EUROSÜSTEEM

The Impact of Firm Financing Constraints on R&D over the Business Cycle

Kadri Männasoo, Jaanika Meriküll

Working Paper Series
3/2015

The Working Paper is available on the Eesti Pank web site at:
http://www.eestipank.ee/en/publications/series/working-papers

For information about subscription call: +372 668 0998; Fax: +372 668 0954
e-mail: publications@eestipank.ee

ISBN 978-9949-493-53-1 (hard copy)
ISBN 978-9949-493-54-8 (pdf)
Eesti Pank. Working Paper Series, ISSN 1406-7161; 3/2015

The Impact of Firm Financing Constraints on R&D over the Business Cycle

Kadri Männasoo and Jaanika Meriküll*

Abstract

This paper studies financing constraints on R&D over the most recent boom and bust episode in Central and Eastern Europe (CEE). Given that financial and venture capital markets in CEE are thin in comparison to those in high-income economies and that many of CEE countries experienced a credit crunch during the last recession, it is proposed that financing constraints have a significant adverse effect on R&D activity in these countries. The paper uses two complementary firm-level data-sources from ten CEE countries. We find that financing constraints have a substantial effect on R&D expenditures, as the probability of credit constrained firms undertaking R&D activities is around 70% lower than for other firms and firms' R&D expenditure sensitivity to cash flow is very high. Despite the severity of the crisis, the adverse effect of financing constraints for R&D did not increase during the financial crisis. We also find that, conditional on credit constraints, firms' R&D activity is higher during a recession.

JEL Codes: O16, O32, O52, E32, P23

Keywords: R&D financing constraints, credit constraints, business cycle, Central and Eastern Europe

Corresponding author's e-mail address: jaanika.merikyll@eestipank.ee

* The authors are grateful to Josef Brada, Richard French, Merike Kukk, Tairi Rõõm, Karsten Staehr and the participants of presentations held in Regensburg and Narva-Jõesuu for their insightful comments. The authors are grateful to Aavo Heinlo for providing the data and Robin Hazlehurst for exellent language editing and for the financial support from Estonian Research Council Grant IUT20-49 and PUT315.

Non-technical summary

The literature on endogenous growth, creative destruction and volatility has brought the Schumpeterian framework back to the forefront of economic thought (Aghion and Howitt (2006), (1998)). The idea that research and development (R&D) is concentrated in recessions and contributes to lower volatility and higher long-term growth is appealing. Many theories have been proposed for ways to understand the joint determination of volatility and growth from firms' R&D investments. Aghion et al. (2010) suggest that firm R&D investments are countercyclical because of opportunity costs; Barlevy (2007) argues the opposite, saying that R&D activity is pro-cyclical because of dynamic positive externalities. The empirical evidence on R&D investment cyclicality is also mixed (see Ouyang (2011) and Rafferty (2003)).

The concepts of R&D cyclicality and credit constraints are strongly intertwined. The Schumpeterian opportunity cost effect of R&D investments manifested in counter-cyclical R&D activity can only be observed in the absence of credit constraints. A large share of R&D is financed internally since R&D projects are often obscure to outside investors and unlikely to generate positive cash flows in the short run. We abstain from a detailed discussion on the modes and sources of R&D financing and refer to Hall and Lerner (2010), who claim that external financing of R&D is much more costly than using internal funds, and given that the internal cash flows dry up and external financing becomes even more costly during a recession, the negative effect of financing constraints on R&D investments may be substantial. The amplified financing constraints during a recession might outweigh the opportunity cost effect of R&D that is otherwise countercyclical.

This paper investigates the effect of financing constraints on R&D activity over the boom-bust cycle in Central and Eastern Europe (CEE). The CEE countries have received less attention in the literature of R&D financing, have less developed financial and venture capital markets (Brown et al. (2011)), and have provided a textbook example of a boom-bust episode over the last ten years. This paper will contribute to the literature by providing comparative firm-level empirical evidence on the effect of credit constraints for R&D over the business cycle and by introducing an empirical methodology that enables to disentangle the direct effect of firm characteristics on R&D and the indirect effect from credit constraints. Although financing constraints play a key role in the cyclicality of R&D (Aghion et al. (2010)), the cyclicality of financing constraints for R&D has received very little attention in the empirical literature. There is only evidence on SMEs that the financing gap between non-innovative and innovative firms diminished during and after the Great Recession (Lee et al. (2015)).

Two complementary data sources are used for empirical testing. First, the 2002, 2005, 2009 and 2012 rounds of the Business Environment and Enterprise Performance Survey (BEEPS) by the EBRD and the World Bank provide rich information about the R&D and innovation activities of firms and about credit constraints, and give financial and other background information. The data from ten new EU members are used: Bulgaria, the Czech Republic, Hungary, Estonia, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. The four rounds from the pre-boom, boom, bust and recovery years are pooled and the effect of credit constraints on R&D activity over the business cycle is estimated in a bivariate model where the endogeneity of credit constraints is addressed. The R&D activity is defined as a binary variable denoting the presence of R&D expenditure in the firm.

The effect of financing constraints on firm R&D is difficult to identify in the cross-sectional setting due to the inability to control for unobserved firm-specific effects. As a second source of data, we use firm-level panel data of R&D expenditure from Estonia to validate our results from the cross-sectional estimation in a panel data setting. The panel data let us test for the role of financing constraints on R&D once firm-specific effects have been controlled for. The panel covers the years from 1998 to 2012, and contains rich information from the balance sheets and profit/loss statements of firms. The disadvantage of this dataset is the indirect measurement of financing constraints; the paper uses the Euler equation methodology to estimate the sensitivity of R&D investments to cash flows. The R&D cash flow sensitivity is taken as an indication of the existence of financing constraints. The approach taken by Brown et al. (2012) is used, where firms' R&D investment sensitivity is tested in a specification with a control for cash holdings and long-term debt finance. The effect of financing constraints on R&D over the business cycle is tested by time dummies and the interaction of time-dummies with cash flow, and by the interaction of yearly real GDP growth and cash flow.

There is evidence of a strong restraining effect from financing constraints on R&D in both of our complementary datasets. The analysis on the BEEPS dataset from ten new EU member states suggest that credit constraints are related to a probability that is around 70% lower of a firm being engaged in R&D. The importance of financing constraints for R&D investments is also confirmed by the R&D panel data from Estonia. The cash flow sensitivity of R&D expenditure is up to four times larger in Estonia than the reported empirical evidence from the high-income countries. The relevance of financing constraints for R&D expenditure is somewhat weaker for mature firms, but the cash flow sensitivity among mature firms is still high according to the standards of high-income countries.

There is no evidence that the effect of financing constraints on R&D is variable over the business cycle. Despite the deep recession and the credit crunch in 2009 in most of the sample countries, there is no evidence that the effect of financing constraints on R&D increased in the recession. Given the high cash flow sensitivity of R&D in our panel, the cash flow sensitivity did not increase any further during the recession. In addition, the estimates from the BEEPS data suggest that, conditional on credit constraints, incentive to undertake R&D is countercyclical and higher in a recession.

Contents

1. Introduction

This paper studies the effect of financing constraints on R&D activity over the boom-bust cycle in Central and Eastern Europe (CEE). The CEE countries have received less attention in the literature of R&D financing, have less developed financial and venture capital markets (Brown et al. (2011)), and have provided a textbook example of a boom-bust episode over the last ten years. This paper will contribute to the literature by providing comparative firm-level empirical evidence on the effect of credit constraints for R&D over the business cycle and by introducing an empirical methodology that enables to disentangle the direct effect of firm characteristics on R&D and the indirect effect from credit constraints. Although financing constraints play a key role in the cyclicality of R&D (Aghion et al. (2010)), the cyclicality of financing constraints for R&D has received very little attention in the empirical literature. There is only evidence on SMEs that the financing gap between non-innovative and innovative firms diminished during and after the Great Recession (Lee et al. (2015)).

Two complementary data sources are used for empirical testing. In both of the datasets, financing constraints prove to be an important factor hampering R&D in Central and Eastern Europe. The probability of credit constrained firms undertaking R&D is around 70% lower in the sample countries. The panel data show that R&D investments are substantially more sensitive to cash flow than is the case in high-income countries and that this cash flow sensitivity of R&D investments was equally high during the years of strong economic growth and during the hardship of the economic crisis in 2009. Conditional on credit constraints, R&D is found to be counter-cyclical with R&D investments concentrated in the recession.

The paper is organised as follows. The introduction is followed by a literature survey on cyclicality, financial constraints and R&D activity along with references to the literature putting these issues in the Central and Eastern European context. The third section gives details of the two complementary data sources and the methodological aspects of the empirical estimation. The fourth section presents and discusses the results and the last section concludes.

2. Background of the study and related literature

2.1. The business cycle and business R&D investment in Central and Eastern Europe

CEE firms conduct substantially less R&D than firms in high-income countries. The share of total R&D expenditure to GDP averaged 1.2% in CEE in 2012, while the same share was twice as large in the EU12 countries at 2.4% and was as much as 2.8% in the USA (Eurostat: science and technology statistics). The gap in R&D expenditure in CEE and Western European countries exceeds the gap in income levels. The average GDP per capita income in PPS is two thirds of the EU average (Eurostat: economy and finance).[1]

Figure 1 presents the dynamics of GDP and business R&D in the sample countries. The growth has been highly volatile in the CEE countries. Most of these countries were growing quickly after their EU accession, with the growth heavily financed by capital inflows, and the booming environment has been described as a positive expectations shock (see for example Staehr (2013) on the Baltic States). When these capital inflows suddenly stopped in the Great Recession and export markets also deteriorated, these countries faced an unusually rapid and deep recession. The single CEE country which escaped a deep recession was Poland, while the others faced economic declines with GDP growth ranging from −5% to −14% in 2009.

[1] The gap in R&D expenditures stems mostly from the intensive margin and not from the extensive margin, according to the micro-data used in this paper. The share of companies conducting R&D is 18.3% in CEE countries and 19.2% in Western and Southern European countries in the BEEPS data for 2004 (see the note in Appendix 1 for the list of countries covered). However, the median level of annual spending on R&D was about 50 000 USD (mean about 170 000 USD) in CEE and 100 000 USD (mean about 380 000 USD) in Western and Southern Europe. Our R&D panel data from only one CEE country show approximately the same level of R&D expenditure in 2004, as the median value per firm is 55 000 USD and the mean is 155 000 USD.

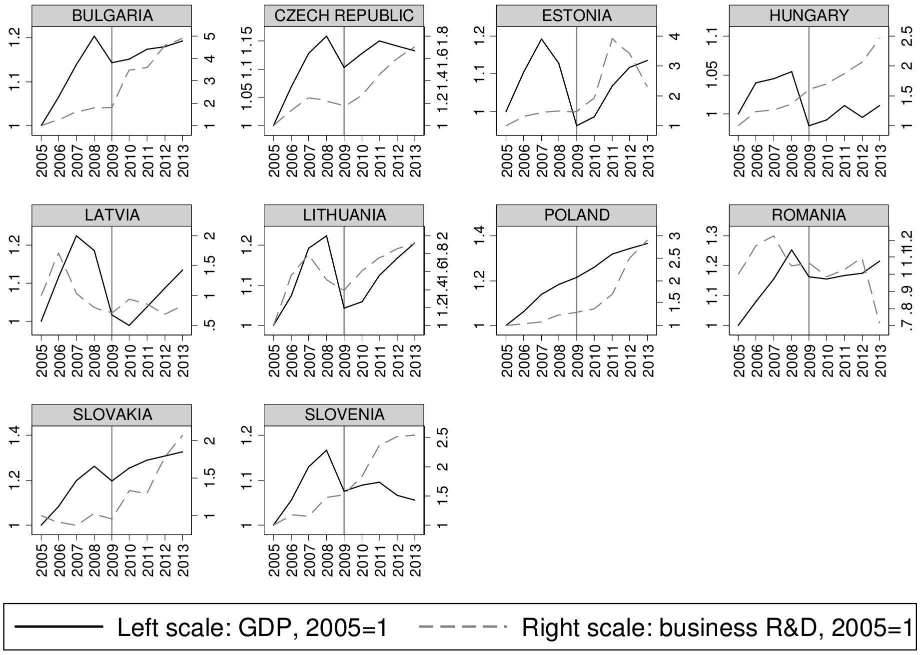


Figure 1: Real GDP and real business R&D expenditures in 2005 prices, 2005–2013

Source: authors' calculations from Eurostat data; GDP series name nama_10_gdp; R&D series name rd_e_berdindr2.

The strong growth before the crisis and the sudden GDP decline in the crisis year of 2009 were similar in most of the countries, while the dynamics of the recovery have varied, with some countries facing a much more sluggish recovery. Most of the countries have experienced growth in R&D expenditure, while there is hardly any evidence that R&D expenditures reacted to the recession in 2009 with a substantial increase or decrease. [2] In the Czech Republic, Latvia and Lithuania there is some evidence of a decline in R&D expenditure in 2009, but as these time series are in general very volatile, these developments are not necessarily related to the recession. In sum there is strong evidence of a boom-bust growth cycle in these countries, but there is no clear evidence of pro or countercyclicality of R&D expenditure at the aggregate level.

The link between R&D expenditure and research output is rather weak in Central and Eastern Europe. Aristovnik (2014) shows that CEE countries have the lowest effectiveness of R&D expenditure in Europe as the number

[2] According to the European R&D Scoreboard the top EU firms continued to invest in innovation despite the crisis (http://europa.eu/rapid/press-release_IP-12-1324_en.htm).

of patents produced is very low given the inputs like R&D expenditure, research personnel and employment in the high-tech sector. According to the European Commission's (2014) innovation scoreboard the CEE countries lag behind Western Europe in most of the innovation indicators, especially in terms of economic effects, though they perform well in research inputs like human resources. Another important qualitative aspect behind the dynamics of aggregated R&D is that CEE firms use bank financing much less for investments and internal funds much more (see Appendix 1 for the financing structure of fixed and working assets). This implies that firm investments are less dependent on the availability of external financing in CEE and so are likely to have been affected less by the credit crunch in 2009.

2.2. R&D financing

There are two types of market failure that lead to underfinancing of R&D (Hall (2002), Hall and Lerner (2010)). First, as knowledge is non-rival, firms will invest less in R&D than is socially optimal. Various tax incentives and subsidies have been introduced and intellectual property rights established to support R&D. Second, external financing for R&D is much more costly than financing using internal funds. This market failure is much harder to solve as sometimes even venture capital cannot solve the problem of the lack of finance for projects with a highly uncertain outcome. This literature is thoroughly reviewed by Hall (2002) and Hall and Lerner (2010), and the following will only briefly summarise their arguments.

R&D projects involve considerable uncertainty about the outcome, long lags from investments to returns, and large sunk costs (Bakker (2013)), which all contribute under the information asymmetry between the inventor and the investor to the high costs of external finance. Hall (2002) and Hall and Lerner (2010) compare the R&D financing market to the model of the market for "lemons", where financing costs in the extreme case of information asymmetry would be so high that the R&D financing market would cease to exist. Firms are also reluctant to expose details about their R&D projects to investors as inventions can be imitated, but this weakens the investors' understanding about the outcome of the project. The moral hazard problem emerging between the owners and the management also contributes to making external financing costs higher than those of internal financing (Hall (2002) and Hall and Lerner (2010)). Managers may be more risk averse than owners and avoid risky long-term investment projects.

Given all this, there are many reasons why firms prefer to finance R&D from internal funds. There is evidence that internal funds have been the major financing source for R&D since the very beginning of the industrial revolution (Bakker (2013)). The cash flow sensitivity of R&D is still the most common test used to check whether R&D is hampered by financing constraints. If extra cash is related to increased R&D expenditure, it is interpreted as evidence of missed R&D investment opportunities due to financing constraints. It is found that small and newly established firms are especially prone to financing constraints for R&D projects (Brown et al. (2009), Martinsson (2010), Brown et al. (2012)). While the investment cash flow sensitivity has declined over recent decades, the R&D cash flow sensitivity remains high (Brown and Petersen (2009)). There is also evidence that financing constraints have a more pronounced negative effect on innovation performance among production firms and among non-exporters (Efthyvoulou and Vahter (2014)).

There are also differences across countries in the external financing of R&D, as US and UK firms rely more on external equity, while continental European firms rely more on bank financing (Brown et al. (2009), Brown et al. (2012)). Brown et al. (2012) show that external equity issues are also important sources of R&D financing and especially so for young firms. If this financing option is left out from the R&D cash flow sensitivity tests, the effect of financing constraints on R&D is underestimated.

Another important factor for R&D financing proves to be cash holdings (Brown and Petersen (2011)). R&D investments have high adjustment costs, and so cash holdings are accumulated to ensure that finances are always available to maintain these investments irrespective of any external financing shocks. Brown et al. (2012) find that after controlling for stock issues and cash holdings, all the variables, stock issues, cash holdings and cash flows, are important for R&D financing. It has been found that even large and successful high-tech firms hold a lot of cash on their balance sheets (Bakker (2013), Hall (2002), Hall and Lerner (2010)), and, for example, Google held cash worth 59 billion dollars at the end of 2013, which corresponds to a cash to total assets ratio of 53% (cash and cash equivalents plus short-term investments to total assets).

There are only a few studies on the role of financing constraints for R&D activity in transition or developing economies. The financial and venture capital markets are less developed in Central and Eastern Europe than in high-income countries (Brown et al. (2011)), which suggests that financing R&D from external sources is more difficult there. Männasoo and Meriküll (2014) find credit constraints to be severe for R&D financing in Central and Eastern Europe. Hall and Maffioli (2008) describe the situation as being similar in Latin American and Caribbean countries in the sense that financing constraints have been perceived as one of the most important factors holding back R&D investments there. Hölzl and Janger (2014) find that financing constraints are the most important innovation barriers in Eastern Europe, while in countries closer to the technological frontier, knowledge and skill barriers are more important than financing constraints. Czarnitzki (2006) shows that financing constraints are more severe for R&D in Western Germany than in Eastern Germany, which is due to the large government subsidies for R&D in the East. The author claims that this result also shows that the market for private R&D financing is dysfunctional in Eastern Germany.

Against this background, we propose our first hypothesis for empirical testing: *Financing constraints are constraining R&D investment in Central and Eastern Europe; given the less developed credit and venture capital markets, the negative effect of financing constraints on R&D is stronger in these countries than it is in high-income countries*.

2.3. R&D activity over the business cycle

The model of Aghion et al. (2010) captures the joint determination of volatility and growth. The propagation mechanism in this model is the endogenous share of long-term investments in total investments. Long-term investments have stronger productivity effects, less cyclical returns and higher liquidity risk. The long-term investment notion in the model shares the features of research and development investments and can help us to understand the relationship between the business cycle and R&D activity. As the returns from short-term investments are smaller than those from long-term investments during a recession, there is a higher demand for long-term investment than for short-term investments during an economic down-turn. This opportunity cost effect drives the main result that the share of long-term investments in total investments is countercyclical.

Another important implication from the Aghion et al. (2010) model is the role of credit constraints in the cyclicality of R&D. If firms face credit constraints they engage less in long-term investment, because these investments can be interrupted because of a liquidity shock. As a result less long-term investment is undertaken and there will be more volatility in the economy and lower growth in the long run. Under tight credit constraints and procyclical liquidity risk, the share of long-term investments in total investments can also turn procyclical.

There are also alternative theoretical models that explain the procyclicality of R&D expenditure. Barlevy (2007) suggests that firms concentrate their inventions in booms because of dynamic positive externalities. There are many country-level empirical studies that suggest that R&D is procyclical (see Ouyang (2011) for an excellent survey). However, there are also opposite results, especially when the role of credit constraints is taken into account. Aghion et al. (2010) also provide empirical support for their model by using OECD country-level data. They demonstrate that the share of long-term structural investments in countries with less developed financial systems is much more dependent on exogenous commodity price shocks.

There are only a few papers that study R&D cyclicality at the firm level. Aghion et al. (2012) use French firm-level data and show R&D investments to be countercyclical for firms with no credit constraints, while R&D investments are procyclical for credit constrained firms. They measure credit constraints as reported payment incidence, the cycle as firm-level growth, and R&D as R&D investment and not total R&D expenditure. They also demonstrate that the effect of the cycle on R&D is asymmetric for credit constrained firms; these R&D investments of these firms fall proportionately more during recessions than they increase during upturns. Beneito et al. (2014) obtain a similar result using Spanish firm-level panel data. In addition, they show that credit constraints matter much less for the cyclicality of R&D in family owned and group affiliated firms. This result suggests that family owned and group affiliated firms rely much more on internal resources in their R&D financing.

There are even fewer studies on firm R&D financing that focus on the Great Recession which started in 2008. Lee et al. (2015) show that innovative firms have impaired access to external financing in general, while the tightening of credit conditions has been stronger for non-innovative firms than for innovative firms during and after the recession. Their results imply that the financing gap between innovative and non-innovative firms in general credit conditions narrowed during and after the recession. They also note that these results may be specific to their database of SMEs from the UK, and Brown et al. (2012) show that R&D firms from the UK use external equity much more for financing and bank-debt much less than do firms in the rest of the Europe. There are also countries where public spending on R&D was substantially increased during the recession, and the countercyclical effect of R&D subsidies during the recession has been empirically confirmed using German data (Brautzsch et al. (2015)).

The second hypothesis for empirical testing suggests that: *Adverse effect of financing constraints on R&D increased during the recession that started in 2008. As internal funds for R&D financing dried up and access to financing worsened substantially during the financial crisis, the effect of financing constraints on R&D financing became even stronger during the recession.*

The third hypothesis for empirical testing suggests that: *Conditional on credit constraints, firm R&D is countercyclical, and if access to financing is not limited, R&D is expected to increase during a recession.*

3. Data and methodology

This paper employs two complementary data sources that demand different approaches for their empirical specification. We address the endogeneity of credit constraints in the cross-sectional BEEPS data by estimating a bivariate probit model. The dynamic specification and system GMM estimation let us control for firm-specific effects and endogeneity in the panel data.

3.1. The multiple cross-section BEEPS data from ten countries

The Business Environment and Enterprise Performance Survey (BEEPS) data are collected by the EBRD and the World Bank and cover a wide set of countries from Eastern Europe and Central Asia (see http://ebrd-beeps.com/ for more information about the survey). Four consecutive waves of the BEEPS have been used: 2002, 2005, 2009 and 2012/2013, and the data used are from ten countries from Central and Eastern Europe: Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. This group of countries was used as they share a quite similar institutional background. The survey contains a representative sample of business enterprises in these countries.

The size threshold of at least five employees has been used since 2009, while there was an age threshold of at least three years before 2009. Given these changes in the methodology, only firms with at least five employees and at least three years of history in operation are used in this paper. The six industries covered are manufacturing, construction, wholesale and retail trade, hotels and restaurants, transport and storage, and business services. Quota sampling was used until 2005 and random stratified sampling has been used since 2009. The probability weights have been available since 2009, but the weights have not been applied because of occasional very high weight values and because of our empirical specification where we control for strata like country, industry and firm size.

The BEEPS data collect a wide set of information about innovation, access to finance, firms' backgrounds, and the business climate. R&D activity is defined as a binary variable in this paper because the information on R&D expenditure is not available in a consistent manner across the successive rounds of the survey.[3] Access to finance is also collected as a binary variable; firms are asked whether they have applied for a loan and whether their application has been rejected. Credit constrained firms are defined as those

[3] R&D expenditure data are available only in wave 2002 and 2005.

whose application for a loan was rejected or who were discouraged from borrowing.[4]

Given our binary measure of these two key variables, the following recursive bivariate model is estimated (Cameron and Trivedi (2010)):

$$y_1^* = x'_1\beta_1 + \varepsilon_1$$
$$y_2^* = x'_2\beta_2 + \varepsilon_2 \tag{1}$$

The variable y_1^* is the unobserved latent variable of credit constraints and y_2^* is the unobserved latent variable of R&D expenditure. Instead of the latent variables the binary variables are observed $y_i = 1$ if $y_i^* > 0$ and $y_i = 0$ otherwise, for $i = 1, 2$. The x'_1 denotes the following explanatory variables used to explain credit constraints: firm age, size, foreign ownership, sales growth, whether it is audited, whether it has received subsidies, and country dummies; x'_2 denotes the following explanatory variables for the R&D equation: *credit constraints*, firm age, size, export share in sales, foreign ownership, share of employees with higher education, growth in sales, industry-level growth proxies, and industry dummies. All the four waves and all ten countries have been pooled for the econometric estimation. The effect of the business cycle on R&D activity is captured by the industry-level growth of value added. The correlation between ε_1 and ε_2 is expected to be non-zero and so the system of two equations is estimated simultaneously by maximum likelihood.

The variables audit, subsidies and country dummies are used as instruments to identify the effect of credit constraints on R&D activity. We expect auditing and subsidies to be a positive signal about firm's credit worthiness for creditors, but do not expect these variables to affect firm R&D engagement. The country dummies are used in the credit constraint equation to control for the financial development at the country level. Although country dummies can be important controls also in the R&D equation, controlling for industry specific effects in R&D equation is more important as R&D is found to be highly concentrated to manufacturing and business services. According to Eurostat 95% of total business R&D expenditures were made by these two sectors in 2012 (Eurostat: series name rd_e_berdindr2).

Table 1 presents the descriptive statistics of the BEEPS data. Most of the variables analysed are binary, but there are also some continuous variables such as firm age, sales growth, share of employees with higher education and share of exports in sales. The sample firms have quite a high share of R&D firms, as about 18% of the firms have some R&D expenditure. The share of

[4] Brown et al. (2011) emphasise the large share of credit discouraged firms in CEE.

credit constrained firms is around 10%, the share of employees with higher education is 19%, the share of exports in sales is 15% and one tenth of the firms are majority foreign owned.

Table 1: Descriptive statistics of the BEEPS data, 2002, 2005, 2009 and 2012/2013 (n=7141)

Variable	Definition	Mean	Std. Dev.	Min	Max
R&D	1 if firm had R&D expenditure, either in-house or contracted, over the last three years, 0 otherwise	0.183	0.387	0	1
Constrained	1 if an application for a loan was rejected or the firm was discouraged from borrowing, 0 otherwise	0.099	0.299	0	1
Age	Firm age in years. The beginning year is set to 1987 if reported earlier	14.003	5.212	3	27
Empl2to49	1 if firm employment is between 2 and 49 employees, 0 otherwise	0.701	0.458	0	1
Empl50to250	1 if firm employment is between 50 and 249 employees, 0 otherwise	0.221	0.415	0	1
Empl250to10000	1 if firm employment is between 250 and 10000 employees, 0 otherwise	0.077	0.267	0	1
Dsales	Real sales growth over the last three years, in per cent	0.160	0.421	−0.999	1.994
UniGrade	Share of firm workforce with a university degree	0.192	0.247	0	1
ExSale	Share of direct and indirect exports in firm sales	0.152	0.290	0	1
Foreign	1 if share of foreign ownership ≥ 50, 0 otherwise	0.105	0.294	0	1
Audit	1 if firm’s financial statements are reviewed by an external auditor, 0 otherwise	0.486	0.500	0	1
Subsidies	1 if firm has received public subsidies from local, national, or EU sources, 0 otherwise	0.141	0.348	0	1
GDP	Industry-level real annual growth of value added	0.063	0.057	−0.349	0.339
Credit dependent	1 if firm needs a loan, 0 if firm does not need a loan	0.675	0.469	0	1
Innovative firms	Firms that have introduced new or significantly improved products or services or introduced new or significantly improved methods for the production or supply of products or services over the last three years	0.588	0.492	0	1

Source: authors’ calculations from BEEPS data.

3.2. Panel data from Estonia

The R&D panel data cover firms conducting R&D in Estonia, one of the sample countries, in 1998–2012. The data cover the whole population of Estonian firms conducting R&D before 2000 and after 2011, and the whole population of larger R&D firms plus a representative random sample of smaller R&D firms between 2000 and 2010. Probability weights have been used to make the sample representative of the whole population over all the sample years. The database is used for the official R&D statistics of business entities. The methodology of the survey follows the Frascati Manual, and the survey is mandatory for all the firms conducting R&D in the country.[5] The firm-level R&D database is merged with the Commercial Register using unique firm identification codes. The Commercial Register contains detailed balance sheet items and profit and loss statement items for firms. The resulting database covers all the R&D firms in the business sector, except financial intermediation, which is not covered in the Commercial Register.

The Euler equation approach by Brown et al. (2012) is applied to estimate the sensitivity of R&D expenditure to cash flow. The R&D cash flow sensitivity is taken as an indication of the existence of financing constraints. This kind of test for the existence of financing constraints is indirect and the firm's self-reported R&D financing obstacles may have been a better proxy for financing constraints. As Bond et al. (2005) noted, the cash flow may be an indication of future profit making ability and may be related to investment activity even if there are no financing constraints. Unfortunately there is no information on firms' self-reported availability of finance in our database. We estimate the Euler equation for different subsections of sample firms that could be expected to have better access to finance; this exercise serves as a robustness test for our measure of financing constraints. Firm size and age are found to be the best predictors of credit constraints in Hadlock and Pierce (2010).

The R&D cash flow sensitivity test by Brown et al. (2012) introduces cash holdings and external equity finance as additional controls in the Euler equation. Increases in cash holdings control for the high adjustment costs of R&D, firms pile up cash on their balance sheets to ensure the continuity of R&D financing if there are interruptions in external financing. Like in the specification of Brown et al. (2012) the change in long-term debt financing is also included as an additional control variable. Unlike in their paper, external equity finance is not included in this paper as our sample mostly contains

[5] See the methodology of the survey and the official statistics for business research and development in Estonia at: http://pub.stat.ee/px-web.2001/I_Databas/Economy/28Science._Technology._Innovation/04Research_and_development_activities/04RD_in_enterprise_sector/RD_21.htm

small and medium sized companies and only a few public firms that can finance themselves with external equity from the stock market. Brown et al. (2012) also include Tobin's Q or sales growth to control for the expected future profitability of firms. Sales growth is used instead in this paper as there are not many public firms in the sample and Tobin's Q data is not available.

The following specification is estimated to test for the role of financing constraints in R&D expenditure:

$$R\&D_{i,t} = \alpha_i + \beta_1 R\&D_{i,t-1} + \beta_2 R\&D_{i,t-1}^2 + \beta_3 \Delta Sales_{i,t} + \beta_4 Sales_{i,t-1} + \beta_5 CashFlow_{i,t} + \beta_6 CashFlow_{i,t-1} + \beta_7 NewDebt_{i,t} + \beta_8 NewDebt_{i,t-1} + \beta_9 \Delta CashHoldings_{i,t} + \beta_{10} \Delta CashHoldings_{i,t-1} + d_t + u_{i,t} \tag{2}$$

where i denotes firms and t denotes time in years, t = 1998-2012. $R\&D_{it}$ denotes total R&D expenditure, including internal and external expenditure; $Sales_{it}$ turnover; $CashFlow_{it}$ the sum of net profits, depreciation and R&D expenditure; $NewDebt_{it}$ the growth in long-term debt; and $CashHoldings_{it}$ the ratio of cash and cash equivalents to total assets. All the variables are divided by the total stock of firm assets at the beginning of the period to deflate from nominal to real values. Time dummies denoted by d_t are included to control for the time-trend in R&D expenditure. A statistically significant and positive value for the sum of β_5 and β_6 would indicate the cash flow sensitivity of R&D expenditure and would be an indication of financing constraints holding back R&D expenditures. The equation is estimated by system GMM (Arellano and Bover (1995)) where lagged R&D expenditure and CashFlow are treated as endogenous.

We examine whether firms' R&D cash flow sensitivity varied over the different phases of the business cycle by introducing interaction terms for the time dummies and the $CashFlow_{it}$ variable. In these estimations the term $\sum_{t=1}^{14} \beta_{5t} d_t \times CashFlow_{i,t}$ has been added to the specification (2)[6]. A statistically significant and negative value of β_{5t} during the boom years indicates that the financing constraints for R&D were revealed during the boom years when both internal and external resources for financing were readily available. The statistically significant and positive value of β_{5t} during the crisis years indicates the larger negative role played by financing constraints on R&D during the crisis years. We also estimate a specification

[6] The lagged cash flow variable will be excluded from this specification due to the threat of over-instrumentation in system GMM. All interaction terms with cash flow are also treated as endogenous and this leads to a substantial increase in the number of instruments.

where aggregate real GDP growth has been interacted with cash flow instead of time dummies as an alternative specification. If the financing constraints were stronger during the weak growth years the sign of the coefficient of this variable would be negative.

There is no good way to test for the cyclicality of R&D in the Euler equation approach. Current or lagged values of financial variables should not be correlated with R&D expenditures according to this specification and the same should hold for the effect of booms or recessions. As a naive approach we test for the correlation of R&D expenditure with aggregate real GDP growth for firms with high cash flow sensitivity of R&D and for firms with low cash flow sensitivity of R&D.

Table 2 presents the descriptive statistics of the R&D panel data from Estonia. All the variables, except employment and age, are scaled by the value of total assets at the beginning of the year. The sample firms are much smaller than those used in previous studies (see for example Bond et al. (2005), Brown et al. (2009), Brown and Petersen (2011), Brown et al. (2012)), which is a major advantage of our dataset as it is representative of all the R&D firms and not just the large and publicly traded companies. Our sample firms are also more R&D intensive than those in previous studies. This discrepancy is to be expected as our sample particularly targets R&D firms, while previous studies have used data from publicly traded firms that also do R&D. Our sample firms also have higher sales growth, a larger sales to assets ratio, a higher cash flows to assets ratio, and higher long-term debt to assets, and are much more cash rich. These characteristics come from the nature of our sample covering all the R&D firms, including very small ones, and because it is obtained from the catching-up environment where firms are young and have high growth rates and higher profit margins. The cash-richness of the sample companies is not necessarily related to the need to safeguard smooth R&D financing from external finance shocks, but may be related to the fact that retained earnings are tax free in Estonia (Masso et al. (2013)).

If financing constraints mean that only a particular group of firms is able to conduct R&D and this is not controlled for in the estimations for R&D firms, the effect of financing constraints on R&D expenditures would be underestimated. We control for the selection by estimating a probit model for each sample year where the dependent variable is the propensity to undertake R&D and the explanatory variables consist of financial variables from the Euler equation plus firms' internationalisation variables. The internationalisation variables like exporting and importing status, and foreign ownership aim to capture the more able firms who would be more likely to be engaged in R&D, but would not necessarily spend larger amounts on R&D. Given the yearly propensity to conduct R&D, the Mills ratio is calculated and added to our Euler equation specification. The Mills ratio has only a very small value, and it is not statistically significant in the model[7]. It is concluded that selection into the group of R&D firms is essentially irrelevant for the estimation of this Euler equation specification.

Table 2: Descriptive statistics of the Estonian R&D panel data, 1998–2012

	All sample (n = 985)		
	Median	Mean	Std. dev.
R&D	0.134	0.449	0.835
Employment	23	123.3	429.1
Age	12	11.9	4.85
Sales	1.463	1.692	1.199
ΔSales	0.020	0.182	0.812
CashFlow	0.339	0.667	0.942
Long-term debt	0	0.065	0.144
NewDebt	0	0.006	0.120
CashHoldings	0.207	0.329	0.351
ΔCashHoldings	0.002	0.010	0.292

Note: all the variables, except employment and age, are scaled by total assets from the beginning of the year. Cash flow is measured gross of R&D expenditure and calculated as the sum of net profits without extraordinary income, depreciation and R&D expenditure. Sales growth, growth of long-term debt and growth of cash holdings are calculated as deflated growth and divided by the total assets at the beginning of the year. The GDP deflator at the two-digit NACE level is used for deflating. All the variables are trimmed of 1% of the lowest and 1% of the highest values, except variables where the first percentile equals zero, and in these cases only the upper tail of the distribution is trimmed at the 99th percentile. Probability weights have been applied.

Source: authors' calculations from Estonian R&D panel data.

4. Results

4.1. Simultaneous estimations from the multiple cross-section of BEEPS data

Table 3 presents the results of the estimation of equation (1). The specification is estimated for three groups of firms: all the sample firms, the subsample of credit dependent firms and the subsample of potentially innovative firms. We expect the effect of credit constraints to be significant at least for credit dependent and innovative firms, which are expected to perceive credit access problems more strongly and reflect this in the self-reported credit constraint measure. The coefficient of the credit constraints turns out to be statistically significant and of large magnitude in all of the subsamples.

[7] The results of these estimates are available from the authors upon request.

Table 3: Bivariate probit of R&D and credit constraints, BEEPS data 2001-2012, dependent variable propensity to conduct R&D

	Dependent variable: probability of undertaking R&D								
		All firms			Credit dependent firms			Innovative firms	
	Overall	Direct	Indirect	Overall	Direct	Indirect	Overall	Direct	Indirect
Constrained	−0.778***	−0.778***		−0.725***	−0.725***		−0.612***	−0.612***	
	(0.070)	(0.070)		(0.095)	(0.095)		(0.131)	(0.131)	
Log(age)	0.065***	−0.036	0.101	0.055***	−0.069**	0.124**	0.141***	0.020	0.121
	(0.020)	(0.047)	(0.086)	(0.021)	(0.031)	(0.038)	(0.027)	(0.076)	(0.165)
Empl2to49	−0.299***	−0.362***	0.064	−0.303***	−0.313***	0.010	−0.274***	−0.311***	0.037
	(0.041)	(0.038)	(0.045)	(0.039)	(0.056)	(0.068)	(0.043)	(0.040)	(0.045)
Empl50to250	−0.095***	−0.120***	0.025	−0.106***	−0.118***	0.012	−0.095***	−0.114**	0.019
	(0.024)	(0.024)	(0.027)	(0.025)	(0.038)	(0.044)	(0.035)	(0.032)	(0.038)
ExSale	0.081***	0.081***		0.099***	0.099***		0.131***	0.131***	
	(0.024)	(0.024)		(0.027)	(0.027)		(0.036)	(0.036)	
Foreign	0.049*	−0.040	0.089	0.029	−0.034	0.063*	0.043	−0.067	0.109
	(0.026)	(0.039)	(0.072)	(0.030)	(0.035)	(0.032)	(0.040)	(0.055)	(0.125)
UniGrade	0.106***	0.106***		0.111	0.111		0.109***	0.109***	
	(0.026)	(0.026)		(0.033)	(0.033)		(0.040)	(0.040)	
Dsales	0.127***	0.062	0.065	0.111**	0.023	0.089**	0.148***	0.098**	0.050
	(0.021)	(0.034)	(0.053)	(0.021)	(0.025)	(0.030)	(0.026)	(0.042)	(0.069)
Industry Demand (+)	−0.106	−0.106		0.068	0.068		−0.649***	−0.649***	
	(0.135)	(0.135)		(0.680)	(0.680)		(0.213)	(0.213)	
Industry Demand (-)	−0.488	−0.488		−0.857*	−0.857*		−1.344*	−1.344*	
	(0.431)	(0.431)		(0.508)	(0.508)		(0.784)	(0.784)	
Audit	0.040***		0.040***	0.049***		0.049***	0.031		0.031
	(0.012)		(0.012)	(0.013)		(0.013)	(0.021)		(0.021)
Subsidies	0.100***		0.101***	0.115***		0.115***	0.099**		0.099**
	(0.025)		(0.025)	(0.026)		(0.026)	(0.043)		(0.043)
No of obs.	7141			4818			4202		
Log likelihood	−5287.3			−4105.0			−3439.1		
Rho	0.902			0.868			0.767		
Wald test of rho=0	23.548***			17.585***			9.002***		
Predicted R&D	0.179			0.200			0.283		
Actual R&D	0.183			0.209			0.258		

Notes: The table presents marginal effects at averages. The overall effect shows the marginal effect from the reduced form, the direct effect shows the marginal effects originating from the R&D equation and the indirect effect shows the marginal effects originating from the credit constraints equation. Bootstrapped standard errors with 100 replications are presented in parentheses. Country dummies are included in the constraint equation and sector dummies in the R&D equation. ***, **, * show statistical significance at the 1, 5 and 10% level. Industry demand (+) captures positive growth values and industry demand (-) negative growth values.
Source: authors' calculations from BEEPS data.

As demonstrated in Figure 1, most of the sample countries experienced strong boom-bust episodes during the sample years and it is expected that credit constraints had a smaller effect on R&D activity during the boom and recovery years and a stronger effect during the recession year of 2009. Table 4 shows the marginal effect of the credit constraint estimated from separate models for each wave of the survey.

Table 4: Predicted values from bivariate probit of R&D and credit constraints, BEEPS data 2001–2012

	Dependent variable: probability of undertaking R&D All firms	
BEEPs waves:	Marginal effect of credit constraints	Predicted value of R&D propensity
Reference year: 2001	−0.650*** (0.039)	0.350
Reference year: 2004	−0.379 (0.382)	0.049
Reference year: 2007	−0.750*** (0.070)	0.240
Reference year: 2012	−0.883*** (0.036)	0.117
Pooled estimates from Table 3	−0.778 (0.070)	0.180

Note: survey wave 2002 relates to the reference year of 2001, wave 2005 to 2004, wave 2009 to 2007 and wave 2012 or 2013 to 2012. Cluster robust standard errors in parenthesis. ***, **, * show statistical significance at the 1, 5 and 10% level.

Source: authors' calculations from BEEPS data.

Table 4 demonstrates that the effect of credit constraints on R&D activity has been similarly high in all the survey waves and over the business cycle. The data with the reference year of 2004 prove to have the largest confidence intervals for the credit constraint coefficient and this is also the wave with the smallest number of R&D firms. The coefficient is estimated much more precisely for the rest of the waves, but with no evidence that the effect of credit constraints are statistically different before or after the Great Recession. The coefficient from the first wave is statistically significantly different from that of the last two waves, but the increase in the coefficient over the last decade is not in line with the economic environment and the intuition that access to finance has improved in the region. We conclude that despite the strong effect of credit constraints on R&D in CEE, there is no evidence that credit constraints became much worse for R&D during the recession.

Given that we cannot control for firm-specific effects in a cross-sectional setting, the effect of credit constraints on R&D over the business cycle is estimated using cross-sectional variation at the industry-level growth. We move on to test for the role of credit constraints in R&D activity by using panel data from one of our BEEPS sample countries, Estonia. The share of credit constrained firms is rather low at 7.8% in this country compared to the shares in the rest of our sample countries, and it is the second lowest behind Slovenia at 6.9%, and barely half the figure of 14.3% in Poland, which is the country with the highest share of credit constrained firms.

4.2. Dynamic panel estimations from the Estonian data

The estimation results for specification (2) of the Euler equation are presented in Table 5. The Arellano-Bond test of second-order autocorrelation is rejected and the Hansen test of the joint validity of instruments is not rejected in all the system GMM specifications. The number of instruments is kept small due to the small number of firms in the panel; lagged values from period *t*–3 are used as instruments for the equation in differences and differenced values from period *t*–2 for the equation in levels.

The baseline specification is presented first. R&D is not as persistent in the Estonian sample as has been found for high-income countries (Brown et al. (2012)), which suggests that R&D expenditure is more short-lived there. There is also a high sensitivity of R&D to cash flows and cash holdings. R&D expenditure is much more sensitive to cash flows than in findings from Western Europe where it is found to be between 0.1 and 0.2 (Martinsson (2010), Cincera and Ravet (2010), Brown et al. (2012)). The sum of cash flow coefficients from the contemporary value and the lagged value is around 0.467, with a 95% confidence interval between 0.279 and 0.655. The point estimate of the coefficient is up to four times higher than found for Western Europe, confirming our findings from BEEPS data that financing constraints strongly hamper R&D expenditure in CEE countries. Cash holdings also matter for R&D, highlighting the importance of cash holdings for smoothing R&D expenditure, while debt financing is not correlated with R&D expenditure.

The second column of Table 5 shows the results of tests for the role of the business cycle on financing constraints by introducing year and cash flow interaction terms. The sum of cash flow and year and cash flow interaction terms is presented in Figure 2. The cash flow sensitivity of R&D is statistically significantly lower in 2006 than in the crisis and post-crisis period. The years 2005 and 2006 were years of exceptionally high increases in the credit flow into non-financial businesses, with yearly growth rates of around 80% and 60%. However, the cash flow sensitivity increases after 2006, there is no clear peak around the deep crisis year of 2009 when credit flows dropped almost 50%, and the effects are in general barely correlated with the business cycle plotted in Figure 1. The developments in the beginning of the period are also not in line with the business cycle, as the highest cash flow sensitivity of the period comes for example in the EU accession year of 2004, which also saw a strong increase in credit flows.

The third column of Table 5 shows the results of tests for the role of the business cycle on financing constraints using another specification and interacting cash flow with real growth of the aggregate economy. The sum of the GDP growth interaction terms with cash flow and lagged cash flow show that the effect from the business cycle on the cash flow sensitivity coefficient is economically very small. For example real yearly growth of 10% is related to a decline in the cash flow sensitivity coefficient of 0.075. We conclude from the two last columns of Table 5 that despite the very high cash flow sensitivity of R&D in Estonia, there is no clear evidence that R&D cash flow sensitivity is strongly correlated with the business cycle, nor that it increased substantially during the Great Recession. This result is also in line with our findings from the BEEPS data that showed equally high credit constraints for R&D before and after the recession.

Table 5: R&D expenditure cash flow sensitivity, 1998–2012 from Estonian R&D panel

	Dependent variable: R&D expenditure		
	Baseline model equation (2)	Model with CashFlow and year dummies interaction terms	Model with CashFlow and aggregate GDP growth interaction terms
R&D(*t*−1)	0.512***	0.283***	0.513***
	(0.143)	(0.105)	(0.129)
R&D^2(*t*−1)	−0.021	−0.008	−0.021*
	(0.014)	(0.021)	(0.012)
ΔSales	−0.040	−0.148**	−0.047
	(0.047)	(0.061)	(0.049)
Sales(*t*−1)	−0.064	−0.095**	−0.053
	(0.045)	(0.041)	(0.044)
CashFlow	0.679***	0.805***	0.693***
	(0.065)	(0.058)	(0.078)
CashFlow(*t*−1)	−0.212**		−0.214**
	(0.103)		(0.091)
NewDebt	0.249	0.757***	0.207
	(0.306)	(0.210)	(0.334)
NewDebt(*t*−1)	−0.554	−0.697	−0.708
	(0.415)	(0.566)	(0.507)
ΔCashHoldings	−0.182	−0.069	−0.173
	(0.118)	(0.107)	(0.116)
ΔCashHoldings(*t*−1)	−0.151**	−0.068	−0.140**
	(0.070)	(0.049)	(0.059)
Additional controls	year dummies	year dummies + year dummies*CashFlow	year dummies + aggregate GDP growth*CashFlow

	Dependent variable: R&D expenditure		
	Baseline model equation (2)	Model with CashFlow and year dummies interaction terms	Model with CashFlow and aggregate GDP growth interaction terms
CashFlow + CashFlow(t−1)	0.467***		0.479***
	(0.096)		(0.098)
NewDebt + NewDebt(t−1)	−0.305	0.060	−0.501
	(0.598)	(0.563)	(0.725)
ΔCashHoldings +	−0.333**	−0.137	−0.314**
ΔCashHoldings(t−1)	(0.134)	(0.120)	(0.126)
GDPgrowth×CashFlow +			−0.750**
(GDPgrowth)×(CashFlow(t−1))			(0.300)
No of obs.	985	994	985
No of groups	273	276	273
Average obs. per group	3.608	3.601	3.608
AR(1) test	−3.022	−2.603	−2.953
AR(2) test	0.398	0.394	0.458
Hansen test (p)	0.274	0.389	0.309
No of instruments	86	97	86

Notes: All the monetary variables are scaled by total assets from the beginning of the year. System GMM estimation with lagged values from t–3 for the equation in differences and from t–2 for the equation in levels. Lagged R&D terms, CashFlow and year times CashFlow variables are treated as endogenous. Robust Windmeijer finite sample corrected standard errors in parenthesis. ***, **, * show statistical significance at the 1, 5 and 10% level.

Source: authors' calculations from Estonian R&D panel data.

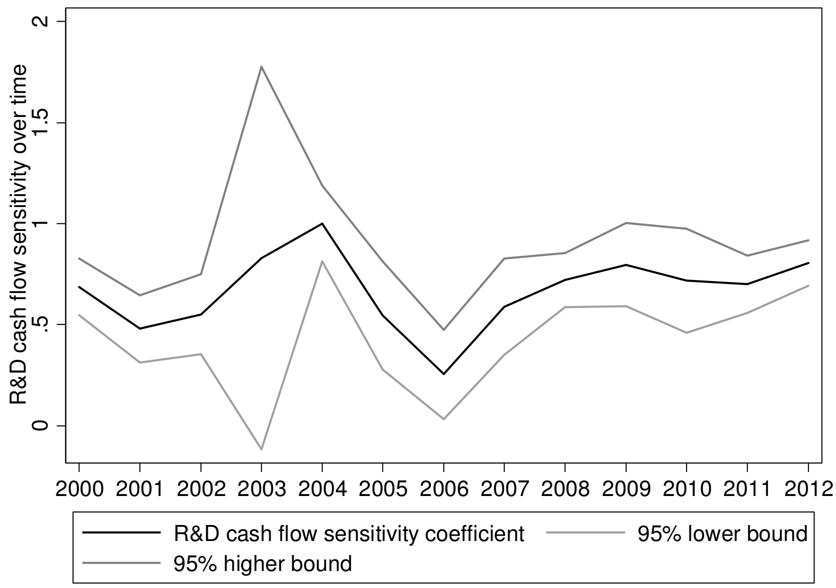


Figure 2: The R&D cash flow sensitivity over the business cycle, 2000–2012 from Estonian R&D panel

Notes: The solid black line shows the year and cash flow interaction terms coefficients from the second column of Table 5; the grey line shows the 95% confidence interval of the coefficients.

Source: authors' calculations from Estonian R&D panel data.

Lastly, we study whether R&D has been pro or countercyclical. Firm-level studies test the cyclicality of R&D by regressing R&D with sales growth and running these regressions for the group of credit constrained and unconstrained firms (Aghion et al. (2012), Beneito et al. (2014)). We will not employ this approach as there is no direct measure of credit constraints in our data and the correlation between sales growth and R&D can also be related to other factors such as good investment opportunities. We construct a financing constraint proxy as a firm-level correlation between R&D and cash flows, and check whether firms with low cash flow sensitivity have stronger countercyclicality of R&D, as is suggested by the model of Aghion et al. (2010). The firms with R&D cash flow sensitivity below the median have a correlation between R&D and aggregate real GDP growth of –0.078 (p=0.034), while firms with R&D cash flow sensitivity above the median have the correlation between R&D and aggregate real GDP growth of –0.026 (p=0.483). The correlation for firms with low cash flow sensitivity is weak, but the results point in the same direction as those from the BEEPS data, indicating that R&D is countercyclical.

A number of robustness checks have been run. First, all the firms that had received some public funding were excluded. There is evidence that some countries increased public funding for business R&D substantially in the recession and that this had a countercyclical effect on growth during the recession (Brautzsch et al. (2015)). Czarnitzki (2006) shows firms being much more dependent on public funding in their R&D investments in transitional Eastern Germany than in Western Germany. We could expect the R&D to be much more cash flow sensitive in firms that depend heavily on financing from state funds as extra income in cash flows shows up immediately in R&D expenditure. This robustness test aims to validate our result that CEE firms' R&D is highly cash flow sensitive whatever the source of financing.

The R&D firms dependent on public funding are defined as firms that get all or some part of their R&D financing directly from a ministry or local municipality, or indirectly from state financed institutions like local development agency or universities. All the public sector funding from abroad, such as EU or other public sector research grants, is also taken as public funding. Around 40% of firms have received some public funding for their R&D and conditional on them getting the funding, the median share of public sources in R&D financing is around 50%. Excluding firms that have received public funds for R&D financing leaves us with firms relying on market based financing or internal financing only. This group of firms relies heavily on internal financing, with more than 80% of these firms financing 100% of their R&D from their own resources, which is in line with the earlier discussion in this paper that financing R&D from external sources is very costly and that private external financing resources for R&D are poorly available in transition countries.

Table 6 column one presents the results of the first robustness test. Surprisingly the Euler equation estimates for the publicly funded firms look very similar to that for all the firms presented in the first column of Table 5. The R&D expenditure is slightly more persistent among R&D firms that use financing from the private sector only, and their R&D is somewhat more strongly smoothed by changes in cash stocks, but the difference from all the firms is not statistically significant nor economically large. The cash flow sensitivity of publicly and privately financed R&D investment is very similar and there is no evidence that the result of high cash flow sensitivity is driven by active state financing.

The second robustness test estimates the Euler equation for older firms only, and the third for larger firms only. The old and the large are defined as firms older than the median age and with more than the median number of employees. Hadlock and Pierce (2010) claim that firm age and size themselves are good predictors of whether a firm is credit constrained and it is expected that the cash flow sensitivity of R&D is lower for older and larger firms. As expected, the cash flow sensitivity of old firms is lower than in the whole sample, supporting the validity of our financing constraints measure. However, this difference is not present for large firms that have even higher cash flow sensitivity than the whole sample. Given that our sample of large firms also covers small and medium-sized companies, it is not surprising that there are no vast differences between firms that are below and above medium size. Firm age seems to be a better predictor of financing constraints among CEE firms, which is also in line with our results from the BEEPS data.

In line with García-Quevedo et al. (2014) we find the R&D of mature firms to be more persistent than that of young firms. As expected, young firms use cash stocks less intensively to smooth their R&D expenditure, but, surprisingly, large firms do it even more intensively than the whole sample of firms. As none of the differences between subgroups of mature vs. young and large vs. small are statistically significant[8], we find no strong inference that the R&D financing of mature or large firms is different.

[8] These results are available from the authors upon request.

Table 6: R&D expenditure cash flow sensitivity among firms financing R&D privately, among mature and among large firms, 1998–2012 from Estonian R&D panel

	Dependent variable: R&D expenditure		
	Firms that finance R&D from private sources only	Mature firms (age > 12 years)	Large firms (employment > 23)
R&D(*t*−1)	0.562***	0.653***	0.434***
	(0.145)	(0.114)	(0.148)
$R\&D^2(t-1)$	−0.016	−0.016	0.004
	(0.010)	(0.015)	(0.008)
ΔSales	−0.059**	0.018	−0.061
	(0.030)	(0.029)	(0.044)
Sales(*t*−1)	−0.051	−0.061	−0.054*
	(0.034)	(0.041)	(0.028)
CashFlow	0.720***	0.541***	0.940***
	(0.069)	(0.095)	(0.028)
CashFlow(*t*−1)	−0.288***	−0.272***	−0.402***
	(0.095)	(0.102)	(0.138)
NewDebt	0.423*	0.397	0.397**
	(0.230)	(0.352)	(0.195)
NewDebt(*t*−1)	−0.196	0.449	−0.224
	(0.250)	(0.419)	(0.189)
ΔCashHoldings	−0.317***	−0.213**	−0.511***
	(0.114)	(0.093)	(0.134)
ΔCashHoldings(*t*−1)	−0.114	−0.026	−0.127
	(0.081)	(0.042)	(0.095)
CashFlow + CashFlow(*t*−1)	0.432***	0.269**	0.538***
	(0.128)	(0.107)	(0.144)
NewDebt + NewDebt(*t*−1)	−0.228	0.846	0.174
	(0.408)	(0.533)	(0.188)
ΔCashHoldings + ΔCashHoldings(*t*−1)	−0.431**	−0.239*	−0.638**
	(0.170)	(0.123)	(0.189)
Additional controls	year dummies	year dummies	year dummies
No of obs.	678	472	598
No of groups	221	131	159
Average obs. per group	3.068	3.603	3.761
AR(1) test	−3.017	−2.217	−2.835
AR(2) test	−0.362	−1.244	0.416
Hansen test (p)	0.491	0.219	0.358
No of instruments	86	72	86

Notes: All the monetary variables are scaled by total assets from the beginning of the year. System GMM estimation with lagged values from *t*−3 for the equation in differences and from *t*−2 for the equation in levels. Lagged R&D terms and CashFlow variables are treated as endogenous. Robust Windmeijer finite sample corrected standard errors in parenthesis. ***, **, * show statistical significance at the 1, 5 and 10% level of significance.

Source: authors' calculations from Estonian R&D panel data.

5. Summary

This paper studied the effect of financing constraints on R&D activity in Central and Eastern Europe over the boom bust cycle. There is evidence of a strong impeding effect from financing constraints on R&D in both of our complementary datasets. The analysis on the BEEPS dataset from ten new EU member states suggest that credit constraints are related to a probability that is around 70% lower of a firm being engaged in R&D. The importance of financing constraints for R&D investments is also confirmed by the R&D panel data from Estonia. The cash flow sensitivity of R&D expenditure is up to four times larger in Estonia than the reported empirical evidence from the high-income countries. The relevance of financing constraints for R&D expenditure is somewhat weaker for mature firms, but the cash flow sensitivity among mature firms is still high according to the standards of high-income countries.

There is no evidence that the effect of financing constraints on R&D is variable over the business cycle. Despite the deep recession and the credit crunch in 2009 in most of the sample countries, there is no evidence that the effect of financing constraints on R&D increased in the recession. Given the high cash flow sensitivity of R&D in our panel, the cash flow sensitivity did not increase any further during the recession. In addition, the estimates from the BEEPS data suggest that, conditional on credit constraints, R&D is countercyclical and higher in a recession.

The first policy conclusion from this paper is that firms in Central and Eastern Europe perceive strong credit constraints and accumulate internal funding for their R&D. Extending public funding for R&D may be one option for remedying the problem of under-investment, but a better institutional set-up may be a relevant policy target for attracting external investors and private capital to improve and diversify the sources of funding for R&D.

The second set of policy implications stems from the finding that R&D firms did not perceive that the financial crisis brought about increased credit constraints or an increased cash flow sensitivity of R&D expenditure. There are two potential explanations for this finding. The first is that R&D projects in CEE firms are small in size, short-term and of an incremental nature, which implies that the lower sunk costs mean the loss from a temporary or permanent interruption of an R&D project is low. This explanation is supported by our finding that firm R&D expenditure is less persistent in CEE than in high-income countries and that the size of R&D expenditure in CEE firms is just about half the size of that in high-income economies. The second possible explanation is that R&D projects are less dependent on external financing conditions because of the lower reliance of CEE firms on external credit. We find internal funds from cash flow and cash stock to be major sources of R&D financing sources, which suggests that firms accumulate resources to smooth R&D expenditure and insure their projects against downturns.

Our finding that the adverse effect of financing constraints on R&D has not increased substantially in recession, suggests that stable R&D funding from public sources is needed by firms throughout the business cycle, and concentrating public R&D funding into times of recession is not necessarily desirable from a financing point of view, though it may have other aims such as counteracting a decline in GDP.

References

AGHION, P., G.-M. ANGELETOS, A. BANERJEE, AND K. MANOVA (2010): Volatility and growth: credit constraints and the composition of investment. *Journal of Monetary Economics*, 57(3), pp. 246–265.

AGHION, P., P. ASKENAZY, N. BERMAN, G. CETTE, AND L. EYMARD (2012): Credit Constraints and the Cyclicality of R&D Investment: Evidence from France. *Journal of the European Economic Association*, 10(5), pp. 1001–1024.

AGHION, P., AND P. HOWITT (2006): Joseph Schumpeter Lecture: Appropriate Growth Policy: A Unifying Framework. *Journal of the European Economic Association*, 4(2–3), pp. 269–314.

AGHION, P., AND P. HOWITT (1998): *Endogenous Growth Theory*. MIT.

ARELLANO, M., AND O. BOVER (1995): Another look at the instrumental-variable estimation of error-components models. *Journal of Econometrics*, 68, pp. 29–52.

ARISTOVNIK, A. (2014): Efficiency of the R&D Sector in the EU-27 at the Regional Level: An Application of DEA. *Lex Localis*, 12(3), pp. 519–531.

BAKKER, G. (2013): Money for nothing: How firms have financed R&D-projects since the Industrial Revolution. *Research Policy*, 42, pp. 1793–1814.

BARLEVY, G. (2007): On the Cyclicality of Research and Development. *American Economic Review*, 97(4), pp. 1131–1164.

BENEITO, P., M.E. ROCHINA-BARRACHINA, AND A. SANCHIS-LLOPIS (2014): Ownership and the cyclicality of firms' R&D investment. *International Entrepreneurship and Management Journal* [DOI 10.1007/s11365-014-0320-9]

BOND, S., D. HARHOFF, AND J. VAN REENEN (2005): Investment, R&D and Financial Constraints in Britain and Germany. *Annales d'Économie et de Statistique*, 79/80, pp. 433–460.

BRAUTZSCH, H.-U., J. GÜNTHER, B. LOOSE, U. LUDWIG, AND N. NULSCH (2015): Can R&D subsidies counteract the economic crisis? – Macroeconomic effects in Germany. *Research Policy*, 44, pp. 623–633.

BROWN, J. R., S.M. FAZZARI, AND B.C. PETERSEN (2009): Financing Innovation and Growth: Cash Flow, External Equity, and the 1990s R&D Boom. *Journal of Finance*, 64(1), pp. 151–185.

BROWN, J. R., G. MARTINSSON, AND B.C. PETERSEN (2012): Do financing constraints matter for R&D? *European Economic Review*, 56, pp. 1512–1529.

BROWN, J. R., AND B.C. PETERSEN (2009): Why has the investment-cash flow sensitivity declined so sharply? Rising R&D and equity market developments. *Journal of Banking & Finance*, 33, pp. 971–984.

BROWN, J. R., AND B.C. PETERSEN (2011): Cash holdings and R&D smoothing. *Journal of Corporate Finance*, 17, pp. 694–709.

BROWN, M., S. ONGENA, A. POPOV, AND P. YESIN (2011): Who Needs Credit and Who Gets Credit in Eastern Europe? *Economic Policy*, 26(65), pp. 93–130.

CAMERON, A. C., AND P.K. TRIVEDI (2010): Microeconometrics Using Stata, *Stata Press*, 706p.

GARCÍA-QUEVEDO, J., G. PELLEGRINO, AND M. VIVARELLI (2014): R&D drivers and age: Are young firms different? *Research Policy*, 43, pp. 1544–1556.

CINCERA, M., AND J. RAVET (2010): Financing constraints and R&D investments of large corporations in Europe and the US. *Science and Public Policy*, 37(6), pp. 455–466.

CZARNITZKI, D. (2006): Research and development in small and medium-sized enterprises: The role of financial constraints and public funding. *Scottish Journal of Political Economy*, 53(3), pp. 335–357.

EFTHYVOULOU, G., AND P. VAHTER (2014): Financial Constraints, Innovation Performance and Sectoral Disaggregation. *The Manchester School* [forthcoming] DOI: 10.1111/manc.12089

EUROPEAN COMMISSION (2014): Innovation Union Scoreboard 2014 [http://ec.europa.eu/enterprise/policies/innovation/files/ius/ius-2014_en.pdf]

HADLOCK, C. J., AND J.R. PIERCE (2010): New Evidence on Measuring Financial Constraints: Moving Beyond the KZ Index. *The Review of Financial Studies*, 23(5), pp. 1909–1940.

HALL, B. H. (2002) The financing of research and development. *Oxford Review of Economic Policy*, 18(1), pp. 35–51.

HALL, B. H., AND J. LERNER (2010): The Financing of R&D and Innovation. In Hall, B.H., and N. Rosenberg (2010): *Handbook of the Economics of Innovation*, Vol. 1, pp. 609–639. Amsterdam: Elsevier.

HALL, B. H., AND A. MAFFIOLI (2008): Evaluating the impact of technology development funds in emerging economies: evidence from

Latin America. *The European Journal of Development Research*, 20(2), pp. 172–198.

HÖLZL, W., AND J JANGER (2014): Distance to the frontier and the perception of innovation barriers across European countries. *Research Policy*, 43, pp. 707–725.

LEE, N., H. SAMEEN, AND M. COWLING (2015): Access to finance for innovative SMEs since the financial crisis. *Research Policy*, 44, pp. 370–380.

MARTINSSON, G. (2010): Equity financing and innovation: Is Europe different from the United States? *Journal of Banking and Finance*, 34, pp. 1215–1224.

MASSO, J., J. Meriküll, AND P. Vahter (2013): Shift from gross profit taxation to distributed profit taxation: are there effects on firms? *Journal of Comparative Economics*, 41(4), pp. 1092–1105.

MÄNNASOO, K., AND J. MERIKÜLL (2014): R&D, Credit Constraints, and Demand Fluctuations: Comparative Micro Evidence from Ten New EU Members. *Eastern European Economics*, 52(2), pp. 49–64.

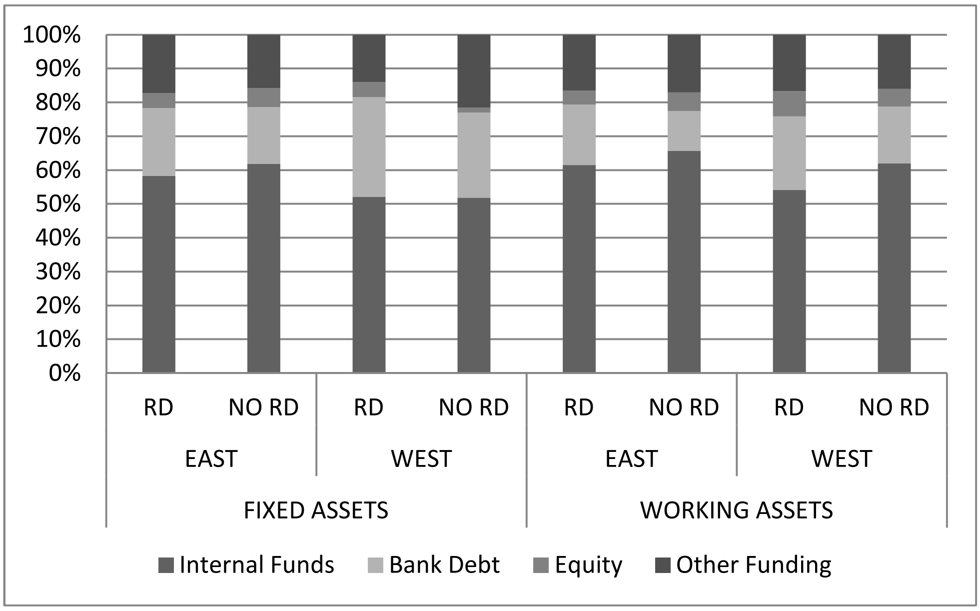
OUYANG, M. (2011): On the Cyclicality of R&D. *The Review of Economics and Statistics*, 93(2), pp. 542–553.

RAFFERTY, M., C. (2003): Do Business Cycles Influence Long-Run Growth? The Effect of Aggregate Demand on Firm-Financed R&D Expenditures. *Eastern Economic Journal*, 29(4), 607–617.

SAVIGNAC, F. (2008): Impact of Financial Constraints on Innovation: What Can Be Learned from a Direct Measure? *Economics of Innovation and New Technology*, 17(6), pp. 553–569.

STAEHR, K. (2013): Austerity in the Baltic States during the Global Financial Crisis. *Intereconomics*, 48(5), pp. 293–302.

Appendix 1



Appendix 1: Firm financing structure of fixed and working assets in European countries, BEEPS data 2004

Note: Central and Eastern Europe: Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia; sample size is 464 R&D firms and 3666 non-R&D firms. Western and Southern Europe: Germany, Portugal, Greece, Spain and Ireland; sample size is 409 R&D firms and 2557 non-R&D firms.

Source: authors' calculations from BEEPS data.

Working Papers of Eesti Pank 2015

No 1
Lenno Uusküla. Firm Turnover and Inflation Dynamics

No 2
Andres Kuusk, Karsten Staehr, Uku Varblane. Sectoral Change and Labour Productivity Growth during Boom, Bust and Recovery in Central and Eastern Europe