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# The Importance of Patent Stock in R&D Expenditures: An Application on Turkısh Manufacturing Industry

***Ar-Ge Harcamalarında Patent Stoğunun Önemi: İmalat Sanayi Üzerine Bir Uygulama***

**Abstract**

The advancement of knowledge-driven economies is largely attributed to research and development (R&D) and technological innovation. Both developed and developing nations are making substantial investments in R&D, which has led to an increased focus on scientific output and the R&D process itself. Many companies engage in R&D activities to enhance their competitive advantage by securing patents. This study utilizes a Tobit model to analyze the relationship between R&D expenditures, patent numbers, patent stock, and turnover during the period from 2003 to 2021. The findings reveal that while patent stock and turnover positively influence R&D expenditures, the number of patents has a negative impact.

**Keywords:** Patent, patent stock, R&D expenditures, knowledge stock, Tobit model

**JEL Codes:** C13, D20, D22

**Özet**

Bilgi odaklı ekonomilerin ilerlemesi büyük ölçüde araştırma ve geliştirme (AR-GE) ve teknolojik inovasyona bağlıdır. Hem gelişmiş hem de gelişmekte olan ülkeler Ar-Ge'ye önemli yatırımlar yapmakta, bu da bilimsel çıktılara ve Ar-Ge sürecinin kendisine daha fazla odaklanılmasına yol açmaktadır. Birçok şirket, patent alarak rekabet avantajlarını artırmak için Ar-Ge faaliyetlerinde bulunmaktadır. Bu çalışmada, 2003-2021 döneminde Ar-Ge harcamaları, patent sayıları, patent stoku ve ciro arasındaki ilişkiyi analiz etmek için bir Tobit modeli kullanılmıştır. Bulgular, patent stoku ve cironun Ar-Ge harcamalarını olumlu yönde etkilerken, patent sayısının olumsuz bir etkiye sahip olduğunu ortaya koymaktadır.

**Anahtar Kelimeler:** Patent, patent stoğu, Ar-ge harcamaları, bilgi stoğu, Tobit model

**JEL Kodları:** C13, D20, D22

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**INTRODUCTION**

Since the 1960s, investment in research and development (R&D) has been recognized as an important factor in improving productivity levels. The rationale for this is that the knowledge that can be created and accumulated through a firm's or industry's R&D efforts can then be used for product innovations or production process and consequently promote nationwide economic development. Indeed, developed countries have made significant expenditures on R&D activities based on this logic (Wang and Tsai, 2003). Studies on the role of technological change in economic growth have demonstrated that technological advancements are a key driver of productivity growth. In fact, the recent slowdown in productivity has raised concerns about a potential decline in technological progress, which has, in turn, highlighted the growing importance of R&D expenditures and other technology-related indicators in shaping both productivity levels and changes in productivity across different countries and time periods (Wakelin, 2001). In both developed and developing economies, technological progress is an important way to improve living standards (Kim and Marschke, 2004).

The expansion of knowledge-based economies is largely driven by research and development (R&D) along with technological innovation. Both developed and developing nations are making substantial investments in R&D, leading to increased attention on scientific output and the overall R&D process. To enhance their competitiveness in the marketplace, many companies focus on R&D activities, often aiming to secure patents. Governments actively support these efforts by offering incentives such as tax breaks, grants, and conditional loans (Kondo, 1999). Increased R&D investment by firms not only promotes economic growth but also strengthens the performance of the national innovation system (López, 2008).

Patents are widely regarded as key indicators of innovation and the R&D process. Their widespread use stems from the availability of long-term patent statistics across countries and regions. While not all inventions are patented, and not every patent proves to be valuable, patents remain the most commonly used metric for measuring innovative output (Thomas et al., 2011). Beyond being economic assets, patents serve as signals of the quality and capability of inventors and organizations. Additionally, they play a crucial role in facilitating knowledge dissemination within society. One of the notable functions of patents is their ability to provide an independent evaluation of the innovation potential of firms and inventors. Innovation, by its nature, is surrounded by uncertainty, making it challenging to assess a firm’s or inventor’s capacity to innovate. This difficulty arises because the innovation process often relies on intangible factors such as experience, creativity, and determination. Since new firms and entrepreneurs are vital drivers of economic growth, patents can significantly enhance the valuation of these entities. Improved assessments enable investors to allocate resources more efficiently, supporting the right firms through financial backing or acquisitions, with meaningful implications for societal progress (Gambardella, 2023).

R&D expenditures influence patent applications in two primary ways. First, they have a direct impact on the number of patent applications filed. Second, R&D spending contributes to the accumulation of knowledge, which, in turn, expands the possibilities for invention and indirectly increases patent activity. This dual effect demonstrates that R&D expenditures boost patent applications both directly and through the enhanced stock of knowledge. The assumption that higher R&D spending leads to an increase in patent applications is quantitatively supported. However, patent applications are not solely driven by R&D

expenditures; factors such as effective R&D management and a firm's patenting strategy also play significant roles. The relationship between increased R&D spending and patent activity can be interpreted in two ways. On one hand, greater investment in R&D broadens the scope of research, raises the likelihood of success, and ultimately results in more patent filings. On the other hand, corporate researchers may face growing pressure to submit patent applications as a way to justify their R&D budgets (Kondo, 1999). Kondo highlights a positive correlation between R&D spending and patent activity at the national level. Among major industrialized nations, those investing heavily in R&D have seen an increase in their share of both domestic and international patent applications. Conversely, countries with lower R&D investments have experienced a decline in their patenting activity both domestically and abroad.

This study investigates whether the incentive force behind R&D expenditures in the manufacturing industry is the number of patents or the patent stock. The question of whether the increase in the number of patents in the manufacturing industry increases R&D expenditures more or whether the patents in stocks encourage more R&D expenditures is sought to be answered. Looking at the literature, Kondo (1999) found that R&D expenditures increase the patent stock. Milani and Neumann (2022), on the other hand, put forward a more recent study and found that patent stock increases R&D expenditures. In this study, the claim of Milani and Neumann (2022) will be investigated for manufacturing firms in Turkey. The study consists of three parts. In the first part, the importance of innovation in the manufacturing industry will be emphasized, and in the second part, a summary of the literature will be given. After introducing the methodology and data set used in the study, research findings will be presented.

## 1. Innovation and Patenting in Manufacturing Industry

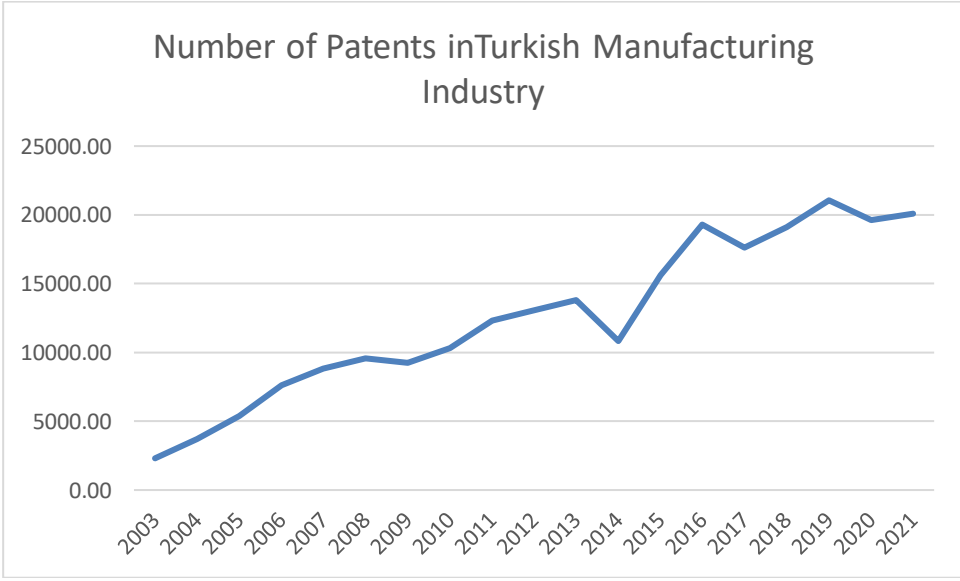
Innovation serves as a cornerstone of strength and growth for businesses. To sustain innovation, remain competitive, and achieve growth, companies must consistently generate new ideas that set them apart from their rivals. Effective innovation demands an understanding of market needs, delivering quality and complementary services, organizational efficiency, and specialized expertise. Technological innovation, defined as the application of creativity that leads to new developments (Weiyu et al., 2022: 2), involves the ongoing process of creating and utilizing novel ideas and knowledge. It encompasses both the adoption of emerging technologies and the development of new organizational practices.

The advent of information and communication technologies has significantly accelerated the dissemination and commercialization of innovations, which, in turn, has boosted economic growth and enhanced global competitiveness. Increased innovation is anticipated to positively and significantly impact production efficiency (Gu and Tang, 2004). In competitive economic systems, firms are compelled to innovate to remain viable in the long term. Manufacturing companies, for instance, are driven to innovate their production processes to adapt to changing environmental conditions, such as shorter product life cycles, growing product complexity, and rapid technological advancements. Innovation, therefore, enables firms to compete internationally and sustain their operations in domestic markets (Lee et al., 2011; Koschatzky et al., 2001).

A firm's capacity for innovation is shaped by several internal factors, including R&D intensity, firm size, outsourcing strategies, market structures, and the technological level of the industry. Companies must determine the most effective approach to enhance their technological capabilities, whether through internal efforts or external collaborations, particularly in the context of R&D partnerships (Becker and Dietz, 2004). Indicators commonly used to measure technological innovation include R&D intensity, patents, technology adoption, and skill development. R&D intensity, often defined as the proportion of output dedicated to R&D expenditure, is a critical measure of innovation. Innovative firms typically invest in R&D to develop or adopt new products and processes for the market. Thus, R&D serves as a fundamental input in the innovation process. Patents, another widely recognized measure of innovation, are frequently used to safeguard intellectual property rights related to technological inventions (Gu and Tang, 2004). Many studies highlight a reciprocal relationship between R&D investment and patenting activity, suggesting that the two reinforce each other.

When the number of patents of manufacturing industry firms in Turkey is analyzed, the course of patents is shown in Figure 1.

**Figure 1. Number of Patents in Manufacturing Industry**




Source: Turkish Patent and Trademark Office

Although the total number of patents in the manufacturing industry showed a decline between 2014 and 2015, it is generally on an upward trend.

## 2. Literature Summary

Numerous studies have investigated the role of patents in various contexts, particularly their connection to economic growth. For instance, Anakpo and Oyenubi (2022) highlighted that indicators of technological innovation, including the number of researchers in R&D, graduates in information and communication technology, patents, STEM graduates, and scientific outputs, exhibit a significant positive impact on per capita economic growth over the long term.

Similarly, Mabrouki (2022) demonstrated that patent activity in Scandinavian countries has a statistically significant and positive influence on economic growth. Nguyen and Doytch (2022) found that patents associated with information and communication technologies positively contribute to economic growth. Additionally, Dereli (2019) revealed that both high-tech exports and patent production act as catalysts for economic growth in Turkey, with effects observable in both the short and long run.

Milani and Neumann (2022) analyzed the patent activities of firms and discovered that the combined influence of patent stocks, internal funds, and operating profit margins significantly affects R&D expenditures in a panel of the top 2000 corporate R&D performers globally. Hall et al. (2007) showed that a firm's market capitalization-to-physical asset replacement value ratio has a strong positive correlation with both R&D and patent stocks. Similarly, Vinuesa et al. (2023) emphasized that firms' ability to innovate through patenting serves as a key driver for enhancing their economic performance. Czarnitzki and Toole (2011) explored how patents stimulate R&D investments by reducing the uncertainty in market conditions that typically hinders firms' investment decisions. Their findings suggest that while R&D investment decreases under high uncertainty, patent protections help mitigate these effects. Yu and Hong (2016) examined the complementary roles of patents and R&D expenditures in explaining stock price fluctuations, concluding that the patent ratio has a stronger explanatory power than R&D spending. Appio et al. (2019), using data from 391 international firms, identified a non-linear relationship between the diversity of patent portfolios and profitability. Kim et al. (2019) studied technology convergence capabilities in 30 manufacturing firms and concluded that higher degrees of technology convergence positively influence overall innovation, as reflected in the total number of patents. Finally, Altuzarra (2019), analyzing data from Spanish manufacturing firms, found a bidirectional causal relationship between R&D spending and patent production.

Looking at the studies using the patent stock, Kondo (1999) showed that R&D investments, directly and through the accumulated technology stock, generate patent applications with a lag of about one and a half years in his model where he used patents as the dependent variable and R&D expenditures as the independent variable. Porter and Stern (2000), in their study for OECD countries, found that patents and R&D expenditures increase the patent stock proportionally. Ülkü (2004) showed that there is a strong positive relationship between patent stock and GDP per capita in both OECD and non-OECD countries. Roper and Hewitt-Dundas (2015) investigate the relationship between firms' patent stocks and innovation and find that patent stocks have weak negative effects on firms' innovation output. Yagi and Managi (2018) found that patent stock is more valuable than population, energy use and natural capital in supporting developing countries. Using panel data from 36 countries, Lee and Kim (2022) examined whether various factors such as existing patent stock, government-funded R&D, government-performed R&D, education and economic freedom affect biotechnology innovation. The results showed that the stock of existing knowledge is a driver of biotechnological innovation. Arora et al. (2008) showed that patents provide incentives for R&D in the manufacturing industry.

Several studies have explored the relationship between the manufacturing industry and patents in Turkey. In his research, Bozkurt (2008) examined the link between sectoral patent registrations, a key indicator of technological development, and sectoral export performance in the Turkish manufacturing sector. The analysis revealed a positive and significant correlation between sectoral patent registrations and export performance. Çütcü (2017), through a survey

of 207 firms in the textile sector, found that factors such as education, patents, and investment had negligible effects on export volumes. Meanwhile, Şahin and Altuğ (2017) investigated patent applications in the manufacturing sub-sectors of Istanbul, Ankara, and Izmir, using the innovative specialization index. Their findings indicated a relationship between innovative specialization and sectoral specialization within the manufacturing sub-sectors in these regions.

As can be seen from the literature summary above, the number of academic studies on patents is very high. Since the studies that draw attention to the importance of the patent stock are relatively fewer than the studies on the number of patents in general and there is no research on the Turkish manufacturing industry in this regard, this study is thought to contribute to the literature.

## 3. Data Set and Method

The study seeks to answer the question of whether patent stock is an incentive for R&D expenditures in the manufacturing industry. For this purpose, R&D expenditures are used as the dependent variable and the number of patents, patent stock and turnover variables are used as independent variables. Detailed information about the data is presented in Table 1.

**Table 1. Data Used in the Study**

| Variable | Type | Source Cited | Year Covered |
|---|---|---|---|
| Manufacturing Industry R&D Expenditures | Dependent Variable | Turkish Statistical Institute | 2009-2021 |
| Number of Patents in Manufacturing Industry | Independent Variable | Turkish Patent and Trademark Office | 2003-2021 |
| Manufacturing Industry Patent Stock | Independent Variable | Calculated by Author | 2003-2021 |
| Manufacturing Industry Turnover | Independent Variable | Turkish Statistical Institute | 2003-2021 |

Based on the data in Table 1, the number of manufacturing industry patents, patent stock and turnover information are used as independent variables to determine the effect of these variables on manufacturing industry R&D expenditures. Literature was utilized in the selection of these variables. Bound et al. (1982), Kim and Marschke (2004), Bointner (2014), Türedi (2016) investigated the relationship between the number of patents and patent stock and R&D expenditures. Coad and Rao (2010), Ahmed and Jinan (2011), Ghaffar and Khan (2014), Ferdaus and Rahman (2017), Dai et al. (2020), Curtis et al. (2020), Ravśelj and Aristovnik (2020), Tung and Binh (2022) investigated the relationship between profitability and firm performance and R&D expenditures. Eviews package program was used in the analysis of variables.

The perpetual inventory method, which is also preferred by Ülkü (2004), Bointner (2014), Milani and Neumann (2022), was used to calculate the patent stock, one of the independent

variables in the study. Since inventions lose their validity over time, the patent stock was calculated with the perpetual inventory method in this study as in other studies.

$$Patent\ Stock_{it} = (1 - \delta)Patent\ Stock_{it-1} + Patent_{it} \quad (1)$$

Equation 1 shows the depreciation rate, which is 6.66% (Revenue Administration, Access: 1.02.2024). The manufacturing industry patent stock for the years 2003-2021 is calculated by using the number of manufacturing industry patents and the depreciation rate for the relevant years in the equation.

### 3.1. Tobit Model

Regression analysis, which provides a mathematical expression of the relationship between an explained variable and one or more explanatory variables, is one of the most basic tools used in statistics. However, not all values of the dependent variable used in some regression analyses can be reached. The Tobit model, which is frequently used to analyze these models with limited dependent variables, is named after James Tobin, its first user, and because of its similarity to the probit model. In 1958, while analyzing household expenditures on durable goods, Tobin was confronted with a model in which the dependent variable was negative because some households did not have such an expenditure item. Based on the knowledge that expenditure can never be negative, Tobin assigned a zero value to this variable until household income exceeds a certain level (Koç and Şahin, 2018).

If the value of the dependent variable is zero for some observations but the value of the explanatory variable exists for all observations, if demand forecasting is done by least squares method with these variables, the mean of the error term will not be zero for variables with zero value. Under such a condition, the estimated model will be both inconsistent and biased. For this reason, in such cases, estimation is made with the limited dependent variable model (Tobit) with limited dependent variable. Estimation with the Tobit model is done with the "maximum likelihood" estimator. Estimation in this way leads to unbiased and consistent results (Özdes et al., 1999).

The starting point for the estimation of the Tobit model is to consider censored dependent variables, i.e. R&D expenditures in this study. The Tobit model can be written as follows.

$$Y^* = \beta X + \theta \quad (2)$$

$$Y = Y^* \quad If\ Y^* > 0 \quad (3)$$

$$Y = 0\ in\ other\ cases \quad (4)$$

In the above equations, Y* denotes the unobservable variable, β is the (k x k) dimensional parameter vector, X is the (k x k) dimensional vector of independent variables, the error term and Y denotes the observable variables.

Since the error terms in Equation (2) are a function of the independent variables, trying to estimate the equation using the least squares method will lead to biased and inconsistent estimates. This is because the mean of the error term will not be zero for variables with zero values as the assumption of normal distribution is violated. If it is assumed that the unobservable Y* has a normal distribution, Tobit estimation can be performed using the maximum likelihood estimator and consistent estimation of the parameters can be achieved in this way.

### 3.2. Model Estimation Results

The results obtained by estimating the Tobit model are presented in Table 2.

**Table 2. Tobit Model Estimation Results**

| Variables | Coefficient | Standard Error | z Statistics | Prob. |
|---|---|---|---|---|
| Number of Patents | -27.23186 | 76.47698 | -0.356079 | 0.7218 |
| Patent Stock | 75.45120 | 44.60975 | 1.691361 | 0.0908 |
| Turnover | 1.59E-06 | 1.02E-07 | 15.57536 | 0.0000 |
| Fixed Term | -944015.0 | 373672.9 | -2.526314 | 0.0115 |

As can be seen from the estimation results, patent stock and turnover variables affect the R&D expenditures of manufacturing industry firms positively, while the number of patents affects them negatively. This result shows that the accumulated stock of knowledge is more effective than the number of patents in increasing R&D expenditures.

## CONCLUSION

In today's fast-paced and dynamic business environment, firms must continuously evolve to stay competitive. Without improvement, their products or services risk losing their edge in the market. Customers' preferences, needs, and expectations for these products change over time, creating additional challenges. Business owners and managers must navigate uncertain conditions while optimizing limited resources. To maintain their competitiveness, companies must preserve and advance their technological capabilities and anticipate future technological trends when planning asset maintenance and operational strategies. Technical innovation is influenced by factors such as firm size, market structure, technological opportunities, sales growth, and profitability. For firms to innovate, investing in R&D is essential. R&D activities generate knowledge, an intangible asset that often delivers long-term economic advantages to the investing organization. As a result, innovative firms typically allocate more resources to R&D compared to their non-innovative counterparts.

Research and development (R&D) encompasses all systematic and creative efforts aimed at expanding the stock of knowledge and applying it to develop new or improved products, processes, or applications. To capture the long-term benefits of R&D investments, econometric analyses often incorporate measures of the knowledge stock generated by R&D activities. If R&D contributes to innovation and economic growth, this occurs through the growth of the knowledge stock, which firms can leverage for various advancements. The fundamental premise linking R&D investment to productivity is that a series of R&D expenditures builds a stock of knowledge that yields returns over time. Establishing this stock requires understanding the rate at which R&D investments contribute to and exit the stock, as well as how the knowledge stock depreciates over time.

In this study, patents were used to represent the stock of knowledge. The role of the stock of knowledge in encouraging R&D expenditures was investigated using the variables of R&D expenditure, number of patents, patent stock and turnover of companies operating in the manufacturing industry in Turkey for the years 2003-2021 using the Tobit model. Since the stock of knowledge will lose value over time, the patent stock was included in the model using the perpetual inventory method. According to the model estimation results, the driving force behind manufacturing industry companies making R&D investments is the stock of knowledge and turnover. The number of patents negatively affects R&D expenditures.

The study can be expanded by including other factors affecting R&D expenditures in the model and further diversifying the knowledge stock.

**AUTHOR CONTRIBUTIONS**

Design: Author 1, Author 2; Data Collection: Author 1, Author 2; Data Processing: Author 1; Author 2; Analysis and/or Interpretation: Author 1, Author 2; Literature Review: Author 1, Author 2; Manuscript Writing: Author 1, Author 2; Critical Review: Author 1, Author 2.

**CONFLICT OF INTEREST**

There is no conflict of interest regarding this study.

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**ETHICAL STATEMENT**

The author(s) declare that all processes of the study comply with research and publication ethics, adhering to ethical standards and principles of scientific citation.

The study does not require ethical permission.

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