「Araştırma Makalesi / Research Article」

Kastamonu Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi
Kastamonu University Journal of Faculty of Economics and Administrative Sciences

Aralık 2024 Cilt: 26 Sayı:2
iibfdergi@kastamonu.edu.tr

Başvuru Tarihi / Received: 09.01.2024
Kabul Tarihi / Accepted: 20.11.2024
DOI: 10.21180/iibfdkastamonu.1417136

Assessment of Researcher Productivity in the Field of Health[1]

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Abstract

The study was conducted to determine the relationship between the number of researchers in the health field and the number of medical patents. In the analysis, the relationship between the number of female and male researchers in the health field and the number of patent applications made in the medical field was analyzed using the panel data method. For this study, 9 countries with regular data on the number of full-time researchers working in the field of health by gender (Male = MRD and Female = FRD) between 2005 and 2018 were identified. The analysis highlights causal relationships from Medical patents (MPatents) to the number of researchers working in the field of health. Moreover, panel cointegration tests confirm that there is a long-term relationship between MPatent and FRD-MRD. The study's findings also show that increases in FRD-MRD positively impact MPatent, and coefficient estimates reveal significant effects. Overall, empirical evidence underscores important and enduring connections between MRD, FRD, and MPatent.

Keywords: *Medical Patent, Healthcare Sector, Researcher, Research and Development*

Jel Codes: *C01, C23, I18*

Sağlık Alanında Araştırmacı Verimliliğinin Değerlendirilmesi

Öz

Çalışma sağlık alanı araştırmacı sayıları ile medikal patent sayıları arasındaki ilişkinin belirlenmesi amacıyla yapılmıştır. Analizde, sağlık alanı kadın ve erkek araştırmacı sayıları ile medikal alanda yapılan patent başvuru sayıları arasındaki ilişki panel veri yöntemi ile analiz edilmiştir. Bu çalışma için 2005-2018 yılları arasında sağlık alanında cinsiyete göre tam zamanlı çalışan araştırmacı sayıları (Erkek= MRD ve Kadın=FRD) ile ilgili düzenli verisi olan 9 ülke belirlenmiştir. Analiz, Medikal patentlerden (MPatent) sağlık alanında çalışan araştırmacı sayılarına doğru nedensellik ilişkilerini vurgulamaktadır. Ayrıca, panel eşbütünleşme testleri MPatent ve FRD-MRD arasında uzun vadeli bir ilişki olduğunu doğrulamaktadır. Çalışmanın bulguları ayrıca FRD-MRD'deki artışların MPatent'i olumlu yönde etkilediğini ve katsayı tahminlerinin kayda değer etkiler ortaya koyduğunu göstermektedir. Genel olarak, ampirik kanıtlar MRD, FRD ve MPatent arasındaki önemli ve kalıcı bağlantıların altını çizmektedir.

Anahtar Kelimeler: *Medikal Patent, Sağlık Sektörü, Araştırmacı, Araştırma ve Geliştirme*

Jel Kodu: *C01, C23, I18*

[1] Bu çalışma, 17-18 Kasım 2022 tarihlerinde düzenlenen Sağlık Hizmetlerinde Yenilikler ve Teknoloji Sempozyumu'nda özet olarak sunulan "Sağlıkta Araştırmacı Verimliliği Üzerine Değerlendirme" başlıklı bildirinin genişletilmiş ve yeniden düzenlenmiş halidir.

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Atıf/Citation: Ekinci, G., Danayiyen, A., Köse, H. (2024), Assessment of Researcher Productivity in the Field of Health, Kastamonu Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 26/2, s. 305-319.

INTRODUCTION

Patents, serving as official documents, provide legal protection for technological innovations and inventions, granting various rights to creators, thereby contributing to the advancement of scientific methodologies and ensuring recognition of innovative contributions (Bozkurt Yüksel, 2008; Ekinci, 2019). Patents legally assure research owners that their ideas protect their economic value and profits. However, with the patent process, the researcher assumes the entire guarantee of the invention (Özcan & Özer, 2018). Patents are a tool to protect inventions developed by companies, institutions, or individuals. For this reason, patents can also be identified as indicators of invention (OECD, 1994). In scientific disciplines and academic findings, patents are utilized as a sign of innovation rather than innovation itself. Patents are seen as a highly reliable measure of innovative movements. In this respect, in academic research, the number of patents is generally used instead of technological innovation and is accepted as a valuable index to measure innovative knowledge production (Akyol & Gurlaş, 2021; Prodan, 2005). While granting special rights and capabilities to the researchers who own them, patents can also play an essential role in promoting innovation. Patents can encourage innovation and economic development if appropriate conditions are met. In the contemporary landscape, the propulsion of economic growth and sustainable development hinges significantly on the relentless march of technological innovation. At the core of this momentum lie the intricate frameworks of patent systems, which serve as the bastions safeguarding inventive ideas and creative breakthroughs. Rooted in the Latin term "patere," meaning "to be open," patents epitomize not only legal protection but also the ethos of fostering innovation by granting creators exclusive rights to their inventions for a designated period.

This nexus between innovation protection and societal advancement is underscored by scholars such as Bozkurt (2008), who elucidate how patents not only formalize scientific inventions but also regulate the rights associated with them. However, this protection necessitates researchers to bear the onus of their inventions, a theme explored by Özcan and Özer (2018). Zooming out to the macro level, a nation's prowess in Research and Development (R&D) endeavors is often quantified by the volume of inventions it churns out. Within the intricate tapestry of R&D, the healthcare sector emerges as a pivotal player, wielding a profound influence on economic growth and societal welfare through the prism of medical patents (Ünal, 2013). Yet, despite its significance, the domain of healthcare R&D remains relatively underexplored, especially concerning the productivity of researchers and potential gender disparities. Against this backdrop, this study endeavors to fill this void by delving into the impact of R&D activities in healthcare, particularly focusing on the cadre of full-time researchers and their correlation with the proliferation of medical patents.

At its core, this study posits a fundamental hypothesis: a tangible relationship exists between the number of healthcare researchers and the prevalence of medical patents. To illuminate this relationship, a series of subsidiary questions are posed, probing into the current landscape and teasing out any gender-based differentials in productivity. As we embark on this intellectual odyssey, the forthcoming sections will unveil the methodological scaffolding underpinning this study, followed by a robust discussion of the findings. By shedding light on the intricate interplay between healthcare R&D and medical patents, this research aspires to carve a path toward a more nuanced comprehension of the pivotal role played by innovation in the realm of health economics.

This study aims to understand the effects of R&D activities in healthcare, in particular the number of full-time researchers, on medical patents. The main hypothesis suggests that there is a relationship between the number of researchers and the number of medical patents. In this context, a series of sub-questions are posed to assess the current situation as well as the level of impact of the number of researchers in healthcare and gender-based productivity differences. In the remainder of the paper, the analytical approaches used will be explained in the methodology section before moving on to the main section where the findings will be discussed. Moreover, this study is expected to make a significant contribution to the field of health economics. Therefore, we will continue to focus on our search for answers to the key questions before moving on to the next section, which will elaborate on the overall objective of the study, its methodological approach, and the results of the discussion.

1. BACKGROUND AND LITERATURE REVIEW

Research and development studies in the field of health are difficult and expensive processes that span many years due to the measurement of their effects on human health. For example, the average period starting with the discovery of a drug and taking its license varies between 8-10 years (in some studies, this period can be up to 20 years) and is carried out with budgets expressed in millions of dollars. In addition, the final result cannot be reached for every product that is discovered, and all studies are canceled when they fail to pass any stage of the research. The infrastructure, equipment, researchers, and materials used in the execution of these studies are quite expensive. For this reason, research on the diagnosis and treatment of diseases requires serious investments for countries and the sector. The number of inventions and innovations developed within the scope of research and development activities is the success indicator of a country's research and development system. Patents, which are considered a criterion of research and development activities, enable inventions and innovations to be transformed into commercial products and give the manufacturer monopoly power (Ünal, 2013).

Research and development activities greatly affect total factor productivity (Coe & Helpman, 1995), making human capital the economic growth determinant (Poorfaraj et al., 2011; Bayraktutan & Kethudaoğlu, 2017). Commercial activities in this area contribute to economic growth by disseminating information (Luintel & Khan, 2005; Sadraoui et al., 2014; Tunalı & Erbelet, 2017). The quantitative and qualitative characteristics of the researchers of a country appear to be factors that also shape the economy of that country. For example, it is stated that the contribution of the mRNA vaccine, which was produced in Germany during the Covid-19 pandemic process and is widely used around the world, to the German economy is around 0.5 points of GDP (Gönültaş, 2021). In studies dealing with the relationship between the number of patents and economic growth, Sinha (2008), Zhang et al. (2012), Göçer et al. (2016), Türedi (2016), Maradana et al. (2017) and Özcan and Özer (2018) stated that the number of patents was effective on economic growth (Vetsikas et al., 2017), high-quality patents supported economic growth (Hassan & Tucci, 2010), but the relationship between patents and economic growth was positive in the long run and negative in the short run and showed that there was a relationship (Josheski & Koteski, 2011), shocks (unpredictable effects) in patents affect GDP negatively, and shocks in GDP also affected patents negatively (Guzman et al., 2012). There are many studies in the literature evaluating research and development expenditures, investments, and the number of researchers.

Fidanboy (2016) found that organizational capabilities have a positive impact on research and development performance among technopolis employees in Turkey. Khan et al. (2010) concluded that research and development activities and human capital are key drivers of productivity, with variations across countries. Guzman et al. (2012) analyzed the relationship between the number of patents and GDP in Mexico between 1980 and 2008, using the cointegration test and Vector Error Correction Model (VECM). The results show that there is a long-run cointegration relationship between the number of patents and economic growth, it has been revealed that shocks (unpredictable effects) in the number of patents harm GDP in the long run, and the shocks in the GDP harm the number of patents in the long term.

Guellec and Potterie (2001) found that research and development in trading partner countries contributes to growth, while public research and development has a higher impact in countries with more intense university and private research. Luintel and Khan (2005) observed significant productivity gains in developing countries due to international knowledge spillovers through trade, while countries with large research sectors have limited impact from international diffusion. Maradana et al. (2017) analyzed he relationship between innovation and economic growth in 19 European countries between 1989 and 2014 in the context of cointegration and causality. Patents, research and development expenditures, the number of researchers, the number of exports and publications, and income per capita were used as innovation indicators. The results show that there was a cointegration relationship between innovation and economic growth in the long run, in the context of causality, it had been shown that there was a causal relationship between innovation and economic growth, but this relationship moves in different directions (such as one-way or two-way) between countries.

Kabaklarlı et al. (2018) analyzed the relationship between high-technology exports and economic growth in OECD countries between 1989 and 2015 using the panel cointegration method. The results show that there was a long-term relationship between high-technology exports and economic growth in OECD countries. They also show that the improvement in patent applications and foreign direct investments played a decisive role in high-tech exports, but the growth rate and investment negatively affected the increase in high-tech exports.

These studies are mostly related to general research and development activities in high-technologization, from education to the defense industry, the number of researchers, patents, economic growth, and development (Luintel & Khan, 2005; Sadraoui et al., 2014; Tunalı & Erbelet, 2017). In the literature, studies evaluating health research and development activities are limited in number. Empirical evaluations were frequently made in these studies. Besides this, the number of studies in which the relationship between the number of researchers working full-time in the field of health and the number of medical patents, which is an indicator of scientific productivity in the field of health, is econometrically related, has been limited (Forero & Moore, 2016). It is thought that this study will contribute to the field of health economics since it evaluates the relationship between the number of full-time researchers in the field of health and the number of medical patents from an economic perspective. This study investigates the number of employees involved in research and development in health. As the field of health research continues to evolve, it is important to assess the productivity of researchers and understand the factors that contribute to innovation in this critical area. This assessment aims to provide valuable insights into the dynamics of health research and its impact on medical innovation. Research productivity in health is a multifaceted and dynamic field that requires a comprehensive assessment approach. Understanding the factors contributing to innovation in health research requires an in-depth examination of the impact of collaborative efforts, interdisciplinary approaches, and funding and resources on the outcomes of medical innovation. Moreover, a nuanced assessment of the relationship between the gender distribution of researchers and the number of patent applications in medicine may be important to uncover the dynamics underlying productivity and innovation. This exploration could shed light on the unique contributions of different perspectives and experiences to the advancement of medical knowledge and technology. By examining the relationship between the number of researchers, gender distribution, and patent applications in medicine, we can better understand the dynamics of productivity and innovation in this vital field (Widjaja & Sijabat, 2019; Carpenter et al., 2014).

In addition to quantitative analysis, qualitative insights from the research community can provide a valuable understanding of the challenges and opportunities in the field of health research. This holistic approach to assessing researcher productivity offers a more comprehensive view of the factors that foster innovation and excellence in the vital field of health research (Villarroel et al., 2019; Ogunsola et al., 2020). For the study, the research methodology will include a statistical analysis of the correlation between the number of full-time researchers in health and the number of medical patents. This analysis will provide valuable insights into the potential relationship between research activity and innovation in the medical field.

Furthermore, the study will examine gender-based productivity differences by analyzing the gender distribution of researchers and its impact on medical patent applications. The literature assessing the relationship between gender inequality and the number of medical patents reveals interesting findings. Sugimoto et al. (2015), in a study investigating how gender-based differences in academia are reflected in the patenting process, found that female researchers received fewer patents compared to men. This finding may suggest that female researchers are relatively less influential in medical innovation. Similarly, a study conducted by Frietsch et al. (2009) showed that women lag behind men in patenting and publishing processes. Such gender-based productivity gaps may provide important clues for understanding the underlying causes of disparities in the number of medical patents. However, more comprehensive and in-depth research is needed to fully understand these findings. Such research could contribute to the development of more effective policies and practices to promote medical innovation through gender equality.

For this reason, this study aimed to determine the relationship between the number of researchers working in the field of health and the number of medical patents, which was considered to be one of the indicators of technological development in the field of health. In this context, 1 (one) main hypothesis and 3 (three) sub-questions were fleshed out to explain the hypothesis.

H_1: The number of researchers and the number of medical patents are related.

Q_{1a}: What is the current status of the number of researchers and medical patents in healthcare?

Q_{1b}: What is the effect level of the number of researchers in healthcare services on medical patents?

Q_{1c}: Was there a difference between the productivity of the number of researchers according to gender?

2. DATA AND METHODOLOGY

In the analysis, the relationship between the number of FRD (Female Researchers =FRD) and MRD (Male Researchers = MRD) and the number of patent applications in the medical field was analyzed through the panel data method. Panel data analysis is a method that allows the evaluation of cross-section data and time series data in a common area. Since the study was considered within the scope of countries with data in a certain year range, this analysis method was considered suitable for the study. In the analysis, an econometric model was established in which the number of researchers was considered as the independent variable and the number of medical patents as the dependent variable. The significance tests of the model were evaluated with the Count panel data methods, and the Granger causality test, cointegration tests, and variance decomposition models were applied to determine the causality and long-term relationships between the variables.

For this study, 9 countries with regular data on the number of full-time researchers working in the field of health disaggregated by gender between 2005-2018 were determined. These countries were the Czech Republic, Hungary, Poland, Portugal, Slovakia, Slovenia, Turkey, Romania, and Chinese Taipei. In the number of medical patents (Mpatent), the number of medical patent applications made within the scope of the Patent Cooperation Treaty (PCT) belonging to selected countries were included in the analysis. In Table 1, the variables used in the analysis, the abbreviations used, the source information from which the data were obtained, and the explanations for the variables are given under the sub-headings.

Table 1: Definition of Variables

Variables	Definition	Unit	Source	Abbreviation
Medical Patent	Total number of medical patents in period t /	Number	OECD	MPatent
Female Researcher Working in the Field of Health	Total Number of Female Researchers in Health in the t period	Full-Time Equivalent	OECD	FRD
Male Researcher Working in the Field of Health	Total Number of Male Researchers in Health in the t period	Full-Time Equivalent	OECD	MRD

3. FINDINGS

According to the descriptive information of the variables subject to the analysis; it is understood that there was a positive relationship between the number of researchers and medical patents.

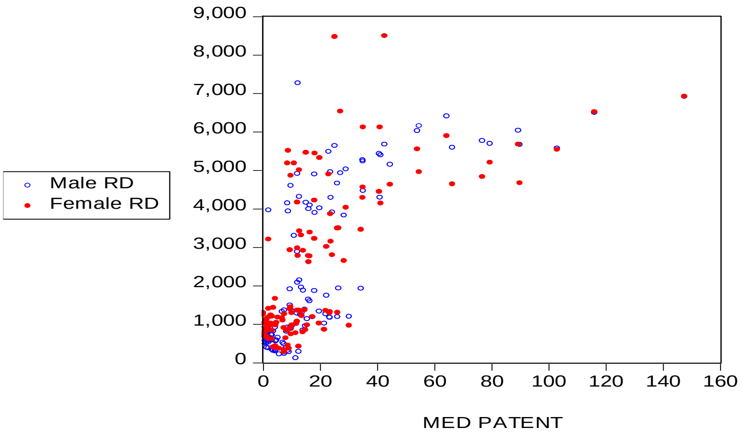

Figure 1: Relationship Between Number of Medical Patents, FRD and MRD, 9 Countries, 2005-2018**;**

Source: Prepared by the authors.

3.1. Econometric Model

When establishing the research model in economic analysis, there are different factors affecting the development of the process among the variables. In our research, the deterministic components in the relationship between the number of researchers and the number of medical patents are defined by the constant term and the number of researchers. Meanwhile, the stochastic components represent other influencing factors that are expected to affect the model but cannot be explicitly defined, and are thus included as error terms. At this stage of the study, the model to be used in econometric analysis is given in Figure 2.

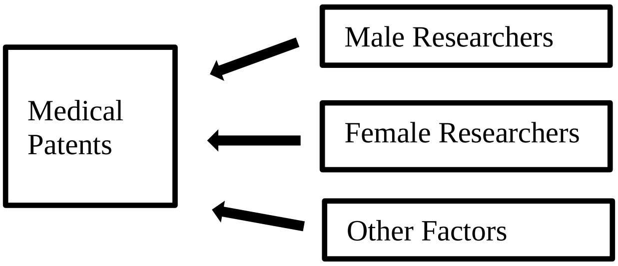

Figure 2: Demonstration Of The Research Model

Source: Prepared by the authors.

The econometric model to be estimated from this equation was established as follows.

$$(1)\ MPatent_{it} = \beta_0 + \beta_1 MRD_{it} + \beta_2 FRD_{it} + u_{it}$$

In the model in the equation; "β_0" coefficient constant expresses the expenditures that occur independently of the explanatory variables. While "β_1" for MRD and "β_2" represent the parameters to be estimated for FRD, "u" represents the error term; "i" denotes the cross-sectional dimension of the panel data, and "t" denotes the time dimension. "MPatent" was taken as the dependent variable.

3.2. Least Squares Test

The Poisson model is used for analyzing count data in panel studies. In the Poisson model, there is a restriction that the variance and mean are equal, and this assumption is frequently violated in real count data sets. This may be due to individual heterogeneity (Kizilgol & Selim, 2017). To deal with overdispersion, a distribution that allows variance to be modeled more flexibly than the Poisson model should be used, the negative binomial distribution being one such distribution (Hu, 2002). In our research, the skewness and kurtosis values of the data indicate normal distribution (JB Normality Test: 0.004774).

The regression results of the Poisson count model for the dependent variable Mpatent with the independent variables MRD and FRD. The coefficients in the table are estimated to measure the effect of each independent variable on the dependent variable. The coefficient for the independent variable MRD is estimated at 0.000330 and found to be statistically significant ($p < 0.0001$). Similarly, the coefficient for the independent variable FRD is estimated at 0.0000676 and is also statistically significant ($p < 0.0001$). The estimated coefficient for the intercept (C) is 1.692931, which is statistically significant ($p = 0.0001$). The R-squared value is calculated as 0.63, and the adjusted R-squared value is 0.62, indicating that the model explains 62% of the variance in the dependent variable. The LR-Statistic (likelihood ratio statistic) is found to be 1784.978, which is a statistic used to test the significance of the model ($p < 0.0001$). Finally, the JB Normality Test result is reported as 0.004774. This test evaluates whether the error terms of the model follow a normal distribution. The result suggests that the error terms approximate a normal distribution.

Table 2: ML/QML - Poisson Count (Newton-Raphson / Marquardt steps) Results

Dependent Variable	Independent Variables	Coefficient	Prob.	R^2	Adjusted R^2	LR-Statistic	Prob (LR-statistic)
Mpatent	**MRD**	0. 000330	0.0000	0.63	0.62	1784.978	0.0000
	FRD	6.76E-05	0.0000				
	C	1.692931	0.0001				
JB Normality Test: 0.004774.							

Source: Prepared by the authors.

3.3. Analysis of Cointegration and Granger Causality/Block Exogeneity Wald Tests

Granger causality analysis is a method that evaluates the contribution of the lagged values of the other variable (sample X_t variable) in explaining the current value of one of the variables (sample Y_t variable) (Granger, 1969). The most important assumption of this analysis is that it is necessary to ensure the stationarity of the variables that are the subject of the research. For this reason, Unit Root Tests were applied to the variables to determine the stationarity status of the variables subject to the research (Baltagi, 2005; Lewin et al., 2002; Im et al., 2009). The results and significance values of these tests are given in Table 3.

Table 3: Unit Root Test Results

A. Unit Root Tests							
Variables			**Levin, Lin ve Chu**	**Breitung t-stat**	**IM, Pesaran and Shin W-stat**	**ADF**	**PP**
MEDICAL PATENT	Level	Individual Effects	0.8860	-	0.8308	0.4124	0.2885
		Individual Effects and İndividual Linear Trends	0.2599	0.9968	0.6986	0.5726	0.1476
		None	0.9970	-	-	0.9730	0.9647
	1. diff.	Individual Effects	0.0018**	-	0.0000*	0.0002*	0.0000*
		Individual Effects and İndividual Linear Trends	0.0025**	0.3230	0.0048**	0.0066**	0.0000*
		None	0.0000*	-	-	0.0000*	0.0000*
MRD	Level	Individual Effects	0.1394	-	0.1913	0.0108**	0.0000*
		Individual Effects and İndividual Linear Trends	0.0367**	0.9991	0.4719	0.1269	0.0034**
		None	09983	-	-	0.9974	0.9973
	1. diff.	Individual Effects	0.0000*	-	0.0000*	0.0000*	0.0000*
		Individual Effects and İndividual Linear Trends	0.0000*	0.9254	0.0000*	0.0000*	0.0000*
		None	0.0000*	-	-	0.0000*	0.0000*
FRD	Level	Individual Effects	0.0020*	-	0.3122	0.0665***	0.0743***
		Individual Effects and İndividual Linear Trends	0.0001*	0.7347	0.0317**	0.0287**	0.0087**
		None	0.9923	-	-	0.9994	0.9995
	1. diff.	Individual Effects	0.0000*	-	0.0000*	0.0000*	0.0000*
		Individual Effects and İndividual Linear Trends	0.0000*	0.1173	0.0088**	0.0086**	0.0000*
		None	0.0000*	-	-	0.0000*	0.0000*

* , **, *** significance at 1%, 5%, 10% level respectively.

According to the unit root test results, the variables become stationary at different levels when the level values and first differences are taken. It was determined that the variables were stationary in common at the I(1) level. For this reason, in the Causality and Co-Integration analyses conducted in the study, the variables were studied at the I(1) level, where the first difference was taken. The second step after this was to determine the lag length. According to Table 4, the lag lengths of the variables are at the 3rd lag according to the LR, FPE, and AIC criteria, and 0th delay according to the SC and HQ tests. Since the lag length could not be defined in the analysis, when 0 was taken as 1, problems such as varying variance, serial correlation, or non-normal distribution were encountered in the residuals of the model (for the 1st delay, LM serial correlation test p=0.0000 <0.05; heteroscedasticity test p=0.0000<0.05). Thus, the lag length of the model was determined as the 3rd lag length according to the LR, FPE, and AIC information criteria, and the Granger Causality and cointegration test was applied using the VAR model.

After determining that all of the variables are I(1) by the unit root test, and the lag length of the model, the long-term relationship was investigated by Johansen cointegration analysis. To test whether there is a long-term relationship between the variables, eigenvalue (max-eigen value) and trace statistics are used. While investigating the long-term relationship between the variables with the Johansen cointegration test, the 3rd lag length was applied to determine the lag length of the VAR model. According to the results of Johansen's (1988) cointegration tests; the trace test statistic of the H_0 hypothesis (r=0), which states that there was no cointegration between Mpatent and FRD-MRD, was found to be 50.25992. Since this value was greater than the critical value of 29.79707 at the 1% significance level, the null hypothesis was rejected and the Trace test indicated 2 cointegrating eqn(s) at the 0.05 level (Table: 4).

Table 4: Cointegration and Granger Casualty/Block Exogeneity Wald Tests

A. VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1431.128	NA	4.80e+11	35.41057	35.49925*	35.44615*
1	-1423.197	15.07834	4.93e+11	35.43697	35.79170	35.57929
2	-1421.761	2.623784	5.95e+11	35.62374	36.24452	35.87280
3	-1397.287	42.90593*	4.07e+11*	35.24165*	36.12848	35.59746
4	-1392.719	7.669259	4.56e+11	35.35109	36.50397	35.81364

B . Cointegration Test

	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.
None *	0.345364	50.25992	29.79707	0.0001
At most 1 *	0.169440	15.94215	15.49471	0.0428
At most 2	0.011099	0.904053	3.841466	0.3417

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level;*denotes rejection of the hypothesis at the 0.05 level.

C. Granger Causality/Block Exogeneity Wald Tests

Hipotesis	Probability	Result	Decision
MPatent ≠> FRD	0.0000	Rejected	MPatent was the Granger cause of FRD
MPatent ≠> MRD	0.0000	Rejected	MPatent was the Granger cause of MRD
FRD ≠> Mpatent	0.2114	Accepted	FRD was not the Granger cause of Mpatent
MRD ≠> Mpatent	0.9152	Accepted	MRD was not the Granger cause of Mpatent
MRD ≠> FRD	0.4698	Accepted	MRD was not the Granger cause of FRD
FRD ≠> MRD	0.0059	Rejected	FRD was the Granger cause of MRD

Roots of Characteristic Polynomial: 0.8159-0.3029; Serial Correlation LM Tests: 0.6594; Residual Portmanteau Tests for Autocorrelations: 0.4750; Normality Tests: 0.0000; Heteroskedasticity Tests: 0.0000

Source: Prepared by the authors.

According to the Granger causality analysis, there was a Granger causality relationship from MPatent to FRD-MRD as well as there was a directional causality relationship from FRD to MRD. The results of the diagnostic tests indicated no heteroscedasticity, serial correlation or cross-sectional dependence in the model, and confirmed that the model did not contain a unit root, supporting the reliability of the results obtained.

Variance decomposition investigates what percentage of the change in a variable is due to itself and what percentage is due to other variables (Akyüz, 2018). As can be seen in Table 5, the MPatent variable was determined by its shocks in the short run. At the end of the 10. period, 94.61% of the MPatent variable was explained by itself, 2.73% was explained by MRD, and 2.66% was explained by the FRD variable.

Table 5: Variance decomposition analysis results of MPatent variable*****

	Mpatent	MRD	FRD
1	100.00	0.00	0.00
2	96.49	1.83	1.67
3	96.06	2.00	1.93
4	94.95	2.51	2.54
5	94.96	2.53	2.49
6	94.88	2.57	2.52
7	94.79	2.63	2.57
8	94.67	2.69	2.63
9	94.64	2.71	2.65
10	94.61	2.73	2.66

* Estimated under 10000 Monte Carlo simulations

4. DISCUSSION AND CONCLUSION

The study embarked on a comprehensive exploration of the intricate relationship between medical patents and research and development (R&D) activities in the healthcare sector, aiming to unravel the multifaceted dynamics underlying innovation in this critical domain. With a meticulous examination spanning from 2005 to 2018 across nine countries, the research delved into nuanced questions regarding the productivity levels of healthcare researchers and the determinants shaping the trajectory of medical patent numbers.

Granger causality analysis proved to be a powerful tool, revealing a directional causality from medical patents (MPatent) to the combined fields of pharmaceuticals and medical research and development (FRD-MRD). Additionally, another directional causality was identified, flowing from FRD to MRD, highlighting the complex interdependence and influence within the realm of healthcare innovation.

Delving deeper into the temporal dimension, panel cointegration tests lent credence to the existence of a long-term relationship between MPatent and FRD-MRD, underscoring the enduring impact of research and development efforts on the creation and dissemination of medical patents. These findings not only validate the intrinsic link between innovation and R&D activities but also underscore the need for sustained investment and commitment to fostering an ecosystem conducive to healthcare innovation. The number of medical researchers increased by an average of 81.2% in 2018 compared to 2005 in all countries except Romania. While this increase was 79.9% for FRD; and 82.5% for MRD; the number of medical patents increased 11.1 times, excluding Slovenia. Besides this result, the number of medical researchers in Romania decreased by around 26%; medical patent numbers decreased by 68.6% in Slovenia. In all countries, health research and development expenditures and investments per capita increased by 81.3%, excluding Romania. Health research and development expenditures and investments per capita in Romania decreased by around 26%. This situation has also been found to be reflected in the number of medical researchers. The main findings of the analysis are as follows: i) According to Granger causality analysis, there is a Granger causality relationship from MPatent to FRD-MRD ii) there is a directional causality relationship from FRD to MRD; iii) the results of the panel cointegration tests confirmed the existence of a long-term relationship between MPatent and FRD-MRD iii) The Poisson Count coefficient estimation results indicated that FRD-MRD had positive effects on MPatent; a one-unit increase in MRD numbers increased the MPatent number by 0.00033; a one-unit increase in the FRD number increased the MPatent numbers by 0.0000673. iv) Variance selection model showed the positive effects of FRD-MRD on MPatent. Variance decomposition results show that the number of researchers explains 5.39 % of medical patent production after 10 years. This result has been interpreted as resulting from other factors affecting the production in the field of medical patents, such as the number of laboratories, R&D expenditures, and investments, copyrights in patents, process in application to patents, and international cooperation.

Moreover, the Poisson count model coefficient estimation results reveal significant insights into the impact of both Male Research and Development (MRD) and Female Research and Development (FRD) on MPatent numbers within the study. According to the findings, a one-unit increase in MRD numbers leads to a 0.00033 unit increase in MPatent counts, while a similar increase in FRD numbers results in a 0.0000673 unit rise in MPatent counts. These results underscore the critical role of research and development investments, both by male and female researchers, in fostering innovation within the healthcare domain. Although the effect of MRD appears more pronounced compared to FRD, both genders contribute significantly to enhancing patent numbers, highlighting the importance of inclusive approaches to research and development initiatives aimed at advancing knowledge and technology in healthcare. The discerned positive effects underscored the critical role played by investments in research and development in catalyzing innovation within the healthcare domain. Notably, the revelation of a higher productivity level among female researchers, as evidenced by the findings of Frandsen et al. (2020) and Aguinis (2018), highlights the importance of gender inclusivity in driving innovation and advancing knowledge in healthcare. Frandsen et al. (2020) conducted a study indicating that there are minimal disparities, if any, in productivity or impact among health sciences researchers from the time of enrollment in the PhD. program and extending 10 years beyond. In some instances, women even outperform men. Additionally, before enrollment, negligible differences in productivity and impact were observed. Similarly, a study conducted by Aguinis (2018) demonstrated that star female inventors exhibit higher productivity compared to their male counterparts. This suggests that their unique perspectives and experiences play a significant role in advancing knowledge and technology. In addition, in the literature, it is emphasized that there are differences between the working behavior of men and women due to the division of labor and differences between the genders, on the other hand, women's working behavior is approached based on men's behavioral model, and as long as economic activity measures maintain their current inadequacies, the phenomenon of women's invisibility in economic activities is also emphasized (Acar, 2012). By examining and highlighting these distinctive contributions, we can develop a more comprehensive understanding of the complex dynamics of researcher productivity in the critical domain of health research.

Beyond the immediate findings, the study contextualized its results within the broader landscape of human capital and economic growth. Drawing upon insights from scholarly literature, the research underscored the pivotal role played by education and health in shaping human capital and fostering economic development. The symbiotic relationship between technology and human capital emerged as a recurring theme, emphasizing the cyclical nature of innovation-driven growth and the imperative of nurturing a skilled workforce adept at leveraging technological advancements to drive progress. Human capital, especially an educated workforce, is the determinant of economic growth (Hirsch & Sulis, 2008). The literature has revealed that there is a reciprocal and long-term relationship between education and health (Yardımcıoğlu, 2013), and that health investments contribute to economic growth and development as a result of quantitative and qualitative support of human life (Strauss & Thomas, 1998; Keskin, 2011; Reinhart, 1999; Bloom & Channing, 2004; Alemu et al., 2006; Tüylüoğlu & Tekin, 2009; Kumar & Kober, 2012). In research and development activities in health, technology introduced by human capital also affects human capital; there is a cyclical situation between technology and human capital that feeds each other. For this reason, it is possible to talk about the existence of a symbiotic relationship between technology and human capital. The results of this study are consistent with the literature, which suggests that general research and development activities supported by researchers contribute to economic growth (Fidanboy, 2016; Khan et al., 2010; Guzman et al., 2012; Guellec & Potterie, 2001; Luintel & Khan, 2005; Maradana et al., 2017; Kabaklarlı et al., 2018). Based on these findings, we accept our hypothesis that there is a relationship between the number of researchers and the number of medical patents.

In light of these profound insights, the study advocates for urgent policy interventions aimed at enhancing human capital and bolstering technology-based industrial production in the healthcare sector. By prioritizing investments in research and development and fostering gender-inclusive policies, policymakers can create an environment conducive to innovation and economic growth, thereby advancing the frontiers of healthcare and driving societal well-being.

It is necessary to urgently implement plans/policies for improving human capital and increasing technology-based industrial production. Considering its contribution to economic growth, it is recommended to increase research and development efficiency by increasing the quantity and quality of health researchers.

ETİK BEYAN VE AÇIKLAMALAR

Etik Kurul Onay Bilgileri Beyanı

Çalışma, etik kurul izni gerektirmeyen bir çalışmadır.

Yazar Katkı Oranı Beyanı

Yazarlar tüm çalışmaları birlikte yürütmüştür.

Çıkar Çatışması Beyanı

Çalışmada potansiyel bir çıkar çatışması bulunmamaktadır.

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