investments while \( (1-\gamma) A_{t-1} \) represents the previous period value adjusted for depreciation. In Equation 4, variable \( v \) represents residual factors. These residual factors do not have direct influences on the formation of R&D stocks.

Following Griliches, Romer (1990) and Jones (1995) (by modifying Romer’s ideas) use knowledge production function as an explanatory variable of the economic growth in Endogenous Growth Theory. Particularly the creation of new ideas has been included in the model depending on the size of funds devoted to knowledge accumulation, R&D expenditures and R&D activities such as the number of scientists and researchers.

In this context, the main purpose of the study is to analyse the knowledge produced by Turkish universities by using knowledge inputs. If the KPF studies in the literature are examined, the outputs in the knowledge production process are seen mostly to be those variables such as patents, R&D expenditures and scientific projects. The output of this study is R&D expenditures. In contrast to common use, the main purpose of non-using the number of patents in Turkey as an output is that patent tracking system is inefficient, patenting is not common traditionally and therefore patents are not thought as an innovation indicator on the basis of universities in Turkey.

In the study, as input the variables of R&D budgets of universities, number of various education staff, R&D staff, Technopolis and Technology Transfer Offices are used in accordance with the literature. These variables are analysed with the logarithmic regression modes OLS method by using 2016 cross-section data for 108 public universities.

All the variables used in the model are grouped and given in Table 1 and Table 2.
4. MODELS

In the study, eight different models are used as shown in Table 3. While in the first 4 models the dependant variable is cumulative R&D expenditures, in the last 4 models it is the R&D figure for the year 2016. Although the analysis is cross-sectional, the reason of including cumulative dependant variable in 4 models is that, as Griliches states, the formation of knowledge output is not the accumulation of a single year, but instead it is the accumulation of a retrospective knowledge accumulation. In order to see the cumulative effect, 4-year R&D expenditure that is available retrospectively is utilised.
In all models for KPF, as the K variable (pecuniary) R&D budget of the universities is used and as the A variable (technocentric) the existence of Technology Transfer Office and/or Technopolis is used. The L variable (labour oriented) is included into the analyses in 8 models both as all together and as separate groups. Here, the aim is to measure the research and educational effects individually.

**Table 3. Eight Different Model About Knowledge Production Functions**

| MODELS | DV                  | PECUNIARY IV’S                  | LABOUR ORIENTED IV’S                          | TECHNOCENTRIC IV’S |
|--------|---------------------|--------------------------------|----------------------------------------------|-------------------|
| 1      | R&D_2016CUM         | R&D_BUDGET                     | ASSIST_PROF, PROF, ASSOC_PROF, LECT, INSTRUCT, SPECIALIST, STUD_MS and STUD_PHD | TTO and TECHP     |
| 2      | R&D_2016CUM         | R&D_BUDGET                     | ASSIST_PROF, PROF, ASSOC_PROF, LECT, INSTRUCT, SPECIALIST and STUD_GRAD | TTO and TECHP     |
| 3      | R&D_2016CUM         | R&D_BUDGET                     | ACAD_STAFF, STUD_MS and STUD_PHD              | TTO and TECHP     |
| 4      | R&D_2016CUM         | R&D_BUDGET                     | ACAD_STAFF and STUD_GRAD                      | TTO and TECHP     |
| 5      | R&D_2016            | R&D_BUDGET                     | ASSIST_PROF, PROF, ASSOC_PROF, LECT, INSTRUCT, SPECIALIST, STUD_MS and STUD_PHD | TTO and TECHP     |
| 6      | R&D_2016            | R&D_BUDGET                     | ASSIST_PROF, PROF, ASSOC_PROF, LECT, INSTRUCT, SPECIALIST and STUD_GRAD | TTO and TECHP     |
| 7      | R&D_2016            | R&D_BUDGET                     | ACAD_STAFF, STUD_MS and STUD_PHD              | TTO and TECHP     |
| 8      | R&D_2016            | R&D_BUDGET                     | ACAD_STAFF and STUD_GRAD                      | TTO and TECHP     |

The results of the first 4 models in which the cumulative R&D expenditures are used as a dependent variable are given in Table 5 below. The reason of low R² in all models is thought to be the use of cross-sectional analysis. The reason of using cross-sectional data is the lack of regular available time series data in Turkey for the variables used in the model. The F-test results reveal that all the variables in the models are jointly significant.

Unexpected negative coefficients may generally be caused by strong correlations between independent variables. For example, as the correlations between prof. and assoc. prof. or assoc. prof. and assist. prof. are around 90%, the use of these two variables in the same model may cause a positive coefficient for one and negative for the other (See Table 4).

**Table 4. Correlation Matrix for Labour Oriented Variables Used in the Study**

|                  | Total     | STUD_MS  | STUD_PHD | PROF   | ASSOC_PROF | ASSIST_PROF | LECT   | INSTRUCT | SPECIALIST |
|------------------|-----------|----------|----------|--------|------------|-------------|--------|----------|------------|
| Total            | 1,000     |          |          |        |            |             |        |          |            |
| STUD_MS          | 0.399     | 1,000    |          |        |            |             |        |          |            |
| STUD_PHD         | 0.527     | 0.893    | 1,000    |        |            |             |        |          |            |
| PROF             | 0.398     | 0.506    | 0.512    | 1,000  |            |             |        |          |            |
| ASSOC_PROF       | 0.309     | 0.477    | 0.388    | 0.899  | 1,000      |             |        |          |            |
| ASSIST_PROF      | 0.213     | 0.447    | 0.272    | 0.674  | 0.865      | 1,000       |        |          |            |
| LECT             | 0.097     | 0.389    | 0.200    | 0.512  | 0.670      | 0.758       | 1,000  |          |            |
| INSTRUCT         | 0.453     | 0.550    | 0.474    | 0.855  | 0.814      | 0.674       | 0.623  | 1,000    |            |
| SPECIALIST       | 0.451     | 0.526    | 0.493    | 0.898  | 0.856      | 0.666       | 0.623  | 0.868    | 1          |

* The threshold value for cells marked with grey is 0.75.
These 4 models indicate that graduate and Ph.D. students have significant effects on the knowledge production in Turkey. It may also be possible to claim that the existence of Technopolis and TTOs have significant effects on the knowledge production.

**Table 5.** Cumulative R&D Expenditures Dependent Variable Four Models

| DV                | LNR&D_2016CUM |
|-------------------|---------------|
| R²                | 0.43 0.41 0.42 0.38 |
| Adjusted R²       | 0.37 0.35 0.39 0.36 |
| F - Test          | 7.38*** 7.43*** 14.5*** 15.83*** |

|                  | Model 1 | Model 2 | Model 3 | Model 4 | Model 1 | Model 2 | Model 3 | Model 4 |
|------------------|---------|---------|---------|---------|---------|---------|---------|---------|
| Constant term    | 10.19   | 8.94    | 7.76    | 5.37    | 4.85*** | 4.18*** | 3.85*** | 2.85*** |
| LNR&D_BUDGET     | 0.07    | 0.09    | 0.08    | 0.09    | 0.94    | 1.20    | 1.22    | 1.33    |
| LNSTD_MS         | 0.06    | -0.06   | 0.19    | 0.18    |         |         |         |         |
| LNSTD_GRAD       | 0.63    | 0.63    | 0.61    | 0.61    | 2.77*** |         |         |         |
| LNSTD_PHD        | 0.57    | 0.59    |         |         | 2.21**  | 2.68*** |         |         |
| LNPROF           | -0.06   | 0.33    |         |         | -0.14   | 0.90    |         |         |
| LNASSOC_PROF     | 0.14    | 0.07    |         |         | 0.32    | 0.16    |         |         |
| LNASSIST_PROF    | -0.13   | -0.44   |         |         | -0.22   | -0.81   |         |         |
| LNACAD_STAFF     |         |         | 0.40    | 0.40    |         |         | 1.40    | 1.37    |
| LLECT            | -0.17   | -0.15   |         |         | -0.67   | -0.60   |         |         |
| LINSTRUCT        | -0.16   | -0.23   |         |         | -0.50   | -0.71   |         |         |
| LNSPECIALIST     | 0.50    | 0.45    |         |         | 1.76*   | 1.58    |         |         |
| TTO_TECHP        | 0.77    | 1.07    | 0.90    | 1.39    | 1.20    | 1.68*   | 1.47    | 2.33**  |

*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level

The results for the constant term reveal an interesting point that R&D expenditures are made without any input. Output may be the result of another knowledge spillover in which no R&D effort exists or is a result of an increase in the stock of knowledge capital. High level of significance in the first 4 models increases the probability of second option.

The results of the last 4 models in which R&D expenditures for the year 2016 are used as the dependent variable are given in Table 6 below. As in the first 4 models, it is striking that Ph.D. and graduate students are significant in these 4 models. However, in these 4 models it is found that assist. prof. have negative and significant effect. Besides, unlike the first 4 models, the positive and significant effects of assoc. prof. and prof. is remarkable. Unlike the first models, the existence of TTO and Technopolis is not significant in these models. All the findings for R², F statistics and constants in the first 4 models are also valid for these 4 models.
Table 6. R&D Expenditures Dependent Variable Four Models

| DV               | LNR&D_2016 |
|------------------|------------|
| \( R^2 \)        | 0.51 0.48 0.49 0.42 |
| Adjusted \( R^2 \) | 0.46 0.43 0.46 0.40 |
| F - Test         | 10.27*** 9.91*** 19.41*** 18.7*** |

| Model 5 | Model 6 | Model 7 | Model 8 | Model 5 | Model 6 | Model 7 | Model 8 |
|---------|---------|---------|---------|---------|---------|---------|---------|
| Coefficients | Coefficients | Coefficients | Coefficients | t Stat | t Stat | t Stat | t Stat |
| Constant term | 8.29 6.27 4.78 0.38 | 3.33*** | 2.44** | 1.98* | 0.16 |
| LNR&D_BUDGET | 0.08 0.11 0.07 0.09 | 0.97 | 1.27 | 0.83 | 0.97 |
| LNSTUD_MS | 0.19 0.04 | 0.48 | 0.09 |
| LNSTUD_PHD | 0.90 1.08 | 2.91*** | 4.08*** | 4.70*** |
| LNSTUD_GRAD | 1.09 1.26 | 3.96*** |
| LNPROF | 0.24 0.84 | 0.50 | 1.89* |
| LNASSOC_PROF | 0.91 0.79 | 1.72* | 1.45 |
| LNASSIST_PROF | -1.20 -1.68 | -1.79* | -2.56** |
| LNACAD_STAFF | 0.13 0.12 | 0.38 | 0.34 |
| LNLECT | -0.07 -0.04 | -0.24 | -0.14 |
| LNINSTRUCT | -0.28 -0.38 | -0.74 | -0.99 |
| LNSPECIALIST | -0.01 -0.08 | -0.03 | -0.23 |
| TTO_TECHP | 0.07 0.53 0.19 1.06 | 0.10 | 0.69 | 0.26 | 1.43 |

*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level

5. CONCLUSION

In the study in which the results of KPF, which is attained for Turkey with the 2012-2016 data, are assessed 8 models are built. The variables used are categorised under 3 groups, namely pecuniary, labour oriented and technocentric. While building the models, the effects of all variables on both the cumulative and annual R&D expenditures for the year 2016 are examined.

In all models it is determined that graduate and Ph.D. students have positive and significant effects on output. In line with the findings in the studies of Stephan, Black and Gurmu in the literature, the effects of graduate and Ph.D. students on output are found as expected. It may be thought that crucial part of the graduate and Ph.D. level students in Turkey maintain a project-based process in order to complete their thesis and this may cause such an effect. Recently, the funds for graduate students increase gradually with the supports of internal or external units/institutions such as the Coordinatorship of Scientific Research Projects in the universities and Scientific and Technological Research Council of Turkey (TÜBİTAK). Therefore, it is thought that the support of graduate student would positively affect the knowledge production process. At this point the encouragement and support of post graduate education may be presented as a policy recommendation.

In the last 4 models in which the dependant variable is not cumulative, the insignificance of the existence of TTOs and Technopolis is an expected result. This, in turn, do not indicate that TTOs and Technopolis have no effect on knowledge production. It is known that due to their structures the positive effects of TTOs and Technopolis occur following a certain period of time. Therefore, the significance of TTOs and Technopolis in the model in which cumulative variable is used affirms this prediction.

In the study, it is thought that those models with cumulative variables give closer results to the expectations. The study is the first effort for Turkey and would shed light to future studies to be made with comprehensive and longer data. Hence, the universities in Turkey would be compared with those in other countries.
REFERENCES

Abdih, Y. and Joutz, F. (2006). Relating the knowledge production function to total factor productivity: An endogenous growth puzzle. *IMF Staff Papers*, 53(2), 242-271.

Acs, Z. J., Anselin, L. and Varga, A. (2002). Patents and innovation counts as measures of regional production of new knowledge. *Research Policy*, 31(7), 1069-1085.

Acs, Z. J., Audretsch, D. B. and Feldman, M. P. (1992). Real effects of academic research: Comment. *The American Economic Review*, 82(1), 363-367.

Acs, Z. J., Audretsch, D. B. and Feldman, M. P. (1994). R & D spillovers and recipient firm size. *The Review of Economics and Statistics*, 76(2), 336-340.

Andersson, M. and Ejermo, O. (2003). Knowledge production in Swedish functional regions 1993-1999 (No. 139). Kites, Centre for Knowledge, Internationalization and Technology Studies, Università Bocconi, Milano, Italy.

Anselin, L., Varga, A. and Acs, Z. (1997). Local geographic spillovers between university research and high technology innovations. *Journal of Urban Economics*, 42(3), 422-448.

Anselin, L., Varga, A. and Acs, Z. (2000). Geographical spillovers and university research: A spatial econometric perspective. *Growth and Change*, 31(4), 501-515.

Acs, Z. J., Audretsch, D. B. and Feldman, M. P. (1992). Real effects of academic research: Comment. *The American Economic Review*, 82(1), 363-367.

Andersson, M. and Ejermo, O. (2003). Knowledge production in Swedish functional regions 1993-1999 (No. 139). Kites, Centre for Knowledge, Internationalization and Technology Studies, Università Bocconi, Milano, Italy.

Anselin, L., Varga, A. and Acs, Z. (1997). Local geographic spillovers between university research and high technology innovations. *Journal of Urban Economics*, 42(3), 422-448.

Anselin, L., Varga, A. and Acs, Z. (2000). Geographical spillovers and university research: A spatial econometric perspective. *Growth and Change*, 31(4), 501-515.

Bartuševičienė, I. and Šakalytė, E. (2013). Organizational assessment: Effectiveness vs. efficiency. *Social Transformations in Contemporary Society*, 1(1), 45-53.

Baumann, J. and Kritikos, A. S. (2016). The link between R&D, innovation and productivity: Are micro firms different?. *Research Policy*, 45(6), 1263-1274.

Bilbao-Osorio, B. and Rodríguez-Pose, A. (2004). From R&D to innovation and economic growth in the EU. *Growth and Change*, 35(4), 434-455.

Buesa, M., Heijs, J., Pellitero, M. M. and Baumert, T. (2006). Regional systems of innovation and the knowledge production function: The Spanish case. *Technovation*, 26(4), 463-472.

Carlsson, B. (1995). *Technological systems and economic performance: The case of factory automation*. Kluwer Academic Publishers, Dordrecht.

Charlot, S., Crescenzi, R. and Musolesi, A. (2014). *Augmented and unconstrained: Revisiting the regional knowledge production function* (No. 2414). SEEDS. Sustainability Environmental Economics and Dynamics Studies.

Chatterjee, D., Dinar, A. and González-Rivera, G. (2016). A knowledge production function of agricultural research and extension: The case of the university of California cooperative extension. *UCR SPP Working Paper Series* (September 2016, WP# 16-06).

Chen, S. H. and He, W. (2014). Study on knowledge propagation in complex networks based on preferences, taking WeChat as example. In *Abstract and Applied Analysis*, 2014, Hindawi.

COHE. (2018). *Council of higher education of Turkey*. Statistics.

Conte, A. and Vivarelli, M. (2005). One or many knowledge production functions. *Mapping Innovative Activity Using Microdata IZA Discussion Paper*, 1878.

Conti, A. and Liu, C. C. (2014). The (changing) knowledge production function: Evidence from the MIT department of biology for 1970–2000. In *The Changing Frontier: Rethinking Science and Innovation Policy* (pp. 49-74), University of Chicago Press.

Czarnitzki, D., Kraft, K. and Etro, F. (2008). The effect of entry on R&D investment of leaders: Theory and empirical evidence. *ZEW-Centre for European Economic Research Discussion Paper* (08-078).

Edquist, C. (Ed.) (1997). *Systems of innovation*. Frances Pinter, London.
Egbu, C. O. (2004). Managing knowledge and intellectual capital for improved organizational innovations in the construction industry: An examination of critical success factors. *Engineering, Construction and Architectural Management*, 11(5), 301-315.

Feldman, M. P. and Florida, R. (1994). The geographic sources of innovation: Technological infrastructure and product innovation in The United States. *Annals of the Association of American Geographers*, 84(2), 210-229.

Fischer, M. M. and Varga, A. (2003). Spatial knowledge spillovers and university research: Evidence from Austria. *The Annals of Regional Science*, 37(2), 303-322.

Freeman, C. (1988). *Japan: A new national system of innovation?*. Technical Change and Economic Theory.

Fritsch, M. (2002). Measuring the quality of regional innovation systems: A knowledge production function Approach. *International Regional Science Review*, 25(1), 86-101.

Griliches, Z. (1979). Issues in assessing the contribution of research and development to productivity growth. *The Bell Journal of Economics*, 10(1), 92-116.

Griliches, Z. (1985). *Productivity, R&D, and basic research at the firm level in the 1970s*. NBER Working Paper No. 1547.

Gurmu, S., Black, G. C. and Stephan, P. E. (2010). The knowledge production function for university patenting. *Economic Inquiry*, 48(1), 192-213.

Jaffe, A. B. (1989). Real effects of academic research. *The American Economic Review*, 79(5), 957-970.

Jones, C. I. (1995). R & D-based models of economic growth. *Journal of Political Economy*, 103(4), 759-784.

Lorber, L. (2017). Universities, knowledge networks and local environment for innovation-based regional development: Case study of the University of Maribor. *Geografický Časopis/Geographical Journal*, 69, 361-383.

Lundvall, B. A. (1988). Innovation as an interactive process: From user-producer interaction to the national system of innovation. 349-369.

Nelson, R. R. (1993). *National systems of innovation: A comparative study*. University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship.

Nelson, R. R. (2002). Bringing institutions into evolutionary growth theory. *In Social Institutions and Economic Development* (9-12), Springer, Dordrecht.

Öhuallacháin, B. and Leslie, T. F. (2007). Rethinking the regional knowledge production function. *Journal of Economic Geography*, 7(6), 737-752.

Perret, J. (2016). An Alternative approach towards the knowledge production function on a regional level: Applications for the USA and Russia. *Schumpeter Discussion Papers 2016-003*.

Ponds, R., Oort, F. V. and Frenken, K. (2009). Innovation, spillovers and university–industry collaboration: An extended knowledge production function approach. *Journal of Economic Geography*, 10(2), 231-255.

Ramani, S. V., El-Aroui, M. A. and Carrère, M. (2008). On estimating a knowledge production function at the firm and sector level using patent statistics. *Research Policy*, 37(9), 1568-1578.

Ranga, L., Debackere, K. and Tunzelmann, N. (2003). Entrepreneurial universities and the dynamics of academic knowledge production: A case study of basic vs. applied research in Belgium. *Scientometrics*, 58(2), 301-320.

Riddel, M. and Schwer, R. K. (2003). Regional innovative capacity with endogenous employment: Empirical evidence from the US. *The Review of Regional Studies*, 33(1), 73.

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, 98(5, Part 2), 71-102.

Varga, A. (1997). *Regional economic effects of university research: A survey*. Unpublished Manuscript, West Virginia University, Regional Research Institute, Morgantown, WV.