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Financial Constraints and the Cyclicity of R&D Investment: Evidence from Slovenia

Simona Bovha-Padilla¹, Joze P. Damijan² and Jozef Konings³

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Abstract

This paper uses firm level data to show how R&D investment responds to shocks in sales growth in credit constrained firms. A credit constrained firm has to rely on its cash flow and borrowing capacity to survive its short-run liquidity shock when hit by a negative shock. This reduces the possibility for further borrowing in order to invest in non-tangible long term R&D, hence a negative shock should hit R&D investments more in firms that are more credit constrained.

We find that in financially constrained firms sales growth is positively associated with R&D investment, suggesting procyclical behavior of R&D investment in credit constrained firms. In contrast, we find that in firms with no financial constraints R&D investment is negatively correlated with sales growth, suggesting countercyclical behavior of R&D, consistent with the Schumpeterian idea of restructuring.

Furthermore, we find that the firm level response in R&D investment to sales growth is stronger in firms that are more financially dependent, such as firms that are no part of a multinational, firms not receiving subsidies or firms with less collateral.

Key words: R&D investment, financial constraints, cyclicity

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1. Introduction

R&D expenditures tend to increase in booms and decrease in recessions. However, this pro-cyclicality in R&D expenditures is at odds with the Schumpeterian view of the business cycle, in which recessions have a cleansing role encouraging firms to restructure, to replace old and inefficient production techniques by new more efficient ones and to innovate. As the opportunity cost of long term investment instead of short-term capital investments is lower in recessions than in booms, the share of long-term investment in total investment should be countercyclical, whereas the share of short-term investment should be procyclical.

One explanation for the pro-cyclical behavior of R&D investment is the presence of finance-constraints as introduced by Stiglitz (1993) Financial constraints obstruct firms' R&D activities in two ways, either by imperfections in credit markets or imperfections in equity markets. As R&D investments are generally not collateralizable,⁴ the scope of innovative activities implemented by a firm is usually constrained by its cash flow and its ability to borrow. Thus, in times of economic downturn, firms are more likely to cut down R&D expenditures. A similar argument is developed in a recent paper by Aghion, Askenazy, Berman, Cette and Eymard (2005). They show both theoretically and empirically, using French firm level data, that the counter-cyclicality of long term investment such as R&D investments does not need to hold once firms cannot borrow enough funds and thus face credit market imperfections. When firms are hit by a negative shock in bad times a credit-constrained firm has to rely on its cash flow and borrowing to survive its short-run liquidity shock, which reduces the possibility for further borrowing in order to innovate. This implies that a negative shock should hit R&D investments more in firms that are more credit constrained and so we should expect to see R&D investments to be pro-cyclical in credit constrained firms, while counter-cyclical in firms with no credit constraints⁵.

Another reason that can explain pro-cyclicality in R&D investment is related to strategic-timing effects, as shown by Barlevy (2004, 2007). He argues that when an innovator patents a new idea, he reveals it to rivals and allows them to improve and adapt his ideas and making the original innovation obsolete. As rivals increase their chances to successfully improve an innovation if they invest more time in their own R&D, it is likely that the benefits from a new discovery that pay further in time will accrue to them and not to the original innovator. Therefore, the incentives for innovators to engage in R&D will largely depend on the short-term benefits of successful innovation. Moreover, since profits are procyclical, innovators will concentrate relatively more on their R&D in boom periods than is socially optimal.

Empirically there exists evidence of pro-cyclicality in R&D investment. In particular, Wälde and Woitek (2004) study the cyclical behaviour of R&D expenditures by business enterprises in G7 countries from 1973 to 2000 and they find evidence of procyclical rather than countercyclical R&D spending. Similarly, Domadenik, Prašnikar and Svejnar (2008) using data on more than 150 of the largest

⁴ A firm undertaking R&D investment is more likely to default when the research project fails so the value of the project as a collateral is riskier and harder acceptable than if the firm offers a real estate to a lender as a collateral.

⁵ Also casual empiricism suggests credit constraints matter in explaining the pro-cyclicality of R&D type of investments, such as investment in information technology. SAP announces a cut of 3000 jobs (Wall Street Journal, Jan.29,2009): "...growth in information technology spending generally correlates directly with rises in gross domestic product....the credit crunch is making it harder for companies to finance investment in information technology projects."

Slovene firms over the period 1996–2000 find that sales have a significant role in inducing R&D expenditures. They demonstrate that this procyclicality of R&D expenditures is related to the availability of firms' internal funds.

Himmelberg and Petersen (1994) demonstrate that R&D spending is sensitive to the firm level cash flow suggesting that financial constraints matter. Rafferty (2003) examines the relation between economic fluctuations and R&D spending on the basis of time-series US aggregate data. He finds that R&D spending is procyclical due to cash flow effects. He concludes that through this cash flow effect, cyclical economic downturns may reduce productivity growth and long-run economic growth.

While there is evidence that R&D expenditures tend to move pro-cyclically, a number of studies point out acyclical or countercyclical behavior of R&D or R&D related activities, such as investment in human capital. Bean (1990) found that human capital accumulation is countercyclical as negative demand shocks stimulate human capital growth. Hall (1991) showed that firms have a better ability to reorganize faster during recessions. Saint-Paul (1993) also observed that negative demand shocks stimulate total factor productivity growth. The common feature of these papers is that the opportunity cost of innovative activity is countercyclical as during recessions the return to production is temporarily reduced and then temporarily increased during expansions. However, as returns to innovative activity appear only in the future, the business cycle does not have a significant impact on returns. Therefore, the relative return to innovative activity should increase during downturns and fall during booms, causing firms to substitute between production and innovative activity over the business cycle. Thus, R&D expenditures are countercyclical. Some empirical studies show countercyclical behavior of firm-financed R&D expenditures. On the basis of the US aggregate data, Gali and Hammour (1992) found that negative aggregate demand shocks stimulate productivity growth. Malley and Muscatelli (1999) used industry-level data from the US manufacturing sector and found that negative demand shocks (negative shocks to employment) stimulate total factor productivity in the long run. Saint-Paul (1993) treated firm-financed R&D as homogeneous quantity and found no relationship between the business cycle and aggregate firm-financed R&D expenditures. However, firms may change the mix of R&D expenditures while leaving total R&D expenditures unchanged in response to the business cycle. Thus, it is possible that basic R&D expenditures are countercyclical, while development R&D expenditures are procyclical.

In this paper we find evidence of both pro-cyclical and counter-cyclical R&D expenditures, depending on whether or not firms face financial constraints. We interpret cyclicity in this paper not as is done in the traditional macro sense as we only have a few years of observations, but rather as idiosyncratic shocks to firm level sales (i.e. firms going through an idiosyncratic downturn versus an upswing). We find that in financially constrained firms R&D expenditures go down when a negative shock hits the firm and vice versa. But in firms that are not financially constrained we find the opposite. Our results are in line with the work of Aghion et al. (2004) on the basis of OECD cross-country data. Their results show that R&D spending (as a share of total investment) is procyclical in countries with low level degree of financial development and countercyclical when financial development is high.⁶ In another paper, Aghion et al. (2005) show that the countercyclicity of long term investment such as R&D investments does not need to hold once firms cannot borrow enough funds and thus face credit market imperfections. When firms are hit by a negative

⁶ Financial development is measured as the value of loans by financial intermediaries to the private sector relative to GDP.

shock in bad times a credit-constrained firm has to rely on its cash flow and borrowing to survive its short-run liquidity shock, which reduces the possibility for further borrowing in order to innovate. This implies that a negative shock should hit R&D investments more in firms that are more credit constrained and so we should expect to see R&D investments to be procyclical in credit constrained firms, while counter-cyclical in firms with no credit constraints⁷.

We test the above specified hypothesis using Slovenian firm-level panel data from the Community Innovation Survey (CIS) that contains information on R&D and total investments as well as information on the extent that firms face financial constraints. Our findings support the pro-cyclicality of R&D investment in credit constrained firms. Furthermore, we find that this effect disappears in firms that are part of a multinational and firms receiving government subsidies. While the former indicates the presence of internal credit markets, the latter suggests a role for policy especially for encouraging the cleansing role of recessions. We carry out a number of robustness tests, including estimating the effect of financial constraints using propensity score matching techniques and analyzing other constraints than just financial ones. . This paper proceeds as follows. The next section summarizes the data used, section 3 presents our econometric approach. Section 4 discusses the results and we draw some conclusions in section 5.

2. Data and descriptive statistics

2.1. Data

We use Slovenian firm level data for the period 1996-2002. They are retrieved from two main data sources. The first is the Community Innovation Survey (CIS), which includes information on R&D expenditures, innovation and obstacles to innovation, such as the extent of financial constraints that firms face. The survey is carried out on a bi-annual basis since 1996 and is based on a censored sample of manufacturing and non-manufacturing firms with no additional conditions put on actual R&D activity or size of these firms. We combine three surveys, the CIS1, the CIS2 and the CIS3⁸ and match them with the income statements (from AJPES⁹) of Slovenian incorporated companies. As we only have income statements of firms in the manufacturing sector we will restrict our analysis to manufacturing only.

Slovenia is an interesting case to study the R&D behavior of firms. On the one hand, it never relied its productivity catching up on attracting FDI, whose accumulated stock in GDP is by far the lowest among the new European Member States (NMS). Instead, firms' foreign trade activities played a more important role than FDI for their productivity growth (Damijan et al., 2003; Damijan and Knell, 2005). Damijan, Kostevc and Polanec (2009) demonstrate that Slovenian firms learned from foreign trade through process innovations induced by their exporting activities. It comes with no surprise then that Slovenia is a leader among the NMS in terms of R&D investments. In 2007, R&D investments accounted for 1.53 % of GDP, with about 1 % of GDP relating to private sector's R&D investments. Innovation and

⁷ Also casual empiricism suggests credit constraints matter in explaining the pro-cyclicality of R&D type of investments, such as investment in information technology. SAP announces a cut of 3000 jobs (Wall Street Journal, January 29, 2009): "...growth in information technology spending generally correlates directly with rises in gross domestic product....the credit crunch is making it harder for companies to finance investment in information technology projects."

⁸ The CIS surveys are carried out by the Slovenian statistical office (SORS).

⁹ AJPES is Agency of the Republic of Slovenia for Public Legal Records and Related Services.

competitiveness policies targeting firm R&D promotion play a central role in economic policies since the mid of 1990s. In this sense, it is interesting to study how R&D investments of Slovenian firms perform in upswings and downturns and whether these are sensitive to firm characteristics and policy measures.

2.2. Descriptive statistics

Table 1 exhibits some summary statistics. The investment rate, relative to the capital stock, is 58%, which is quite high compared to typical investment rates in the West European countries. For instance, Degryse and de Jong (2006) report an average investment rate of 19.5% for Dutch firms. One possible explanation of the high investment rate in Slovenian manufacturing could be the catching up process that has been characterizing most transition countries in the Central and Eastern Europe. The legacy of the socialist Yugoslav labor managed system implied that investment rates, prior to the transition were low as in other Central European countries, resulting in an old and obsolete capital stock. Therefore increased investment rates can be expected when an economy is turning into a more market and Western oriented system.

R&D investments represent 12% of total investment in the average manufacturing firm. However, when taking into account firms with some R&D the share increases to 25%, a number which is almost half of that reported by Himmelberg and Petersen (1994) for the USA. 61% of this R&D is done in-house. Furthermore, R&D expenditures stand only for 2% of total sales in the typical firm. About 26% of the manufacturing firms are product innovators and 21% engage in process innovation. Foreign participation in local firms takes place in 7% of the firms.

Table 1: Summary statistics, 2002

	Mean and standard deviation	
Employment	67	(222)
Investment relative to the capital stock	0.58	(1.13)
R&D intensity (R&D/Sales)	0.02	(0.08)
R&D/(R&D+investment)	0.12	(0.25)
R&D/(R&D+investment) of firms only reporting	0.25	(0.31)
R&D		
Own R&D in total R&D	0.61	(0.36)
Sales growth	0.17	(0.40)
Product innovation	0.26	(0.44)
Process innovation	0.21	(0.41)
Inward foreign direct investment	0.073	(0.26)

Source: SORS and AJPES; authors' calculations.

Information on factors that may hamper innovation is available from the CIS surveys from 2000 on. Respondents were asked to give a score to each potential obstacle on a scale going from zero (not relevant) to three (highly relevant). In Table 2 we report the proportion of firms considering a particular factor to be relevant (i.e. firms scoring one or more). We compare the scores between innovators and other firms. About 29% of the firms in our sample are classified as innovators. Since both policy makers and academic research have pointed out that important innovations occur often in young innovative firms (e.g. Schneider and Veugelers (2008)) we also fine tune our definition of innovators and define young and innovative companies (YICs) in line with the recently revised European Commission's State Aid Rules. The EU defines YICs as *small enterprises, less than 6 years old, having being certified by external experts on the basis of a business plan, as capable of developing products or processes which are technologically new or substantially improved and which carry a*

risk of technological commercial failure, or have an R&D intensity (R&D/Sales) of at least 15% in the last three years or currently (for start-ups). In our sample, there are very few firms which have an R&D intensity of more than 15% that also satisfy the other criteria in this category. Therefore we define YICs as firms engaging in R&D, with the average R&D intensity of 13%, less than 6 years old, have positive R&D and employ less than 250 workers. Only 3.7% of the firms in our sample satisfy this criterion.

Results in Table 2 clearly demonstrate that innovators face more obstacles than non-innovators, with the most frequent one being financial constraints. Almost 85% of the innovating firms experience financial constraints, compared to 75% of the non-innovators. In addition, 84% of the innovators find innovation costs too high, which indirectly suggests additional financial constraints to innovation. When we only consider the young and innovative firms, YICs, results are even more striking. Almost 94% of all YICs consider financial constraints to be important and 92% find innovation costs too high. This compares to 71.5% and 68.9% respectively for the Non-YIC group. Additional constraints that rank high for YICs as opposed to regular innovators are lack of qualified personnel and insufficient flexibility of regulations and standards. These results are in line with results from the German CIS where YICs report similar constraints (Schneider and Veugelers (2008)).

Table 2: Test of mean differences among innovating and non-innovating firms in 2002

	innovator	Non-innovator	t-test	YIC	Non-YIC	t-test
Financial constraints	84.8%	75.7%	5.48*	93.5%	71.5%	4.2*
Excessive economic risk	78.3%	68.6%	5.26*	84.0%	64.4%	3.4*
Innovation cost too high	84.0%	70.4%	6.82*	92.1%	68.9%	3.0*
Organizational rigidities	63.9%	55.3%	3.72*	63.1%	52.3%	1.3
Lack of qualified personnel	79.2%	71.3%	4.44*	92.2%	66.6%	4.7*
Lack of information on technology	74.3%	63.8%	5.40*	80.7%	59.7%	3.7*
Lack of information on markets	75.9%	65.6%	5.44*	85.7%	61.1%	4.3*
Insufficient flexibility of regulations or standards	63.2%	61.9%	0.64	93.5%	71.5%	4.2*
Lack of consumer responsiveness to new products	68.9%	68.0%	0.50	84.0%	64.4%	3.5*

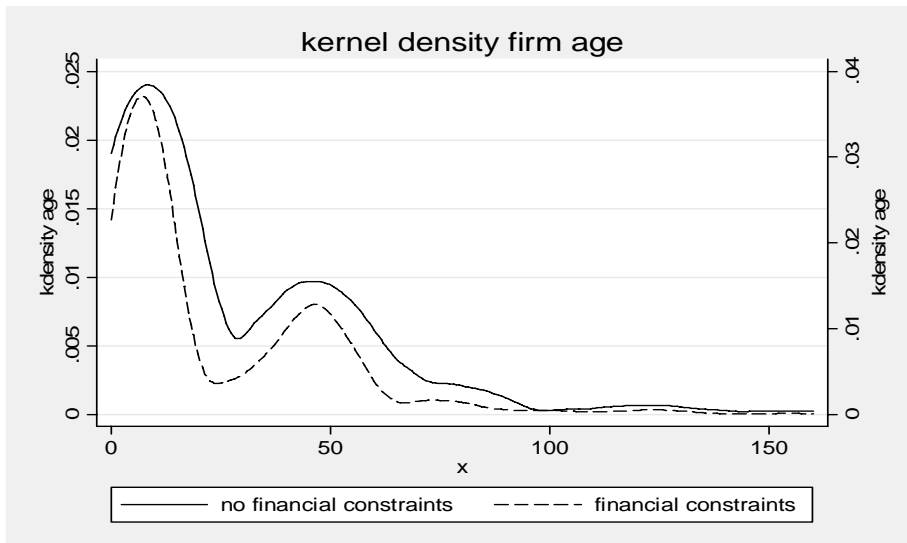
Note: * indicates that the t-test for mean differences is significant at 5%. YIC denotes Young and Innovative Company, which is defined as a firm with positive R&D, average R&D intensity of 13%, less than 6 years old and employing less than 250 workers

Source: SORS; authors' calculations.

Table 2 demonstrates that especially financial constraints seem to matter for innovators and even more so for young innovators. The latter can be due to the

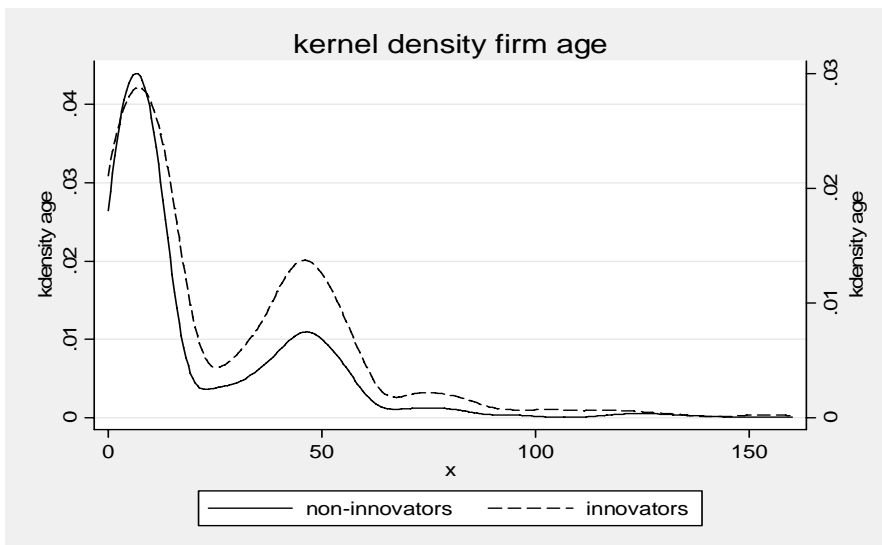
asymmetric information in the market, as young firms in particular would find it harder to find access to capital, given they have a higher default risk. Figure 1 show the kernel density distribution of firm age in our sample according to financial constraints. The distribution of firms with no financial constraints is more to the right relative to financially constrained firms, which indicates that typically young firms face more financial constraints compared to old firms. In Figure 2 we compare innovating firms with non-innovators (the same picture holds when we split the sample according to R&D investment). We observe that in fact the density function of innovators is to the right of the one of non-innovators, indicating that innovators are on average slightly older than non-innovators. If financial constraints are an important obstacle for young firms to innovate, we may expect this pattern to emerge.

Figure 1: Distribution of firm age according to financial constraints, 2002



Source: SORS; authors' calculations.

Figure 2: Distribution of firm age according to innovation status, 2002



Source: SORS; authors' calculations.

In order to test whether financial constraints have an impact on long term R&D investment and therefore on the propensity to innovate we will use the reported

indicator of financial constraints in the CIS data. The drawback of using this indicator, however, is that this is only reported from the CIS of the year 2000 onwards. Furthermore, it is a qualitative measure based on a survey and therefore it reflects perceived financial constraints. In order to test whether this measure is a good proxy to measure financial constraints we test in a first step whether it correlates well with the amount of external debt firms can obtain. In particular, we would expect that financially constrained firms would find it harder to obtain new loans and therefore to accumulate debt. We therefore estimate first how financial constraints have an impact on debt in the firm. In doing so, we also take into account other factors that might determine debt, such as the size of the firm (proxied by employment), the cash flow of the firm and the collateral (proxied by tangible fixed assets). Finally, to control for general demand shocks we also include the growth in sales as a factor explaining debt. We expect that a positive shock should be associated with increased debt accumulation and vice versa.

In Table 3 we report the results of this experiment. In all the specifications we find that our indicator of financial constraints is negatively correlated with debt and since we report fixed effects estimations we can interpret this as a within firm time effect, i.e. firms that become financially constrained have lower debt. Also, our other indicators have the expected sign as can be seen from columns (2) and (3). Firms with more collateral, proxied by tangible fixed assets, tend to have easier access to external funds. Likewise, large firms, proxied by employment, seem to find it easier to get access to external funds. While cash flow has a positive coefficient, it is not statistically significant. Finally, positive sales shocks seem to have a positive effect on debt. The results in Table 3 are in fact best interpreted as correlations. Given that we only have two years of data (2000 and 2002) for which firms report this indicator of financial constraints, we cannot really engage in a dynamic approach nor making assessments about causality. Nevertheless, given that the correlations are in line with our expectations, it seems that proxying financial constraints with the survey indicator can be justified.

Table 3: Financial constraints and Access to Debt

	(1)	(2)	(3)
<i>FC</i>	-0.109*** (0.034)	-0.109*** (0.036)	-0.078*** (0.031)
<i>Employment</i>	-	0.669*** (0.091)	0.243*** (0.082)
<i>Cash Flow</i>	-	0.072*** (0.022)	0.012 (0.019)
<i>Tangible Fixed Assets</i>	-	-	0.558*** (0.034)
Δs	-	-	0.218*** (0.040)
# observations	2237	1939	1937

Note: Dependent variable is debt to assets ratio. All specifications include firm level fixed effects. All variables are measured in natural logarithms. Standard errors in parentheses, ** and * indicate statistical significance at the 10% and 5%, respectively.

Source: SORS and AJPES; authors' calculations.

3. Model and Econometric Approach

In this section we follow closely the model and approach proposed by Aghion, Askenazy, Berman, Cetten and Eymard (2005), which gives two main theoretical predictions that are of relevance for the current paper. First, a firm's relative R&D investment is more procyclical, in the sense that it reacts more positively to the firm's current sales, the more credit constrained the firm is. Second, tighter credit constraints interact with sales asymmetrically over the business cycle. Thus, in downturns credit constraints are more binding than in upturns. The intuition behind these two predictions goes as follows. Firms chose between short-term capital investment and long-term R&D investment. R&D investment requires financing obtained from current earnings and borrowing. If current earnings are high, as in booms, a firm is able to borrow more as it also has more collateral. However, when it is hit by a bad shock, current earnings are depressed, which lowers the ability to borrow and even more so in credit constrained firms (such as young and small firms). As a result, the ability to invest in long term R&D, which in addition has an uncertain collateral value, will decline. Thus, relative R&D investment should be more pro-cyclical in credit constrained firms than short term investment in say tangible fixed assets. The effect should be amplified in downturns as in recessions default risks increases and therefore banks become more conservative. In what follows we will test these predictions using a micro approach. This implies that we try to identify idiosyncratic shocks to firms, which have implications for firm level relative R&D investment.

In order to test these predictions we follow Aghion et al (2005), who use a reduced form approach:

$$\frac{RD_{it}}{I_{it} + RD_{it}} = \alpha_0 + \alpha_1 \Delta s_{it} + \alpha_2 FC_{it} + \alpha_3 \Delta s_{it} \times FC_{it} + \mu_t + \nu_i + \varepsilon_{it}, \quad (1)$$

where subscript i stands for firm i , subscript t denotes time, RD refers to investment expenditures in Research and Development, I refers to investment in tangible fixed assets, Δs refers to sales growth, FC is an indicator equal to 1 if the firm faces financial constraints and zero else. We further control for year fixed effects (μ) and firm fixed effects (ν). By controlling for firm fixed effects we capture potential self selection of firms becoming investors in R&D, including differences in corporate governance between firms that do not change from one year to the next. The year fixed effects capture common time trends affecting R&D in all firms.

4. Results

4.1. Main results

Results are reported in Table 4. The first column shows how sales growth affects the share of R&D investment. The coefficient is negative, but not statistically significant. When we restrict the sample to firms that engage in some R&D investment, in column 2, we note that R&D investment responds negatively to firm level sales growth or counter-cyclically in line with a Schumpeterian creative destruction story. In column 3 we turn back to the full sample, but interact sales growth with our indicator of financial constraints. In line with the prediction of the Aghion et al (2005) model, we find that firms facing financial constraints (the interaction term) respond pro-cyclically to R&D investment, while firms not facing

financial constraints react in a counter-cyclical fashion. In particular, a reduction in firm level sales with 10% would be associated with an increase in R&D investment of 1% in non-financially constrained firms and a reduction of 0.3% in financially constrained firms ($-0.114+0.141=0.03$) The direct effect of financial constraints is negative, but not statistically significant. In the fourth column we repeat this exercise, but only for firms that engage in some R&D. We note that the same results hold, but that the coefficients are much larger and that financial constraints also have a direct negative effect on R&D investment.

While these results are consistent with what we would expect, there remains a concern that reported financial constraints might as well reflect other hampering factors, as reported in table 2. We therefore also include these other hampering factors in the analysis to check whether this is affecting our main result. We do this in column (5) and (6). In column (5) we just add organizational rigidities as an extra hampering factor. We can note that our results remain robust, although the direct effect of financial constraints is only estimated to be significant at the 10% level. In column (6) we also add the other hampering factors and again we can note that our main results remain robust. Only the direct effect of financial constraints is no longer significant.

Table 4: Main Results

	(1) All firms	(2) Only firms doing R&D	(3) All firms	(4) Only firms doing R&D	(5) Only firms doing R&D	(6) Only firms doing R&D
Δs	-0.021 (0.041)	- 0.113** (0.061)	- 0.114** (0.06)	- 0.315** (0.102)	- 0.30** (0.10)	- 0.29** (0.105)
FC	-	-	-0.001 (0.04)	- 0.142** (0.069)	-0.12* (0.07)	-0.09 (0.08)
$\Delta s \times FC$	-	-	0.141* (0.087)	0.320** (0.133)	0.32** (0.13)	0.31** (0.136)
<i>Organization</i>	-	-	-	-	-0.040 (0.05)	-0.029 (0.057)
<i>Information</i>	-	-	-	-	-	-0.030 (0.067)
<i>Qualified people</i>	-	-	-	-	-	0.014 (0.069)
<i>Excessive Risk</i>	-	-	-	-	-	-0.049 (0.066)
# observations	1535	691	1475	671	671	671

Note: Dependent variable is relative R&D investment ($RD_{it}/(I_{it} + RD_{it})$). All specifications include year effects and firm level fixed effects. Standard errors in parentheses, ** and * indicate statistical significance at 10% and 5%, respectively.

4.2. Robustness checks I: Financial dependency of firms

An important concern is the measurement of financial constraints and its endogeneity. It may be the case that both a firm's decision to invest in R&D and its financial constraints may be related to some omitted variable, apart from the fixed effect or the year effect that we include. The results of Table 4 should be stronger in firms that are financially more dependent. We will proxy financial dependency using various approaches. First, if a firm is part of a multinational we would expect it to

have easier access to credit, due to internal credit markets (see also Javorcik and Spatareanu (2008)). Likewise, if a firm receives some kind of government subsidy, it is less financially dependent. And finally, a firm that has a lot of collateral should find it easier to get access to finance. Getting a more significant result on the financially dependent sub-sample, would suggest that the endogeneity bias is weak and that our measure of financial constraints is in fact a good proxy for firm level financial constraints.

In Table 5 we check whether the effects are stronger (weaker) when firms are more (less) financially dependent. To this end, we use additional information on the firm characteristics. In particular, we may expect that firms that are part of a multinational face less financial constraints. The results in Table 5 confirm that the cyclicity of R&D investment is stronger in firms that are more financially dependent. In fact, firms which are not foreign owned, firms which are not subject to government R&D subsidies and firms with less amount of assets are more likely to pro-cyclically reduce R&D investment.

Table 5: Robustness checks with the indicators of financial dependence

	(1) FDI	(2) No FDI	(3) Subsidi es	(4) No Subsidies	(5) High Assets	(6) Low Assets
Δs	-0.012 (0.171)	-0.152** (0.071)	-0.060 (0.969)	- 0.123** (0.068)	-0.000 (0.075)	- 0.235*** (0.127)
FC	-0.044 (0.069)	-0.002 (0.045)	0.179 (0.30)	-0.001 (0.043)	0.006 (0.038)	0.011 (0.097)
$\Delta s \times FC$	0.128 (0.208)	0.160* (0.090)	-0.007 (0.962)	0.177** (0.09)	0.033 (0.090)	0.304** * (0.194)
# obs	223	1252	176	1299	799	676

Note: Dependent variable is relative R&D investment ($RD_{it}/(I_{it} + RD_{it})$). All specifications include year effects and firm level fixed effects. Standard errors in parentheses, ** and * indicate statistical significance at 10% and 5%, respectively.

A final prediction that we seek to test is whether firms facing downturns are affected more by financial constraints than firms facing upturns. To this end, we split the sample of firms in two groups, i.e. those firms that have below average sales growth versus those with above average sales growth. As shown in Table 6, the theoretical predictions are again confirmed. Firms that face relatively less favorable market conditions are more responsive to financial constraints and sales growth than firms in upswings.

Table 6: Robustness checks for asymmetric responses

	(1) Below Average Sales growth	(2) Above Average Sales growth
Δs	-0.819* (0.53)	-0.043 (0.09)
FC	-0.146** (0.08)	-0.104 (0.09)
$\Delta s \times FC$	0.953* (0.59)	0.301 (0.203)
# observations	947	528

Note: Dependent variable is relative R&D investment ($RD_{it}/(I_{it} + RD_{it})$). All specifications include year effects and firm level fixed effects. Standard errors in parentheses, ** and * indicate statistical significance at 10% and 5%, respectively.

The above results suggest that financial constraints do change the cyclical behavior of long term investment in R&D. However, the procyclicality in R&D could be explained by decreased investment in physical capital during slumps in credit constrained firms. So, if we find that investment in physical capital responds to changes in sales in countercyclical fashion in financially constrained firms, then our previous results are just the result of a compositional effect. We therefore test in Table 7 whether investments in tangible fixed assets are responsive to firm level sales growth and financial constraints using the same specifications. We define investment – as is usually done in the investment literature – relative to tangible fixed assets in the previous period. The results in columns 1 and 2 confirm indeed that short term investment is procyclical and not responsive to financial constraints. The results suggest that investment in R&D is indeed different in terms of cyclicity than short term investment, the first being countercyclical and the latter procyclical. It is, however, financial constraints that change the nature of R&D investment from countercyclical to procyclical.

Table 7: Short term Investment in Capital

	(1)	(2)
Δs	0.445** (0.034)	0.570** (0.17)
FC		0.012 (0.08)
$\Delta s \times FC$		-0.055 (0.206)
# observations	13066	2295

Note: Dependent variable is tangible fixed assets growth ($\log(I_{it}/I_{it-1})$). All specifications include year effects and firm level fixed effects. Standard errors in parentheses, ** and * indicate statistical significance at 10% and 5%, respectively.

4.3. Robustness checks II: Econometric Approach - matched sampling

The results presented so far indicate that financially constrained firms are more likely to reduce R&D expenditures during economic downturns. A problem in the approach we followed so far is that it does not take into account self-selection and endogeneity of financial constraints. For instance, it could well be that firms that are less likely to engage in R&D investment also in the absence of financial constraints will be even less inclined to do so when facing financial constraints. Hence, to determine the actual effect of financial constraints on firm R&D investment during economic downturns, we need to estimate this effect by comparing otherwise similar firms. One way of obtaining such a control group of firms is by selecting firms with a similar propensity to R&D investment. To this end, we use matching techniques to construct a controlled experiment. In particular, we use the firm propensity to R&D investment in order to match firms engaging in R&D with otherwise similar firms with no R&D. This allows us to evaluate the importance of financial constraints on R&D investments. We estimate the probability to engage in R&D using the following specification:

$$(2) \quad \Pr(RD_{it} = 1) = \alpha + \beta_1 \left(\frac{VA}{Emp} \right)_{it-1} + \beta_2 Emp_{it-1} + \beta_3 \left(\frac{K}{Emp} \right)_{it-1} + \beta_4 IFDI_{it-1} + \beta_5 OFDI_{it-1} + \beta_6 EX_{it-1} + \varepsilon_{it}$$

where the current probability to engage in R&D in firm i is determined by its lagged labor productivity (VA/Emp), its size in terms of employment (Emp), capital intensity (K/Emp), its foreign ownership (a dummy for inward FDI, $IFDI$), its export status (EX) and its multinational activity (a dummy for outward FDI, $OFDI$).

The fitted values obtained from estimating the above model are used to pair up R&D and non R&D performing firms¹⁰. These matched pairs are subsequently used to estimate the average treatment effect of financial constraint on relative R&D investment growth. We match R&D and non R&D performing firms using nearest neighbor matching (with random draws) which pairs up the treated with the closest non-treated observations with respect to the propensity score. Given that our sample size is relatively small, all the standard errors reported were generated by bootstrapping with 100 repetitions.

Table 8 presents the results of average treatment effects estimates of financial constraints on firms' relative R&D investment growth with differently specified subsamples of firms. Note that with this econometric technique it is impossible to resemble completely our OLS empirical models. While OLS allows for a variety of included dependent variables and their interactions, the matching technique allows only that matched treated and non-treated firms differ in one selected variable, which is financial constraints, in our case. However, in order to resemble the earlier OLS specifications we restrict our sample of firms to more narrow subsamples of firms. These subsamples of firms are firms characterized by above or below average growth in sales, foreign owned and non-foreign owned firms, and firms that received government R&D subsidies and those which did not.

For the full sample of firms (row 1), financial constraints are shown to have no significant effect on overall relative R&D investment growth of firms. This result is similar to the one found in the OLS specification (compare model 3 in Table 4). However, when constraining the sample, firms characterized by above average growth in sales are shown not to cut their relative R&D investments (row 2), while firms with below average growth in sales do reduce their relative R&D investments due to financial constraint when faced with the negative (idiosyncratic) business cycle (row 3). These results confirm entirely our findings with OLS reported in Table 6.

¹⁰ This requires that the balancing property is satisfied. The balancing property ensures that once the observations have been stratified into blocks according to the propensity score, the right hand side variables of (2) do not differ significantly between the groups of treated and non-treated observations within a block. The more closely the firms are matched with respect to regressors in (2), the more likely it is that the observed differences in firms' relative R&D investment growth result purely from the fact that some firms are more affected by financial constraints than the others and not due to their innate different propensity to engage in R&D.

Table 8: Average treatment effect estimates of financial constraints on firms' R&D investments

	Subsample	n. treat.	n. contr.	ATT	Std. Err.	t
1	All firms	1148	54	-1.13	0,93	-1.21
	<i>Firms characterized by:</i>					
2	Above average growth	449	24	0.096	0.50	0.19
3	Below average growth	699	25	** -3.540	1.69	-2.10
4	FDI	194	14	** 1.263	0.29	4.30
5	non-FDI	1531	53	** -0.904	0.35	-2.59
6	Subsidy	133	14	0.443	0.51	0.88
7	No subsidy	1015	43	* -2.051	1.07	-1.91

Note: Dependent variable is growth in relative R&D investment ($\log(RD_{it}/(I_{it} + RD_{it})/RD_{it-1}/(I_{it-1} + RD_{it-1}))$). *n.treat* and *n.contr.* is number of treated and number of control firms, respectively. *ATT* is average treatment effect. All standard errors reported were generated by bootstrapping with 100 repetitions. ** and * indicate statistical significance at 10% and 5%, respectively.

Constraining the sample to the FDI and non-FDI subsamples (rows 4 and 5), confirms again that foreign owned firms are not likely to reduce their relative R&D investment due to financial constraints, while firms with no access to internal credit markets are likely to make significant cuts in R&D investments. These results are in line with the OLS results reported in Table 5 (columns 1 and 2), though a bit stronger in terms of the significance of the coefficients. Also our earlier results on R&D subsidies are confirmed in rows 6 and 7 of table 8, where we show the results for the subsample of firms that received government R&D subsidies and those which did not. Firms that received government R&D subsidies do not reduce their R&D investment when faced with the financial constraints, while firms without R&D subsidies make significant cuts in R&D investments due to financial constraints.

5. Conclusions and policy implications

This paper studies the cyclicity of R&D investments using a unique data set of Slovenian firms. The framework we use is based on Aghion et al (2005), arguing that when firms are hit by a negative shock in bad times a credit-constrained firm has to rely on its cash flow and borrowing to survive its short-run liquidity shock, which reduces the possibility for further borrowing in order to innovate. This implies that a negative shock should hit R&D investments more in firms that are more credit constrained. Hence, R&D investments are more likely to be procyclical in credit constrained firms.

Our findings give support for the procyclicality of R&D investment in credit constrained firms. Furthermore, we find that the effect disappears in firms, which are less financially dependent, i.e. in firms that are part of a multinational and firms receiving government subsidies. The former indicates the importance of the presence of internal credit markets. The latter, however, suggests a role for policy especially for encouraging the cleansing role of recessions. R&D subsidies help in particular small and medium firms to keep track in R&D investments during the economic downturns.

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