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EFFECT OF R&D ON PRODUCT AND PROCESS INNOVATION IN THE TURKISH MANUFACTURING INDUSTRY*

TÜRK İMALAT SANAYİSİNDE AR-GE'NİN ÜRÜN VE SÜREÇ İNOVASYONU ÜZERİNDEKİ ETKİSİ*

Atakan AKINCI[1], Hasan VERGİL[2]

Öz

AR-GE faaliyetleri, inovasyonun ortaya çıkışını ve teknolojinin büyüme hızını artırmak için vazgeçilmez bir itici güçtür. Mikro veriler kullanılarak Türkiye'deki AR-GE faaliyetlerinin sektörler üzerindeki etkisi üzerine yapılmış çalışmalar hâlâ yetersizdir. Bu eksikliği doldurmak için bu çalışmada, AR-GE değişkenleri alt kırılımları yapılarak Türk imalat sanayisinde AR-GE'nin ürün ve süreç inovasyonu üzerindeki etkilerinin analizinin yapılması amaçlanmıştır. Bu çalışma, ayrıca Türkiye'deki AR-GE planlarını destekleyici politika önerileri sunmaktadır. Bu amaçları gerçekleştirmek için, panel veri tahmin yöntemleri kullanılmıştır. NACE Rev.2'ye göre sınıflandırılmış ve 2009-2016 yıllarını kapsayan bir panel veri seti TURKSTAT tarafından yapılan anketlerden derlenen dört farklı mikro veri seti birleştirilerek oluşturulmuştur. AR-GE harcamasının, AR-GE yoğunluğunun (AR-GE yatırımı göstergesi olarak), AR-GE personel oranı (know-how göstergesi olarak) ve inovasyonun diğer belirleyicilerinin etkilerini tahmin etmek için probit model kullanılmıştır. Ayrıca, içsel, dışsal, dışsal-yurt içi ve dışsal-yurt dışı olarak toplam AR-GE harcaması dört alt kırılıma ayrılmıştır. Araştırmanın temel bulguları, AR-GE harcamalarının ürün ve süreç inovasyonu üzerindeki etkilerinin alt kırılımlara göre değiştiğini göstermektedir. Toplam ve içsel AR-GE harcaması hem ürün hem de süreç inovasyonu üzerinde pozitif etkiye sahipken, dışsal ve dışsal-yurt içi AR-GE harcaması sadece ürün inovasyonu üzerinde ve dışsal-yurtdışı AR-GE harcaması sadece süreç inovasyonu üzerinde pozitif etkiye sahiptir. Sadece dışsal, dışsal-yurt içi ve dışsal-yurt dışı AR-GE yoğunluğu ürün ve süreç inovasyonu üzerinde pozitif etkiye sahiptir.

Anahtar Kelime: Ürün İnovasyonu, Süreç İnovasyonu, İmalat Sanayi, AR-GE Harcaması, AR-GE Politikası.

Abstract

R&D activities are an indispensable driving force to increase the likelihood of occurrence of innovation and the growth rate of technology. Studies on the impact of R&D activities on sectors in Türkiye using micro data are still insufficient. To fill this gap, this study aims to analyze the effects of R&D on product and process innovation in the Turkish manufacturing industry by making sub-breakdowns of R&D variables. The research also presents policy recommendations to support R&D plans in Türkiye. To accomplish these objectives, panel data estimation methods are used. A panel data set was generated by merging four different microdata sets provided by TURKSTAT, which is classified by NACE Rev.2 and covers the years between 2009 and 2016. Probit model is used to estimate the effects of R&D expenditure, R&D intensity (as an indicator of R&D investment), R&D personnel ratio (as an indicator of know-how), and other determinants of innovation. Moreover, total R&D expenditure is separated into four breakdowns such as internal, external, external-domestic, and external-foreign. Key findings of the research show that the effects of R&D expenditure on product and process innovations vary by its sub-breakdowns. Total and internal R&D expenditure have a positive effect on both product and process innovations while external and external-domestic R&D expenditure have a positive effect only on product innovation, and external-foreign R&D expenditure only on process innovation. Only external, external-domestic, and external-foreign R&D intensity have a positive effect on both product and process innovation.

Keywords: Product Innovation, Process Innovation, Manufacturing Industry, R&D Expenditure, R&D Policy.

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[1] PhD Candidate, Istanbul University, Institute of Graduate Studies in Social Sciences, Department of Economics (English), atakanakinci@outlook.com, ORCID: 0000-0001-9652-2011
[2] Prof. Dr., Istanbul University, Faculty of Economics, Department of Economics, hasan.vergil@istanbul.edu.tr, ORCID: 0000-0001-9629-3036

Genişletilmiş Özet

Teknolojik gelişme, endüstri devriminden beri artarak devam etmektedir. Yapılan teorik ve uygulamalı çalışmaların hemen hepsinde, büyümenin motoru olarak teknolojik yeniliklere vurgu yapılmakta ve ekonomik büyüme sürecinde teknolojik ilerlemelerin kaynakları ve yöntemleri anlaşılmaya çalışılmaktadır. Ülkeler arasındaki değişik alanlarda görülen rekabet de araştırma ve geliştirme (AR-GE) faaliyetlerinin teşvik edilmesini ve inovasyonların ortaya çıkış sürecinin hızlandırılmasını zorunlu kılmaktadır.

Türkiye, son yıllarda yüksek büyüme oranlarıyla dünyada dikkat çekmektedir. Bu yüksek büyüme oranlarının gerçekleşmesinde şimdiye kadar en yüksek pay sermaye stokundaki artışlara aittir. Fakat Türkiye'nin yüksek büyüme oranlarını sürdürülebilir hale getirmesi için toplam faktör verimliliğinin ekonomik büyüme içerisindeki payını yükseltmesi ve mevcut teknoloji büyüme oranını da artırması gerekir. Teknolojinin büyüme oranını ve inovasyonun gerçekleşme olasılığını arttırmanın en önemli yöntemi ise daha fazla AR-GE faaliyetlerinde bulunmaktır. 1964 yılında %2'ye ve 1993 yılında %1'e ulaşmayı hedef olarak belirleyen Türkiye, son yıllarda çeşitli programlar aracılığıyla AR-GE'ye teşviki sürdürmesine rağmen AR-GE harcamalarının Gayri Safi Yurt İçi Hasıla (GSYİH) içindeki payı 2018 yılında %1'e ulaşmıştır. Bu oran ile Türkiye, OECD ülkeleri arasında son sıralarda yer almaktadır.

AR-GE faaliyetleri üzerine yapılan politikaların başarılı olması AR-GE faaliyetlerinin doğru analiz edilmesine bağlıdır. Özellikle, AR-GE faaliyetlerine ayrılan kaynakların bilimsel ve teknolojik bilginin ilerlemesinde, ekonomik ve teknolojik problemlerin çözümünde kullanılması önemlidir. Bu anlamda, AR-GE faaliyetleri için yapılan harcamaların arttırılması ve bu kaynakların hem ekonomik hem toplumsal açıdan faydalı projelere ve alanlara yönlendirilmesi gerekmektedir. Etkin ve etkili bir şekilde sürdürülmesi amacıyla bu sürecin ciddi takip ve analiz edilmesi gerekmektedir.

AR-GE faaliyetleri, teknoloji büyüme hızını ve inovasyonun gerçekleşme olasılığını arttırmak için vazgeçilmez itici bir güçtür. Bu bağlamda, bu araştırmanın amaçları AR-GE'nin önemini vurgulamak, Türk imalat sanayisinde AR-GE'nin ürün inovasyonu ve süreç inovasyonu üzerindeki etkilerini analiz etmek, AR-GE harcamaları ve AR-GE yoğunluğu değişkenlerinin etkilerini kendi içinde ayrıştırarak incelemek ve bu sebeplerle literatürdeki eksiği doldurmaktır.

Bu çalışmada, firma seviyesinde mikro veriler kullanılarak 2009-2016 dönemi Türk imalat sanayisi için AR-GE harcamalarının ve AR-GE yoğunluğunun süreç ve ürün inovasyonlarının olma olasılığı üzerindeki etkisi analiz edilmektedir. Bu analizde hem AR-GE harcamaları hem de AR-GE yoğunluğu değişkenleri "toplam, dahili/içsel, harici/dışsal, harici/dışsal-yurt içi ve harici/dışsal-yurt dışı" ayrımı yapılarak beş farklı şekilde ele alınmaktadır. AR-GE harcamasının ve AR-GE yoğunluğunun bu şekilde ayrımı yapılarak Türk imalat sanayisinde AR-GE'nin ürün ve süreç inovasyonlarının gerçekleşme olasılığı üzerindeki etkisinin analizine literatürde daha önce rastlanmaması, çalışmanın özgün niteliğini göstermektedir. Bu nedenle bu çalışma, Türk imalat sanayisi ve AR-GE literatürüne katkı sağlamaktadır. Ayrıca, politika yapıcıların teknoloji belirleme konularında karar almalarında ve ileride yürütülecek program ve politikaların tasarlanmasında bu çalışma katkı sağlayacaktır. Bu araştırma, "The Effect of Research and Development Expenditures on Technological Change: The Case of Turkish Manufacturing Industry" adlı doktora tezinden üretilmiştir.

Araştırmanın amaçlarını gerçekleştirmek amacıyla, bir istatistiksel yöntem olarak panel veri analizi kullanılacaktır. NACE Rev.2'ye göre sınıflandırılmış ve 2009-2016 yıllarını kapsayan bir panel veri seti hem idari kayıtlardan hem de Türkiye İstatistik Kurumu (TÜİK) tarafından yapılan anketlerden derlenen dört farklı mikro veri seti birleştirilerek oluşturulmuştur. Bu veri setleri, TÜİK'in A grubu gizli veri setlerinden olan 2009 yılından beri (idari kayıtlara dayanarak) yayınladığı Yıllık Sanayi ve Hizmet İstatistikleri Mikro Veri Seti, 1990 yılından beri yayınladığı Yıllık Sanayi Ürün (PRODCOM) İstatistikleri Mikro Veri Seti, 2003 yılından beri yayınladığı Sanayi ve Hizmet Kuruluşları Araştırma Geliştirme Faaliyetleri Araştırması Mikro Veri Seti ve 2004 yılından beri yayınladığı Yenilik Araştırması Mikro Veri Seti'dir. Bu çalışmada, AR-GE harcaması, AR-GE yoğunluğu (AR-GE yatırım göstergesi olarak), AR-GE personel oranı (know-how göstergesi olarak), ciro, Herfindahl-Hirschman endeksi, doktora ve yüksek lisans mezunu AR-GE personeli sayısı, sanayi üretim endeksi ve reel sektör güven endeksi gibi değişkenlerin Türk imalat sanayisinde ve alt sektörlerinde ürün inovasyonunun ve süreç inovasyonunun gerçekleşme olasılığı üzerindeki etkilerini tahmin etmek için probit model kullanılmaktadır.

Çalışmanın temel bulguları, AR-GE faaliyetlerinin ürün ve süreç inovasyonunu destekleyeceğini ve harekete geçireceğini/kolaylaştıracağını göstermektedir. Aynı zamanda, AR-GE harcamasının ve AR-GE yoğunluğunun ürün inovasyonu ve süreç inovasyonu üzerindeki etkilerinin alt kırılımlara göre değiştiğini göstermektedir.

Sonuç olarak, AR-GE ve sanayi politikalarının inovasyon türlerine ve AR-GE alt kırılımlarına göre farklı bir şekilde belirlenmesi gerekir. Ürün inovasyonunun gerçekleşme olasılığını arttırmak için toplam, içsel, dışsal, dışsal-yurt içi AR-GE harcaması ve dışsal, dışsal-yurt içi, dışsal-yurt dışı AR-GE yoğunluğu arttırılmalıdır. Süreç inovasyonunun gerçekleşme olasılığını arttırmak için ise dışsal-yurt dışı AR-GE harcaması ve dışsal, dışsal-yurt içi, dışsal-yurt dışı AR-GE yoğunluğu arttırılmalıdır. Ancak, ürün ve süreç inovasyonunun gerçekleşme olasılığını arttırmak için firmalar öncelikle içsel AR-GE harcamasını arttırmalıdırlar. Eğer firmaların ihtiyacı varsa, ikincil olarak ürün inovasyonu konusunda dışsal-yurt içi, süreç inovasyonu konusunda dışsal-yurt dışı AR-GE harcamasını arttırabilirler. Bunun yanında, ülkede AR-GE ortamı teşviklerle desteklenerek yurt dışı AR-GE harcaması olabildiğince azaltılmalıdır.

Analiz, TÜİK Veri Araştırma Merkezi'nde Stata programı kullanılarak yapılmıştır. Mikro veri setlerinin A grubu gizli veriler olması, idari kayıtlardan elde edilen verilerin 2009 yılından itibaren sağlanması, yenilik araştırması anketinin yapısındaki değişiklikler nedeniyle yalnızca 2016 yılına kadar verilerin kullanılabilmesi, inovasyonun gölge değişken ile ölçülmesi bu araştırmanın başlıca kısıtlarını oluşturmaktadır. Gelecek çalışmalarda, araştırmacılar sektörel AR-GE dinamiklerini ve inovasyonun belirleyicilerini anlamak için Türk imalat sanayi alt sektörlerinin detaylı analizine odaklanabilirler.

INTRODUCTION

Technological progress based on inventions and innovations is a significant source of economic development and growth. In this sense, countries' attitude to science and technology has a strategic role in the economy and a country should determine effective policies on research and experimental development (R&D) activities, technology, and innovation. Developed and developing countries consider these topics increasingly in last decades. Determining effective policies on R&D, technology, and innovation requires well-designed data and its analysis professionally. After many discussions among countries, OECD NESTI[3] agreed on Frascati Manual in 1963 and Oslo Manual in 1992 as a methodology for collecting and using R&D statistics, and as a guideline for collecting, reporting, and using data on innovations respectively (Organisation for Economic Co-operation and Development, 1963, 1992).

Frascati Manual 2015 defines R&D as "*research and experimental development*" that "*comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge*" (Organisation for Economic Co-operation and Development, 2015). The Oslo Manual 2018 separate innovation types into product innovation and business process innovation. A product innovation is defined as "*a new or improved good or service that differs significantly from the firm's previous goods or services and that has been introduced on the market*", and a business process innovation is defined as "*a new or improved business process for one or more business functions that differs significantly from the firm's previous business processes and that has been brought into use in the firm*" (Organisation for Economic Co-operation and Development/Statistical Office of the European Union [OECD/EUROSTAT], 2018). Based on these developments, Turkish Statistical Institute (TURKSTAT) has conducted innovation surveys since 2004 in Türkiye[4] (Turkish Statistical Institute [TURKSTAT], 2020a).

Innovation has four dimensions such as "*knowledge, novelty implementation, and value creation*" (OECD/EUROSTAT, 2018). Knowledge is one of the driving forces of innovation which is necessary for a country that wants to grow and develop. R&D activities are very important for production of knowledge and knowledge accumulation. This study focuses on R&D activities to explore its dimensions in a country with several instruments such as R&D expenditures, R&D incentives, new laws on R&D and innovation. For instance, as a main hypothesis of this study, if a country or a firm increases its expenditure on R&D and/or its R&D intensity, likelihood of occurrence of innovation increases.

Türkiye is a country that aims to grow and to develop based on technological progress which is produced by R&D activities, and innovations. Türkiye has introduced several five-year development plans (5YDP) and many industry and technology strategic plans (ITSP) based on 5YDP. For example, in 2020-2024 Industry and Technology Strategic Plan, the mission was identified as "to constitute a competitive, sustainable, domestic, and national industrial structure based on high-tech" and the vision was identified as "Türkiye with powerful industry and national technology" (Ministry of Industry and Technology, 2020). Türkiye tends to focus on improving its industrial structure and technology as a top-priority agenda item in its industry and technology policies recent years, since Türkiye clearly recognizes that an improvement in industrial structure and technology based on invention and innovation is one of the most effective ways to solve economic problems such as unsatisfactory high-tech production, foreign trade deficit, etc. In conjunction with the mission and the vision, it can be said that Türkiye is aware of the importance of R&D activities, R&D expenditures, high skilled R&D personnel, and effective policies on R&D more than ever. To accomplish those aims, Türkiye should support and accelerate R&D activities. According to third 5YDP (State Planning Organization, 1973), Türkiye's share of R&D expenditure in gross national product (GNP) were 0.41 in 1964, 0.36 in 1969, and 0.35 in 1970. In 1989, Türkiye set goals such as increase in the share of R&D expenditure in gross national product (GNP) from 0.2 to 2 percent in a decade (Scientific and Technological Research Council of Türkiye [TÜBİTAK], 1989). In the Turkish Science and Technology Policy 1993-2003 document, the

[3] Organisation for Economic Co-operation and Development (OECD) Working Party of National Experts on Science and Technology Indicators (NESTI).
[4] Circular no. 2021/24 on use of 'Türkiye' as a brand instead of 'Turkey', 'Turkei', 'Turquie', and other similar phrases in all types of activities and correspondence was promulgated in the Official Gazette no. 31679 on 4 December 2021.

share was explained as 0.33 percent in 1993 and the aim was being more than 1 percent in a decade (Scientific and Technological Research Council of Türkiye [TÜBİTAK], 1993). The goal for the share was lowered from 2 percent to 1 percent. However, the share reached around 0.5 percent in 2001 even though the goal was lowered (Figure 1). In other words, the goal of 1993-2003 document could not achieved.

In 2001, The Law on Technology Development Zones has been enacted with the aim of structuring industry to be more competitive and export-oriented by supporting collaboration among universities, R&D institutions, and manufacturing sectors (Presidency of The Republic of Türkiye Official Gazette, 2001). In 2008, The Law on Supporting Research, Development and Design Activities has been enacted with the aim of structuring economy to be more competitive internationally in terms of supporting technological knowledge production, innovation in product and process, raising product quality and standards, increase in productivity, decrease in production costs, technology intensive production, accelerating foreign direct investments inflow to Türkiye, and increase in R&D and design personnel and skilled labor employment (Presidency of The Republic of Türkiye Official Gazette, 2008).

Although there are many 5YDPs and Laws about R&D, innovation, and technology issues, the share of R&D expenditure in GDP reached 1.03 percent in 2018 in Türkiye. This share is lower than the share of OECD (2.44 percent) and European Union (2.07 percent) (Organisation for Economic Co-operation and Development [OECD], 2022). In the same year, there are many countries that their shares are higher than Türkiye's such as 4.8 percent for Israel, 4.52 for South Korea, 3.35 for Chinese Taipei, 3.32 for Sweden, 3.22 for Japan, 3.11 for Germany, 3.09 for Austria, 3.01 for United States, 2.97 for Denmark, 2.86 for Belgium, 2.76 for Finland, 2.2 for France, 2.14 for China, 2.14 for Netherlands, 2.05 for Norway, 2 for Iceland, 1.95 for Slovenia, 1.9 for Czech Republic, 1.81 for Singapore, 1.74 for Canada, 1.71 for United Kingdom, 1.51 for Hungary, 1.42 for Italy, 1.41 for Estonia, 1.35 for Portugal, 1.24 for Spain, 1.21 for Greece, 1.21 for Poland, 1.17 for Ireland, and 1.17 for Luxembourg (OECD, 2022).

Based on the shares of Türkiye over time and other country experiences, these questions can be asked; 'what is the effect of R&D expenditures on product and process innovation in Turkish manufacturing industry?' and 'Does R&D expenditure increase the likelihood of occurrence of innovation in Turkish manufacturing industry?'. This study aims to emphasize the importance of R&D in technological progress in Türkiye by analyzing the effects of R&D on likelihood of occurrence of product and process innovation in Turkish manufacturing industry. The study uses micro-firm data and separates R&D variables into its breakdowns. To accomplish these aims, this study analyzes the effect of R&D expenditure (five types) and R&D intensity (five types) on likelihood of occurrence of both product and process innovation in Turkish manufacturing industry classified by NACE[5] Rev.2 and between the years of 2009 and 2016 for all manufacturing industry. This article contributes to the literature by analyzing for the first time the effects of five types of R&D expenditures and R&D intensities on product and process innovation in the Turkish manufacturing industry.

The empirical results conclude that R&D activities will support and catalyze product and process innovation. Total, internal, external, external-domestic R&D expenditure and external, external-domestic, external-foreign R&D intensity should be increased for enhancing the positive effect on likelihood of occurrence of product innovation. External-foreign R&D expenditure and external, external-domestic, external-foreign R&D intensity should be increased for enhancing the positive effect on likelihood of occurrence of process innovation. Additionally, R&D policies and industrial policies should be determined differently according to innovation types and R&D sub-breakdowns.

This study is organized as follows. Section 1 presents the literature review. Section 2 presents data and methodology. Section 3 presents the empirical results. Last part is conclusion of the research which includes policy recommendations and new ways/topics to study for researchers who want to contribute to R&D literature and Turkish manufacturing industry.

[5] The statistical classification of economic activities in the European Community.

1. LITERATURE REVIEW

A country must acquire its own technology based on R&D activities to support its own economic growth and development. This technological progress is the most important source for economic growth thanks to the increase in inventions and innovations (as a form of scientific knowledge) regarding physical and human capital (Todaro and Smith, 2015). Some studies such as Schumpeter (1934, trans. 1983), Solow (1956), Arrow (1962), Phelps (1966), Lucas (1988), Romer (1986, 1990), and Aghion and Howitt (1992) emphasized the importance of technological innovation as an engine of growth.

Arrow (1962) explained the source of technological change as “a product of experience” by emphasizing “learning by doing”. Lucas (1988) emphasized Arrow’s idea and explained the source as knowledge accumulation. At this point, it is understood that education and research institutions have, as emphasized by Arrow (1962), a strategic role in the economy. Phelps (1966) referred to researchers as investment in technology and specified increase in speed of knowledge accumulation due to researchers’ ascending productivity. Romer (1986, 1990) uses knowledge and research sector as a source of productivity. In this sense, researchers as R&D personnel in labor force support to increase in R&D activities, and therefore acceleration of knowledge production and knowledge accumulation can be seen. Ulku (2007) explained that more researchers in the labor force cause more innovation only in the large market of OECD countries. In the light of this literature, R&D is the first focal point of this study because it is important to analyze R&D activities for developing efficient policies on R&D.

Developing efficient policies on R&D activities, innovation, and technology necessitates detailed analysis on them to support an economy. Many researchers (Maclaurin, 1942, 1950a, 1950b, 1953, 1954; Cole, 1942; Hamberg, 1964; Taymaz and Saatci, 1997; Freeman and Soete, 1997, trans. 2004) have called attention to the importance of understanding and investigating of innovation and firms’ innovativeness in an economy. In Türkiye, in 1991, Taymaz (1997) took part in a project on collecting and analyzing data about small and medium-sized enterprises (SMEs) in the manufacturing industry at the micro level. With this project, two surveys such as “Innovative Potential of SMEs” and “Inventory of Machinery and Equipment in the Textile and Engineering Industries” were emerged and conducted in 1992 and 1995 respectively (Taymaz, 1997). Türkiye realized the importance of data to develop efficient policies on manufacturing industry, R&D activities, innovation, and technology. It may be said that the project became a driving force for TURKSTAT in terms of the next projects.

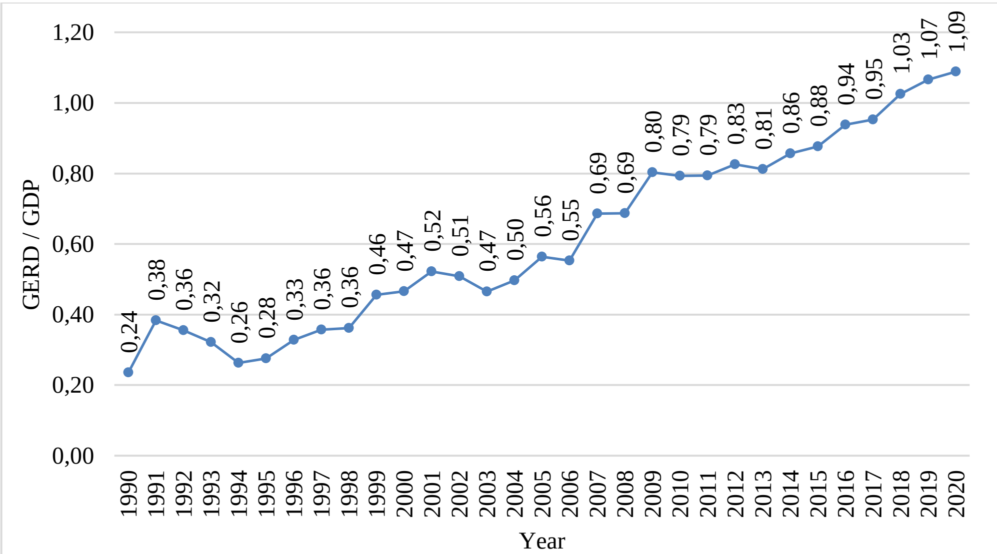
In the early 1990s, Aghion and Howitt (1992) defined six ways of knowledge accumulation such as formal education, on-the-job training, basic scientific research, learning by doing, process innovation, and product innovation. According to them, process innovation and product innovation are significant sources for knowledge accumulation. In this sense, both product and process innovation are the other focal point of this study.

The relation among R&D, process innovation and product innovation is one of the much-discussed topic in the world (Martinez-Ros, 1999; Raymond and St-Pierre, 2010; Nieto and Rodriguez, 2011; Song and Oh, 2015; Adeyeye et al., 2016; Un and Rodriguez, 2018) and in Türkiye (Pamukcu and Boer De, 2000; Uzun, 2001; Ozdemir-Gungor and Gozlu , 2012; Attar, 2017; Burmaoglu and Sesen, 2017; Dogan, 2017; Ozturk, 2018-2019).

In Spanish manufacturing industry case, according to Martinez-Ros (1999), the probability to innovate is higher in capital-intensive firms and exporter firms between 1990 and 1993, and decisions of product and process innovation are complementary with each other. Nieto and Rodriguez (2011) focused on offshoring R&D that has a positive impact on firm’s innovation performance, and this impact is higher on product innovation than process innovation in Spanish manufacturing industry between 2004 and 2007. Un and Rodriguez (2018) analyzed the effect of external R&D expenditure on product innovation in Spanish manufacturing industry between 1990 and 2002 by separating as external-domestic R&D expenditure and external-foreign R&D expenditure, and as a result of this study external-domestic R&D expenditure has a more effect on product innovation, and there is inverted-U relationship between external R&D usage and product innovation, and between external R&D usage and internal R&D. In Canadian manufacturing case, Raymond and St-Pierre (2010) shows that the effect of R&D on product innovation is mediated by process innovation. In the case of South Korea, Song and Oh (2015) analyzed energy intensive industry (EII), and according to results, R&D personnel ratio and number of R&D personnel affects both innovations, R&D intensity affects only process innovation positively.

In Turkish manufacturing industry case, Pamukcu and Boer De (2000) focused on identifying determinants of innovation such as international technology transfers, skill level of labor, competition on the international markets, international technology transfer, and price level, and analyzed their effects on probability of innovation in 1994 for the period between 1989 and 1993, and these determinants have a positive effect on the probability of innovation. Uzun (2001) stated that innovation activities are higher in large firms in Turkish manufacturing industry between 1995 and 1997, and in most of Turkish manufacturing sectors, the source of more than half of the total sales is technologically new and improved products—product innovation. Ozdemir-Gungor and Gozlu (2012) showed internal and external determinants of product and process innovation for Turkish companies in 2008, and firms engaged in product innovation activities are also in process innovation. Burmaoglu and Sesen (2017), like many other studies, aimed to identify determinants of product innovation and service innovation of firms in Türkiye in 2008, and they stated that financial support, external information, and networking are critical factors for innovation process. Dogan (2017) focused mainly on total factor productivity in her dissertation and analyzed the effects of R&D and fixed capital investment on the probability of occurrence of product and process innovation with logit model only in last pages of it. According to results of this part: *i)* there is no effect of R&D intensity (R&D expenditures/total capital investment) on the probability of product innovation but there is on process innovation *ii)* interaction between R&D intensity and fixed investment intensity (fixed investment expenditures/total capital stock) effects the probability of product innovation, *iii)* there is effect of group variable on both product and process innovation. Ozturk (2018-2019) analyzed innovative entrepreneur in Türkiye and presented some results under the data limitation such as: *i)* some characteristics of firm such as profit-oriented, supported by governmental institutions, having an R&D department, employing skilled personnel more than average have positive effect on the probability of innovation, *ii)* some other characteristics of firm such as producing only in Türkiye, having foreign capital have negative effect on the probability of innovation, *iii)* firms in Türkiye act with profit motive and prefer organization and marketing innovations generally which yield profit in a short time and with less cost instead of other innovation types.

Figure 1: Gross Domestic Expenditure on R&D / Gross Domestic Product, Türkiye, 1990-2020



Source: (OECD, 2022).

Attar (2017) showed that product and process innovation are significant sources of technological progress in Türkiye. In 2018, the share of Turkish manufacturing industry in GDP was 19 percent as the largest share ("Annual Gross Domestic Product, 2018", 2019) and it was 22,2 percent as the largest share in 2021 ("Annual Gross Domestic Product, 2021", 2022). To support increase in the share, the share of R&D expenditure in GDP should be increased more and more by contrast with last three decades (Figure 1). The analysis of this industry is significant to contribute to developing and determining efficient policies on Turkish manufacturing industry and to increase in this share. To develop efficient policies on R&D, technology and innovation, factors that affect R&D activities in Türkiye should be investigated more (Taymaz and Saatci, 1997). Especially, in this sense, investigation of R&D expenditure as an independent variable and its effect on innovation is significant under the main hypothesis of this study, if a country or a firm increases its expenditure on R&D and/or its R&D intensity, likelihood of occurrence of innovation increases.

2. DATA AND METHODOLOGY

2.1. Data

There are four different micro data sets such as Annual Industry and Service Statistics (AISS), Research and Development Activities Surveys in Business Enterprise Sector (RDAS), Annual Industrial Products (PRODCOM) Statistics, and Community Innovation Survey (IS). Micro data sets of these statistics are 'Group-A Data' (confidential data) provided by TURKSTAT and researchers can access them only in Data Research Centers of TURKSTAT with data confidentiality under a signed protocol.

The most critical data sets in the analysis are AISS, RDAS, and IS. Meanwhile, micro data set of PRODCOM is only used for the 'firm id no'[6] data. Data is compiled annually except IS that is biennially for a three-year period. The data collection method of RDAS and IS is web-based electronic questionnaire. AISS is based on administrative records.

From IS micro data set, variables such as product and process innovation are used as dependent variables. The question of product and process innovation in IS survey asks whether a firm introduced innovation (1) or not (0) during the last three years. From the AISS micro data set, variables such as turnover and number of employees are used. From RDAS micro data set, variables such as intramural (internal) and extramural (external) R&D expenditures are used.

In this study, firm-level unbalanced panel micro data set was generated by merging micro level data sets mentioned above with key variable 'firm id no'. In sample micro panel data, approximately 1243 groups were obtained for the period between 2009 and 2016. There are two reasons why the study covers eight years. The first reason is that TURKSTAT provides AISS micro data set since 2009 because of changes in data source. In 2013, the data source become administrative records and data revision started from 2009 and for the period after 2009. Another reason is that the design in IS questionnaire changed because of 4th edition of Oslo Manual published (OECD/EUROSTAT, 2018).

Questionnaires provide definitions of concepts including "research and experimental development (R&D)", "R&D expenditure", "internal", "external", "product", "process".

The concept of research and experimental development (R&D) is defined in the RDAS questionnaire, and it is same definition that is in the Frascati Manual 2015. This definition is explained in the introduction part. Especially, some cases are given in the instructions for the questionnaire such as: "*development of internet technology*", "*industrial design for R&D project*", "*industrial engineering in prototype development for new or improved products*", and "*software development including innovation*". Following examples are given in the instructions for R&D in software development such as:

- "*Searching for alternative methods of computation"* (e.g. "*quantum computation and quantum information theory*") is example for basic research.,
- "*Investigation into the application of information processing in new fields or in new ways"* (e.g. "*developing a new programming language, new operating systems, and programme generators"*), and "*investigation into the application of information processing to develop tools* (e.g. "*geographical information and expert systems*") are examples for applied research,
- "*Development of new applications software, substantial improvements to operating systems and application programmes*" are examples for experimental development.

The concept of intramural (internal) and extramural (external) R&D expenditures are defined in the RDAS questionnaire. The former one is defined as "*all expenditures for R&D performed within a*

[6] Firm id no is only used for a few years for merging process.

statistical unit or sector of the economy during a specific period, whatever the source of funds". The latter one is defined as "*R&D expenditure carried out by the domestic institutions/organisations*" – domestic and "*R&D expenditure carried out by the institutions/organisations on abroad*" – foreign. Total R&D expenditure for the firm can be acquired by summing internal and external R&D expenditures.

The concept of product and process innovation is defined in the IS questionnaire[7]. This questionnaire (Community Innovation Survey) is conducted by many countries such as European countries. Product innovation is defined as "*the market introduction of a new or significantly improved good or service with respect to its capabilities, user friendliness, components or sub-systems*" (The European Commission, 2012) and a good is exemplified as "*usually a tangible object such as a smartphone, furniture, or packaged software, but downloadable software, music and film are also goods*". The other, process innovation, is defined as "*the implementation of a new or significantly improved production process, distribution method, or supporting activity*" (The European Commission, 2012). This innovation must be new to the firm even if it is not new to its market. It may have been developed originally by the firm or by the other firms. It does not include purely organizational innovations.

Table 1. Explanatory Variables Used in The Analysis

Explanatory Variable Label	Details
Total R&D Expenditure	inflation-adjusted and in natural logarithm "*ln*"
Total Internal R&D Expenditure	
Total External R&D Expenditure	
Total External-Domestic R&D Expenditure	
Total External-Foreign R&D Expenditure	
Total R&D Intensity	$\frac{\text{R\&D Expenditure}}{\text{Turnover}}$
Internal R&D Intensity	
External R&D Intensity	
External-Domestic R&D Intensity	
External-Foreign R&D Intensity	
R&D (Personnel) Intensity	$\frac{\text{Total R\&D Personnel Number}}{\text{Total Personnel Number}}$
Turnover	Inflation-Adjusted
Square of Inflation-Adjusted Turnover	(Inflation-Adjusted Turnover)^2
Herfindahl-Hirschman Index	Calculated from AISS micro data set
Number of R&D Personnel	PhD + MA (high educated)
Industrial Production Index	Unadjusted, Yearly Average, 2009=100
Real Sector Confidence Index	Yearly Average

Independent variables used in the analysis are acquired mainly from micro data sets and TURKSTAT's public data (industrial production index and real sector confidence index) (Table 1).

Descriptive statistics of the variables used in the analysis are shown in Table 2. According to the data, the number of observations is 4223 and the number of groups is 1243. Product (PD) and process (PC) innovation variables are binary. For example, PD or PC are 1 if a firm introduced innovation while they are 0 if a firm did not introduce innovation.

Table 2. Descriptive Statistics of the Variables Used in The Analysis

Variable	Obs	Mean	Std. Dev.	Min	Max
Product Innovation (PD)	4,223	0.734	0.442	0	1
Process Innovation (PC)	4,223	0.758	0.428	0	1
Total R&D Expenditure	4,223	13.304	1.747	7.760927	20.14096
Total Internal R&D Expenditure	4,223	13.266	1.736	7.760927	20.13278
Total External R&D Expenditure	4,223	1.909	4.382	0	18.43079
Total External-Domestic R&D Expenditure	4,223	1.638	4.026	0	17.5184
Total External-Foreign R&D Expenditure	4,223	0.768	2.968	0	18.42295
Total R&D Intensity	4,223	0.202	7.176	0.0000276	413.8979
Internal R&D Intensity	4,223	0.195	6.893	0.0000208	393.3279

[7] It may be seen only by permission of TURKSTAT. It is not public on its website. However, I share same questionnaire from the European Commission (EC) website in the references. That is why I used EC's source.

External R&D Intensity	4,223	0.007	0.319	0	20.57004
External-Domestic R&D Intensity	4,223	0.007	0.318	0	20.57004
External-Foreign R&D Intensity	4,223	0.001	0.015	0	0.8553251
R&D (Personnel) Intensity	4,223	0.159	1.290	0.0002658	34
Turnover	4,223	292000000	1070000000	1894	33800000000
Square of Inflation-Adjusted Turnover	4,223	1240000000 000000000	2520000000 0000000000	3587236	11400000000000 00000000
Herfindahl-Hirschman Index	4,223	0.036	0.086	0.0012157	0.8505268
Number of R&D Personnel (PhD+MA)	4,223	7.205	46.917	0	1473
Industrial Production Index	4,223	140.943	20.465	100	168.5592
Real Sector Confidence Index	4,223	105.151	5.344	87.3	110.4

2.2. Methodology

In the light of the literature, the analysis was conducted to investigate the effect of R&D expenditure on product and process innovation in Turkish manufacturing industry classified by NACE Rev.2 (the statistical classification of economic activities in the European Community) and between 2009 and 2016. Table 3 shows hypotheses constructed for this study.

Table 3. Hypotheses

H1:	**Increase in total *R&D expenditure* increases the likelihood of occurrence of *product innovation*.**
H1a:	Increase in **Internal R&D expenditure** increases the likelihood of occurrence of product innovation.
H1b:	Increase in **External R&D expenditure** increases the likelihood of occurrence of product innovation.
H1c:	Increase in **External-Domestic R&D expenditure** increases the likelihood of occurrence of product innovation.
H1d:	Increase in **External-Foreign R&D expenditure** increases the likelihood of occurrence of product innovation.
H2:	**Increase in total *R&D intensity* increases the likelihood of occurrence of *product innovation*.**
H2a:	Increase in **Internal R&D intensity** increases the likelihood of occurrence of product innovation.
H2b:	Increase in **External R&D intensity** increases the likelihood of occurrence of product innovation.
H2c:	Increase in **External-Domestic R&D intensity** increases the likelihood of occurrence of product innovation.
H2d:	Increase in **External-Foreign R&D intensity** increases the likelihood of occurrence of product innovation.
H3:	**Increase in total *R&D expenditure* increases the likelihood of occurrence of *process innovation*.**
H3a:	Increase in **Internal R&D expenditure** increases the likelihood of occurrence of process innovation.
H3b:	Increase in **External R&D expenditure** increases the likelihood of occurrence of process innovation.
H3c:	Increase in **External-Domestic R&D expenditure** increases the likelihood of occurrence of process innovation.
H3d:	Increase in **External-Foreign R&D expenditure** increases the likelihood of occurrence of process innovation.
H4:	**Increase in total *R&D intensity* increases the likelihood of occurrence of *process innovation*.**
H4a:	Increase in **Internal R&D intensity** increases the likelihood of occurrence of process innovation.
H4b:	Increase in **External R&D intensity** increases the likelihood of occurrence of process innovation.
H4c:	Increase in **External-Domestic R&D intensity** increases the likelihood of occurrence of process innovation.
H4d:	Increase in **External-Foreign R&D intensity** increases the likelihood of occurrence of process innovation.

Firm-level unbalanced panel data set was generated by considering differences in document types, data recording, and data types. Because of these kinds of differences in micro data sets, the data generating process took a while. After, duplicated data is cleaned from the panel data set. In order not to reduce the degree of freedom, some missing data such as number of personnel and R&D expenditure are filled with zero. Main variables are generated and shown in Table 1.

External R&D expenditure is separated into two parts such as external-domestic R&D expenditure and external-foreign R&D expenditure, based upon the idea of Un and Rodrigues (2018). External-domestic R&D expenditure means that expenditures for R&D activities that are conducted by an organization or institution in the country while external-foreign R&D expenditure for R&D activities on abroad. In this study, the analysis is focused on R&D expenditure and its four sub-breakdowns such as internal, external, external-domestic, and external-foreign.

R&D intensity is one of the much-discussed variables in literature. Horowitz (1962), Hamberg (1964), and Freeman and Soete (2004) pointed out R&D intensity related to R&D expenditure and R&D

intensity related to R&D personnel number. In this study, both R&D intensity variables were used and called R&D intensity and R&D personnel intensity respectively. R&D intensity is a proxy variable as indicator of R&D investment, and R&D personnel intensity is a proxy variable as indicator of know-how. In this study, the analysis is also focused on R&D intensity, the former one. Moreover, R&D intensity is calculated with total R&D expenditure and its four sub-breakdowns. Therefore, R&D intensity is also used as total, internal, external, external-domestic, and external-foreign.

This study has objectives of emphasizing the importance of R&D in terms of growth and development based on innovation and technology, analyzing the effect of R&D on likelihood of occurrence of product and process innovation in Turkish manufacturing industry. These are done by separation of R&D variables into its breakdowns.

To accomplish these objectives, firm-level panel data was generated with four different micro data sets provided by TURKSTAT. A panel (longitudinal, micro panel) data is described as "*same cross-sectional unit surveyed over time*" (Gujarati and Porter, 2009) and "*data for multiple entities in which each entity is observed at two or more time periods*" (Stock and Watson, 2020).

In the panel data, there are binary responses of firms for product and process innovation. Binary response models are important to analyze binary dependent variables. Such models including the logit and probit models are aimed to analyze the probability of an event occurring. The logit model explains $\ln\{y/(1-y)\}$ (natural log of odds), and the probit model explains ϕ^{-1} (y) where $\phi(\,)$ is the normal cumulative distribution function. To analyze the effect of R&D expenditure on the likelihood of occurrence of product and process innovation in Turkish manufacturing industry, the probit model was used in the panel data analysis.

Probit regression are nonlinear regression model and uses standard normal cumulative probability distribution function (Stock and Watson, 2020), and it is designed for binary variables like our dependent variables such as product and process innovation (if a firm introduced innovation—1 or not—0). In this study, probit regression is with binary dependent variables product innovation (PD) and process innovation (PC). This regression models the probability that a firm introduced innovation—1 (likelihood of occurrence of innovation), and it has multiple independent variables (regressors).

The probit model with a multiple regressors in this study as:

$$Pr(Y=1|X_1, X_2, \ldots, X_k\,) = \phi(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k) \quad (1)$$

where ϕ is the cumulative standard normal distribution function (c.d.f.). It can be said that the likelihood of occurrence of innovation is assumed to be determined by this distribution (c.d.f.). In this study, Y is binary dependent variable which is product innovation (PD) and process innovation (PC), X is independent variables such as R&D expenditure types (RE), R&D intensity types (RI), R&D personnel intensity, turnover, Herfindahl-Hirschman index, number of R&D personnel with a graduate degree, industrial production index, and real sector confidence index.

There are two types of panel probit models including random-effects probit model and population-averaged probit model. Sribney (n.d.) explained differences between random-effects and population-averaged estimators. Moreover, he emphasized that population parameters of random-effects model (β) and population-averaged model (β^*) are same if correlation is zero ($\mu_i = 0$) and underlined that population-averaged model (marginal models) expresses clearly marginal distribution. This model describes changes in the population mean given changes in regressors. In this analysis, population-averaged panel probit model[8] was used under some conditions such as robust standard errors, confidence interval level 90 percent, and exchangeable within-group correlation structure, and the model use a generalized estimating equation (GEE) approach.

In this study, there are four main models together with hypotheses mentioned in Table 3. Product Innovation models with R&D expenditure labeled as PDRE and with R&D intensity as PDRI, while process innovation models with R&D expenditure labeled as PCRE and with R&D intensity as PCRI, as mentioned by Song and Oh (2015). Together with five different R&D expenditure variables and five

[8] It is explained by Stata (2021) that another way to fit population-averaged panel data models is generalized estimating equation (GEE) that fits generalized linear models, and you can choose within-group correlation structure for panel data sets.

different R&D intensity variables mentioned in Table 1, there are twenty models in total (in Table 4) to analyze the effect of R&D expenditure on the probability of occurrence of product and process innovation in all Turkish manufacturing industry between 2009 and 2016. This analysis was focused on firms that conduct R&D activities.

Table 4. R&D Models

Product Innovation (PD) Models	Process Innovation (PC) Models	Variable Label	Other variables
PDRE1	PCRE1	Total R&D Expenditure	R&D (Personnel) Intensity Inflation-Adjusted Turnover (Inflation-Adjusted Turnover)^2 Herfindahl-Hirschman Index Number of R&D Personnel Industrial Production Index Real Sector Confidence Index
PDRE2	PCRE2	Total Internal R&D Expenditure	
PDRE3	PCRE3	Total External R&D Expenditure	
PDRE4	PCRE4	Total External-Domestic R&D Expenditure	
PDRE5	PCRE5	Total External-Foreign R&D Expenditure	
PDRI1	PCRI1	Total R&D Intensity	
PDRI2	PCRI2	Internal R&D Intensity	
PDRI3	PCRI3	External R&D Intensity	
PDRI4	PCRI4	External-Domestic R&D Intensity	
PDRI5	PCRI5	External-Foreign R&D Intensity	

Turkish manufacturing industry is classified by NACE Rev.2. According to generated panel data, because there were no enough observation number, some sub-industries could not be analyzed separately such as (with NACE Rev.2 divisions) 11-manufacture of beverages, 15-manufacture of leather and related products, 16-manufacture of wood and of products of wood and cork, except furniture); manufacture of articles of straw and plaiting materials, 17-manufacture of paper and paper products, 18-printing and reproduction of recorded media, 19-manufacture of coke and refined petroleum products, 32-other manufacturing, 33-repair and installation of machinery and equipment. Additionally, because of estimates diverging (correlation>1) and convergence not achieved, 26-manufacture of computer, electronic and optical products was not analyzed. However, the rest of sub-industries in Turkish manufacturing industry can be analyzed separately such as 10-manufacture of food products, 13-manufacture of textiles, 14-manufacture of wearing apparel, 20-manufacture of chemicals and chemical products, 21-manufacture of basic pharmaceutical products and pharmaceutical preparations, 22-manufacture of rubber and plastic products, 23-manufacture of other non-metallic mineral products, 24-manufacture of basic metals, 25-manufacture of fabricated metal products, except machinery and equipment, 27-manufacture of electrical equipment, 28-manufacture of machinery and equipment, 29-manufacture of motor vehicles, trailers and semi-trailers, 30-manufacture of other transport equipment, 31-manufacture of furniture. Because there is no data for firms who conduct R&D activities in tobacco products sector (12-manufacture of tobacco products), it was not considered.

In this study, Turkish manufacturing industry was analyzed as a whole. Two innovation activities are used as a dependent variable such as product and process innovation. Two distinct variables such as R&D expenditure and R&D intensity are used to measure R&D activities in Turkish manufacturing industries. PDRE, PDRI, PCRE, and PCRI models were estimated with their sub-models. In the next section, the results of the analyses were presented.

3. EMPIRICAL RESULTS

Turkish manufacturing industry was analyzed as a whole in this part for product and process innovation. Because there are no R&D activities in 12-manufacture of tobacco products, it is not included in the analysis.

3.1. Product Innovation in Turkish Manufacturing Industry as a Whole

R&D Expenditure. In PDRE1 and PDRE2 models, total R&D expenditure and internal R&D expenditure are statistically significant at the 1% significance level. In PDRE3 and PDRE4 models, external R&D expenditure and external-domestic R&D expenditure are statistically significant at the

5% significance level. Model PDRE5 couldn't be analyzed because of convergence not achieved. These R&D expenditures that mentioned here have a positive effect on the likelihood of occurrence of product innovation.

R&D Intensity. In PDRI1 and PDRI2 models, total R&D intensity and internal R&D intensity are not statistically significant at the 10% significance level. In PDRI3 and PDRI4 models, external R&D intensity and external-domestic R&D intensity are statistically significant at the 1% significance level. In PDRI5 model, external-foreign R&D intensity is statistically significant at the 10% significance level. External R&D intensity, external-domestic R&D intensity, and external-foreign R&D intensity have a positive effect on likelihood of occurrence of product innovation.

Table 5. R&D Expenditure (RE) and R&D Intensity (RI) for Product Innovation

Hypothesis	Model	Coef.	Semirobust Std. Err.	z	p > |z|	dy/dx
H1:	PDRE1	.1267727 ***	.0195155	6.50	**0.000**	.0422289
H1a:	PDRE2	.1268494 ***	.0194804	6.51	**0.000**	.0422762
H1b:	PDRE3	.0116638 **	.0048064	2.43	**0.015**	.0039172
H1c:	PDRE4	.0101054 **	.0048958	2.06	**0.039**	.0033948
H1d:	PDRE5	-	-	-	-	-
H2:	PDRI1	.0021031	.0039684	0.53	0.596	.0007081
H2a:	PDRI2	.002074	.0040771	0.51	0.611	.0006983
H2b:	PDRI3	.6277259 ***	.1821199	3.45	**0.001**	.2110222
H2c:	PDRI4	.6919345 ***	.1817517	3.81	**0.000**	.2325867
H2d:	PDRI5	.793799 *	.4272043	1.86	**0.063**	.2629332

Panel data was generated from four different micro datasets by the author.
z is z-statistics. dy/dx is marginal effects after panel probit.
Significance level: * p<0.1 ** p<0.05 *** p<0.01

Source: (TURKSTAT).

3.2. Process Innovation in Turkish Manufacturing Industry as a Whole

R&D Expenditure. In PCRE1, PCRE2, and PCRE5 models, total R&D expenditure, internal R&D expenditure, and external-foreign R&D expenditure are statistically significant at the 1% significance level. They have a positive effect on the likelihood of occurrence of process innovation. In PCRE3 and PCRE4 models, external R&D expenditure and external-domestic R&D expenditure are not statistically significant at the 10% significance level.

R&D Intensity. In PCRI1 and PCRI2 models, total R&D intensity and internal R&D intensity are not statistically significant at the 10% significance level. In PCRI3 and PCRI4 models, external R&D intensity and external-domestic R&D intensity are statistically significant at the 1% significance level. In PCRI5 model, external-foreign R&D intensity is statistically significant at the 5% significance level. External R&D intensity, external-domestic R&D, and external-foreign R&D intensity have a positive effect on the likelihood of occurrence of process innovation.

Table 6. R&D Expenditure (RE) and R&D Intensity (RI) for Process Innovation

Hypothesis	Model	Coef.	Semirobust Std. Err.	z	p > |z|	dy/dx
H3:	PCRE1	.1301747 ***	.0179656	7.25	**0.000**	.0408538
H3a:	PCRE2	.130789 ***	.0180676	7.24	**0.000**	.0410551
H3b:	PCRE3	.0033748	.0052454	0.64	0.520	.0010655
H3c:	PCRE4	.0002835	.0053502	0.05	0.958	.0000895
H3d:	PCRE5	.0288654 ***	.0102914	2.80	**0.005**	.0090997
H4:	PCRI1	.0017965	.0040236	0.45	0.655	.0005675
H4a:	PCRI2	.0017557	.0041204	0.43	0.670	.0005546
H4b:	PCRI3	.8402827 ***	.1936959	4.34	**0.000**	.2646266
H4c:	PCRI4	.7958199 ***	.1781985	4.47	**0.000**	.2507277
H4d:	PCRI5	29.23187 **	14.16099	2.06	**0.039**	9.130824

Panel data was generated from four different micro datasets by the first author.
z is z-statistics. dy/dx is marginal effects after panel probit.
Significance level: * p<0.1 ** p<0.05 *** p<0.01

Source: (TURKSTAT).

CONCLUSION

This study aims to examine the effect of R&D expenditure and R&D intensity on likelihood of occurrence of product and process innovation in Turkish manufacturing industry for the period between 2009 and 2016, respectively.

The empirical results are summarized and separated into two parts such as R&D expenditure part and R&D intensity part. As a summary of the first part, R&D expenditure has effects on product and process innovation. Total R&D expenditure and internal R&D expenditure are statistically significant at the 1% significance level and have a positive effect on both product and process innovation. External R&D expenditure and external-domestic R&D expenditure have positive effect only on product innovation (statistically significant at the 5% significance level) while external-foreign R&D expenditure has positive effect only on process innovation (statistically significant at the 1% significance level). As a summary of the second part, only external R&D intensity, external-domestic R&D intensity, and external-foreign R&D intensity have positive effect on both product and process innovation. External R&D intensity and external-domestic R&D intensity are statistically significant at the 1% significance level for both product and process innovation. External-foreign R&D intensity is statistically significant at the 1% significance level for product innovation, and statistically significant at the 5% significance level for process innovation.

R&D policies and industrial policies should be determined differently according to innovation types, R&D expenditure types, and R&D intensity types. From R&D expenditure perspective, firms can increase their total R&D expenditure and internal R&D expenditure to increase the likelihood of occurrence of both product and process innovation. Firms can increase their external R&D expenditure and external-domestic R&D expenditure if they need external R&D to increase the likelihood of occurrence of product innovation. Firms can increase their external-foreign R&D expenditure if they need external R&D from abroad to increase the likelihood of occurrence of process innovation. From R&D intensity perspective, firms can increase external R&D intensity, external-domestic R&D intensity, and external-foreign R&D intensity if they need external R&D to increase the likelihood of occurrence of both product and process innovation. To increase these intensities, firms should increase the share of external R&D expenditure, external-domestic R&D expenditure, and external-foreign R&D expenditure in turnover. Technically, these external R&D expenditures will increase total R&D expenditure and therefore both product and process innovation will be affected.

Empirical results of this study strongly support to last 5YDP and its R&D and innovation policies that Turkish government introduced in 2019. As a result of this study, R&D activities supported by R&D expenditure and R&D intensity will catalyze and increase the likelihood of occurrence of product and process innovation in Turkish manufacturing industry.

According to empirical results, micro-level (for firms) and macro-level (for government) policy recommendations can be explained separately such as:

- Firms should increase their internal R&D expenditures primarily to increase the likelihood of occurrence of product and process innovation. If firms need external R&D activities, for product innovation they can increase their external-domestic R&D expenditure secondarily, and for process innovation they can increase external-foreign R&D expenditure secondarily.
- If firms need external R&D activities to increase the likelihood of occurrence of product and process innovation, they can increase their external-domestic R&D intensity primarily, and external-foreign R&D intensity secondarily.
- To increase the likelihood of occurrence of product and process innovation, government should support firms more to increase their internal R&D activities primarily with some policies such as R&D incentives, tax reduction, and so on.
- To minimize R&D expenditure to abroad, the government should determine fields that firms need external R&D from abroad. These fields should be boosted by incentives. Therefore, external-foreign R&D expenditure by firms can be decreased while external-domestic R&D expenditure can be increased.

- To increase know-how by R&D research, and to keep intellectual property rights in the country, government should provide an environment for firms to come together and cluster in the country. This environment supports R&D activities, know-how, and intellectual property rights.
- Government should provide an efficient education system to support R&D environment, innovation culture, and collaboration culture.
- The government should improve and keep up-to-date technological infrastructure and institutional necessities to accelerate R&D activities.

This study has some limitations such as dummy variable problem, change in structure of innovation survey, data confidentiality, and providing limited data by TURKSTAT. First, innovation survey based on Oslo Manual measures product and process innovation by using dummy variable (if a firm introduced innovation—1 and if a firm does not introduced innovation—0). To measure innovation is complicated phase with dummy variables that may cause biased results. Second, innovation survey structure was changed in 2018 and thus the analysis could not be done for all surveys because of incompatibility with the previous one. Third, Group-A micro data sets provided by TURKSTAT are under the rule of data confidentiality thus only the results of the analysis can be shared. Last, TURKSTAT provides a limited period of data because the data was revised from 2009 until today according to administration records. That is why this study is based on the period between 2009 and 2016.

For further study, researchers may focus on analyzing sub-sectors separately and in detail to understand sectoral R&D dynamics and determinants of innovation. For instance, further analyses on Turkish manufacturing industry regarding 3 digits, 4 digits, and 6 digits of NACE Rev.2 classification should be investigated in detail.

Ethics Statement: *In this study, no method requiring the permission of the "Ethics Committee" was used. A protocol was signed between Istanbul University and TURKSTAT in order to use micro data of some questionnaire conducted by TURKSTAT for Ph.D. dissertation. This study is derived from a Ph.D. dissertation. In case of detection of a contrary situation, Beykent University Journal of Social Sciences has no responsibility, and all responsibility belongs to the author (s) of the study.*
Author Contributions Statement: *1st author's contribution rate 75%, 2nd author's contribution rate 25%.*
Conflict of Interest**:** *There is no conflict of interest among the authors.*

Etik Beyan: *Bu çalışmada "Etik Kurul" izini alınmasını gerektiren bir yöntem kullanılmamıştır. Türkiye İstatistik Kurumu (TÜİK) tarafından yapılan bazı anketlerin mikro verilerinin doktora tezi için kullanılması amacıyla İstanbul Üniversitesi ve TÜİK arasında bir protokol imzalanmıştır. Bu çalışma ise doktora tezinden üretilmiştir. Aksi bir durumun tespiti halinde Beykent Üniversitesi Sosyal Bilimler Dergisinin hiçbir sorumluluğu olmayıp tüm sorumluluk çalışmanın yazar (lar) ına aittir.*
Yazar Katkı Beyanı*:1'inci yazarın katkı oranı %.75, 2'nci yazarın katkı oranı ise %25'tir.*
Çıkar Beyanı*: Yazarlar arasında çıkar çatışması yoktur.*

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