Prague Economic Papers
2023, Volume 32, Issue 3
https://doi.org/10.18267/j.pep.832

PRAGUE UNIVERSITY OF ECONOMICS AND BUSINESS

Evaluation of Relative R&D-led Growth with Specific Reference to Heterogeneous Time-varying R&D Decision: A Novel Approach

Ömer Tuğsal Doruk [a]

a Adana Alparslan Türkeş Science and Technology University, Department of Business, Adana, Turkey & GLO Fellow, GLO, Essen

email: otdoruk@atu.edu.tr

Abstract:
The relationship between R&D expenditures and firm growth is examined for a cross-country firm-level dataset for the EU countries in the period from 1989 to 2019. A panel dynamic average treatment effect is estimated using a panel time-varying dynamic difference-in-differences model. The methodology can be counted as novel. The results show a positive and significant relationship between R&D and firm growth within the first five years of R&D investment in the 22 EU countries, over 700 firms and 30 years. The main novelty of the present study comes from examining the time-varying effect of R&D expenditures on firm growth for manufacturing firms in EU countries.

Keywords: R&D, firm growth, EU countries, time-varying R&D-led growth, dynamic time-varying difference in differences

JEL Codes: L25, L29, O00

Introduction

After the 1990s, with rapid development in the information and communication technology sector (ICT), research and development (R&D) or innovation took on a central role in economies. The link between R&D and economic growth is positive in the long run (Grossman and Helpman, 1991; Lucas, 1988; Romer, 1990). Grossman and Helpman (1991) point out that industrial innovation may ameliorate development conditions in the long run. As a result, firms implement R&D projects to gain a competitive advantage, as Schumpeter (1942) pointed out the creative destruction by smaller firms in an economy. Thus, researching the link between firm growth and R&D investments is necessary for EU manufacturing firms. By examining the effect of R&D on firm growth for EU firms in a time-varying manner, a novel empirical approach is utilized for firms operating in Euro area countries. A panel time-varying dynamic difference-in-differences method is used to examine the R&D-led growth of European firms in the period 1989–2019.

As a result, the current study examines R&D-led growth using a comparative approach that includes R&D non-performer firms as a control group. The approach is based on the time-varying average treatment effect of R&D expenditures on firm growth over a period of 30 years. The time-varying R&D-led growth of R&D-performer firms is examined in comparison to R&D non-performer firms in Eurozone countries. Bayomi et al. (1999), Bronzini and Piselli (2006), Coe and Helpman (1995), Frantzen (2000) and Griliches (1973, 1980) have found that the relationship between R&D and economic growth is positive in the long run by using macro-level or aggregate-level data. By using micro-level or firm-level analysis, Capasso et al. (2015), Chung et al. (2019), Chen and Yu (2022), Coad and Grassano (2019), Coad and Rao (2015), Coad et al. (2016), Demirel and Mazzucato (2012), Deschryvere (2014), Di Cintio et al. (2017), Falk (2012), García-Manjón et al. (2012), McKelvie et al. (2018), Oliveira and Fortunato (2017), Spescha (2019), Stam and Wennberg (2009) and Zhu et al. (2021) have found that the role of R&D on firm growth is positive. For the sectoral level, they have examined the link between R&D and industrial growth and found that the link between R&D and industrial growth is positive. The present study concentrates on EU countries since R&D expenditures have an essential share in the EU economies. However, the present study offers a new and unique contribution to the existing R&D-led growth literature by focusing on the time-varying effect of R&D on firm growth for firms in EU countries. Therefore, the present study uses a novel methodology to contribute to the existing R&D-led growth literature.

This study analyses the impact of R&D on firm growth over time. Using a sample of more than 700 firms from 22 EU countries over 30 years, the main model is estimated. However, when control variables are added, the number of firms in the sample drops to 267. The low representativeness of the second model in this framework makes it difficult to generalize the results obtained in this study. However, in the existing literature, difficulty accessing R&D information or non-reporting by the firm is a common situation. In this framework, the R&D-driven firm growth approach, which is considered with 700 firms in the main model of the study, has the potential to make a significant contribution to the related literature when investigating the impact of time-based R&D investment on firm growth.

The rest of this article is organized as follows. After a literature review, Section 2 provides the dataset, methodology and hypothesis. Econometric findings are presented in Section 3 and discussed in Section 4. In the last section, recommendations with limitations are given along with a general conclusion.

1. Literature Review

The relationship between knowledge and economic growth is not a new topic in the relevant literature. For Marshall (1890), knowledge is the most potent production engine (see also the review by Carlaw et al., 2006). However, the earlier economic growth models do not have enough power to understand the role of technology in long-term economic growth.

Technological change is an essential catalyst for economic growth in the neoclassical growth model, also known as the Solowian growth model. In the production function:

$$Y = A \times f(K, L) \tag{1}$$

where K and L are capital and labour, respectively. However, A shows that technological change is exogenous in the Solow model. For Solow (1956), the main production factor for the countries is technology, and technology is calculated as a Solow residual. After the Solow model, which assumes technological progress to be an exogenous factor of production, the neoclassical endogenous growth models were constructed. Furthermore, for Schumpeter (1942), innovation, or R&D, plays a vital role in creative destruction for economic growth and development.

Arrow (1962) underlined that technological change lies on the learning curve and plays a vital role in economic growth. Griliches (1979) was the first author to introduce R&D into the production function (see Blanco et al., 2013), emphasizing that R&D expenditures are one of the main catalysts for productivity growth or economic growth. Judd (1985) also examines the role of R&D on economic growth using the computable general equilibrium (CGE) model; however, the role of R&D is not efficient in the long term since Judd's model assumes R&D to have diminishing returns (Sokolov-Mladenovic et al., 2016).

The relationship between innovation and economic growth is examined within the new growth theory concept (Sokolov-Mladenovic et al., 2016) and theoretically articulated by Romer (1990). In Romer's model, R&D is regarded as an essential source for economic growth. R&D-led growth models have been examined by Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992) and Lucas (1988). In Romer's (1990) model, technology is a non-rival good, and firms are more profitable due to this non-rival status of knowledge. Technology is compatible with a monopoly in Romer's model, and R&D thus has increasing returns to scale. In Romer's model, R&D has a positive impact on economic growth in the long run. Technology, or R&D, has increasing returns and is a part of non-rivalry or monopoly, which relaxes the assumptions of the previous models.

The new economic geography-led growth models also emphasize the role of R&D in growth, as Montmartin and Massard (2013) pointed out. In this line, Martin and Ottoviano (2001) and Montmartin (2013) have shown that growth is dependent on the link between economic geography and R&D. Thus, the geographical design of R&D has a positive effect on growth. Aghion et al. (1997, 2001) have emphasized that the role of innovation and technological catch-up between competitors positively affects growth in the current literature.

Besides the theoretical approaches to R&D-led growth, there is substantial applied literature. In the applied literature, the analyses examining the link between R&D and economic growth are divided into country-wide, sectoral, and firm-level analyses. For country-wide analyses, Coe and Helpman (1995), Frantzen (2000), Bronzini and Piselli (2006) and Bayomi et al. (1999) have found that the relationship between R&D and economic growth is positive in the long run. Griliches (1973; 1980) has examined the link between R&D and industrial growth at the sectoral level, finding that the link between R&D and industrial growth is positive. For firm-level analyses, the studies of Chung et al. (2019), Chen and Yu (2022), Coad and Grassano (2019), Coad and Rao (2015), Coad et al. (2016), Capasso et al. (2015), Demirel and Mazzucato (2012), Deschryvere (2014), Di Cintio et al. (2017), Falk (2012), García-Manjón et al. (2012), Mc Kelvie et al. (2018), Oliveira and Fortunato (2017), Spescha (2019), Stam and Wennberg (2009) and Zhu et al. (2021) have examined R&D-led growth in the existing literature (see Table 1).

For the studies that use firm-level datasets, according to the literature review, it is seen that the relationship between R&D and firm growth is addressed from different perspectives. In the last decade, the relationship between R&D and firm growth has been investigated by means of quantiles that deal with lags instead of the current period and are generally oriented towards the increase in R&D expenditures. However, the relative impact of R&D expenditures on firm growth and the heterogeneous treatment of firms with R&D expenditures at different times at the firm level are clearly a significant contribution to the literature (see Table 1 for the R&D-led growth empirical literature). Capasso et al. (2015) concluded that most companies are not able to report R&D. Hence, there are significant limitations in the data on R&D expenditures. However, this study estimates "relative" firm growth by including not only firms with positive R&D expenditures but also firms with no R&D expenditures in the sample, as used in the literature (e.g., Capasso et al., 2015). Unlike the previous studies, the effect of R&D expenditures on firm growth is examined in the present study using the time-varying effect of R&D expenditures on firm growth by using a cross-country firm-level dataset. The effect of R&D expenditures on firm growth cannot be seen in the current term, and therefore such an effect is estimated using time-varying dynamic difference-in-differences methodology for the sample. Thus, the present study offers a new insight to the current literature. The literature review clearly shows the contribution of the present study to the existing R&D-led growth-related literature.

Table 1: Selected studies in empirical R&D growth literature

Study	Country	Sample	Method	Does R&D support firm growth?	Was lag of R&D spending used? If so, which lag level was used?
Chung et al. (2019)	South Korea	2007–2018, Pharmaceutical firms	OLS, fixed effect, penalized quantile regression with fixed effect	Yes, but the effect is different for different firm groups.	Yes, t–1.
Chen and Yu (2022)	China	2018	Hierarchical regression and OLS	Yes.	No.
Coad and Grassano (2019)	EU	2001–2015	SVAR	Yes (Only, t–1 has positive effect on growth).	Yes, t–1 and t–2.
Coad and Rao (2015)	USA	1973–2004 US manufacturing firms	OLS, LAD, and panel VAR	Yes.	Yes, t–1 t–2 and t–3.
Coad et al. (2016)	Spain	2004–2012	Panel quantile regression model	Yes, the effect is different in sub samples.	Yes, t–1.
Capasso et al. (2015)	Netherlands	1996–2006, 2-year cross-sectional data	OLS, Tobit, and quantile regression model	Yes, but different for firm groups.	Yes, t–1 up to t–5.
Demirel and Mazzucato (2012)	USA	1950–2008 Pharmaceutical firms	GMM	Yes, but the effect is different in subsamples.	Yes, only t–1.
Deschryvere (2014)	Finland	1998–2008	LAD	Yes.	Yes, t–1, t–2 and t–3.
Di Cintio et al. (2017)	Italy	2001, 2004 and 2007	Quantile regression	Yes.	No.
Falk (2012)	Austria	1995–2006	LAD, quantile regression	Yes.	Yes, t–1 and t–2.
García-Manjón et al. (2012)	EU	2003–2007, European firms	OLS, quantile regression and GMM	Yes.	Yes, only t–1.
Mc Kelvie et al. (2018)	Sweden	Cross section based on questionnaire/survey	OLS	Yes.	Yes, t–1 and t–2.
Oliveira and Fortunato (2017)	Portugal	1990–2001	OLS, GMM	No.	Yes, t–1 and t–2.
Spescha (2019)	Switzerland	1995–2012	OLS, GMM	Yes, but the effect is different in subsamples.	Yes, t–1 (but marginal effects are estimated up to 75 years).
Stam and Wennberg (2009)	Netherlands	1994	OLS	No for new firms within 6 years.	Yes, t–1 and t–2 (but R&D is examined within 6 years).
Zhu et al. (2021)	China	2012–2017, manufacturing firms	Quantile regression, OLS and GMM	Yes (but the second lag has no significant effect on growth).	Yes, t–1 and t–2.

Note**:** OLS = ordinary least squares, LAD = least absolute deviations. GMM = generalized method of moments.

2. Dataset, Methodology and Hypothesis

The dataset consists of industrial firms that are publicly held. The period selected is between 1989 and 2019. The firm-level data are taken from Thomson Reuters Refinitiv, which provides the necessary and reliable information about financial statements, corporate filings, and managerial and financial information. To avoid the disruptive effect of COVID-19 on R&D investment and firm growth, the time endpoint of the sample is selected as 2019. With the exception of the R&D performer dummy variable, outliers are cleaned by excluding variable points in percentiles above 99% and below 1%, following the empirical literature on finance and economics (see Andres et al., 2014; Banyi et al., 2008; Brown and Petersen, 2009; Hovakimian and Li, 2011; Tian and Twite, 2014).

Outliers may represent poor accounting conditions, mergers and acquisitions, or some extraordinary situations at the firm level, and they may cause a misinterpretation of the results. Finally, the dataset consists of 723 manufacturing firms after eliminating firms with the above conditions. The total firm-year observations are 7021 for the econometric analysis.

A panel time-varying dynamic difference-in-differences method with fixed effects is used to study the time-varying average treatment effect of R&D expenditures on firm growth. In this model, each firm makes an R&D investment at a different time that is considered. This model, as far as the author is aware, has not been used in the existing R&D-led growth literature. Furthermore, it is consistent with the study's objectives that each firm makes its R&D investment at a different time, as evidenced by a comparison of R&D non-performer firms in the sample. The econometric model estimated in the present study is defined as follows:

$$Growth_{i,t} = \beta_0 + \beta_1 \Pr eR\,\&\,D_{i,t-1} + \sum_{i=0}^{10} \beta' \; PostR\,\&\,D_{i,t} + v_{i,t} + \varepsilon_{i,t} \qquad (2)$$

In Equation 1, the variable *PostR&D* denotes the time after the R&D investment, which is different for each firm in the sample. The variable *PreR&D* shows the year before the R&D expenditures. It is up to 10 years since an R&D investment can typically generate an outcome for manufacturing firms in the long run (studies use 10-year-based R&D project maturity; see Hemantha et al., 1999; Perlitz et al., 1999). Coad and Rao (2010) and Capasso et al. (2015) emphasized that it is expected that R&D will have a cost impact in the short term but will start to make a commercial contribution (or, in other words, a commercially valuable discovery) in the long term.

The dependent variable is firm growth, measured as the growth rate of sales, which is used as a proxy for the outcome at the firm level. In its logarithm, this variable is constructed as a difference between current net sales and lag net sales. Following the current literature, because of the ability to reflect both short-term and long-term changes in firms (Davidsson and Wiklund, 2006; Ergün and Doruk, 2020), furthermore, as Aghion et al. (2005) underlined, R&D expands demand and production, and therefore sales growth is used to measure this effect. In Equation 2, growth denotes firm growth, which is measured as the logarithmic difference between the current sales and the sales in the previous terms. This model finds the relevant and average treatment effect of R&D on firm growth.

For robustness checks, Equation 2 is re-estimated by using different confounding variables that affect firm growth and that can affect the relationship between R&D and firm growth:

$$Growth_{i,t} = \beta_0 + \beta_1 PostR\&D_{i,t} + \beta_2 R\&Dp_{i,t} + \beta'_n X_{i,n} + v_{i,t} + \varepsilon_{i,t} \tag{3}$$

where X denotes the control variable matrix in the econometric model. As Cerulli et al. (2020) underlined, pre- and post-treatment effects are visible in this approach. The lag effect is vital for the R&D-led growth approach; in other words, the current treatment (in the present study: R&D expenditures) affects future firm growth. It is not expected that the current treatment effect is significant for R&D-led growth.

The first control variable is leverage (*Lev*). *Lev* denotes the leverage at the firm level and is estimated by dividing total debt by total assets; all the items (total debt and total assets) are taken from the firm's balance sheet. The variable *Lev* controls the financial risk level in the econometric model. Since the R&D investment has high fixed costs, the financial risk level may hinder the R&D investment. Financial risks may represent financial uncertainty (see Kou et al., 2014), and high leverage can limit firm growth (Bernanke et al., 1994). Financial leverage, denoted as $Lev_{i,t}$, shows the effect of the firm-level gearing ratio on firm growth.

Profitability ($\pi/K_{i,t}$) denotes the net operational profit, and is calculated as the net operating income to capital ratio. To correct for multicollinearity and size effects, this variable is scaled by lagged or beginning-of-period capital stock. As current literature (Romer, 1990; Cincera and Ravet, 2010; Cincera et al., 2016) points out, profitability or internal finance is essential for the link between R&D and firm growth[1].

Firm size (*SIZE*) is selected as Storey (1994) underlined that small firms realize faster growth following successful innovations; Exposito and Sanchis-Llopis (2019) also showed that innovation affects the financial and operational structure of SMEs. Small firms suffer from liability constraints, cash flow volatility (or unstable cash flow streams), limited access to capital markets, and lower competitiveness (see Kalleberg and Leicht, 1991; Berger and Udell, 2006; Singh et al., 2008). Age (denoted as *AGE*) represents the firm age. It represents

1 The correlation analysis for the independent variables show that there is no multicollinearity problem in the model. The correlation between independent variables is not more than 40%.

the fact that young firms may have low growth rates or that technology-intensive young firms have high growth rates.

R&Dp is the treatment variable and denotes the firms counted as "R&D performer firms". If a firm's R&D expenditures are greater than zero, the firm is selected as an R&D performer; otherwise, this treatment variable (a binary variable) is set to 0. Firms that do not report R&D expenditures are classified as non-performers. Table 2 shows the descriptive statistics for the variables *Gsales* and *R&Dp*. The sample is unbalanced. The average firm growth is around 0.02 (or 2% in percentage terms).

Table 2: Descriptive statistics

Variable	Mean	Std. dev.	Min	Max	Observations
$Gsales_{i,t}$	0.02	0.20	–1.16	1.42	N = 7021, n = 723, T = 9.71
$R\&D_p$	0.52	0.49	0	1	N = 7021, n = 723, T = 9.71

Source: author's own calculations

2.1 Hypothesis

The main hypothesis of the present study comes from the intuition that the effect of R&D investment has no instant effect on firm growth. Then, the hypothesis of the present paper can be defined as follows:

> ***H1:*** *It is expected that there are no immediate effects of R&D investment on firm growth for the firms operating in EU countries.*

Then, the present study asks the question, if there is no instant effect of R&D on firm growth, how long the R&D investment positively affects firm growth in the EU context. The hypothesis is very critical to understanding the R&D-led growth of firms in the EU, and the present study is therefore designed to explore the time-varying effect of R&D investment on firm growth in the EU.

3. Estimation Results

The estimation results from econometric estimations of the base model are depicted in Table 3.

Table 3: Average treatment effect with panel time-varying dynamic difference-in-differences model

(1) $Gsales_{i,t}$						
β_0	**t–1**	**t =0**	**T+1**	**T+2**	**T+3**	
0.0464*** (4.25)	−0.0158 (−0.99)	0.0110 (0.60)	0.00197 (0.13)	−0.0563*** (−3.66)	−0.00517 (−0.38)	
T+4	**T+5**	**T+6**	**T+7**	**T+8**	**T+9**	**T+10**
0.0399** (2.94)	0.00395 (0.33)	−0.0171 (−1.46)	−0.00875 (−0.73)	0.00384 (0.36)	−0.00266 (−0.20)	0.00477 (0.46)
N				7021		
No. of firms				723		
***R^2* within**				0.005		
***R^2* between**				0.01		
Parallel-trend assumption diagnostics: F(1, 722) = 0.98 Prob > F = 0.32						
RESULT: Parallel trend passed						

Note: *t* statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Source: author's own estimations

The findings obtained from econometric estimations of the base model show that the relationship between R&D and growth is negative and insignificant in the period from the current term to the fourth year of R&D investment in the main model. In other words, as expected, there is no current effect of R&D investments on firm growth, and there is no statistically significant and positive relationship between R&D and firm growth up to the fourth year of the R&D investment spending. In the fourth year, the effect of R&D investment on firm growth becomes positive and statistically significant, as seen in Table 2. However, the positive effect fades away after the fourth year since there may be competition due to the imitation, as Cerulli (2021) and Schumpeter (1942) underline. In this context, it can be stated that the effect of R&D investment on firm growth is not expected to be positive or significant in the current term in the EU context. According to the findings of the panel binary time-varying treatment method, the effect of R&D investment on firm growth is insignificant or negative within the first three years. The findings prove the changing nature of the R&D-firm growth nexus for manufacturing firms in EU countries. The results demonstrate the effect of R&D investment on firm growth in the EU context in an exploratory manner using a novel approach. Note that the effect of R&D investment on firm growth is also relative since the coefficients show the relative effect of R&D investment on firm growth. The model is based on R&D investor firms as the treatment group; the R&D non-performers (or firms not investing in R&D) are the control group in the econometric model.

Low R^2 is a situation generally encountered in panel datasets. This is due to the heterogeneity of the horizontal cross-section in panel datasets, which explains the variance of the dependent variable over time. This cross-sectional heterogeneity is also a heterogeneity that contributes significantly to reducing omitted variable bias. As Sisodia and Soares (2015) and Amihud and Goyenko (2013) emphasize, model soundness is not necessarily related to a high R^2; increasing the number of independent variables used in a regression raises the value associated with R^2, and in certain circumstances, a lower R^2 suggests higher selectivity. Therefore, in most panel datasets, a low R^2 is not a cause for concern or a problem.

The main intuition behind this estimation is that the primary motivation of the R&D investment is to gain a competitive advantage, as pointed out by Schumpeter (1942). As a result, the findings demonstrate the creative destruction effect of R&D investment on firm growth in the EU context. As far as the author knows, this is the first study to prove the effect of R&D investment on firm growth on a relative and time-varying basis.

Table 4 shows the results of the robustness test, in which the control variables are added to the econometric model. The results show that the effects of leverage and profit on firm growth are positive and statistically significant at the 5% level. In comparison, the effect of size on firm growth is positive but is statistically significant at the 10% level. The effect of a firm's age on growth is negative and statistically significant at the 5% level. The obtained findings show that firm leverage, profit, and firm size affect firm growth positively, whereas there is a negative and statistically significant relationship between a firm's age and firm growth in EU countries.

Nevertheless, using the control variables in the econometric model – firm-level financial conditions and firm scale – the effect of R&D on firm growth is positive within the first four years. As the firm control variables are added to the econometric model, the sample size is dramatically reduced to 267 firms because there is no available information for all firms in the sample. However, it can be stated that the effect of R&D on firm growth is practical within the first four years.

As for control variables, profit rate and firm size have a positive and statistically significant effect on firm growth. At the same time, there is no statistically significant relationship between leverage and firm growth. Furthermore, a firm's age has a negative and statistically significant effect on firm growth.

Table 4: Average treatment effect with panel time-varying dynamic difference-in-differences model with control variables

(1) $Gsales_{i,t}$					
β0	**t–1**	**t=0**	**T+1**	**T+2**	**T+3**
–1.204* (–2.11)	–0.0285 (–0.98)	–0.00615 (–0.19)	0.00130 (0.05)	–0.0505* (–2.45)	–0.0127 (–0.54)
T+4	**T+5**	**T+6**	**T+7**	**T+8**	**T+9**
0.0456* (2.04)	0.0318 (1.26)	–0.0246 (–1.05)	0.000232 (0.01)	–0.000289 (–0.01)	–0.0160 (–0.71)
T+10	$SIZE_{i,t}$	$AGE_{i,t}$	$\pi/K_{i,t}$	$LEV_{i,t}$	
–0.00276 (–0.17)	0.0689* (2.25)	–0.00358 (–1.83)+	0.0855* (2.09)	0.0617 (0.87)	
N				1751	
No. of firms				267	
R^2 within				0.06	
R^2 between				0.009	

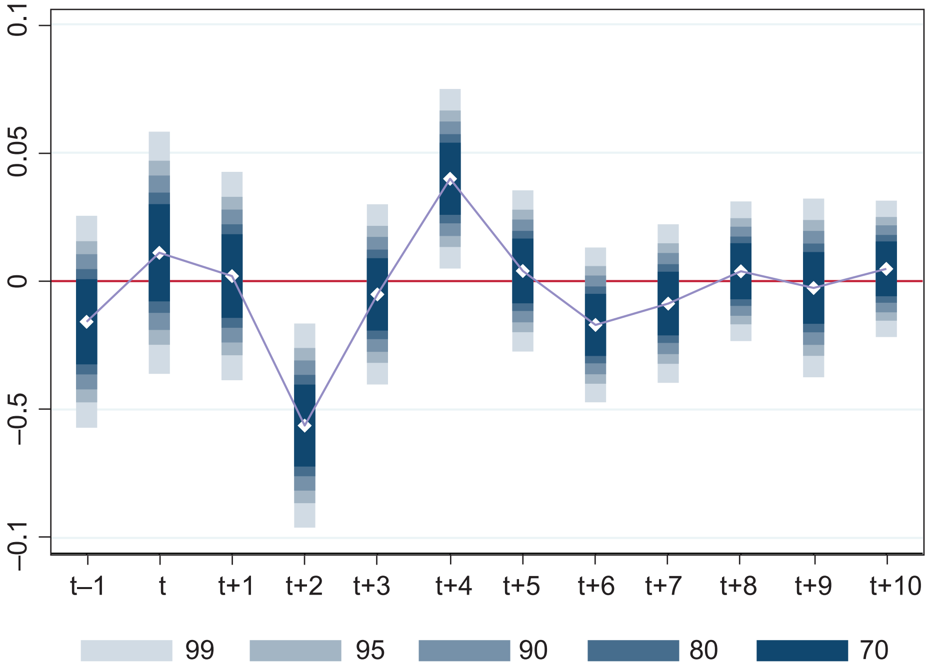
Parallel-trend assumption diagnostics:
F(1, 266) = 0.96
Prob > F = 0.32

RESULT: Parallel trend passed

Note: *t* statistics in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Source: author's own estimations

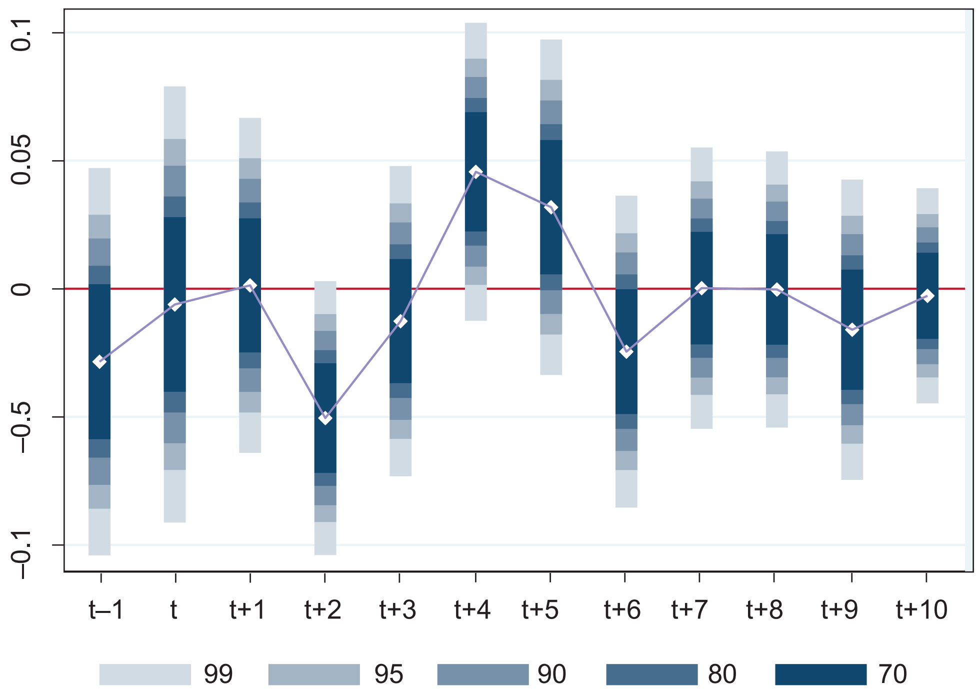
The results obtained by comparing R&D investments in the pre-R&D investment period (t−1) with the post-R&D investment period and considering the period of R&D investment separately for each firm are presented in Figure 1. The findings show that the effect of R&D investment on firm growth is positive after four years, while the previous periods after the initiation of R&D investment showed negative effects for firms in the EU. The robustness check with the control variables also gave the same results as in Figure 1 and Table 2.

Figure 1: Effect of R&D on firm growth in EU



Source: Author's own estimations. Shaded areas show confidence intervals. For this estimation, the parallel trend assumption is passed.

Figure 2: Effect of R&D on firm growth of EU firms: robustness check results



Source**:** Author's own estimations. Shaded areas show confidence intervals. For this estimation, the parallel trend assumption is passed.

4. Discussion

In the present study, a different and novel approach is utilized to examine the R&D-led growth hypothesis for the widely understudied EU firms in the Euro area. In the microeconomic context, no study has looked at the time-varying treatment effect of R&D investment on firm growth. The present study offers a time-varying treatment effect of R&D investment on the firm growth of EU firms.

The main model results show that the effect of R&D on firm growth is not significant in the short term. As we know that R&D projects have very high starting costs and phases to complete, the effect of R&D on firm growth can be seen in the long run. The findings from the main model prove this assumption by using a novel methodology and dataset. The robustness check is also utilized by using a set of different control variables that can significantly affect firm growth. The robustness check results show that the main model results are unaltered.

The results of the econometric models show a link between R&D and firm growth in EU manufacturing firms. The findings obtained in the study are not similar to those of the studies discussed here. Capasso et al. (2015), Chung et al. (2019), Chen and Yu (2022), Coad and Grassano (2019), Coad and Rao (2015), Coad et al. (2016), Demirel and Mazzucato (2012), Deschryvere (2014), Di Cintio et al. (2017), Falk (2012), García-Manjón et al. (2012), McKelvie et al. (2018), Oliveira and Fortunato (2017), Spescha (2019), Stam and Wennberg (2009) and Zhu et al. (2021) have empirically examined R&D-led growth, but the present study adds a different insight to the existing literature. Although the findings of this study are similar to those of some other studies (Capasso et al., 2015; Coad and Rao, 2010) that indicate that the effect of R&D investments on firm-level dynamics is medium-term, in this study, R&D expenditures are analysed separately for each firm, and the effect on firm growth is investigated relatively with a novel methodology. It is thought that the study will make a significant contribution to the literature and shed new light on this issue.

5. Conclusion

The present study examined the effect of R&D investment on firm growth for manufacturing firms operating in EU countries using a novel and time-varying econometric methodology. In the long run, the role of knowledge on economic growth has a special place for economic growth, because innovation accelerates economic growth in the long run. However, in the short run, whether R&D investment accelerates firm growth is questionable and ambiguous in the existing literature. Therefore, the present study examines the time-varying effect of R&D on firm growth in the EU context for the period 1989–2019.

The main contribution of this paper to the R&D-led growth literature is twofold. Firstly, unlike the previous studies, the present study focuses on firm growth; this paper uses a cross-country dataset by considering the time-varying effect of R&D investment on firm growth in the EU countries. Secondly, using a comprehensive and cross-country dataset, the current study promotes firm growth by focusing on R&D investment.

The estimation findings show that the effect of R&D investment on firm growth is significant and positive after four years of R&D investment. The findings are beneficial to policymakers and C-suite executives in several ways. Firstly, the effect of R&D investment on firm growth after the first four years of its initiation is beneficial to policymakers who design R&D incentives. Policymakers can use our findings to design R&D incentives and various support programmes. Secondly, the C-suite executives can design and consider this time-varying growth effect of R&D investment in their project evaluation criteria. As we know, R&D investment is a very trend-shifting factor, as indicated by Solow (1956) and Schumpeter (1942); however, the cost of R&D investment is about four years for firms that want to improve their growth performance.

The limitation of the present study comes from the lack of data. While the present study uses a comprehensive firm dataset for 22 EU countries, all the firms are publicly held. In other words, the present study does not use information on private firms. Thus, the results of this paper may not be generalized to private firms. For further studies, the relationship between R&D and growth in private firms could be examined using cross-country data.

Future studies are recommended to replicate R&D-led growth in emerging or developed countries with more dense datasets and to reveal important differences. In this framework, analyses of R&D-led growth by the level of development of countries (taking into account important issues such as patent protection rights and intellectual property rights) at the firm level based on the time series used in this study can make important contributions.

Appendix

Table A1: Country list

Country of exchange	Freq.	Percent
Austria	226	3.22
Belgium	399	5.68
Cyprus	42	0.60
Estonia	25	0.36
Finland	539	7.68
France	1,675	23.86
Germany	1,878	26.75
Greece	463	6.59
Ireland	32	0.46
Italy	640	9.12
Latvia	102	1.45
Lithuania	66	0.94
Luxembourg	24	0.34
Malta	10	0.14
Netherlands	288	4.10
Portugal	114	1.62
Slovakia	40	0.57
Slovenia	40	0.57
Spain	418	5.95
Total	7,021	100.00

References

Aghion P., Howitt P. (1992). A Model of Growth through Creative Destruction. *Econometrica*, 60(2), 323–351. https://doi.org/10.2307/2951599

Aghion P., Harris C., Vickers J. (1997). Competition And Growth with Step-By-Step Innovation: An Example. *European Economic Review*, 41, 771–782. https://doi.org/10.1016/S0014-2921(97)00036-6

Aghion P., Harris C., Howitt P., Vickers J. (2001). Competition, Imitation and Growth with Step-By-Step Innovation. *Review of Economic Studies*, 68, 467–492. https://doi.org/10.1111/1467-937X.00177

Aghion, P., Bloom, N., Blundell, R., Griffith, R., Howitt, P. (2005). Competition and Innovation: An Inverted-U Relationship. *The Quarterly Journal of Economics*, 120(2), 701–728. https://doi.org/10.1093/qje/120.2.701

Amihud, Y., Goyenko, R. (2013). Mutual Fund's R2 as Predictor of Performance. *The Review of Financial Studies*, 26, 667–94. https://doi.org/10.1093/rfs/hhs182

Andres, C., Cumming, D., Karabiber, T., Schweizer, D. (2014). Do Markets Anticipate Capital Structure Decisions? – Feedback Effects in Equity Liquidity. *Journal of Corporate Finance*, 27, 133–156. https://doi.org/10.1016/j.jcorpfin.2014.02.006

Arrow, K. (1962). The Economic Implications of Learning by Doing. *Review of Economic Studies*, 29, 157–173. https://doi.org/10.2307/2295952

Banyi, M. L., Dyl, E. A., Kahle, K. M. (2008). Errors in Estimating Share Repurchases. *Journal of Corporate Finance*, 14(4), 460–474. https://doi.org/10.1016/j.jcorpfin.2008.06.004

Bayoumi, T., Coe, D.T., Helpman, E. (1999). R&D Spillovers and Global Growth. *Journal of International Economics*, 47, 399–428. https://doi.org/10.1016/S0022-1996(98)00018-X

Berger, A. N., Udell, G. F. (2006). A More Complete Conceptual Framework for SME Finance. *Journal of Banking & Finance*, 30(11), 2945–2966. https://doi.org/10.1016/j.jbankfin.2006.05.008

Bernanke, B. S., Gertler, M., Gilchrist, S. (1994). The Financial Accelerator and The Flight to Quality. NBER Working Paper no. 4789, Cambridge, Mass.

Blanco, L, Prieger, J., Gu, J. (2013). The Impact of Research and Development on Economic Growth and Productivity in the US States. Pepperdine University, School of Public Policy Working Papers. Paper No. 48.

Bronzini, R., Piselli, P. (2006). Determinants of Long-Run Regional Productivity with Geographical Spillovers: The Role of R&D, Human Capital and Public Infrastructure. *Regional Science and Urban Economics*, 39(2), 187–199. https://doi.org/10.1016/j.regsciurbeco.2008.07.002

Brown, J. R., Petersen, B. C. (2009). Why Has the Investment-Cash Flow Sensitivity Declined So Sharply? Rising R&D and Equity Market Developments. *Journal of Banking & Finance*, 33(5), 971–984. https://doi.org/10.1016/j.jbankfin.2008.10.009

Capasso, M., Treibich, T., Verspagen, B. (2015). The Medium-Term Effect of R&D on Firm Growth. *Small Business Economics*, 45, 39–62. https://doi.org/10.1007/s11187-015-9640-6

Carlaw, K., Oxley, L., Walker, P., Thorns, D., Nuth, M. (2006). Beyond The Hype: Intellectual Property and the Knowledge Society/Knowledge Economy. *Journal Of Economic Surveys,* 20(4), 633–690. https://doi.org/10.1111/j.1467-6419.2006.00262.x

Cerulli, G., Marin, G., Pierucci, F., Poti, B. (2020). Do Company-Owned Academic Patents Influence Firm Performance? Evidence From the Italian Industry. *The Journal of Technology Transfer*, https://doi.org/10.1007/s10961-020-09840-3

Chen, S., Yu, D. (2022). Exploring The Impact of External Collaboration on Firm Growth Capability: The Mediating Roles of R&D Efforts. *Humanities and Social Sciences Communications*, 9(1), 1–12. https://doi.org/10.1057/s41599-022-01429-5

Chung, H., Eum, S., Lee, C. (2019). Firm Growth and R&D in the Korean Pharmaceutical Industry. *Sustainability*, 11(10), 2865. https://doi.org/10.3390/su11102865

Cincera, M., Ravet, J. (2010). Financing Constraints and R&D Investments of Large Corporations in Europe and the US. *Science and Public Policy*, 37(6), 455–466. https://doi.org/10.3152/030234210X508642

Cincera, M., Ravet, J., Veugelers, R. (2016). The Sensitivity of R&D Investments to Cash Flows: Comparing Young and Old EU and US Leading Innovators. *Economics Of Innovation And New Technology*, 25(3), 304–320. https://doi.org/10.1080/10438599.2015.1076201

Coad, A., Grassano, N. (2019). Firm Growth and R&D Investment: SVAR Evidence from the World's Top R&D Investors. *Industry and Innovation*, 26(5), 508–533. https://doi.org/10.1080/13662716.2018.1459295

Coad, A., Rao, R. (2010). Firm Growth and R&D Expenditure. *Economics of Innovation and New Technology*, 19(2), 127–145. https://doi.org/10.1080/10438590802472531.

Coad, A., Segarra, A., Teruel, M. (2016). Innovation and Firm Growth: Does Firm Age Play A Role? *Research Policy*, 45(2), 387–400. https://doi.org/10.1016/j.respol.2015.10.015

Coe, D. T., Helpman, E. (1995). International R & D Spillovers. *European Economic Review*, 39, 859–887. https://doi.org/10.1016/0014-2921(94)00100-E

Davidsson P., Wiklund, J. (2006). *Conceptual and Empirical Challenges in The Study of Firm Growth*. In Delmar, F, Wiklund, J, & Davidsson, P (Eds.) Entrepreneurship and the Growth of Firms. Edward Elgar Publishing, United Kingdom, pp. 39–61.

Demirel, P., Mazzucato, M. (2012). Innovation and Firm Growth: Is R&D Worth It? *Industry and Innovation*, 19(1), 45–62. https://doi.org/10.1080/13662716.2012.649057

Deschryvere, M. (2014). R&D, Firm Growth and the Role of Innovation Persistence: An Analysis of Finnish SMEs and Large Firms. *Small Business Economics*, 43, 767–785. https://doi.org/10.1007/s11187-014-9559-3.

Di Cintio, M., Ghosh, S., Grassi, E. (2017). Firm Growth, R&D Expenditures and Exports: an Empirical Analysis of Italian SMEs. *Research Policy*, 46(4), 836–852. https://doi.org/10.1016/j.respol.2017.02.006

Ergün, B., Doruk, Ö. T. (2020). Effect Of Financial Constraints on The Growth of Family and Nonfamily Firms in Turkey. *Financial Innovation*, 6(1), 1–24. https://doi.org/10.1186/s40854-020-00188-z

Expósito, A., Sanchis-Llopis, J. A. (2019). The Relationship between Types of Innovation and SMEs' Performance: A Multi-Dimensional Empirical Assessment. *Eurasian Business Review*, 9(2), 115–135. https://doi.org/10.1007/s40821-018-00116-3

Falk, M. (2012). Quantile Estimates of the Impact of R&D Intensity on Firm Performance. *Small Business Economics*, 39, 19–37. https://doi.org/10.1007/s11187-010-9290-7

Farrell, K., Unlu, E., Yu, J. (2014). Stock Repurchases as an Earnings Management Mechanism: The Impact of Financing Constraints. *Journal of Corporate Finance*, 25, 1–15. https://doi.org/10.1016/j.jcorpfin.2013.10.004

Frantzen, D. (2000). R&D, Human Capital and International Technology Spillovers: A Cross Country Analysis. *The Scandinavian Journal of Economics*, 102(1), 57–75. https://doi.org/10.1111/1467-9442.00184

Fritsch, M., Franke, G. (2004). Innovation, Regional Knowledge Spillovers and R&D Cooperation. *Research Policy*, 33(2), 245–255. https://doi.org/10.1016/S0048-7333(03)00123-9

Griliches, Z. (1985). Productivity, R&D, and Basic Research at the Firm Level in the 1970's. *American Economic Review*, 76(1), 141–154.

Griliches, Z. (1980). R&D and the Productivity Slowdown. *American Economic Review*, 70(2), 343–348.

Griliches, Z. (1979). Issues in Assessing the Contribution of Research and Development to Productivity Growth. *Bell Journal of Economics*, 10(1), 92–116. https://doi.org/10.2307/3003321

Griliches, Z. (1973). *Research Expenditures and Growth Accounting*. in Science and Technology in Economic Growth (Ed: B.R. Williams), New York: John Wiley and Sons, pp. 59–83.

Grossman, G., Helpman, E. (1991). *Innovation and Growth in the Global Economy*. Cambridge, MA: MIT Press.

Hemantha S. B., Chan S. Park. (1999). Economic Analysis Of R&D Projects: An Options Approach. *The Engineering Economist*, 44(1), 1–35. https://doi.org/10.1080/00137919908967506

Hovakimian, A., Li, G. (2011). In Search of Conclusive Evidence: How to Test for Adjustment to Target Capital Structure. *Journal of Corporate Finance*, 17(1), 33–44. https://doi.org/10.1016/j.jcorpfin.2010.07.004

Judd, K. (1985). On the Performance of Patents. *Econometrica*, 53, 567–585. https://doi.org/10.2307/1911655

Kalleberg, A. L., Leicht, K. T. (1991). Gender and Organizational Performance: Determinants of Small Business Survival and Success. *Academy Of Management Journal*, 34(1), 136–161.

Kou, G., Peng, Y., Wang, G. (2014). Evaluation of Clustering Algorithms for Financial Risk Analysis Using MCDM Methods. *Information Science*, 275, 1–12. https://doi.org/10.1016/j.ins.2014.02.137

Lucas, R. (1988). On the Mechanics of Economic Development. *Journal of Monetary Economics*, 22, 3–42. https://doi.org/10.1016/0304-3932(88)90168-7

Marshall, A. (1890). *Principles of Economics*. Vol. 1. London: Macmillan.

Martin P., Ottaviano G. (2001). Growth and Agglomeration. *International Economic Review*, 42(4), 947–968. https://doi.org/10.1111/1468-2354.00141

McKelvie, A., Brattström, A., Wennberg, K. (2017). How Young Firms Achieve Growth: Reconciling the Roles of Growth Motivation and Innovative Activities. *Small Business Economics*, 49, 273–293. https://doi.org/10.1007/s11187-017-9847-9

Montmartin B. (2013). Centralized R&D Subsidy Policy in an NEGG Model: A Welfare Analysis. *Louvain Economic Review*, 79(1), 5–34. https://doi.org/10.3917/rel.791.0005

Montmartin, B., Massard. N. (2013). Is Financial Support for Private R&D Always Justified? A Discussion Based on Literature on Growth. Working paper GATE 2013-28. 2013.

Oliveira, B., Fortunato, A. (2017). Firm Growth and R&D: Evidence from the Portuguese Manufacturing Industry. *Journal of Evolutionary Economics*, 27, 613627. https://doi.org/10.1007/s00191-016-0487-z

Perlitz, M., Peske, T., Schrank, R. (1999). Real Options Valuation: The New Frontier in R&D Project Evaluation? *R&D Management*, 29(3), 255–270. https://doi.org/10.1111/1467-9310.00135

Romer, P. (1990). Endogenous Technological Change. *Journal of Political Economy*, 98, 71–102.

Schumpeter, J. (1942). *Capitalism, Socialism, and Democracy*. New York, NY: Harper.

Singh, R. K., Garg, S. K., Deshmukh, S. G. (2008). Strategy Development by SMEs for Competitiveness: A Review. *Benchmarking: An International Journal*, 15(5), 525–547. https://doi.org/10.1108/14635770810903132

Sisodia, G. S., Soares, I. (2015). Panel Data Analysis for Renewable Energy Investment Determinants in Europe. *Applied Economics Letters*, 22(5), 397–401. https://doi.org/10.1080/13504851.2014.946176

Sokolov-Mladenović, S., Cvetanović, S., Mladenović, I. (2016). R&D Expenditure and Economic Growth: EU28 Evidence for the Period 2002–2012. *Economic Research-Ekonomska Istraživanja*, 29(1), 1005–1020. https://doi.org/10.1080/1331677X.2016.1211948

Solow, R. (1956). A Contribution to the Theory of Economic Growth. *Quarterly Journal of Economics*, 70, 65–94. https://doi.org/10.2307/1884513

Spescha, A. (2019). R&D Expenditures and Firm Growth–Is Small Beautiful? *Economics of Innovation and New Technology*, 28(2), 156–179. https://doi.org/10.1080/10438599.2018.1443154

Stam, E., Wennberg, K. (2009). The Roles of R&D in New Firm Growth. *Small Business Economics*, 33, 77–89. https://doi.org/10.1007/s11187-009-9183-9

Storey, D.J. (1994). New Firm Growth and Bank Financing. *Small Business Economics*, 6(2), 139–150. https://doi.org/10.1007/BF01065186

Tian, G. Y., Twite, G. (2011). Corporate Governance, External Market Discipline and Firm Productivity. *Journal of Corporate Finance*, 17(3), 403–417. https://doi.org/10.1016/j.jcorpfin.2010.12.004