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Araştırma Makalesi

R&D and Productivity in Manufacturing for OECD Countries[1]

OECD Ülkeleri için İmalatta Ar-Ge ve Verimlilik

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Abstract
This paper investigates the effects of R&D expenditures in the manufacturing industry on the productivity of the manufacturing industry for OECD countries. This study differs from the previous studies in that the share of manufacturing value-added to the total value-added is employed instead of value-added per employee of the manufacturing industry. The main independent variable is the share of the manufacturing R&D expenditures in the total R&D expenditures. Since the dependent variable is naturally percentage, unlike other studies, the panel Tobit model is used. Also, autocorrelation and heteroscedasticity problems are corrected by applying the dynamic jackknife procedure. The findings indicate that "the value-added share of the manufacturing industry in total" increases by 1.8% if "the share of R&D expenditures of the manufacturing industry in total" is doubled.
Keywords: R&D, value-added, productivity, OECD, tobit
Jel Codes: C23, C24, O25, O33

Öz
Bu çalışma OECD ülkeleri için imalat sanayi Ar-Ge harcamalarının imalat sanayi verimliliğine etkisini incelemektedir. Bu çalışmada diğer çalışmalardan farklı olarak işçi başına katma değer yerine imalat sanayi katma değerinin toplam katma değer içindeki payı kullanılmıştır. Temel bağımsız değişken imalat sanayi Ar-Ge harcamasının toplam Ar-Ge harcamaları içindeki payıdır. Değişkenlerin yüzde pay olmasından dolayı diğer çalışmalardan farklı olarak panel Tobit modelinden yararlanılmıştır. Ayrıca otokorelasyon ve değişen varyans problemleri dinamik jackknife prosedürü ile düzeltilmiştir. Elde edilen bulgular "imalat sanayi Ar-Ge harcamalarının toplam içindeki payı" iki katına çıktığında "imalat sanayi katma değerinin toplam içindeki payı"nın %1.8 artacağına işaret etmektedir.
Anahtar Kelimeler: Ar-Ge, katma değer, verimlilik, OECD, tobit
Jel Kodları: C23, C24, O25, O33

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1. Introduction

Increasing traditional inputs to improve productivity is an inadequate effort after a certain stage. Therefore, it should be substituted by an increase in innovation activities. The link between innovation activities and productivity has long been of interest in economics literature. This relationship has been investigated in many dimensions (i.e. country, region, and firm, etc.). Since productivity is largely attributed to research and development (R&D) expenditures, the manufacturing industry is closely studied by scholars.

One of the first steps taken to explain this relationship was by Griliches (1964) who found that public investment in research and extension positively affected agricultural value-added in 39 US states. Another important study was made by Crépon et al. (1998) and their model (namely, CDM model) became popular in the investigation of the connection between innovation input, innovation output, and productivity at the firm level. They found that patents per employee and the share of innovative sales increase value-added per employee for French manufacturing firms.

The literature on innovation activities and productivity can be divided into two as studies on R&D and as studies on innovation. Considering the literature on R&D and productivity, some studies use basic R&D variables. For example, Verspagen (1995) reveals that R&D capital per employee promotes output only in the high-tech sector but it has no effect in low and mid-tech sectors for 15 manufacturing sectors in 11 OECD countries. Harhoff (1998) finds that the positive impact of R&D capital stock per employee on productivity for high technology firms in German manufacturing firms is higher than that of the other firms in the dataset. However, a part of the literature uses diversified R&D variables. For Chinese industry, Hu (2001) shows private R&D positively affects the output. According to the results of Guellec & Van de la Potterie (2003) for 16 OECD countries, the greatest effect on multifactor productivity is due to foreign R&D. Another study using diversified R&D variables is made by Tsang et al. (2008). They find that foreign firms generate more value-added than domestic firms in terms of four types of R&D in Singapore. Also, Lokshin et al. (2008) for Dutch manufacturing firms and Kancs & Siliverstovs (2016) for the firms in OECD countries find non-linear relationships between R&D and productivity.

Considering the literature on innovation and productivity, some studies use basic innovation variables. For example, the results of Mairesse et al. (2012) show that new product output increases value-added per employee in four manufacturing sectors in China with the electric equipment sector having the highest increase. Acosta et al. (2015) demonstrate the positive impact of innovation on productivity for the Spanish food sector. German-Soto & Flores (2015) find that innovation increases productivity in Mexico's rich, middle income, northern, and central states. Furthermore, by studying the literature one can see various innovation variables. Frequently used innovation variables are product and process innovation, and technological and non-technological innovation. For instance, Griffith et al. (2006) examine the role of innovation on productivity for France, Germany, Spain, and the UK. They show that both product and process innovations enhance labor productivity in France. In Spain and the UK product innovation positively affects productivity when process innovation has no significant effects. Also, there are no significant impacts either of product or process innovations on productivity. Hall et al. (2009) reveal both product and process innovations increase Italian firms' productivity. Bauman & Kritikos (2015) point out that product innovation has a positive impact on productivity when process innovation has no significant impact in German micro-firms.

For manufacturing and service sectors in Chile, Alvarez et al. (2015) find that technological and non-technological innovations have positive influences on productivity. The results of Aboal & Garda (2016) indicate technological and non-technological innovations increase productivity both in the manufacturing and the services sectors in Uruguay. When non-technological innovations play a more important role in productivity in the service sector, technological innovation has greater effects on productivity in the manufacturing sector. According to De Fuentes et. al. (2015), technological innovation, non-technological innovation, innovation intensity increase productivity in both the manufacturing and service sectors of Mexico.

Tello (2017) demonstrates that science, technology, and innovation investments have a positive effect on productivity in knowledge-intensive business services, traditional services, and low-tech manufacturing sectors when there is no significant effect in the high-tech manufacturing industry. Technological innovation is found to have a positive impact on knowledge-intensive business services when non-technological innovation has not. Finally, there are no significant effects of both technological and non-technological innovations on productivity in the remaining sectors. Fu et al. (2018) examine the role of innovation on productivity in the formal and the informal sectors in Ghana. They find technological innovation has a greater effect on productivity than non-technological innovation has. Also, innovation plays a more important role in formal firms. Finally, Bartz-Zuccala et al. (2018) show that management applications and innovations increase productivity in 30 Eastern Europe and Central Asian countries.

The influence of R&D capital differs from physical capital. The former increases the level of technology while the latter decreases the level. Liik et al. (2014) use stochastic frontier analysis for the OECD to demonstrate this result. Griffith et al. (2004) analyzed the relationship of R&D and total factor productivity for twelve OECD countries. They find R&D is crucial for both innovation and technological catch-up.

The enhancement of R&D is unquestionable. This study differs from the previous studies because it focuses on the influence of the share of R&D in manufacturing on the share of value-added in manufacturing. This study questions the importance of R&D investment for the manufacturing industry.

2. Data, Model, and Methodology

The unbalanced data spanning 1970-2010[4] are sourced from Structural Analysis Databases (STAN)[5] of OECD (2021) Statistics website for 34 OECD countries[6]. Abbreviations and explanations on the variables can be seen in Table 1.

[4] The industry level data for OECD countries are valuable although the data ise limited to year 2010.

[5] https://stats.oecd.org/Index.aspx?QueryId=28930 (Access Date: 5.2.2021)

[6] Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.

Table 1. Variables

Abbreviation	Explanation
$vashare$	Value-added share of manufacturing industry is the ratio of manufacturing value-added to total value-added.
$empshare$	Employment share of manufacturing industry is the ratio of employment in manufacturing industry to total employment.
$invshare$	Investment share of manufacturing industry is the ratio of gross fixed capital formation in manufacturing industry to total gross fixed capital formation.
$labprod$	Labour productivity index is the ratio of manufacturing value-added volume over employment in manufacturing industry to manufacturing value-added (in 2000) over employment in manufacturing industry (in 2000).
$labcost$	Unit labour cost index is the ratio of labour compensation in manufacturing industry over manufacturing value-added volume to labour compensation in manufacturing industry (in 2000) over manufacturing value-added volume (in 2000).
$expimp$	Export import ratio is the ratio of exports to imports in manufacturing industry.
$rdshare$	R&D expenditure share is the ratio of R&D expenditures in manufacturing industry to R&D expenditures in total.

Table 2 gives summary statistics on the series. As seen, the share of the manufacturing industry in total value-added is 20% in OECD countries for the 1970-2010 period. Also, the industry that has the highest share of R&D expenditures is manufacturing with an average of 71%. Germany has both the highest share of R&D in manufacturing with 96% and the highest value-added share of manufacturing with 36%.

Table 2. Summary statistics

Variable	Obs	Mean	Std. Dev.	Min.	Max.
$vashare$	1097	20.368	4.993	6.46	36.54
$empshare$	962	19.664	4.918	8.91	35.77
$invshare$	877	14.928	5.559	4.43	35.99
$labprod$	929	83.944	32.115	9.88	252.21
$labcost$	980	82.347	35.399	0.06	262.91
$expimp$	1039	99.753	36.206	18.63	315.17
$rdshare$	565	71.308	16.765	14.79	96.06

The average value-added shares of each country are given in Figure 1. As seen, Germany, Ireland, and Korea have the highest means of value-added shares. The average shares of these countries range between 26% and 27%. The lowest means of value-added shares belong to Greece, Luxembourg, and Norway. The average shares of the lowest countries having the lowest scores are around 15%.

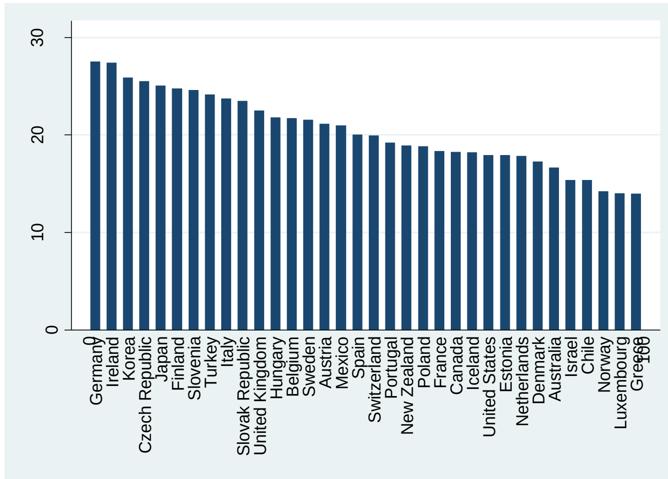

Figure 1. Manufacturing value-added shares of each OECD country

The average shares of R&D expenditures in the manufacturing industry are presented in Figure 2. The top countries are Germany, Japan, and France. Their average shares range between 88% and 93%. Chile, Estonia, and Israel have the lowest countries of R&D expenditures. The highest and lowest countries for value-added and R&D shares are not similar except Germany which is a leading manufacturing country.

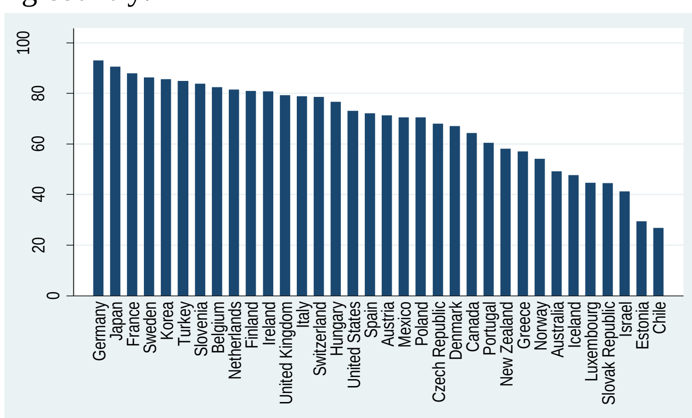

Figure 2. Manufacturing R&D expenditure shares of each OECD country

The relationship between the value added share and R&D expenditures share in the manufacturing industry for OECD countries depicted at Figure 3. Germany has the highest R&D shares with lower value added share compared to Ireland. On the other hand, Iceland has the lowest share for both variables. Moreover, the positive relationship for OECD countries can be seen from the figure.

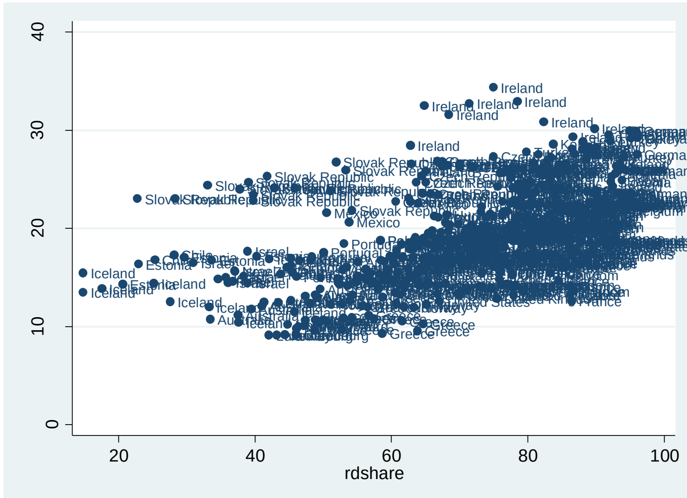

Figure 3. The relationship of manufacturing value added shares and R&D expenditures

In this study, $vashare$ is treated as a function of conventional inputs and various indicators as follows:

$$vashare = f(empshare, invshare, labprod, labcost, expimp, rdshare)$$

The panel Tobit model is employed to estimate the relationship above. Truncating and censoring arise only if there are positive observations for the regression model. The Tobit model is a regression that censored from below at zero (Cameron & Trivedi 2005: 536):

$$Y^{*} = \alpha_0 + \alpha_1 X + u$$

Here, X is the independent variable, Y^{*} is the latent variable, α's are the coefficients to be estimated, and u is the error term. The dependent variable Y is described as follows (Cameron & Trivedi, 2005: 536):

$$Y = \begin{cases} Y^{*} \ if \ Y^{*} > 0 \\ \ldots \ if \ Y^{*} \leq 0 \end{cases}$$

Here, ... shows that Y is not observed when $Y^{*} \leq 0$ (Cameron & Trivedi, 2005: 536).

3. Empirical Results

Table 3 shows the panel Tobit estimation results. Autocorrelation and heteroskedasticity problems are diagnosed by using the Wooldridge (2002) autocorrelation test and the Modified Wald test (Greene 2000) for groupwise heteroskedasticity. Because of these problems, a dynamic jackknife panel Tobit regression is estimated (estimations of fixed and random-effects models can be found in Appendix Table A.1.).

Columns 1, 2, and 3 give Tobit estimations without jackknife. First of all, the signs of the variables are found as expected. Also, each coefficient is statistically significant. Estimation 1 shows positive effects of the share of employment and the share of investment on the manufacturing value-added.

The same is valid for estimation 2, but the effect of employment is lower. When labor productivity and export-import ratio increase the value-added, the labor costs decrease it. Estimation 3 includes the variable of interest and a dummy variable (out) which denotes outliers. Accordingly, there are no important changes in the coefficients. Also, R&D expenditures are found to increase the value-added.

Table 3. Estimation results

VARIABLES	(1) Tobit	(2) Tobit	(3) Tobit	(4) Jackknife Tobit	(5) Jackknife Tobit	(6) Jackknife Tobit
$lagvashare$				0.857***	0.710***	0.644***
				(0. 0443)	(0.0474)	(0.07795)
$empshare$	0.717***	0.667***	0.780***	0.0855***	0.140***	0.168**
	(0.0148)	(0.0231)	(0.0385)	(0.0331)	(0.0380)	(0.0661)
$invshare$	0.141***	0.203***	0.147***	0.0665***	0.101***	0.103***
	(0.0186)	(0.0149)	(0.0168)	(0.0170)	(0.0167)	(0.0205)
$labprod$		0.00965***	0.0132***		-0.000407	-0.000815
		(0.00222)	(0.00251)		(0.0019)	(0.00243)
$labcost$		-0.0195***	-0.0276***		-0.00998***	-0.0152***
		(0.00238)	(0.00360)		(0.0020)	(0.00415)
$expimp$		0.0449***	0.0361***		0.0176***	0.0213***
		(0.00343)	(0.00441)		(0.0030)	(0.00427)
$rdshare$			0.0154**			0.0179***
			(0.00728)			(0.0064)
out			1.065***			0.582
			(0.317)			(0.437)
$sigma\_u$	2.643***	2.477***	2.812***	0.390***	0.654***	0.780***
	(0.351)	(0.333)	(0.388)	(0.1335)	(0.1545)	(0.235)
$sigma\_e$	1.330***	0.949***	0.780***	0.785***	0.703***	0.659***
	(0.0336)	(0.0250)	(0.0265)	(0.0363)	(0.0292)	(0.045)
$Constant$	3.604***	0.365	-0.557	-0.0497	0.587	0.293
	(0.572)	(0.857)	(1.237)	(0.191)	(0.496)	(0.747)
$Observations$	813	754	465	795	741	463
$\#\ of\ countries$	29	29	29	29	29	29

*** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.

Columns 4, 5, and 6 show Dynamic Jackknife Tobit estimations. These results are free from autocorrelation and heteroscedasticity problems. Each regression includes one period lagged value of the dependent variable ($lagvashare$). All coefficients have expected signs. Each coefficient is statistically significant except for $labprod$ and out. In general, the jackknife procedure appears to reduce the magnitudes of the coefficients. Estimation 4 shows the positive effects of the share of employment and the share of investment on the manufacturing value-added. The coefficient of the lagged value-added variable is also positive and significant. In estimation 5, the coefficient of labor productivity, which is significant in estimations 2 and 3, proved to be insignificant. Estimation 6 gives the results of the widest model. It is observed that the coefficients of $labprod$ and out are not statistically significant. Except for $labcost$, each variable positively affects $vashare$. According to this final model, a 1% increase in "the share of R&D expenditures of the manufacturing industry in total" increases "the share of manufacturing value-added in total" by 0.018%.

4. Conclusions

The importance of R&D for productivity is unquestionable. The crucial question arises for the manufacturing industry: How much does the share of R&D invested in the manufacturing industry enhances the share of productivity in manufacturing? To test this hypothesis, the data for 40 years (1970-2010) of 34 OECD countries are used. As the dependent variable is a ratio, the Tobit model is appropriate to utilize. Due to autocorrelation and heteroscedasticity problems, the model is estimated with Dynamic Jackknife Panel Tobit. All the control variables have the expected signs. The main independent variable, the share of manufacturing R&D in total R&D, has a positive sign and is statistically significant. As the share of R&D in manufacturing doubles, the share of manufacturing value-added enhances by 1.8%.

The relation between R&D and productivity is self-evident from previous studies. This study also shows that the share designed for the industry is also crucial. For further study, this analysis should be replicated for other industries for comparison.

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APPENDIX

Table A.1. Fixed and random-effects panel estimation results

VARIABLES	(1) FE	(2) FE	(3) FE	(4) RE	(5) RE	(6) RE
$empshare$	0.716***	0.554***	0.519***	0.717***	0.664***	0.762***
	(0.0247)	(0.0259)	(0.0341)	(0.0148)	(0.0230)	(0.0376)
$invshare$	0.191***	0.119***	0.0861***	0.141***	0.202***	0.146***
	(0.0230)	(0.0212)	(0.0278)	(0.0187)	(0.0150)	(0.0173)
$labprod$		-0.00479	0.000586		0.00931***	0.0121***
		(0.00301)	(0.00400)		(0.00221)	(0.00248)
$labcost$		-0.0196***	-0.0353***		-0.0197***	-0.0279***
		(0.00386)	(0.00759)		(0.00240)	(0.00367)
$expimp$		0.0737***	0.0721***		0.0455***	0.0377***
		(0.00326)	(0.00449)		(0.00342)	(0.00440)
$rdshare$			0.0410***			0.0180**
			(0.00886)			(0.00731)
out			0.961			1.055***
			(0.628)			(0.325)
$Constant$	3.392***	2.352***	1.881*	3.604***	0.425	-0.406
	(0.382)	(0.633)	(1.119)	(0.596)	(0.825)	(1.198)
$Observations$	813	754	465	813	754	465
$R-squared$	0.722	0.838	0.812			
$\#\ of\ countries$				29	29	29

*** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.