RIETI Discussion Paper Series 17-E-101

R&D and Product Dynamics

MIYAGAWA Tsutomu
RIETI

EDAMURA Kazuma
Japan Productivity Center

KAWAKAMI Atsushi
Toyo University

RIETI
Research Institute of Economy, Trade & Industry, IAA
The Research Institute of Economy, Trade and Industry
http://www.rieti.go.jp/en/

RIETI Discussion Paper Series 17-E-101

July 2017

R&D and Product Dynamics

MIYAGAWA Tsutomu

(Gakushuin University and RIETI)

EDAMURA Kazuma

(Japan Productivity Center)

KAWAKAMI Atsushi

(Toyo University)

Abstract

In endogenous growth models and mid-term business cycles as seen in the works of Romer (1987) and Comin and Gertler (2006), it is assumed that there are positive effects of product variety. Using product-firm level data, we examine these effects empirically. Using data from the Census of Manufacture, the Survey of Research and Development (R&D), and the Basic Survey of Japanese Business Structure and Activities, we construct a database that includes number of products, R&D expenditures, and data on firm performance. We find that the number of products in R&D firms is higher than that of non-R&D firms, and that R&D firms are more sensitive than non-R&D firms for product dynamics. In the Poisson regression model, we also observe positive effects of R&D activities on product dynamics in empirical studies. As the increase in product variety contributes to productivity growth, our empirical results support the government's policies for enhancing R&D activities.

Keywords: Endogenous growth theory, Medium term business cycles, R&D, Product variety

JEL classification numbers: E32, O31, O47

* We thank Professor Yano (RIETI President), Dr. Morikawa (RIETI Vice President), Professor Fukao (Hitotsubashi University), Professor Miyakawa (Hitotsubashi University), and Professor Yamauchi (Meijigakuin University) for their helpful comments. This study is conducted as part of the project "The Role of Intangibles on Prodcutivity Improvement" undertaken at the Research Institute of Economy, Trade and Industry (RIETI) and supported in part by a Grant-in-Aid for Scientific Research from the Ministry of Education, Culture, Sports, Science and Technology (No. 15H03351, No. 16H06322) of Japan.

1. Introduction

Endogenous growth theory that has developed since the mid 1980s shows that R&D activities increase the steady state growth rate through the improvement of aggregate productivity. In addition, numerous empirical studies have shown that R&D investment improves productivity at the firm level as well as at the aggregate level. These studies have supported the implementation of government policies that enhance R&D.

However, many empirical studies have not necessarily followed the mechanism of endogenous growth theory correctly. For example, in the endogenous growth theory developed by Romer (1987), productivity growth is attained through an increase in product variety and the degree of product variety is affected by R&D activities, which is represented by the intensity of researchers.[1] However, most empirical studies have focused on the effects of R&D activities on productivity growth directly.[2]

Our paper aims to fill this gap between endogenous growth theory, and empirical studies related to R&D and productivity growth. Following Romer (1987) and Rivera-Batiz and Romer (1991), we focus on the mechanism whereby the increase in product variety leads to productivity growth. In our study, the increase in product variety is represented by the increase of number of products created by a firm. As shown in Kawakami and Miyagawa (2013) and Dekle, Kawakami, Kiyotaki, and Miyagawa (2015), we construct a product-firm level database by using the Japanese Census of Manufacture, a survey conducted by the Ministry of Economy, Trade and Industry (METI). In this database, each product is classified at the 6-digit level. We

[1] Uzawa (1965) showed the intensity of researchers affect economic growth at the first time.

[2] Some empirical studies have shown the effects of R&D activities on number of patents. However, the effects of the number of patents on product variety or productivity growth are inconclusive.

match this database with the R&D data in the Japanese Survey of Research and Development conducted by the Statistics Bureau in Ministry of Internal Affairs and Communications, and the Basic Survey of Japanese Business Structure and Activities conducted by METI. Using these data, we examine the effects of R&D on changes in number of products.

Our empirical results show that an increase in R&D investment leads to an increase in number of products created by a firm. As in Kawakami and Miyagawa (2013), we show that an increase in this kind of product variety leads to productivity growth, and the combined effects of our empirical results with those in Kawakami and Miyagawa (2013) show that the mechanism demonstrated in Romer (1987) and Rivera-Batiz, and Romer (1991) works at the firm level.

In the next section, we give an overview of the related literature. In the third section, we explain the dataset that we use in our empirical studies. In the fourth section, we introduce a simple growth theory that gives a theoretical foundation of our empirical studies and show empirical results. In the final section, we summarize our results and offer some policy implications.

2. Related literature

Durlauf, Johnson, and Temple (2005) and Caselli (2005) showed that most empirical studies on economic growth are cross-country studies.[3] As Broda, Greenfield, and Weinstein (2006) (hereinafter we refer to as BGW (2006)) pointed out, few studies have tried to fill the gap between the evidence from micro data and growth theory.

Based on the endogenous model developed by Romer (1987) and Rivera-Batiz and Romer (1991), BGW (2006) examine the effects of an increase in number of imported products

[3] Jones (1995) tried to test the endogenous growth theory using time series data.

on productivity. Using the United Nation's COMTRADE database, they estimate import demand and export supply functions and obtain substitutability parameters. Utilizing these parameters, they examine the impacts of product variety on productivity growth.

Using the endogenous growth theory, Jones and Williams (1998) and Comin and Mulani (2009) reexamine the effects of R&D expenditures on economic growth that were developed by Griliches (1980). Although Jones and Williams (1998) do not use firm level but industry level data, their estimations based on endogenous growth theory show underinvestment in R&D.[4] Comin and Mulani (2009) consider two types of innovations; R&D based innovation and general innovation. As market share is gained by general innovation, economic resources will shift to R&D. Using aggregate and firm level data, they show this shift increases the volatility in labor productivity growth at the firm level and renders the effects of R&D on productivity inconclusive. Hall et al. (2012) considers that not only R&D activities but also IT investment contribute to productivity growth through innovation. Their estimation strategy, using Italian manufacturing firm level data, is divided into two stages. In the first stage, they estimate an innovation function that depends on R&D and IT investment. However, in their study, innovation includes not only product innovation but also other innovations such as process innovation and organizational innovation. Using the probability of innovation obtained in the first stage estimation, they examined the effects of innovation on productivity improvement.

Our study is also closely related to the empirical studies on product switching developed by Bernard, Redding and Scott (2010) (hereinafter referred to as BRS (2010)). Using the 5-digit product level data in the US, they show that firms aggressive on product adding and dropping improve in not only productivity growth but also in output, employment and wages. Following

[4] Miyagawa and Hisa (2013) applied their estimation to measure the rate of return on intangible investment including R&D expenditures. Bloom, Schankerman, and Van Reenen (2013) reexamined the rate of return on R&D expenditures considering spillover effects and product market rivalry, although their estimation was not directly related to an endogenous growth model.

BRS (2010), Kawakami and Miyagawa (2013) also show similar effects to BRS (2010) in Japan, using the 6-digit product and firm level data from the Japanese Census of Manufacture conducted by the Ministry of Economy, Trade and Industry (METI). Using the same Japanese data, Bernard and Okubo (2013) also show that productivity in multiple product firms is higher than in single product firms.

Studies on multiple product firms have extended to studies on international trade and business cycles. Bernard, Redding and Schott (2011) extended their work to international trade. De Loecker (2011) examined the effects of trade liberalization on productivity using multiproduct firm data in the textile industry in Belgium. Bilbiie, Ghironi, and Melitz (2012) and Dekle, Kiyotaki and Jeong (2014) constructed a macroeconomic model including multiproduct firms and examined the impact of aggregate shocks on endogenous variables such as GDP, consumption, investment and number of products. Although two studies examined the impacts of aggregate shocks on endogenous variables using calibration technique, Dekle, Kawakami, Kiyotaki and Miyagawa (2015) examined the effects of aggregate shocks on the number of products using product and firm level data that was compiled in Kawakami and Miyagawa (2013).[5]

3. A Basic Model for Empirical Study and Data Construction

Our empirical study is based on an endogenous growth model with product variety developed by Romer (1987) and Rivera-Batiz and Romer (1991). In their model, the final output (Y) is

[5] Bernard and Okubo (2015) also examined the effects of multiproduct firms on Japanese business cycles.

produced by labor (N) and differentiated intermediate goods (x_i).[6]

(1) $$Y = N^{1-\alpha}\int_0^M x_i^{\alpha}\,di$$

where $X = \int_0^M x_i\,di$

If we assume that each intermediate good is produced in the same amount, the final output is expressed as follows,

(2) $$Y = M^{1-\alpha} N^{1-\alpha} X^{\alpha}.$$

Substituting $X = Mx$ into (2), we obtain

(3) $$Y = MN^{1-\alpha} x^{\alpha}.$$

As GDP is defined as $GDP = Y - X$,

(4) $$GDP = M(N^{1-\alpha} x^{\alpha} - x).$$

If we assume that labor supply is constant, the GDP growth rate (g) is equal to the growth rate of product variety.

[6] The basic growth model follows Ch. 3 of Aghion and Howitt (2009).

(5) $$g = \frac{\dot{M}}{M}$$

A growth model with product variety assumes that growth in the number of intermediate goods depends on R&D (R), which uses final output.

(6) $$\dot{M} = \mu R$$

In a standard endogenous model, R&D in Equation (6) is endogenously determined through the process the zero profit condition in the research sector and profit maximization in the intermediate goods sector. Finally, we obtain

(7) $$g = \frac{\mu \frac{1-\alpha}{\alpha} N \alpha^{\frac{2}{1-\alpha}} - \beta}{\upsilon}$$

where β is time preference and $1/\upsilon$ is the elasticity of intertemporal substitution.

Equation (7) implies that the long-run growth rate depends on the scale of labor supply. However, in our study, we focus on the implication in Equation (6) that shows that R&D expenditure increases product variety.[7]

To examine the effects of R&D expenditures on product variety, we use three datasets: the Census of Manufacture, the Survey of Research and Development and the Basic Survey of

[7] BGW (2006) focuses on the mechanism behind Equation (3).

Japanese Business Structure and Activities. We obtain the six-digit product level data by using the Census of Manufacture.[8] Like Kawakami and Miyagawa (2013) and Dekle, Kawakami, Kiyotaki, and Miyagawa (2015), we construct the number of products at the firm level by matching product data at the establishment level with the firm level data in the Census of Manufacture. From the Survey of Research and Development, we identify R&D firms and non-R&D firms. We then obtain other firm level data such as sales, export values, physical assets, number of employees, and age from the Basic Survey of Japanese Business Structure and Activities. By using the firm code and year, we integrate the three datasets into one. This dataset covers 2000 to 2010, because the starting year of R&D expenditures at the firm level is 2001. The summary of statistics is shown in Table 1

(Place Table1 around here)

4. Overview of Product Dynamics in R&D Firms and Non-R&D Firms

Using our dataset, we examine product dynamics of R&D and non-R&D firms. Figure 1 shows the number of products in R&D firms and non-R&D firms. We find that R&D firms create more products than non-R&D firms. However, the average number of products in this paper is higher than that in previous studies such as Kawakami and Miyagawa (2013) and Dekle, Kawakami, Kiyotaki, and Miyagawa (2015), as the coverage of the Survey of Research and Development is narrower than that in the Census of Manufacture.

(Place Figure 1 around here)

[8] As the classification of products was revised in 2002 and 2008, we ensure consistent classification of products from 2001 to 2010.

Figures 2 and 3 show the number of added products and dropped products in two types of firms, respectively. In Figure 2, we find that not only R&D firms but also non-R&D firms add products aggressively as the aggregate economy recovered. However, the number of added products in R&D firms fell drastically after the Great Financial Crisis. At the same time, the number of dropped products in R&D firms increased drastically. The number of dropped products in R&D firms also increased in 2002, when the aggregate economy declined after the collapse of the IT bubble in the US. Our findings that R&D firms are more cyclical than non-R&D firms are consistent with Comin and Gertler (2006) and Comin (2011), where R&D expenditures are sensitive to business cycle shocks.

(Place Figures 2 and 3 around here)

Other features in R&D and non-R&D firms are summarized in Figures 4 to 10. We find that the age of R&D firms is higher than that of non-R&D firms (Figure 4). In Japan, older firms are more aggressive in R&D activities than younger firms. Figure 5 shows the scale of R&D and non-R&D firms. The scale represented by the number of employees in R&D firms are much larger than in non-R&D firms. The ratio of exports to sales in R&D firms is higher than in non-R&D firms (Figure 6). In addition, the export ratio in non-R&D firms seems to be cyclical. In particular, this ratio in non-R&D firms increased in the second half of the 2000s and declined after the Global Financial Crisis. The movements corresponded to those in the real effective exchange rate in Japanese Yen. As Melitz (2003) and Dekle, Kawakami, Kiyotaki, and Miyagawa (2015) show that high productivity firms are not sensitive to exchange rate fluctuations, the movements in the export ratio in relatively low productive non-R&D firms are consistent with their arguments.

(Place Figures 4 to 6 around here)

As for the ratio of sales to man-hour, which is an approximate measure of labor productivity, we find a growing gap between R&D firms and non-R&D firms after the mid 2000s (Figure 7). This measure in non R&D firms declined drastically after the World Financial Crisis, although R&D firms maintained relatively high labor productivity. However, TFPs of both types of firms are not vastly different, which implies that non-R&D firms kept their TFP level to increase capital (Figure 8). The cyclical movements in TFP in R&D firms are also consistent with the arguments in Comin and Gertler (2006) and Comin (2011). The movements in ROA are also cyclical in both types of firms and there is no difference between R&D firms and non-R&D firms (Figure 9). After the mid 2000s, there is no difference in ROE between R&D firms and non-R&D firms, although the ROE in R&D firms was higher than that in non-R&D firms in the first half of the 2000s (Figure 10).

(Place Figures 7 to 10 around here)

5. Empirical Tests on the Effect of R&D on Product Dynamics

We estimate the following equation to examine the effects of R&D activities on product dynamics.

(8) $$PD_{it} = \alpha \ln RD_{it-1} + \beta \sum_{j=1}^{n} \beta_{jit} X_{jit} + \lambda_k + \mu_t + \varepsilon_{it}$$

In Equation (8), PD_{it} is a measure of product dynamics. We use three measures as dependent variables: 1) the change in number of products ($M_{it} - M_{it-1}$), 2) the Davis and Haltiwanger measure for change in number of products ($(M_{it} - M_{it-1})/((M_{it} + M_{it-1})/2)$, and 3) the added product rate ($addedproduccts / M_{it-1}$). [9] RD_{it-1} represents the R&D measure. We use two types of R&D measures in the estimation: one is R&D expenditure at t-1 and the other is R&D stock at t-1.[10]

X_j is a control variable. A control variables is the Lerner index (= operating profits-financial costs), which represents the competitive environment.

As R&D expenditure is an endogenous variable in endogenous growth models and mid-term business cycles models, we estimate Equation (8) not only by fixed effects estimations but also by the instrumental variable method. We take firm age and the export ratio as instrumental variables.

Our estimation results are shown in Tables 2 to 3. In Table 2, the change in the number of products is a dependent variable. In fixed effects estimations, we obtain positive coefficients on R&D variables. In particular, when we take R&D stock as an explanatory variable, its coefficient is significant. However, in IV estimations, the coefficients of R&D variables are negative.

(Place Tables 2 and 3 around here)

---

[9] The Davis and Haltiwanger measure is used for their study on job creation and destruction. See Davis, Haltiwanger and Schuh (1996)

[10] In our estimation, we use R&D data from the Basic Survey of Business Structure and Activities.

When we use the Davis and Haltiwanger measure as a dependent variable, we obtain positive coefficients on R&D variables in the case of fixed estimations. As in Table 2, the coefficients on R&D variables are negative in the IV estimations.

The estimation results of Equation (9) are not robust, however. Therefore, we estimate the following Poisson regression model, because the number of products is a count data and previous literature such as Bernard Redding and Schott (2010) and Dekle et al. (2014) assume the productivity of new products follows the Poisson distribution.

$$(9)\quad E(M_{it} \mid \ln RD_{it-1}, X_{it-1}) = \exp(\gamma_0 + \gamma_1 \ln RD_{it-1} + \gamma_2 X_{it-1})$$

Table 4 shows estimation results of Equation (9). When we take the number of products as a dependent variable, we obtain positive and significant coefficients on R&D variables. When we change the dependent variable from the number of products to added products, coefficients on R&D variables are also positive, but insignificant. In the Poisson regression model, we use firm age and export ratio as well as the Lerner index as control variables. In all estimations, we obtain positive and significant coefficients on firm age. The result implies that older firms create new products in Japan.

(Place Tables 4 around here)

6. Concluding Remarks

In endogenous growth models and medium-term business cycle models, the positive effects of R&D activities on product variety play a crucial role. However, we do not find conclusive empirical evidence of these effects. Using product and firm level data, we examine these effects.

We match R&D expenditure data in the Survey of Research and Development with product and firm level data in the Census of Manufacture and several firm characteristics in the Basic Survey of Japanese Business Structure and Activities. This database shows some interesting differences between R&D firms and non-R&D firms. R&D firms make more products than non-R&D firms. The size of R&D firms is larger than that in non-R&D firms. R&D firms are also more aggressive in exports than non-R&D firms.

Although we examine the effects of R&D activities on product dynamics by estimating a linear model, the estimation results are inconclusive. Then, we estimate a Poisson regression model. In this estimation, we obtain positive significant effects of R&D on number of products.

As our empirical studies show the possibility of positive effects of R&D on product innovation, this supports government policies enhancing R&D activities. However, we have to improve our study to confirm our results because the data on R&D in our study includes not only R&D expenditures for product innovation but also those in other innovations such as process innovation and organizational reforms. The estimation results in Hall et al. (2012) showed that the total R&D expenditures were not able to explain any specific innovation. The inconclusive results in our linear regression models may be caused by a reason similar to Hall et al. (2012). In future research, we will make the effort to take the R&D data for product innovation.

References

Aghion, Philippe, and Peter Howitt (2009) *The Economics of Growth*, The MIT Press, Cambridge, Massachusetts, US.

Aghion, Philippe, Richard Blundell, Rachel Griffith, Peter Howitt, and Susanne Prantl (2009) "The Effects of Entry on Incumbent Innovation and Productivity" *Review of Economics and Statistics* 91 (1), pp. 20-32.

Bernard, Andrew, B. and Toshihiro Okubo (2013) "Multi Product Plants and Product Switching in Japan" RIETI Discussion Paper Series 13-e-069.

Bernard, Andrew, B. and Toshihiro Okubo (2015) "Product Switching and Business Cycle" RIETI Discussion Paper Series 15-e-103.

Bernard, Andrew, B., Stephen J. Redding, and Peter K. Schott (2010) "Multi-Product Firms and Product Switching," *The American Economic Review*, 100, pp. 70-97

Bernard, Andrew, B., Stephen J. Redding, and Peter K. Schott (2011) "Multi-Product Firms and Trade Liberalization," *Quarterly Journal of Economics*, 126 (3), pp. 1271-1318.

Bilbiie, Florin O., Fabio Ghironi, and Marc J. Melitz (2012) "Endogenous Entry, Product Variety, and Business Cycles" *Journal of Political Economy* 120 (2), pp. 304-345.

Broda, Christian, Joshua Greenfield, and David Weinstein (2006) "From Groundnuts to Globalization: A Structural Estimate of Trade and Growth" NBER Working Paper No. 12512.

Comin, Diego (2011) "An Exploration of the Japanese Slowdown during the 1990s" Koichi Hamada, Anil Kashyap, and David Weinstein eds., *Japan's Bubble, Deflation and Long-term Stagnation,* The MIT Press, Cambridge, Massachusetts, US.

Comin, Diego, and Mark Gertler (2006) "Medium-Term Business Cycles" *The American*

Economic Review 96 (2), pp. 523-551.

Comin, Diego and Sunil Mulani (2009) “A Theory of Growth and Volatility at the Aggregate and Firm Level” *Journal of Monetary Economics* 56, pp. 1023-1042.

Caselli, Francesco (2005) “Accounting Cross-Country Differences” Philippe Aghion and Steven Durlauf eds., *Handbook of Economic Growth*, North Holland.

Davis, Steven, John Haltiwanger, and Scott Schuh (1996), *Job Creation and Destruction*, Cambridge, M.A.: MIT Press.

Dekle, Robert, Hyeok Jeong, and Nobuhiro Kiyotaki (2014) “Dynamics of Firms and Trade in General Equilibrium” unpublished manuscript March, 2014.

Dekle, Robert, Atsushi Kawakami, Nobuhiro Kiyotaki, and Tsutomu Miyagawa (2015) “Product Dynamics and Aggregate Shocks: Evidence Japanese Product and Firm Level Data” RIETI Discussion Paper Series 15-e-137.

De Loecker, Jan (2011) “Product Differentiation, Multiproduct Firms, and Estimating the Impact of Trade Liberalization on Productivity” *Econometrica* 79 (5) pp. 1407-1451.

Durlauf, Steven, Paul Johnson, and Jonathan Temple (2005) “Growth Econometrics” Philippe Aghion and Steven Durlauf eds., *Handbook of Economic Growth*, North Holland.

Hall, Bronwyn, H., Francesca Lotti, and Jacques Mairesse (2012), “Evidence on the Impact of R&D and ICT Investments on Innovation and Productivity in Italian Firms” *Economics of Innovation and New Technology* 22, pp. 1-29.

Kawakami, Atsushi, and Tsutomu Miyagawa (2013) “Product Switching and Firm Performance in Japan” *Public Policy Review* 9, pp. 287-314, Policy Research Institute, Ministry of Finance.

Jones, Charles and John Williams (1998) “Measuring the Social Returns to R&D” *Quarterly Journal of Economics* 113, pp. 1119-1135.

Melitz, Marc J., (2003) “The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity” *Econometrica* 71, pp. 1695-1725.

Romer, Paul (1987) “Growth Based on Increasing Returns Due to Specialization” *The American Economic Review* 77, pp. 56-62.

Rivera-Batiz, Francisco, and Paul Romer (1991) “Economic Integration and Endogenous Growth” *Quarterly Journal of Economics* 106, pp. 531-555.

Uzawa, Hirofumi (1965) “Optimal Technical Change in an Aggregative Model of Economic Growth” *International Economic Review* 6, pp. 18-31.

Table 1 Basic Statistics

	Number of observations	Mean	Median	Standard devation	Min.	Max.
Number of product	19524	5.199	4	6.424	1	143
Added product	19524	0.549	0	1.622	0	62
R&D Stock (billion Yen)	16774	15.408	1.038	98.130	0	2423.549
Lerner Index	19522	0.217	0.195	0.139	-0.674	1
Age	19485	52.715	55	19.704	0	167
Export ratio	12765	0.134	0.056	0.182	0	1

Table 2　Fixed effects estimation of the change in the number of products

dep	M(t)-M(t-1)			
model	(1)	(2)	(3)	(4)
ln [R&D(t-1)]	0.0216	-0.8677		
	[0.0158]	[0.8124]		
ln [R&D Stock (t-1)]			0.0844**	-1.0168
			[0.0394]	[0.8829]
Lerner Index	-0.0193	-0.3692	-0.0392	-0.4243
	[0.2376]	[0.4909]	[0.2427]	[0.4251]
M(t-1)	-0.4905***	-0.5099***	-0.4958***	-0.5109***
	[0.0073]	[0.0104]	[0.0075]	[0.0121]
_cons	1.068	8.8349*	1.1455	11.0457
	[0.9845]	[5.3378]	[0.8500]	[6.8770]
Year dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
N	14534	9888	13785	9374
N_g	3434	2573	3255	2436
r2_a	0.0886		0.0966	
Estimation method	FE	ln(age), export ratio	FE	ln(age), export ratio

＊Standard errors are expressed in parentheses. *, **, and *** show significance at 10%, 5%, and 1% levels, respectively.

Table 3　Fixed effects estimation of the Davis and Haltiwanger measure

dep	(M(t)-M(t-1))/((M(t)+M(t-1))/2			
model	(1)	(2)	(3)	(4)
ln [R&D(t-1)]	0.0007	-0.0708		
	[0.0008]	[0.0465]		
ln [R&D Stock (t-1)]			0.0021	-0.0846*
			[0.0021]	[0.0458]
Lerner Index	-0.0022	-0.0385	-0.0022	-0.0378*
	[0.0125]	[0.0281]	[0.0127]	[0.0221]
M(t-1)	-0.0153***	-0.0146***	-0.0154***	-0.0142***
	[0.0004]	[0.0006]	[0.0004]	[0.0006]
_cons	-0.0022	0.5354*	0.0163	0.7251**
	[0.0517]	[0.3058]	[0.0447]	[0.3568]
Year dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
N	14534	9888	13785	9374
N_g	3434	2573	3255	2436
r2_a	-0.1118		-0.11	
Estimation method	FE	ln(age), export ratio	FE	ln(age), export ratio

＊Standard errors are expressed in parentheses. *, **, and *** show significance at 10%, 5%, and 1% levels, respectively.

Table 4 Poisson estimation of the number of products and added products

dep	M(t)		adding(t)	
model	(1)	(2)	(3)	(4)
ln [R&D(t-1)]	0.0359***		0.0138	
	[0.0041]		[0.0114]	
ln [R&D Stock (t-1)]		0.0455***		0.0099
		[0.0048]		[0.0127]
Lerner Index	-0.2927***	-0.3126***	-0.6065***	-0.5530**
	[0.0737]	[0.0769]	[0.2106]	[0.2166]
ln[age]	0.1127***	0.1084***	0.1595***	0.1545***
	[0.0164]	[0.0168]	[0.0471]	[0.0479]
export ratio	0.0137	0.0018	0.0392	0.0765
	[0.0507]	[0.0527]	[0.1408]	[0.1448]
ln [M(t-1)]	0.0672***	0.0650***	0.0438***	0.0431***
	[0.0014]	[0.0014]	[0.0034]	[0.0034]
_cons	0.3812	0.3267	-1.3069**	-1.0875*
	[0.2580]	[0.2916]	[0.6107]	[0.6489]
Year dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
N	9888	9374	9888	9374
N_g	2573	2436	2573	2436
Log Likelihood	-19545.2918	-18534.5085	-8468.2921	-8031.0218

＊Standard errors are expressed in parentheses. *, **, and *** show significance at 10%, 5%, and 1% levels, respectively.

Figure 1 Number of products in R&D and non R&D firms

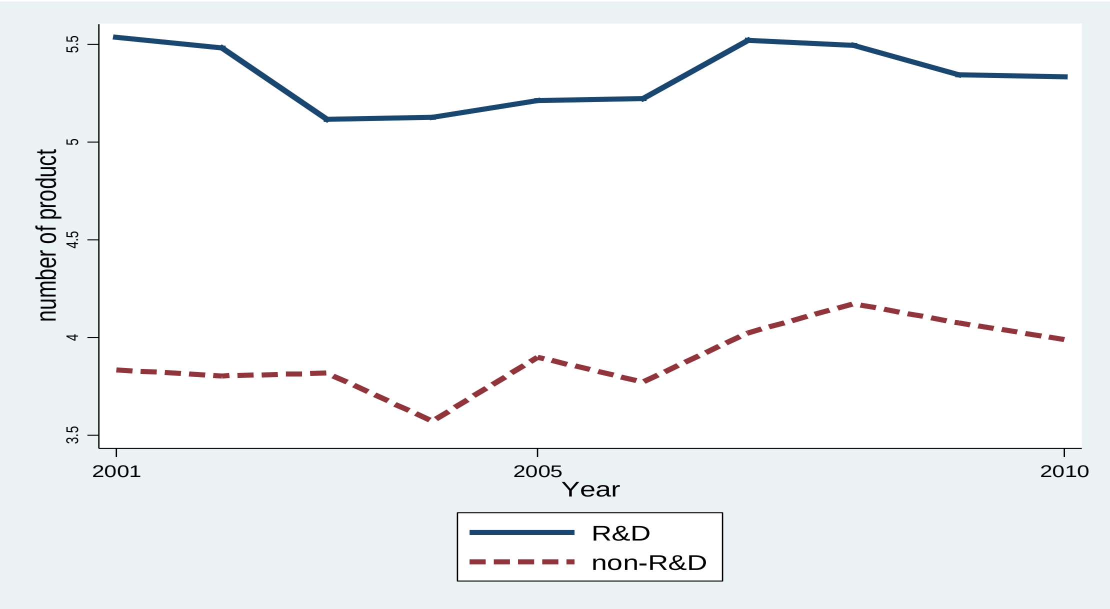

Figure 2 Number of added products in R&D and non R&D firms

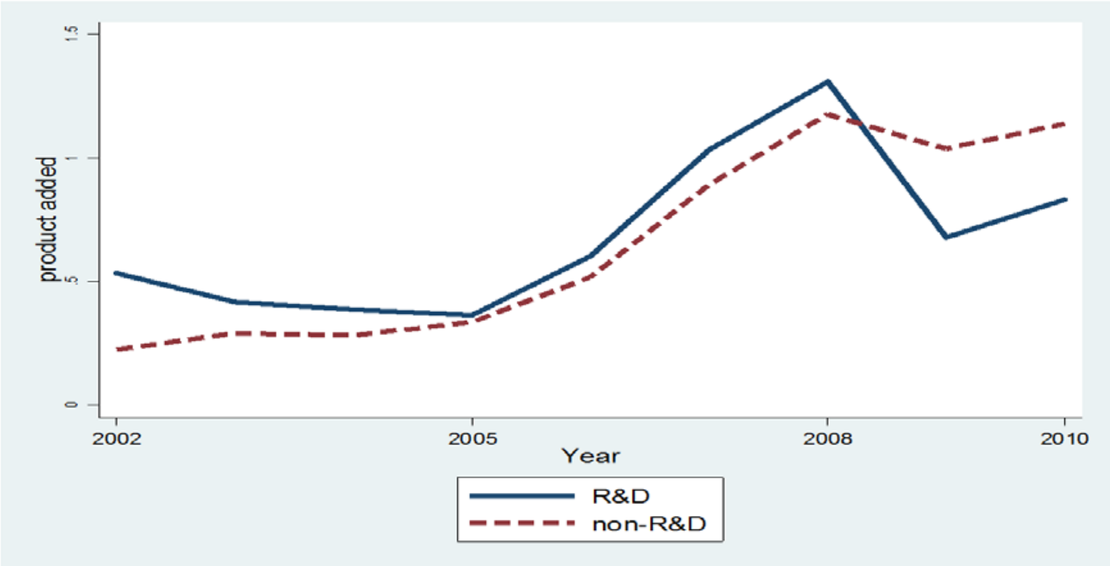

Figure 3 Number of dropped products in R&D and non R&D firms

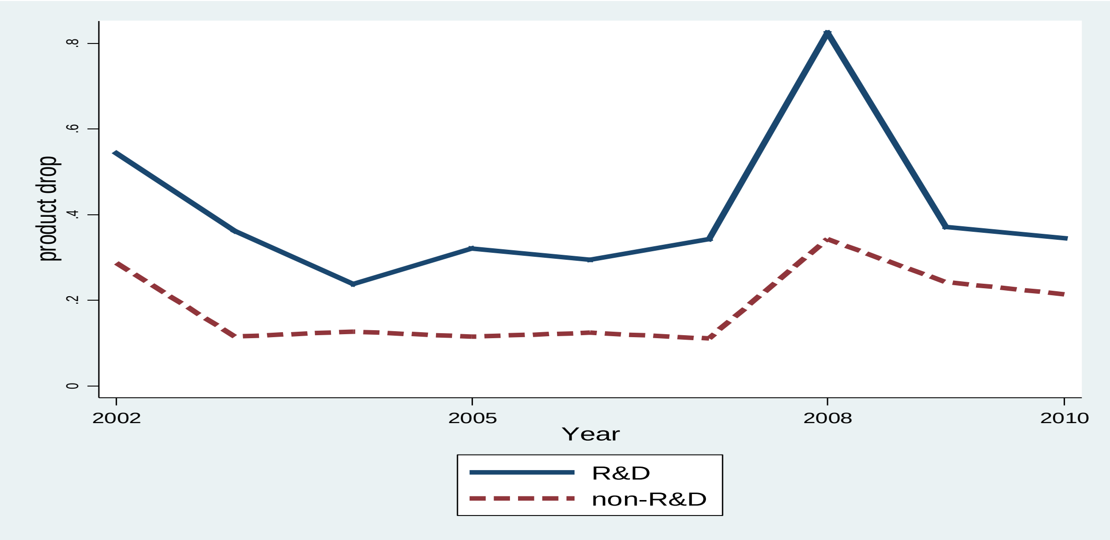

Figure 4 Firm age in R&D and non R&D firms

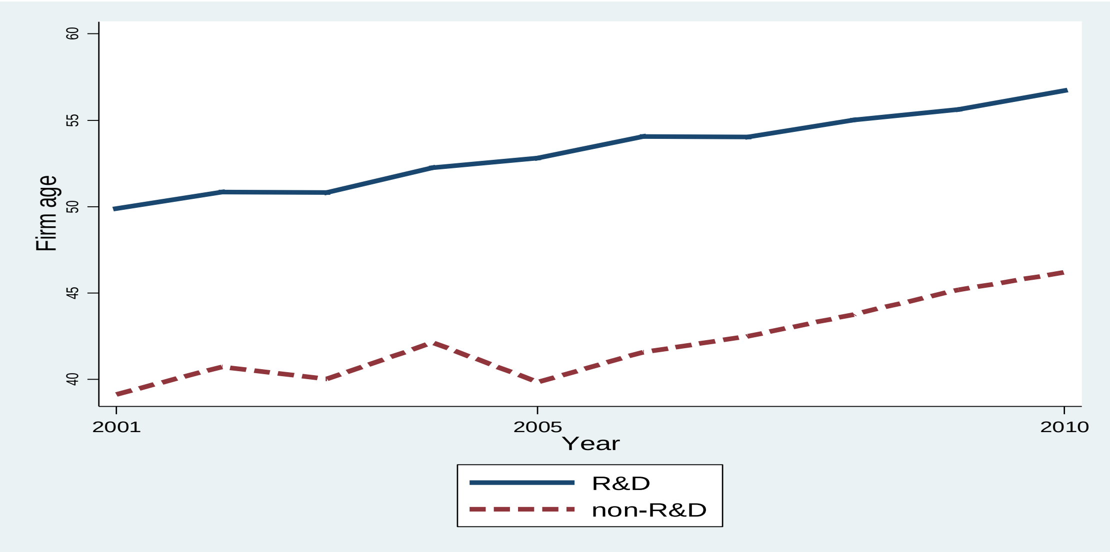

Figure 5 Firm size measured by number of employees in R&D and non R&D firms

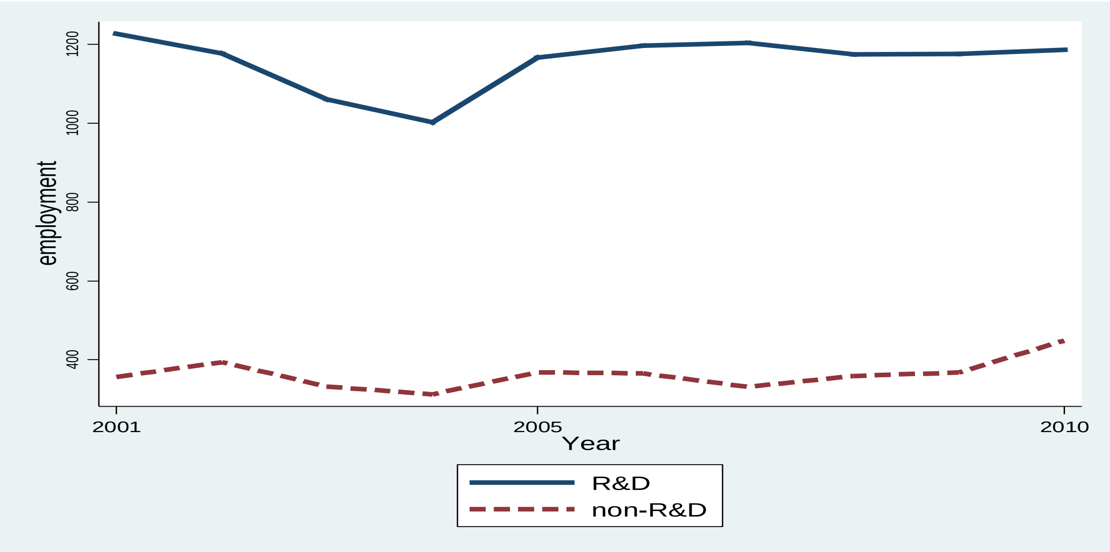

Figure 6 Export ratio in R&D and non R&D firms

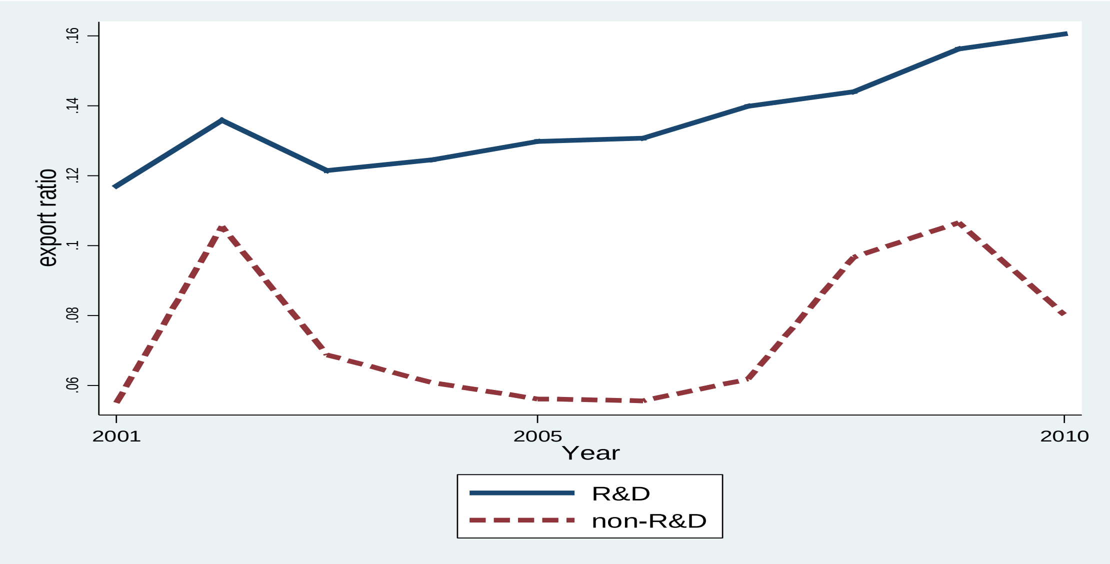

Figure 7 Sales/man hour in R&D and non R&D firms

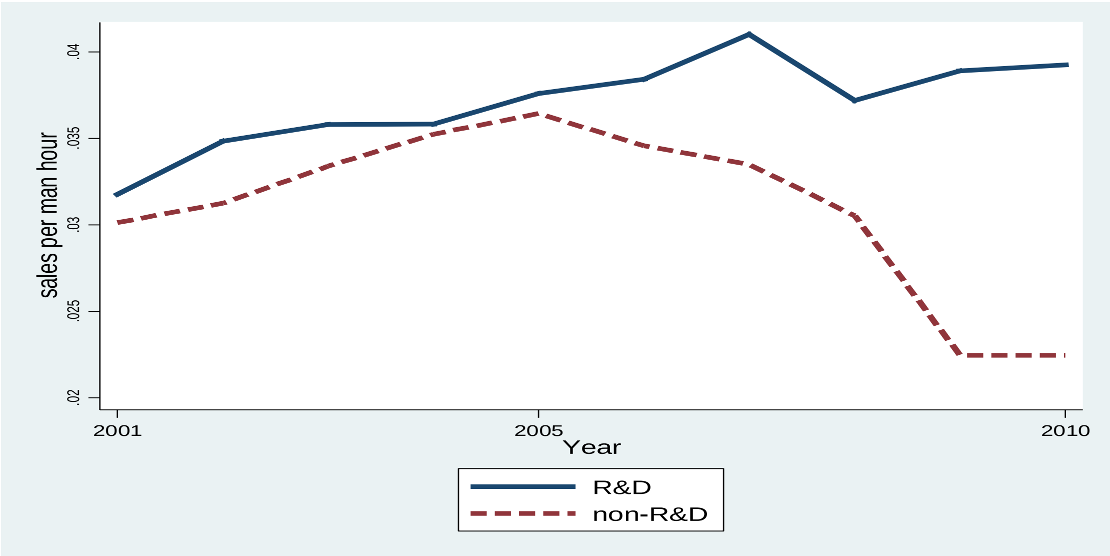

Figure 8 TFP in R&D and non R&D firms

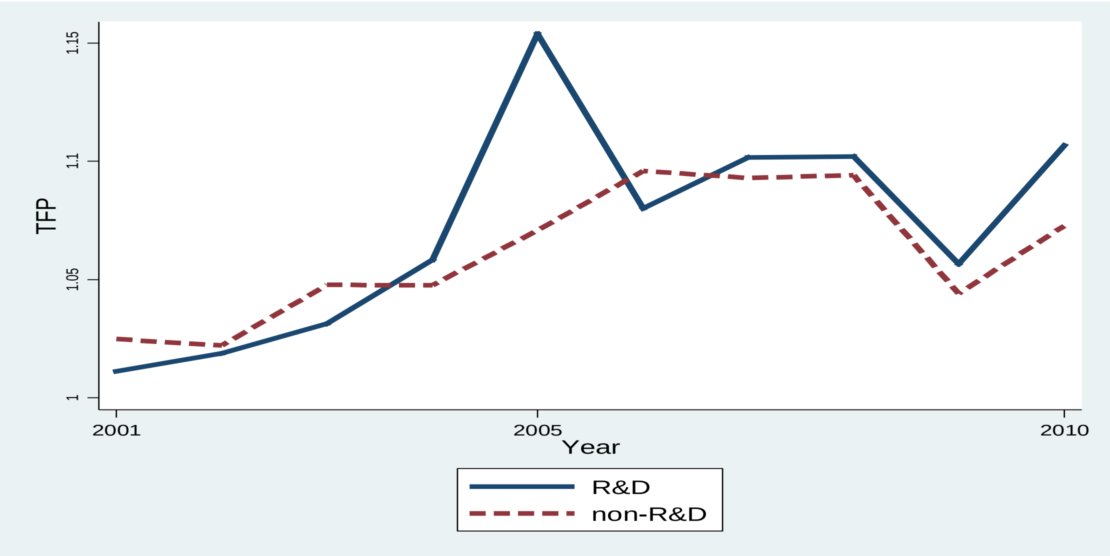

Figure 9 ROA in R&D and non R&D firms

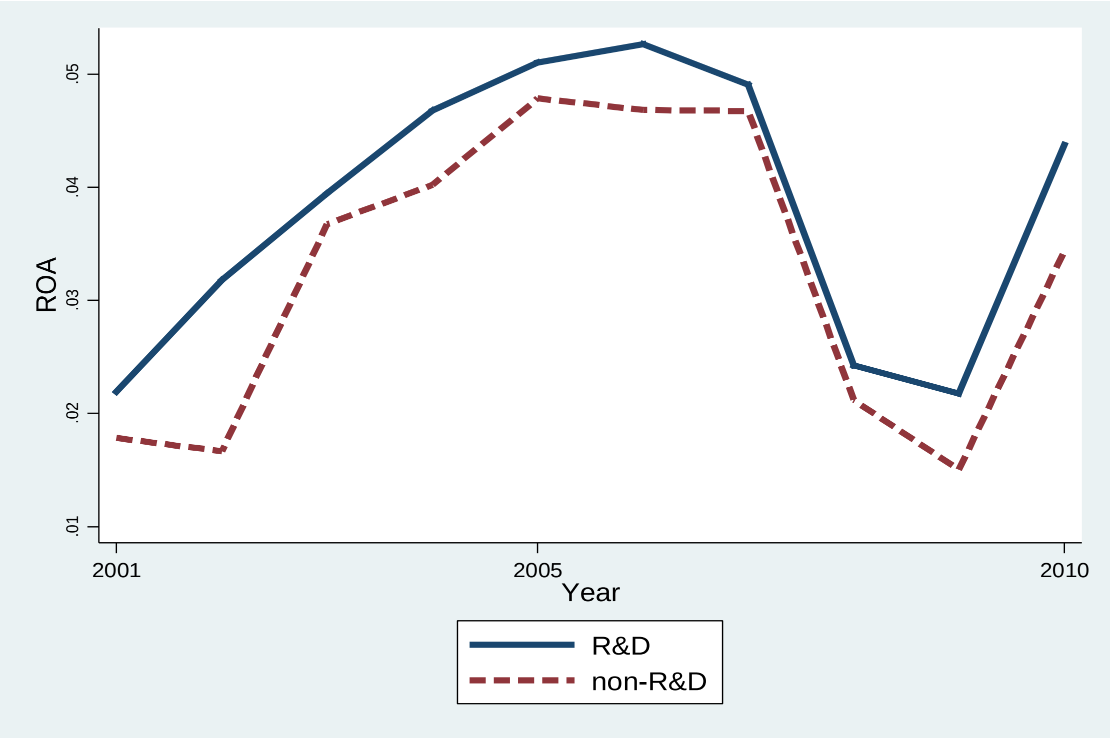

Figure 10 ROE in R&D and non R&D firms