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Internal funding determinants of R&D expenditures for U.S. mature firms

Manuela Tvaronaviciene
Vilnius Gediminas Technical University (Vilnius Tech), Vilnius;
General Jonas Zemaitis Military Academy of Lithuania,
Lithuania
manuela.tvaronaviciene@vilniustech.lt
ORCID 0000-0001-8983-2580

Arunas Burinskas
Vilnius University,
Lithuania
arunas.burinskas@evaf.vu.lt
ORCID 0000-0002-9667-3730

Abstract. Since research and development (R&D) investment identified as the main factor for economic development in contemporary endogenous models, many studies investigated the determinants of such investment. Though there is no disagreement that internal financing sources are vital for R&D expenditures (at least for matured firms), there are still ongoing discussions as to which of them takes priority: revenue or cash flows. This paper analyses the impact of firms' revenue and cash flow on R&D expenditures by employing a dynamic linear model. Also, we use the Vector Error Correction Model to test the variance composition. Our research confirms that, in the beginning, positive revenue dynamics serve as the most critical signal for business to invest in R&D activity. However, later profit that firms earn comes to the first place in the ladder of their motivation.

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1. INTRODUCTION

The investment into R&D activity is one of the most critical components for companies in accumulating 'know-how' and developing new technologies that, in the long term, as the theory claims, lead to productivity and, consequently, sustainable economic growth. Many empirical studies have confirmed that expenditure into R&D's activity allows for achieving the desired economic growth. Therefore, empirical

research on R&D is still not diminished to assess what the best economic policy instruments can be to promote the country's economic growth. The scientific literature highlights that, among other R&D determinants groups, R&D expenditures sources of internal funding play a significant role. It confirmed the insights made by Schumpeter that revenue and cash flow are used in making a decision on the investment into R&D activity.

However, not all studies confirm that firms' internal cash flows are more important than their income. Some studies found no substantial evidence that cash flow or its lags had a significant impact on R&D expenditures. However, some studies show that mature companies are less dependent on cash flows to finance R&D's activities. Besides, if both the income and cash flow of companies are the most important for R&D activity, then this can be intuitively predicted that the innovative activities of the companies follow an autoregression pattern and can last as long as market conditions are favourable. Therefore, being successful and profitable in business activities, firms might become inert in investing in R&D.

Overall, there is a remaining discussion of what is more important in internal financing: revenue or cash flows? Therefore, the paper aims to analyse the determinants of R&D expenditures and compare them. To this end, the authors of the paper decided to provide a panel data regression model to the dynamic nature of R&D expenditures by including more lags of dependent and independent variables (differences of log form) as many as needed and sticking with dynamic linear model (DLM) approach. In the second phase of our research, after we had established statistically valid relationships of R&D expenditures with chosen variables, we tested R&D expenditures variance composition to estimate how much influence they have on the firms' R&D activity.

Our research revealed that, though firstly positive revenue dynamics serve as the most crucial signal for firms' investment into R&D's activities, later prove the earnings of firms, which comes to the first place in the ladder of their motivation.

2. LITERATURE REVIEW

As Moncada-Paterno-Castello and Grassano (2020) very accurately noticed, R&D spending has long been of interest to innovation analysts, who use it as an example of the contribution of innovation and see it as a factor in growth, productivity, and competitiveness. Due to this reason, intensity targets oriented to R&D are the main topics of many countries' research and innovation policy agenda, where most of the R&D effort comes from the private sector.

Also, many theoretical works and empirical studies are demonstrating the huge importance of R&D's activity for the economic growth of the country (Petrin, 2018; Nurpeisova et al., 2020). It is, therefore, not surprising that there is a continued increase in the number of studies trying to determine how R&D expenditures affect corporate performance. Here, authors Canarella et al. (2018) identified that R&D expenditures have a positive influence on corporate growth: as a result, large companies have no lower growth rates than small and medium-sized enterprises. Sameti et al. (2010) report that Research and development efforts lead to greater product diversity and higher product quality. This increases productivity, increases value-added, and further increases GDP growth. While R&D activity promotes GDP growth, GDP growth can also lead to more significant incentives for R&D investments (Khalatur et al., 2020; Korshenkov, E., Ignatyev, S. 2020).

However, in addition to the fact that many studies aimed to determine what significant role R&D plays as a factor in economic growth and economic development in general, there is a large part of and still growing in numbers the literature with research focused on identifying R&D investment and expenditure determinants.

In their literature review, Doloreux et al. (2016) state that "it is a debate on the determinants of R&D: authors provide conflicting opinions, which are not conclusive. This has led to a large amount of academic research examining research and development in manufacturing companies, but shortcomings remain in the service industry. Previous work on R&D has focused on its role in developing the internal capacity of firms and the effectiveness of innovation: in fact, the ability to carry out R&D itself is capacity. Therefore, R&D has a dual role: in shaping the processes of knowledge accumulation, it builds internal capacity, and itself is a key contribution to absorption capacity, the ability of a company to recognise the value of new information, absorb it and adapt it for commercial purposes".

In his review of empirical research on R&D determinants, Becker (2013) reports that the results of various studies allow distinguishing between 5 R&D factor groups: the company's domestic finance and sales; competition in commodity markets; government policies; the dissemination of knowledge from local research and education institutions and spillovers from foreign R&D. According to Becker (2013), internal finance, and in particular cash flow and income, has a positive impact on R&D expenditures. However, the greatest influence has been observed in countries such as the U.S. and the U.K. Meanwhile, competition usually has a positive relationship with R&D activity, which is fully in line with the theoretical models of international trade and industrial organisation. However, studies in recent years have shown that this link is of a U-curve shape. In addition, technologically advanced companies, as a rule, show only a positive connection, while laggard firms show negative effects. Similarly, subsidies granted to enterprises by governments through the programs of industrial and/or innovative policies have a positive link with R&D investments. This is particularly the case for small and medium-sized enterprises, which, as a rule, have less access to sources of financing for their business. On the other hand, the geographical proximity of enterprises to universities and other knowledge hubs clearly determines the growth of R&D expenditures. This is particularly the case in high-tech sectors, where existing companies not only increase investment in R&D but also in highly qualified personnel (Mishchuk et al., 2016).

As Becker observes (2013), it is not entirely clear whether foreign R&D has a positive or negative impact on firms' R&D investments in a particular country. Some studies show evidence of the crowding-out effect.

In the end, Becker (2013) confirms Schumpeter's insights into the fact that it is corporate revenue and cash flows as two major R&D factors for enterprise and industry. However, the influence of these factors on R&D varies depending on the age, size, and country of the undertakings in which those undertakings operate. Private sector R&D expenditures are more pro-cyclical if companies face restrictions on obtaining credit. Meanwhile, smaller companies are more sensitive to a wide range of influences on R&D expenditures.

However, not all studies confirm that companies' internal cash flows are more important than their income. In the context of the U.K. and German producers, Bond et al. (2005) found no solid evidence that cash flows and/or their lags had a significant influence on R&D expenditure. The exception is high-tech companies; there is an increased likelihood when companies undertake R&D at all.

Also, Sasidharan et al. (2017), when investigating Indian companies, found evidence that corporate behaviour due to R&D expenditure varies depending on the business cycle. For example, innovative companies are reluctant to invest in R&D activities at a time when markets are in decline.

Meanwhile, in the investigation of 1171 firms from China and South Korea, Xu et al. (2018) found that cash reserve has a positive effect on R&D expenditures. However, looking into China and South Korea environment, not all factors affect the tendency of companies to invest in such activities in the same way. While in South Korea, only debt ratios are the only limiting factor for R&D expenditures, there are more such factors in China, including the size of companies and private equity investments. Therefore, they conclude that as a productivity-seeking country, China should create a better national environment for entrepreneurship and innovation by removing barriers, strengthening governmental services, and

encouraging students, researchers, and engineers to establish companies. But South Korea, as a country developing innovation, should pass intellectual property rights laws and provide adequate support for science parks and business incubators for new and growing businesses. The national government should also stimulate SMEs to increase R&D spending providing a range of tax incentives and R&D subsidies to maximise social welfare.

In addition to these recommendations, Xu et al. (2018) suggest managers of Chinese and Korean manufacturing companies establish long-term and reliable relationships with investors in order to significantly reduce the level of information asymmetry. The Chuang (2017) study also confirmed that South Korean companies actively accumulated net R&D activity in the period of 2008 during the financial crisis.

Similarly, a study by Hillier et al. (2011), which looked at European, Japanese and U.S. companies, found that those multinationals with more robust corporate governance skills are not so sensitive to cash flow comparing to local companies.

Brown et al. (2011) noted that cash flows are more sensitive to young but not longer-lasting U.S. companies to the extent necessary to smooth out their levelling of R&D expenditures. Small businesses are also more inclined to finance R&D expenditures with shareholders' capital investments (Brownand Floros, 2012; Borisova & Brown, 2013).

If the income and cash flows of companies are really so important for R&D's activities, then it can be intuitively predicted that the innovative activities of the companies follow an autoregression pattern and can last as long as market conditions are favourable to this only. Therefore, it is not surprising that García-Quevedo et al. (2014) reported results that firm and market characteristics play a clear role in fostering innovation among firms of all ages. In particular, although market concentration and the degree of product diversification are important in promoting R&D only in the case of mature companies, R&D expenditure by young companies seems to be more sensitive to demand variables.

Such findings remain unchanged in more recent studies. Here's Alam et al. (2019) report about firms from an emerging market that are likely to apply internal expenditures for financing R&D activity. In its Turkish company study, Limanlı (2015) found that the likelihood of investing in research and development increases depending on the size of the firm. This increment is not linear in magnitude. Over time, if the size of the firm continues to grow, the likelihood of R&D investment begins to decline.

In addition to these findings, some empirical research studies confirm the significance of firms' internal finance to their self-awareness of being able and being in need of R&D activities and funding thereof. For example, Manez et al. (2015) brought fascinating empirical research study in terms not only in results but in employed methodology too. Instead of choosing the most commonly used dynamic first-order autoregressive specification models, they preferred the choice of duration model technique. They found that the involvement of companies in R&D is partly an independent process; Policies to promote R&D may not only have an impact on the current R&D performance of companies but may also have a long-term impact in stimulating future R&D.

3. METHODOLOGY

In our study, we aimed at establishing links between R&D expenditures and firms' revenues (REV) and other variables that we considered as fitted for internal financing sources: Gross profit (G.P.), EBITDA and return on investment (ROI). We also investigated whether variables that might account for external financing sources (such as multiple and real interest rate (RIR); export and import volumes (EXP, IMP) and prices (I.Q., I.R.); bank loans for industries (CIL)) affect R&D expenditures.

We chose to design our research in the micro-level by testing quarterly data of 49 randomly chosen U.S. industrial firms which shares are traded publicly starting from the 4th quarter of 2011 up to the 3rd quarter of 2020. The statistics describing the tested variables is provided in Table 1.

For choosing methodology, we paid attention that most empirical studies related to the determinants of R&D expenditures by using a panel data model:

$$rit = a + \beta' Xit + \varepsilon it \quad (1)$$

Where: *i* is the cross-section units usually presenting sectors or countries; *t* presents period, *r* means R&D expenditure; *X* is a vector used to describe explanatory variables; α – constant; *εit* – error value.

Author Becker (2013) notices, that with the exception of a convenient empirical starting point for the analysis of R&D determinants according to Eq. 1, it can be considered a stochastic form of the R&D capital demand equation derived from the CES production function, where R&D and R&D investment flows are proportional to each other at steady-state.'

Also, such a model does not solve the problem of unobserved instability between periods and the cross-section units. To address it, we came to a solution of control this heterogeneity by including fixed effects in the equations of regression.

The scenario following the equation (1) can thus be re-written by including dummy variables estimator of fixed within-group or/and time periods effects or least squares:

$$rit = \gamma' Xit + fit + \varepsilon it \quad (2)$$

Where: *f* means fixed effect.

Table 1

The statistics are describing tested variables.

	Firms' performance indicators									
	R&D	Revenue	Gross profit	EBITDA	ROI	EXPORT	IMPORT	EXPORT PRICES	IMPORT PRICES	CIL
Mean	1175.782	12195.59	6002.604	39.80031	0.159097	138.8794	144.0274	108.649	110.4112	1013296
Median	660.0001	5851	3809	40.5148	0.11915	1339.4733	144.6682	107.8174	107.5654	990295
Maximum	10976	127363	39052	43.86949	2.3838	150.2001	161.9406	115.1498	121.8999	1266481
Minimum	1.0001	1	4.0001	27.65377	-0.6322	112.854	125.5136	101.2839	100.3129	712155
Std. Dev.	1372.563	18161.76	6362.025	1.963767	0.226931	8.630271	11.9839	4.295545	6.909845	152636.1
Skewness	2.485522	3.088976	1.743028	-2.43445	3.404761	-0.728172	-0.026762	0.061508	0.420439	-0.148471
Kurtosis	12.35141	14.04741	6.29393	10.49477	24.48528	3.379937	1.666743	1.681901	1.57939	1.893736
Jarque-Bera	6178.153	8825.035	1267.058	4399.935	27981.6	124.7797	98.07258	96.53452	150.1136	72.26906
Probability	0	0	0	0	0	0	0	0	0	0
Sum	1554384	16122575	7935442	52616.01	210.3259	183598.5	190404.2	1436333.9	145963.7	1.34E+09
Sum sq. dev.	2.49E+09	4.36E+11	5.35E+10	5.09E+03	6.80E+01	9.84E+04	1.90E+05	2.44E+04	6.31E+04	3.08E+13
Observations	1322	1322	1322	1322	1322	1322	1322	1322	1322	1322

Source: own calculation

However, in most cases, R&D investment phenomena demonstrate its dynamic nature. Primarily because firms are inert in their R&D expenditures (García-Quevedo et al., 2014), i.e. if they have already started it, they invest in these activities as long as it is profitable. As this activity is expensive, most of these costs are the cost of the highly skilled and costly labour force. Also, future corporate expectations are essential and should be accounted as Tobin made it explicit in the q-models of investment (Becker, 2013). In her literature review, Becker (2013) noticed that most standard methodology for investment equations incorporate adjusted cost dynamics into the R&D model, which by nature is static (2), where the two main

methods: one of them neoclassical accelerator model incorporating ad-hoc dynamics and an Euler equation derived from promising, dynamic returns. maximisation of firms; most studies use the previous method of model dynamics by introducing a lagging dependent variable into (2):

$$rit = \rho ri, t-1 + \delta' Xit + fit + \varepsilon it \quad (3)$$

In the first phase of our study, we decided to adjust our model to the dynamic nature by including more lags of dependent and independent variables (differences of log form) as many as needed and sticking with dynamic linear model (DLM) approach (Kalli, M. and Griffin, J. E., 2014):

$$r_{i,t} = \sum_{i=0}^{m} x_{it}\,\beta_{it} + f_{it} + \varepsilon_{it}, \qquad \mathrm{t} = 1, \ldots, \mathrm{T}, \qquad \mathrm{i} = 0, \ldots, \mathrm{m} \quad (4)$$

Where: $x_{0,t}$ is equal to 1 for all *t* (allowing for an intercept). These $x_{1,t}, \ldots, x_{m,t}$ may include lags of response and exogenous variables. $\beta_{i,t}$ – vector of unknown coefficients for the *i*th regressor at period *t*, e_t is at period *t* generated from a normal distribution with mean equal to zero and time-varying variance i.e., $e_t \sim N(0, \sigma_t^2)$. The D.R. model is completed by assuming that $\beta_{1,t}, \ldots, \beta_{m,t}$ vectors follow the process of linear stochastic analysis (which include vector autoregression or random walk). The assumption is ensured by the transformation of time series taking the differences in logarithmic scale (West & Harrison, 2006).

In the second phase of our research, after we had established statistically valid relationships of R&D expenditures with chosen variables, we tested their variance composition to estimate how much influence they have on the company's R&D activities. According to the aim, the authors of the paper employed Vector Error Correction Model (VECM) technique used by Saidi, K., & Mongi, C. (2018). However, for lag constraint, we followed by the practice common among practitioners:

$$n\,p < T/3 \quad (5)$$

where *n* – number of variables, *p* – number of lags and *T* – time periods.

Lastly, we conclude our analysis with a variance decomposition of the expenditures related to R&D.

4. EMPIRICAL RESULTS AND DISCUSSION

The results of the dynamic linear regression employed for the panel data are presented in Table 2. Firstly, Chow and L.M. tests strongly suggested that the best way of equation estimation is by taking a common effect approach (not fixed or a random one) for both cross-section and period. In addition, Durbin Watson and Pesaran CD tests confirm

Also, our research results demonstrate that R&D expenditures of firms are inert, i.e. firms might be keen to invest in R&D up to 3 quarters since they have started the first investment in the field. Meanwhile, revenue serves as a major impulse for R&D expenditures. However, the gross profit of tested firms is as a signal for R&D expenditures that lasts twice longer – up to 6 lags.

However, the results of our research do not confirm that firms' decisions on R&D expenditures would be influenced by external funding factors. In our case, it is bank loans with a statistical significance that barely passes 10% limits (the *p* statistics for all other coefficients of the variables included in the equation are lower than 1%).

Overall, our study confirms that matured industrial firms are motivated to investing in R&D activity by their internal finance: revenue and profits they gain in the market.

We used our study to assess what is more important for companies from the internal finance variables studied: revenue or gross profit? To that end, we applied VECM technique with a recursive ordering estimation: logs of revenue, gross profit, EBITDA and R&D expenditures.

Table 2

The panel data dynamic regression analysis results

	c	dln r L^{-1}	dln r L^{-2}	dln r L^{-3}	dln gp L^{-1}	dln gp L^{-2}	dln gp L^{-5}	dln gp L^{-6}	dln rev	dln rev L^{-3}	dln cil L^{-2}
dln r	0.0085 (1.2619)	-0.70607 (-36.8026)	-0.08393 (-8.5129)	-0.07623 (-5.5015)	0.14037 (3.9372)	0.22844 (8.2590)	0.13373 (4.5128)	0.12019 (3.7639)	0.64070 (19.858)	0.07678 (4.0199)	-0.27494 (-1.6426)

Observations	1315
Number of ids	37
Periods	36
Adj. R^2	0.80683
DW stat.	1.923169
Chow test/cross section F/p	0.9908
Chow test/period F/p	0.8357
The L.M. test (cross-section)	4.445726
The L.M. test (time)	1.365262
Cross-section	C.E.
Period	C.E.
Pesaran CD: statistic/p	-0.774162/0.4388

Source: own calculation

Variance decomposition of R&D expenditures is given in Figure 1.

Having calculated and applied an optimal lags number – 4, all considered roots of polynomial were lower than 1. After we had tested for cointegration with the Johansen test, we adjusted our equation to address the impact of 3 cointegration equations.

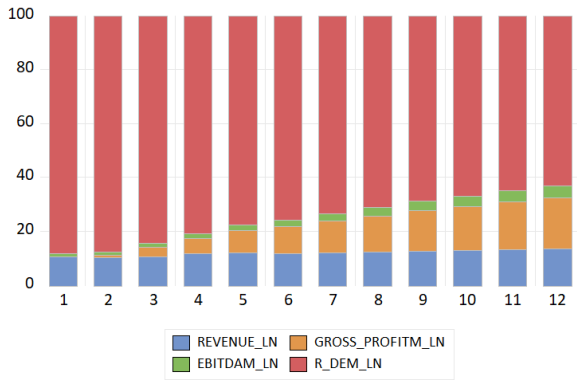

Figure 1. Variance decomposition of R&D expenditures (R_DEM_LN) using Cholesky (d.f. adjusted) factors

Source: own calculation

Our variance decomposition of R&D expenditures reveals the great importance of firms being inert in their investment in R&D activities for some time since they have already started it.

Also, firstly, being motivated solely by gained revenues, with time, the importance of internal funding by gross profit grows significantly and even becomes more important than revenue.

However, these results should be treated with caution for the time being, as only 49 companies have been analysed due to data limitations: many companies do not publish data on their R&D expenditures.

5. CONCLUSION

The topic of investments into R&D has been in line with the long focus area analysing the importance of such type of firms' spending for innovation, as well as for long-term and sustainable economic growth. Many theoretical and empirical studies have already been dedicated to examining both R&D's impact on economic growth and the factors that affect companies' investments in R&D's activities.

Many authors point to companies' heterogeneous behaviour regarding R&D investment. At the same time, some empirical work basically confirms that internal financing resources are essential for businesses, in particular, older and mature enterprises, while young businesses rely more on sources of external funding. Other studies confirm the significance of firms internal financial resources to their awaraness of being able and being in need of R&D activities (Bilan et al., 2019; Kliestik et al., 2020).

In literature, among the most important internal sources of funding for R&D expenditures, revenues and cash flows are distinguished. However, the literature analysis has revealed that there is no empirical work to assess the dynamics of the significance of such sources of internal funding for companies' solutions to invest in R&D. We have not been able to find any sources focused on how the tendency of companies to invest in R&D is varying as their income, profits and cash flow change.

In this empirical study, we address this problem by applying DLM and VECM models, initially distinguishing the most important in time sources of internal funding: revenue and gross profit. After that, we examined the dynamics of their significance by observing the R&D expenditures by the decomposition of its variance.

In our study, we gained evidence that, though firstly positive revenue dynamics serve as the most critical signal for firms to invest in R&D activities, later profit comes to firms when they get the first place in the ladder of their motivation. In terms of R&D expenditure, firms can become inert, i.e. they might be keen to invest in this kind of activity up to 3 quarters since the first investment in the field. However, the gross profit of tested firms is as a signal for R&D expenditures that lasts twice longer – up to 6 quarters.

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