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Factors Impacting on Product and Process Innovation Capability: An Empirical Analysis on Manufacturing Firms in Turkey

Ürün ve Süreç İnovasyon Yeteneğini Etkileyen Faktörler: Türkiye'deki İmalat Firmaları Üzerine Ampirik Bir Analiz

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ÖZ

Bu çalışmanın amacı Türkiye'deki imalat sanayi firmalarının ürün ve süreç inovasyonu yeteneklerini etkileyen faktörleri ampirik olarak araştırmaktır. Bu amaçla, 2019 yılı Dünya Bankası İşletme Araştırması (WEBS) verileri kullanılarak, binary lojistik ve bivariate probit regresyon analizleri yöntemiyle, inovasyonu etkileyen faktörler analiz edilmiştir. Çalışmanın temel bulguları şu şekilde özetlenebilir: (i) "içsel Ar-Ge" faaliyetleri firmaların hem ürün hem de süreç inovasyonu faaliyetlerinde belirleyici bir güç olarak ortaya çıkmaktadır; (ii) "Yabancı Teknoloji Kullanımı" süreç inovasyonu konusunda zayıf bir etki ortaya koyarken, firmaların ürün inovasyonu için temel bir itici güç olarak ortaya çıkmaktadır. Bu bulgu, firmaların ürün inovasyonu olasılığının yabancı teknoloji kullanımı ile arttığını ortaya koymaktadır; (iii) "Yabancı Sahiplik", bivariate probit regresyon analizi bulgularına göre, süreç inovasyonu faaliyetlerini olumlu olarak etkilemektedir; (iv) "Beşerî Sermaye Gelişimi", binary lojistik regresyon analizi bulgularına göre, ürün ve süreç inovasyonu faaliyetlerini pozitif olarak etkilemektedir. Bulgular, Türk imalat sanayi firmalarının inovasyon faaliyetlerini teşvik etmede kurum içi Ar-Ge faaliyetlerinin ve yabancı teknoloji kullanımının önemini ortaya koymaktadır.

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ABSTRACT

The purpose of the study is to empirically investigate the factors that impact on both product and process innovation capabilities of the manufacturing firms in Turkey. For this purpose, by using the 2019 World Bank Enterprise Survey (WEBS) database, the factors affecting innovation were analyzed by conducting binary logistic and bivariate probit regression analysis methods. The key findings can be summarized as follows: (i) remarkably, "internal R&D" activities of the firms emerge as a determining force in both product and process innovation activities of firms; (ii) while "Foreign Technology Use" reveals a weak effect on process innovation, it emerges as a key driver for firms' product innovation. This means that the likelihood of firms' product innovation increases with the use of foreign technology; (iii) "Foreign Ownership" positively affects process innovation activities, according to the bivariate probit regression analysis; (iv) "Human Capital Development" positively impacts on both product and process innovation activities according to the findings of binary logistic regression analysis. The findings of the study reveal the importance of in-house R&D activities and using foreign technology in promoting the innovation activities of Turkish manufacturing firms.

1. Introduction

In today's rapidly evolving global marketplace, the pursuit of innovation has become a central driver for the sustained growth and competitiveness of manufacturing firms. As a pivotal intersection between economic development, technological advancement, and market dynamics, innovation capability has garnered significant attention from scholars, practitioners, and policymakers alike (Neely et al., 2001). Also, in today's business landscape, innovation stands as a pivotal instrument for enterprises seeking to gain a competitive edge, enhance profitability, and generate value by introducing novel offerings into the market (Memiş

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& Korucuk, 2023).

Currently manufacturing firms in different contexts try to make use of innovation. It is important for manufacturing firms for several reasons. It can lead to the development of new technologies, processes, and techniques that help manufacturing firms streamline their operations and improve efficiency. This can result in cost savings, increased productivity, and higher competitiveness. Also, it allows manufacturing firms to develop new and improved products that meet changing customer demands and preferences. By introducing innovative products, firms can stay ahead of their competitors and attract a larger customer base. Additionally, it helps manufacturing firms adapt to changes in the market and overcome challenges. By constantly innovating, firms can respond to shifts in consumer behavior, market trends, and industry advancements more effectively. Furthermore, it enables manufacturing firms to sustain long-term growth by continuously improving their products, processes, and business models. This helps them stay relevant in a rapidly evolving market and maintain a competitive edge. Through innovation, manufacturing firms can differentiate themselves from their competitors. By offering unique and innovative products, firms can establish themselves as industry leaders and attract more customers. In addition to the mentioned pros of innovation, embracing innovation often involves collaboration with external partners, such as suppliers, research institutions, and other industry players. This can lead to valuable networking opportunities and knowledge sharing, which can further enhance a firm's innovation capabilities (Hagedoorn & Duysters, 2002; Sönmez & Pamukçu, 2013).

Innovation capability encompasses an organization's inherent ability to consistently generate novel ideas, proficiently develop and implement innovative solutions, and remain adaptable in response to evolving market conditions. It includes both the ability to create new products, services, or processes, as well as the ability to manage and leverage those innovations to gain a competitive advantage (Kahn, 2018). Having strong innovation capability means that an organization has a culture that encourages and rewards creativity, a systematic approach to generating and evaluating new ideas, and the processes, resources, and skills necessary to turn those ideas into successful innovations. It also involves the ability to anticipate and respond to market trends and competitive forces, continuously improving products and services to meet evolving customer needs (Peres et al., 2010).

While studies agree that innovation is key to the success of manufacturing firms, the unanswered question on this regard is the degree of importance and effectiveness of the key determinants of innovation mainly human capital development (HCD), internal R&D, foreign technology use (FTU) and foreign ownership (FO) for the two main types of innovation namely product and process innovation. To the best of our knowledge none of the studies have touched upon the subject topic in the context of Turkey.

The purpose of this study is to investigate the determinants of innovation capability of the manufacturing firms in Turkey. For this purpose, by conducting empirical research, we are trying to understand how factors such as HCD, internal R&D, FTU, and FO impact both product and process innovation activities of the manufacturing firms in Turkey. In other words, we try to explore the fact if HCD, internal R&D, FTU and FO have different impacts on product and process innovation. This study also aims to provide valuable insights that can inform strategic decision-making and policy development. In addition, the findings may play a role in advancing the academic discourse surrounding innovation and a role in moving manufacturing firms forward in a competitive business ecosystem. Ultimately, this study seeks to enrich our understanding of the intricate relationship between innovation, firm-level dynamics, and the broader economic environment.

The rest of the study is organized as follows. The first section is allocated to introduction which presents the stylized facts about the innovation. Section 2 presents the literature review on the findings of the empirical studies on product and process innovation. Next section describes the data and methodology. Section 4 presents the empirical analysis and findings. The last section contains discussion and conclusion.

2. Literature Review

In recent years, the study of innovation capability within the manufacturing sector has gained prominence as a critical factor in enhancing firm competitiveness and driving economic growth. Research in this field has highlighted the dynamic interplay of various determinants that shape a firm's ability to innovate, both in terms of products and processes. This literature review synthesizes key findings from existing studies on innovation capability, focusing specifically on manufacturing firms operating in Turkey. Product innovation, characterized by the creation and introduction of novel products or improvements to existing ones, is a pivotal driver of firm success. Research findings suggests that a combination of internal and external factors influences a firm's product innovation capability. Internal determinants include organizational culture, leadership commitment, R&D investments, and human capital. For instance, Valencia et al., (2010) found that firms fostering a culture of experimentation and risk-taking tend to exhibit higher levels of product innovation. External determinants encompass factors such as collaboration with research institutions, access to external knowledge, and industry competition. Tsai (2009) emphasized the significance of collaborative networks in enhancing product innovation capabilities, enabling firms to tap into a broader knowledge base and diverse expertise. Process innovation, involving the enhancement or transformation of production methods and operational processes, is equally crucial for manufacturing firms seeking competitive advantage. Organizational factors, technological infrastructure, and regulatory environment play pivotal roles in shaping process innovation capability. Gupta et al., (2020) highlighted the importance of flexible manufacturing systems and technology adoption in driving process innovation among manufacturing firms. Furthermore, the literature underscores the role of government policies, industry support mechanisms, and international trade in influencing process innovation. Patanakul & Pinto (2014) and Sivak et al., (2011) demonstrated that favorable government policies and incentives can catalyze process innovation activities in the manufacturing sector.

Determinants of innovation capability can vary across industries, sectors, and organizational contexts, and the relative importance of each determinant may differ for each situation. According to different studies (Baldwin & Johnson, 1995; Ma et al., 2019; McGuirk et al., 2015), HCD plays a significant role in influencing the product and process innovation capability of manufacturing firms. Investing in employee skills, knowledge, and expertise can lead to improved creativity, problem-solving abilities, and a deeper understanding of industry trends. This, in turn, can drive innovation in product design, development, and manufacturing processes. Well-trained and skilled employees are more likely to generate novel ideas, implement efficient processes, and adapt to changing technological advancements, all of which contribute to the overall innovation capability of the firm.

According to some of the relevant studies, one of the key determinants of innovation is internal R&D activities (Adalikwu, 2011; Gallié & Legros, 2012; Pegkas et al., 2019). It can significantly impact the product and process innovation capability of manufacturing firms. Internal R&D allows firms to conduct in-depth research, experiment with new ideas, and develop novel technologies, which can lead to the creation of innovative products and more efficient manufacturing processes. By investing in internal R&D, firms can stay at the forefront of technological advancements, adapt to market changes, and maintain a competitive edge in their industry.

As different studies have found, another factor effecting product and process innovation capability of manufacturing firms is foreign technology use (Liu & White, 1997). Sönmez & Pamukçu (2013) in their study suggest that the impact of foreign technology use on local firms in emerging economies, particularly in the Turkish manufacturing industry, is primarily channeled through technology spillovers facilitated by Foreign Direct Investment (FDI). The study's econometric analysis reveals that when a comprehensive definition of foreign ownership is considered, horizontal technology spillovers occur from foreign to local firms within the same sector. Notably, export-oriented firms do not experience significant benefits from these spillovers, unlike firms that predominantly cater to the local market. Interestingly, the impact of foreign technology use varies based on the extent of foreign ownership, as spillovers appear to stem from foreign firms with majority or full foreign ownership, while no discernible effect is associated with minority-owned foreign firms. These findings shed light on the nuanced relationship between foreign technology infusion and firm-level growth in the Turkish manufacturing industry during the specified period. The utilization of foreign technology can have a notable impact on the product and process innovation capability of manufacturing firms. Access to foreign technology can bring in new ideas, advanced techniques, and specialized knowledge that may not have been previously available domestically. This infusion of technology can lead to improvements in product quality, production efficiency, and the development of innovative products and processes. Collaborating with or adopting foreign technology can enhance a manufacturing firm's ability to stay at the forefront of innovation and remain competitive in the global market.

Some studies in the literature have found foreign ownership to be playing a key role in product and process innovation capability of manufacturing firms (Díaz-Díaz et al., 2008). Foreign ownership can indeed influence the product and process innovation capability of manufacturing firms. When a manufacturing firm is owned by foreign entities, it may benefit from increased access to international markets, networks, and technologies. This can potentially lead to the transfer of knowledge, best practices, and innovative ideas from the foreign parent company or other subsidiaries. Foreign ownership can also bring in diverse perspectives and expertise, fostering a culture of innovation within the firm. However, the extent of the impact depends on various factors such as the level of collaboration, the transfer of technology, and the management practices of the foreign owners. In some cases, foreign ownership might lead to a focus on cost-cutting and standardized processes, which could limit the emphasis on local product and process innovation. Ultimately, the effects of foreign ownership on innovation capability can vary based on the specific circumstances and strategies of the manufacturing firm. Memiş & Korucuk's (2019) study prioritizes innovation elements in food enterprises using Dematel and Vikor techniques. According to the study, service innovation ranks highest, followed by customer, organizational, management, process, marketing, and technology innovation, with product innovation as the least significant (Memiş & Korucuk, 2019).

The unique context of manufacturing firms operating in Turkey adds a layer of complexity to the study of innovation capability. Turkey's dynamic economy, strategic geographical location, and diverse industrial sectors contribute to a distinctive innovation landscape. Several studies have examined the impact of cultural factors, supply chain dynamics, and access to finance on innovation performance in firms (Mahendra et al., 2015; Topal & Sahin, 2018). However, there remains a gap in the literature regarding a comprehensive comparative exploration of the determinants of both product and process innovation capability specific to the Turkish manufacturing context. Based on the availability of data, this study aims to address this gap by comparatively examining a set of four factors namely; (i) HCD, (ii) internal R&D, (iii) foreign technology use (FTU) and (iv) foreign ownership (FO) that shape innovation capability. In sum, the literature review underscores the multifaceted nature of innovation capability and its pivotal role in the success of manufacturing firms. By synthesizing insights from prior studies, this study lays the foundation for a comprehensive comparative analysis of the determinants of both product and process innovation capability within the unique context of manufacturing firms operating in Turkey.

3. Data and Methodology

3.1 Data

This study draws upon data sourced from the World Bank Enterprise Survey (WEBS), a comprehensive data collection initiative that spanned from September 2018 to May 2019 (World Bank, 2019). The WEBS has played a pivotal role in enabling a rigorous exploration of the determinants of product and process innovation capability within Turkey's manufacturing sector. The WEBS employed a robust methodology to gather data from a diverse spectrum of manufacturing firms operating in Turkey. By leveraging an internationally recognized framework, the survey ensured a standardized approach to data collection, encompassing various dimensions pertinent to innovation capability. The dataset we utilize is extensive, incorporating data from a total of 1,664 manufacturing firms in Turkey. This breadth of coverage significantly enhances the representativeness of our study and underscores the applicability of our findings to the entire manufacturing sector. Within the WEBS dataset, we have access to an array of variables meticulously designed to capture key aspects relevant to our research objectives. These variables include, among others, product and process innovation, HCD, internal R&D activities, FTU and FO status. The WEBS, renowned for its adherence to rigorous quality standards, incorporated robust validation processes and quality control checks. This ensures the integrity, accuracy, and reliability of the data we employ for our analyses. The WEBS dataset stands as an invaluable resource empowering our research to illuminate the multifaceted determinants of product and process innovation capability within Turkey's manufacturing landscape. By harnessing this rich dataset, we endeavor to uncover nuanced insights into the interplay between various factors and their impact on innovation outcomes, contributing to both academic discourse and practical decision-making. In essence, the data derived from the WEBS, conducted between September 2018 and May 2019 and encompassing information from 1,664 manufacturing firms in Turkey, forms the bedrock upon which our study is conducted. This dataset underpins our analysis, facilitating an in-depth examination of the intricate dynamics surrounding innovation capability in the manufacturing sector.

In the following Table 1, we present the variables used in two distinct regression models to comparatively examine the impact of innovation determinants on product and process innovation. The dependent variables are "*Product Innovation*" and "*Process Innovation*", which are represented as dummy variables taking a value of 1 if the firm has the respective innovation type, and 0 otherwise. The independent variables include key factors that may influence innovation outcomes. These variables are: "HCD", a dummy variable indicating the presence of product innovation; "Internal R&D", a dummy variable reflecting the firm's engagement in internal R&D activities; "FTU", a dummy variable denoting the use of foreign technology; and "FO", a dummy variable indicating the presence of foreign ownership. The Table 1 below provides a comprehensive overview of these variables for each firm included in the analysis.

Table 1: Dependent and Independent Variables

Variables	**Explanation**
Product Innovation	1 if the firm has product innovation, and 0 otherwise.
Process Innovation	1 if the firm has process innovation, and 0 otherwise.
Human Capital Development (HCD)	1 if the firm has invested in HCD, and 0 otherwise.
Foreign Technology Use (FTU)	1 if the firm utilizes foreign technology, and 0 otherwise.
Foreign Ownership (FO)	1 if the firm has foreign ownership, and 0 otherwise.
Internal R&D	1 if the firm conducts internal R&D activities, and 0 otherwise.

Source: Constructed by authors based on the WEBS database.

3.2 Methodology

In this study, firstly, we have employed a binary logistic regression analysis. It is a widely used method in similar studies and a well-established statistical technique (Kühne et al., 2013; Genis-Gruber & Öğüt, 2014; Adeyeye et al., 2016; Seo et al. 2017; Lukovszki et al., 2021). This analysis method offers distinct advantages over alternative approaches. Its key differences lie in its ability to model the relationship between a binary dependent variable and one or more independent variables. Unlike other methods, it provides probabilities and odds ratios, making it well-suited for analyzing and predicting binary outcomes (Maroof, 2012).

The dependent variables in this study are of binary nature. So, the binary logistic regression analysis is used to analyze the relationship between independent variables and a binary outcome variable, which in our case represents the presence or absence of product innovation and process innovation activities of the manufacturing firms in Turkey. In our study, we are interested in exploring the determinants of product and process innovation capability of the manufacturing firms in Turkey. So, we conduct binary logistic regression to model the probability of a firm having product innovation (equation 1) and process innovation (equation 2) based on a set of independent variables. The dependent variables in two equations are of a dummy nature, taking a value of 1 if the firm has the respective innovation, and 0 otherwise. For each equation, we build a binary logistic regression that estimates the log-odds of the respective innovation occurring based on the values of the independent variables. The equation 1 below presents the product innovation model, and equation 2 presents the process innovation model. Therefore, following empirical models are estimated:

$$\log(odds\ of\ having\ Product\ Innovation)_i = \beta_0 + \beta_1(HCD)_i + \beta_2(FTU)_i + \beta_3(FO)_i + \beta_4(Internal\ R\&D)_i \quad (1)$$

$$\log(odds\ of\ having\ Process\ Innovation)_i = \beta_0 + \beta_1(HCD)_i + \beta_2(FTU)_i + \beta_3(FO)_i + \beta_4(Internal\ R\&D)_i \quad (2)$$

The former model denotes firm i's product innovation capability, and the latter shows the firm i's process innovation capability. Where, β's are coefficients representing the effect of each independent variable. HCD, FTU, FO and Internal R&D are the independent variables representing characteristics of the firms likely to impact the firm i's product and process innovation capability as defined in the Table 1. In addition, to find the subject relation in a separate bivariate model we have used both product and process innovation as two dependent variables alongside the independent models of the mentioned types of innovation.

In this study, secondly, we have conducted bivariate probit regression analysis alongside Pearson's chi-square test to comprehensively investigate the associations between the key variables. Bivariate probit regression provided a robust statistical framework for probing these relationships in greater depth (Ur Rehman, 2016; Gómez et al., 2016), while Pearson's chi-square test allowed us to rigorously examine associations among the variables. This dual approach facilitated a thorough exploration of the intricate connections between the variables, enhancing our understanding of innovation dynamics within the mentioned contexts. Therefore, two bivariate probit models are formulated as follows in equations 3 and 4:

$$Product\ Innovation_i\ (Y_1)\ Y_1^* = \beta_0 + \beta_1(HCD)_i + \beta_2(FTU)_i + \beta_3(FO)_i + \beta_4(Internal\ R\&D)_i + \varepsilon 1\ \ldots 1 \quad (3)$$

$$Y_1 = 1\ if\ Y_1^* > 0, else\ Y_1 = 0$$

$$Process\ Innovation_i\ (Y_2)\ Y_2^* = \gamma_0 + \gamma_1(HCD)_i + \gamma_2(FTU)_i + \gamma_3(FO)_i + \gamma_4(Internal\ R\&D)_i\ \varepsilon 2\ \ldots 2 \quad (4)$$

$$Y_2 = 1\ if\ Y_2^* > 0, else\ Y_2 = 0$$

We also investigate the joint occurrence of two binary dependent variables, namely, production (Y1) and process innovation (Y2), which represent the presence (1) or absence (0) of these types of innovation. The model incorporates four key binary independent variables including HCD, FTU, FO, and internal R&D. The coefficients (β1, β2, β3, β4 for Y1 and γ1, γ2, γ3, γ4 for Y2) associated with these independent variables elucidate their impact on the likelihood of innovation. Error terms (ε1 and ε2) account for latent variation in the equations 3 and 4 above. The bivariate probit regression framework facilitates a simultaneous examination of the determinants of both production and process innovation while acknowledging potential interdependencies between them.

4. Empirical Analysis and Findings

4.1 Correlation Matrix and Pearson's Chi-Square Test

Employing a correlation matrix serves to illuminate the interplay between the variables under examination. By quantifying the degree and direction of relationships among HCD, FTU, FO, and internal R&D the correlation matrix provides a valuable initial insight into potential associations. This foundational analysis not only guides subsequent steps by identifying potential connections for further investigation but also informs the choice of appropriate statistical methods to explore predictive relationships and enhance the study's overall rigor and depth of understanding.

The correlation matrices for independent variables are pivotal tools in uncovering the intricate relationships existing among the variables analyzed. These matrices encapsulate the strength and nature of associations between each independent variable, aiding in identifying direct or inverse connections. The numerical coefficients within the matrices offer a quantified measure of these relationships, with values near 1 or -1 indicating pronounced correlations and those near 0 suggesting weaker linkages. Serving as a foundational analysis, these correlation matrices shape subsequent research directions by guiding hypotheses refinement, statistical technique selection, and informing potential multicollinearity concerns. Ultimately, they provide a crucial initial insight into the interplay among independent variables, fostering a more comprehensive understanding of the research domain. Table 2 displays the correlations between the independent variables analyzed. As can be seen from the Table 2, they are low. The result of correlation matrix is as follows:

Table 2. Correlation Matrix for Independent Variables

Variables	(1)	(2)	(3)	(4)
(1) Human Capital Development (HCD)	1.000			
(2) Foreign Technology Use (FTU)	0.054	1.000		
(3) Foreign Ownership (FO)	0.118	0.082	1.000	
(4) Internal R&D	0.212	0.294	0.068	1.000

As shown in Table 2, the range of correlation coefficients, spanning from 0.054 to 1, reflects a spectrum of relationships among the variables. Notably, a minimal positive correlation of 0.054 ties the HCD and FTU, hinting at a subtle link between them. A more significant positive correlation of 0.212 underscores a meaningful connection between HCD and internal R&D, indicating that elevated development levels coincide with heightened engagement in internal R&D activities. Additionally, a weak positive correlation of 0.118 associates HCD with FO, signaling a potential yet not dominant relationship. Similarly, the correlation of 0.082 between FTU and FO implies a modest potential connection. Furthermore, a moderate positive correlation of 0.294 emerges between FTU and internal R&D activities, accentuating a more prominent relationship. This suggests that heightened utilization of foreign technology corresponds with increased involvement in internal R&D endeavors. Lastly, a subtle positive correlation of 0.068 is noted between FO and internal R&D, suggesting a minor correspondence. These correlation insights pave the way for subsequent statistical modeling, offering a comprehensive perspective on how variables interact within the study's framework.

In order to analyze the relationship between the dependent and independent variables, Pearson's chi-square independence test is used. According to the test results displayed in Table 3, we can conclude that there is an association between the variables.

Table 3. Results of Chi-Square Test

	HCD		**FTU**		**FO**		**Internal R&D**	
	Chi2	**P-value**	**Chi2**	**P-value**	**Chi2**	**P-value**	**Chi2**	**P-value**
Product Innovation	26.49	0.000***	65.64	0.000***	2.99	0.0838*	239.35	0.000***
Process Innovation	18.84	0.000***	24.72	0.000***	18.45	0.000***	81.49	0.000***

Note: *** p<0.01, ** p<0.05, * p<0.10

The correlation analysis and chi-square test results highlight several interesting relationships between the variables. These relationships can serve as a foundation for exploring predictive connections through binary logistic regression and bivariate probit regression. Given the correlations observed, a regression can serve as an appropriate analytical method to further investigate and quantify these relationships. Therefore, binary logistic and bivariate probit regression analysis allows for the assessment of the impact of independent variables on a binary outcome, aligning with the nature of the data we have used. By employing a regression analysis, we aim to go beyond correlations and establish a predictive model that considers multiple variables simultaneously.

4.2 Binary Logistic Regression Analysis

The empirical results derived from the binary logistic regression analysis aimed at exploring the impact of innovation determinants on product and process innovation are presented in Tables 4 and 5. We investigate the impact of key independent variables on two distinct dependent variables: "*product innovation*" and "*process innovation*". These dependent variables are represented as dummy variables, taking a value of 1 if the firm exhibits the respective type of innovation, and 0 if not. Our study examines the influence of several factors on these innovation outcomes, including "HCD", a dummy variable reflecting the presence of product innovation; "internal R&D", a dummy variable denoting engagement in internal R&D activities; "FTU", a dummy variable indicating utilization of foreign technology; and "FO", a dummy variable signifying the presence of foreign ownership. In the Tables 4 and 5 below, "odds ratio" presents the odds ratio for each variable, indicating how the odds of dependent variable change with a unit change in the independent, while holding other variables constant. Also, "95% CI" represents the 95% confidence interval for the odds ratio. It is worth mentioning that "p-value" indicates the statistical significance of each independent variable.

Table 4 displays the results of a binary regression model where the dependent variable is "*product innovation*". Regarding the findings, the odds ratio of 1.45 with a p-value of 0.082 for HCD suggests that, holding other variables constant, the odds of "product innovation" are 1.45 times higher for cases with HCD compared to those without. However, the p-value indicates that the relationship may not be highly statistically significant at conventional levels (p<0.05), so we should interpret this result cautiously (although it is statistically significant at p<0.10). Regarding the FTU, with an odds ratio of 2.11 and a low p-value of 0.002 for FTU, we can infer that, holding other variables constant, the odds of "product innovation" are 2.11 times higher when FTU is present compared to when it is not. The low p-value suggests that this relationship is highly statistically significant (p<0.01). In terms of the FO, the odds ratio of 1.33 with a p-value of 0.559 for FO indicates that, holding other variables constant, there is not a strong and statistically significant association between FO and the odds of "product innovation". Also, about internal R&D, an odds ratio of 9.96 with a p-value of 0.000 for internal R&D means that, holding other variables constant, the odds of "product innovation" are 9.96 times higher when internal R&D is present compared to when it is not. The very low p-value indicates that this relationship is highly statistically significant (p<0.01). Finally, the constant term with a value of 0.031 and a p-value of 0.000 represents the estimated log-odds of "product innovation" when all independent variables are zero. The very low p-value suggests that the constant term is highly statistically significant (p<0.01).

Table 4. Binary Logistic Regression Results for “Product Innovation” (Dependent Variable)

Independent Variables	**Odds Ratio**	**95% CI**	**P value**
Human Capital Development (HCD)	1.45*	(0.92, 2.30)	0.082
Foreign Tech Use (FTU)	2.11***	(1.33, 3.35)	0.002
Foreign Ownership (FO)	1.33	(0.64, 2.77)	0.559
Internal R&D	9.96***	(6.36, 15.59)	0.000
Constant	0.031***	(0.009, 0.102)	0.000
n 1.571			
Pseudo r2 0.199			
Chi2 171.733			
AIC 701.007			
BIC 727.804			
Prob > chi2 0.000			

Note: *** p<0.01, ** p<0.05, * p<0.10.

Table 5 below displays the results of a binary regression model where the dependent variable is "process innovation". Regarding the results, an odds ratio of 1.89 with a p-value of 0.078 for HCD means that, holding all other variables constant, the odds of "process innovation" are 1.89 times higher for cases with HCD compared to those without. However, the p-value suggests that the relationship may not be highly statistically significant at conventional levels (p<0.05), so we should interpret this result cautiously (although it is statistically significant at p<0.10). Regarding the adoption of foreign technology in a firm, an odds ratio of 1.73 with a p-value of 0.153 for FTU implies that, holding other variables constant, the odds of "process innovation" are 1.73 times higher when FTU is present compared to when it is not. However, the p-value suggests that this relationship is statistically insignificant. Regarding the FO in a firm, an odds ratio of 3.71 with a p-value of 0.14 indicates that, holding other variables constant, the odds of "process innovation" are 3.71 times higher for cases with FO compared to those without. However, the p-value suggests that this relationship is statistically insignificant. Finally, an odds ratio of 8.45 with a p-value of 0.000 for internal R&D means that, holding other variables constant, the odds of "process innovation" are 8.45 times higher when internal R&D is present compared to when it is not. The very low p-value indicates that this relationship is highly statistically significant (p<0.01). The constant term with a value of 0.0077 and a p-value of 0.000 represents the estimated log-odds of "process innovation" when all independent variables are zero. The very low p-value indicates that the constant term is highly statistically significant (p<0.01).

Table 5. Binary Logistic Regression Results for “Process Innovation” (Dependent Variable)

Independent Variables	**Odds Ratio**	**95% CI**	**P value**
Human Capital Development (HCD)	1.89*	(0.95, 3.75)	0.078
Foreign Tech Use (FTU)	1.73	(0.80, 3.72)	0.153
Foreign Ownership (FO)	3.71	(0.57, 24.05)	0.140
Internal R&D	8.45***	(4.91, 14.50)	0.000
Constant	0.0077***	(0.0002, 0.27)	0.000
n 1.566			
Pseudo r2 0.183			
Chi2 68.324			
AIC 314.037			
BIC 340.819			
Prob > chi2 0.000			

Note: *** p<0.01, ** p<0.05, * p<0.10.

4.3 Bivariate Probit Regression Analysis

The results of bivariate probit regression analysis are displayed in Table 6. For product innovation, the coefficient of HCD is statistically insignificant. This suggests that changes in HCD do not significantly impact the probability of product innovation. In contrast, FTU exhibits a highly significant positive impact on product innovation ($p<0.01$), indicating that an increase in the utilization of foreign technology substantially boosts the likelihood of product innovation activities of the firms. On the other hand, FO is not statistically significant, implying that FO does not significantly influence the product innovation. The findings also revealed that internal R&D efforts with a highly significant coefficient ($p<0.01$) have a substantial positive impact on the product innovation.

Table 6: Results for Bivariate Probit Regression

	Product Innovation		Process Innovation	
Independent Variables	**Coef.**	**P-value**	**Coef.**	**P-value**
Human Capital Development (HCD)	0.141	0.204	0.172	0.283
Foreign Tech Use (FTU)	0.425***	0.002	0.321*	0.080
Foreign Ownership (FO)	0.123	0.652	0.676**	0.019
Internal R&D	1.226***	0.000	0.974***	0.000
Constant	-1.879***	0.000	-2.428***	0.000
Rho	0.606***	0.000		
n	1,559			
Chi2	192.111			
AIC	965.751			
Prob > chi2	0.000			

Note: *** p<0.01, ** p<0.05, * p<0.10

For process innovation, HCD is not statistically significant, suggesting that changes in HCD do not significantly affect the likelihood of process innovation. FTU demonstrates a marginally significant positive effect ($p<0.10$), implying that an increase in the FTU may positively influence the probability of process innovation. On the other hand, FO is statistically significant ($p<0.05$), indicating that FO has a significant positive impact on the probability of process innovation. Findings revealed that, internal R&D is also a strong driver for process innovation with a highly significant coefficient ($p<0.01$), implying that internal R&D efforts strongly enhance the likelihood of process innovation.

In both models, the constant terms have negative values and are highly statistically significant ($p<0.01$). This suggests that when all independent variables are zero, the probability of both product and process innovation is low. Furthermore, based on the results of bivariate probit regression, there is a notable positive correlation (rho = 0.606, $p<0.01$) between product and process innovation indicating that these two types of innovation often occur together. This correlation suggests that improvements in one tend to coincide with enhancements in the other. The overall model demonstrates a good fit (Chi2=192.111, $p<0.01$).

In sum, based on the results of bivariate probit regression, internal R&D plays a pivotal role in driving both product and process innovation ($p<0.01$). FTU significantly influences product innovation and has a potential effect on process innovation. FO positively impacts process innovation, but it does not significantly affect product innovation. Lastly, HCD does not appear to have a substantial significant impact on either type of innovation. The positive correlation between product and process innovation suggests a co-occurrence of these two types of innovation.

5. Discussion and Conclusion

This study empirically investigates the determinants of both product and process innovation activities of manufacturing firms in Turkey. Firstly, by employing two separate binary regression models, we seek to unravel the multifaceted relationships between the independent variables and the likelihood of innovation in these two distinct dimensions. The findings from the first binary regression model shed light on the factors influencing product innovation. The findings reveal that the HCD exhibits a potential positive association with product innovation, although the relationship is not highly statistically significant ($p<0.10$). In contrast, the FTU emerged as a significant driver of product innovation ($p<0.01$). This compelling finding suggests that firms embracing foreign technology are more likely to engage in product innovation, underscoring the role of technological adoption in fostering innovative endeavors. Also, the findings revealed that there is no significant association between the FO and product innovation. This result implies that other factors might have a more pronounced impact on driving innovation in this context. Perhaps the most remarkable observation pertains to internal R&D. The findings emphasize the significant role of internal R&D efforts in boosting product innovation ($p<0.01$). This strong relationship underscores the importance of fostering a culture of innovation within a firm. The findings from the second binary regression model, transitioning to process innovation, offer further insights. The findings reveal that HCD has a positive impact on process innovation, although the relationship may not be highly statistically significant ($p<0.10$). The findings show that either FTU or FO does not significant impact on process innovation. Finally, the internal R&D remains a robust predictor of process innovation ($p<0.01$).

The findings from the bivariate logistic regression for both "product innovation" and "process innovation" highlight key determinants. According to the results, HCD does not significant impact on either product or process innovation. In contrast, FTU strongly drives both product and process innovation. FO shows significant positive influence on process innovation but insignificant positive impact on product innovation. Most notably, internal R&D plays a consistent and highly significant role in enhancing both product and process innovation activities of the firms. These results underscore the critical importance of technology adoption and internal R&D efforts in fostering innovation across product and process domains, providing valuable insights for firms aiming to innovate effectively.

This study contributes to the literature by highlighting the complexities of innovation determinants of the manufacturing firms in Turkey. It emphasizes the influence of foreign technology adoption and reinforces the enduring significance of internal R&D efforts in fostering innovation. Also, the study aligns with prior research on the role of internal R&D in innovation (Berchicci, 2013; Zhang & Tang, 2017). However, it offers unique insights specific to Turkish manufacturing firms, such as the nuanced impact of HCD and the significant link between FTU and product innovation. We acknowledge limitations, including our cross-sectional data and potential self-reporting bias. These factors may affect the study's generalizability and causal conclusions. Future research should explore causality with longitudinal data, expand sample sizes, and delve into the nuanced relationships between human capital development and innovation in the Turkish manufacturing context.

In conclusion, this study utilizes both binary logistic regression and bivariate probit regression analysis to comprehensively examine the determinants of product and process innovation. While certain variables may exhibit varied impacts between the models, the consistently high significance of internal R&D efforts emerges as a pivotal catalyst for driving innovation within firms for both product and process domains. These findings emphasize the critical role of internal innovation efforts of the firms and the adoption of foreign technology in advancing innovation activities. However, the nuanced relationships and varying statistical significance among independent variables call for careful interpretation and further exploration of these dynamic interplays. These insights provide valuable guidance to organizations striving to foster innovation effectively and remain competitive in today's dynamic business environment.

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