R&D in Boom and Bust: Evidence from the World Bank Financial Crisis Survey

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Abstract

The full implications of the global financial crisis of 2008–2009 are yet to be revealed. The crucial question is whether a crisis of such severe magnitude will set "cleansing mechanisms" into motion as suggested by the opportunity cost argument of R&D, or rather destroy the long-term productivity enhancing incentives? The World Bank Financial Crisis Survey collects direct self-reported measures of firms' credit frictions and R&D during 2009–2010 from six countries: Bulgaria, Latvia, Lithuania, Hungary, Romania and Turkey. Employing this dataset, we seek evidence of how the firms' R&D responded to the demand and credit contraction at the time of the crisis. Looking at two distinct episodes, the sustained economic growth in 2001–2007 and the sudden slump in 2009–2010, we observe a paradigm shift in firms' R&D decisions: whilst the R&D is counter-cyclical during the pre-crisis period, a pro-cyclical pattern emerges in response to the crisis.

JEL Code: G31, E32, O30, O52

Keywords: R&D cyclicality, demand shocks, credit constraints, financial crisis

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Non-technical summary

The emerging markets in Central, South-East and East-European countries have been severely affected by the recent global financial crisis of 2008–2009. Productivity augmented growth has become a central issue for economic policy.

The theory of economic growth predicts that R&D is an engine of economic growth. The social benefits generated by R&D substantially exceed the private returns. The asymmetric information problem and uncertain and lagged returns make R&D investments particularly dependent on sustained funding. Moreover, this becomes vital at a time of demand and credit contraction.

Understanding the cyclicality in R&D provides a crucial link between short-run fluctuations and long-run growth. This means that even temporary fluctuations have further implications for a country's long-term growth outlook through the incentives they make for potential innovators and R&D creators. The opportunity cost approach in the literature on growth and volatility suggests that in periods when an economy peaks it is more profitable to invest in short-run production than in long-term investments as R&D. An adverse productivity shock, in contrast, motivates entrepreneurs to invest in long-term R&D as the opportunity cost in terms of forgone current production is low. In this way a countervailing cyclical effect appears between R&D and short-term investments. This exposition is, however, a subject of theoretical and empirical debate, with mixed evidence revealed from country, industry or firm-level analyses.

The aim of the current paper is to look at the association between the R&D of a firm and fluctuating demand conditional on the presence of credit constraints. We focus on two distinct episodes — the years of economic upturn in 2001–2007 and the sudden slump in 2009–2010. The strong increase in firm sales, in sector value added and in number of employees over 2001–2007 reversed into deep decline during the crisis. Against this background we seek to find evidence on R&D patterns in an environment of negative demand shock and squeezed liquidity in contrast to the buoyant pre-crisis period.

The analysis is based on the World Bank Financial Crisis Survey (FCS) 2010 and the World Bank/EBRD Business Environment and Enterprise Performance survey (BEEPs) 2002–2008/2009. Both surveys collect direct self-reported measures of firms' credit frictions and R&D. The sample covers six countries from Central, South- and East-Europe (CSEE): Bulgaria, Latvia, Lithuania, Hungary, Romania and Turkey. Eurostat industry-level statistics have been used to compile two demand proxy variables — sector-level annual growth in real value added and in the number of employees.

The main variables of interest are the R&D and credit constraints of firms, and these are defined as follows. We employ binary variables which give the propensity of a firm to increase R&D spending in the Financial Crisis Survey of 2010 and the likelihood of the firm conducting R&D from the BEEPs in 2001–2007. The credit constraint variable is defined in a similar manner for both the observation periods, being conditioned on two terms, first the firm's dependence on external finance and secondly its access to finance. All firms that are dependent on external funding but are rejected by lenders or discouraged from borrowing are defined as credit constrained. The rest of the firms, whose need for external credit is met or who do not need external funding, are defined as unconstrained.

The simultaneous estimation procedure — a recursive probit model — has been used to account for the co-determined relationship between R&D and credit constraints.

Our results show the regime shift in the R&D strategy of firms over two markedly different periods. Whilst R&D was counter-cyclical to demand during the pre-crisis period of 2001–2007, a pro-cyclical, survival-focused, pattern emerged in aftermath of the crisis. Encountering an abnormal fall in demand, companies refrained from R&D despite the extremely low opportunity cost. Interestingly the credit constraints effect upon R&D remained absent throughout the observation period. This might seem counterintuitive, but in the context of underdeveloped credit markets the firms' reliance on external funding is low. Moreover the extreme demand drop during the crisis has dried-up the firms need for external finances.

The overall implication is that abnormal demand shocks are detrimental to R&D and may have long-term adverse effects upon an economy's outlook for sustained growth. For this reason an adequate level of R&D targeted support at the bottom of the cycle would ease the shift to the higher production frontier and prepare firms for the new rise.

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1. Introduction

Modern theories on endogenous growth, and the Schumpeterian growth theory in particular, stress the importance of innovation, R&D and knowledge creation for economic restructuring and eventually for sustained long-term growth [1]. The so-called cleansing mechanism or the "virtue of bad times" in the Schumpeterian view of business cycles suggests that recessions help to correct for inefficiencies whilst forcing firms to focus on a productivity-enhancing agenda. An opportunity cost effect steps in here, as long-term innovative activities gain priority over short-term capital investments in a time of recession. The counter-cyclical nature of innovation is an appealing property. Evening out some of the cyclical volatility enables firms to navigate towards a more balanced development path. However, the counter-cyclicality argument of investments that enhance long-term productivity will be valid only as long as firms' access to credit is not limited. This is hardly the case whenever the firm is hit by an adverse (idiosyncratic or aggregate) shock. A negative shock has an effect on the current earnings of firms, reducing the availability of internal funds and undermining the general capacity of firms to borrow or raise external funds. This means that the extent to which credit constraints bind depends on whether the firm faces an upturn or downturn in the market.

The aim of the current paper is to explore how the R&D strategy of firms responds to severe economic distress. For this purpose we look at two drastically different regimes, one covering the years 2001–2007 in expanding markets and the other covering the period of crisis and severe contraction in 2009–2010. We look at six countries covered by the World Bank Financial Crisis Survey in our study: Bulgaria, Hungary, Latvia, Lithuania, Romania and Turkey. All these countries have transitional or catching-up economies that witnessed fast growth in 2001–2007 and an abrupt fall after the global financial crisis in 2009–2010.

The paper is organised as follows. Sections 2 and 3 provide a literature survey discussing the cyclicality of R&D and the credit constraint issues; in Section 4 we present the data, methodology and results of the estimations; Section 5 concludes.

[1] See Aghion and Howitt (1992) for theoretical model and Sylwester (2001) for empirical survey.

2. The cyclicality of R&D

The avenue of research investigating the impact of volatility on growth has moved to the forefront in the research agenda[2]. The influential model proposed by Aghion, Angeletos, Banerjee, Manova — AABM (see Aghion et al., 2005, 2010) starts by making a distinction between short-term capital investments and long-term productivity enhancing investments such as R&D. The argument is made that in the absence of credit constraints, investments that enhance long-term growth behave in a counter-cyclical manner. The implication is straightforward and pertains to the opportunity cost effect. Put simply, as lower demand makes the return on short-term investments lower in recessions, the opportunity cost of long-term productivity-enhancing investments also becomes lower. This implies that it is more profitable to invest in short-term production with high-level productivity at the peak times of positive demand than it is in long-term R&D, which involves an uncertainty component and a delay in returns. An adverse productivity shock on the other hand motivates entrepreneurs to invest in long-term R&D as the opportunity cost in terms of forgone current production is low. The theory is also appealing in terms of social welfare, as reallocating a proportion of R&D from booms to recessions would allow the economy to grow at a lower resource cost (Barlevy, 2007).

Aghion et al.(2010) claim, however, that under sufficiently tight credit constraints the long-term investments become pro-cyclical leading to both "lower mean growth and amplified volatility". Their model identifies a propagating impact that credit constraints have on the cyclical composition of investment. In particular, there is a wedge which reflects the probability of failure determined by allocation of investments between the short and long terms. This wedge is counter-cyclical, decreasing in booms and increasing in recessions. The implication is that a negative shock will leave firms short of internal resources and will limit access to external funds. As a result the probability of failure increases and the shift from long-term to short-term investments simply improves the firm's liquidity stance.

Barlevy (2007) proposes a theory that R&D expenditures behave in a pro-cyclical manner contrary to the opportunity cost argument. According to his model, R&D will be more biased toward a boom the bigger the ratio of profits in booms to profits in recessions is. For this to be true requires profits to be more pro-cyclical than the cost of R&D. He also shows that industries with more pro-cyclical profits proxied by stock values tend to have more pro-cyclical R&D growth. A number of references to earlier empirical literature are given in Barlevy (2007), which confirm the pro-cyclical behaviour of R&D.

[2] See, for example, the discussion by Francois and Lloyd-Ellis (2009).

The empirical evidence has not given consistent support to either the pro- or the counter-cyclicality argument. Studying long-term relationships in U.S. aggregate data Rafferty (2003) demonstrates pro-cyclical and asymmetric patterns for firm-financed R&D. He claims that increased after-tax cash flows raise R&D expenditures and that more R&D has been lost during recessions than has been gained during expansions, with a negative net effect of business cycles on aggregate R&D. The evidence of an annual panel of 20 U.S. manufacturing industries over 1958–1998 (Ouyang, 2011) indicates a more mixed result with pro-cyclical R&D responding asymmetrically and inversely to demand shock. In the follow-up paper by Ouyang (2010) she constructs a model which suggests that R&D appears counter-cyclical with low credit constraints, but pro-cyclical with sufficiently high credit constraints, as "mixed cyclicality is displayed for moderate degree of credit constraints". Her theory also claims that the Schumpeterian virtue of bad times holds only if the marginal opportunity cost of R&D dominates over the marginal expected return.

Using an annual panel of 21 OECD countries over the period of 1960–2000, the analysis by Aghion et al. (2010) shows that long-term growth-enhancing investments respond less to exogenous shocks in countries with more developed financial sectors. Aghion et al. (2008) have also given firm-level evidence to their model using a panel dataset covering 13,000 French firms over the period 1980–2000. They use a proxy variable called "payment incident" from a record of payment failures in a blacklist, which affects firms' access to new credit, in order to measure credit constraints. Aghion et al. (2008) show a stronger positive correlation between sales and R&D spending in more credit constrained firms. Also the credit-constrained firms suffer more from demand volatility, which has an asymmetric effect on R&D investments, as these become more harmed in slumps than they are encouraged in booms. Along similar lines Bovha-Padilla et al. (2009) conduct a panel study on Slovenian firms for the period 1996–2002 and observe the pro-cyclicality of R&D investment in credit constrained firms, with the effect disappearing in less financially dependent firms which have access to parent company funding or government subsidies. A recent contribution by Voigt and Moncada-Paterno-Castello (2009) suggests that corporate R&D in the EU has remained resilient to the economic and financial crisis in 2008–2009. However, their estimates are based on rather descriptive and unconditioned estimations.

3. Credit frictions

Theoretical literature on growth, business cycles and the investment behaviour of firms concerns imperfect capital markets increasingly more. The asymmetric information problem and uncertain and lagged returns make R&D

investments particularly sensitive to credit constraints. [3]

The impact of credit constraints on a firm's performance is predominantly negative. Recent evidence by Campello et al. (2010) on the global financial crisis of 2008–2009 shows that constrained firms in the USA, Europe, and Asia witnessed deeper cuts in employment, technology and capital spending. Their study also interestingly highlights that constrained firms drew more heavily on lines of credit in order to frontload funds in fear of restricted access to credit in the future. Aghion et al. (2008), Mancusi and Vezzulli (2010), Ouyang (2010, 2011) and Savignac (2008) have found strong support for the evidence that financial constraints have an adverse effect upon R&D and innovation respectively. The study of the relationship between productivity and financial constraints in Estonia by Badia and Slootmaekers (2008) concluded that financial constraints had a large negative impact on productivity in the R&D sector.

The reverse relationship of the impact of R&D intensity on liquidity constraints is tested by Piga and Atzeni (2007). Their empirical findings from a survey of Italian manufacturing firms show that credit constraints depend on the R&D intensity of the firm and that an inverse U-shaped relationship is observed between R&D activity and the probability of the firm being credit constrained. They also note that firms with no R&D are less likely to apply for new credit.

The measures of credit constraints vary across the studies. The unavailability of explicit information imposes the restriction that indirect measures of financial constraints such as firm size, age, dividends distribution, credit rating or accounting variables prevail in the literature. One typical approach to financial constraints is the measurement of the sensitivity of investments to internally generated cash flows using the Q-theory and Euler-equation models. A recent survey on issues of measurement of financial constraints is provided by Hadlock and Pierce (2010), who also propose their own novel approach. Hadlock and Pierce (2010) find that the age and size of firms alone perform as good predictors of the level of financial constraint.

On the empirical front Ouyang (2010, 2011) employs two proxies capturing financial constraints faced by US manufacturing industries, which are the firm's liquid assets and its net worth. In her interpretation the first variable reflects the firm's need for external funds, while the net worth acts as the collateral for a loan. As mentioned above, Aghion et al. (2008) use a payment incident or blacklist record as a proxy variable for picking up credit constraints

[3]The adverse selection between investors financing R&D and entrepreneurs undertaking R&D has been investigated by Plehn-Dujowich (2009) showing that an increase in the mean skill level enhances growth via greater R&D productivity and investment.

at the firm level.

Kaplan and Zingales (1997) question the measurement of financial constraints through investment-cash-flow sensitivities, extracting access to credit information from the public statements of firms instead. Empirical evidence on the use of direct financial or credit constraint measures is scarce due to the limited amount of data. Campello et al. (2010) argue in favour of a direct survey-based measure of financial constraint, demonstrating that traditional constraint measures fail to identify meaningful patterns in their sample survey data. In the same vein, the analysis by Ayyagari et al. (2008) draws on the World Bank Business Environment Survey, similar in nature to the Business Environment and Enterprise Performance Survey, where they capture firm managers' direct responses to perceived financial obstacles. Savignac (2008) also employs the direct, qualitative indicator for financial constraints derived from the survey conducted by the French Ministry of Industry in order to obtain information about the financing conditions for innovative projects among manufacturing firms in France. His arguments in favour of a direct measure for financial constraints are that it avoids the interpretation problems of indirect indicators, such as cash-flows, and that it provides specific and new information about the financial problems encountered by firms, while accounting variables or the credit rating index reflect the global financial situation of the firm (Savignac, 2008). Mancusi and Vezzulli (2010) find a strong association between the direct measure of financial constraints (based on firm's perception) and indirect measures proposed in the literature[4].

4. Empirical analysis and results

4.1. Methodology

The econometric analysis of this paper employs the recursive bivariate probit model. According to Monfardini and Radice (2008) the bivariate probit model with endogenous dummy is the appropriate inference tool "whenever there are good "a priori" reasons to consider a dependent binary variable to be simultaneously determined with a dichotomous regressor".

Savignac (2008) has employed a recursive bivariate probit to estimate the propensity of French firms to innovate when they are subject to endogenous financial constraints. Mancusi and Vezzulli (2010) pursue the same estimation procedure with respect to R&D and financial constraints on a large number of Italian manufacturing firms. Masso and Vahter (2008), and Masso et al.

[4]Kaplan and Zingales (1997) and Whited and Wu (2000) liquidity constraints indexes.

(2010), employ a bivariate probit model to estimate the knowledge production function for the product and process innovation of Estonian firms used in later modelling stages to investigate the linkages between productivity and innovation and the FDI impact on innovation. The credit rationing patterns of R&D intensive firms have been studied with a bivariate probit model by Piga and Atzeni (2007).

In our model the endogenous financial constraint is regressed with the following variables: (1) log of the firm's age in years since it started operations in a particular country; (2) the firm's size measured by number of employees; (3) a dummy variable reflecting publicly listed firms; (4) the share of foreign ownership; (5) annual growth in firm real sales; (6) private bank funding in the firm's total fixed investments funding, (7) a dummy variable for the presence of 90-day overdue loans; (8) the share of sales sold on credit; (9) an indicator for whether the firm is audited; and finally (10) the dummy variable for the existence of state subsidies.[5]

The argument in favour of a recursive model is that financial constraints can be considered endogenous to R&D. Not only do the financial constraints have an impact on the likelihood of the firm conducting R&D, but also the qualities which distinguish R&D firms, such as skill and technology intensity or competitiveness, make them more attractive for creditors. It follows from this that estimating separately the likelihood of a firm conducting R&D and the likelihood of it being financially constrained would lead to inconsistent results. A two-step procedure where predicted values from the financial constraint equation (a selection equation) are fed into the R&D equation (the outcome equation) is potentially inefficient insofar as it does not account for the possible correlation between the disturbance terms in the two equations (Greene, 1998). Binary models in general are demanding in terms of sample sizes, more so in bivariate binary outcome models.[6]

Considering a recursive system with binary endogenous variables we get:

$$\begin{cases} y_1 = \beta_1 x_1 + \epsilon_1 \\ y_2 = \beta_2 x_2 + \gamma_2 y_1 + \epsilon_2 \end{cases}$$

where y_1 represents the unobserved severity of financial constraints in a reduced form equation and y_2 stands for the likelihood of the firm conducting R&D in the structural form equation. x_1 and x_2 denote the exogenous variables explaining respectively the presence of financial constraints and the R&D de-

[5] In comparison Savignac (2008) estimates the firm's financial constraints using the following five measures: (1) the share of the banking debt, (2) the share of the firm's own financing in its total financing resources, (3) a logarithm of tangible assets as a proxy for the collateral, (4) the firm's gross operating profit margin ratio, and finally (5) the firm's size.

[6] Monfardini and Radice (2008).

cision. The errors ϵ_1 and ϵ_2 are jointly normally distributed with zero mean, unit variance and correlation of ρ where $|\rho| > 0$[7]. The correlation between error terms can be interpreted as the correlation between the unobservable explanatory variables of the two equations.

A widespread opinion in the literature is that the parameters of the second equation in structural form are not identified unless the reduced form equation contains at least one variable that is not one of the regressors in the structural form equation. This assertion, stated by Maddala (1983) is contradicted in a recent paper by Wilde (2000), who shows that exclusion restrictions are not needed, provided there is one varying exogenous regressor in each equation.

For MLE four probabilities (totalling 1) are needed, as in a standard bivariate probit model without endogenity, as follows Lee (2010):

$$\begin{aligned} Pr(y_1 = 1, y_2 = 1) &= P(\varepsilon_1 > -\beta_1 x_1, \varepsilon_2 > -\gamma_2 - \beta_2 x_2) \\ Pr(y_1 = 1, y_2 = 0) &= P(\varepsilon_1 > -\beta_1 x_1, \varepsilon_2 < -\gamma_2 - \beta_2 x_2) \\ Pr(y_1 = 0, y_2 = 1) &= P(\varepsilon_1 < -\beta_1 x_1, \varepsilon_2 > -\beta_2 x_2) \\ Pr(y_1 = 0, y_2 = 0) &= P(\varepsilon_1 < -\beta_1 x_1, \varepsilon_2 < -\beta_2 x_2) \end{aligned}$$

As y_1 and y_2 are observed as dichotomous variables, it is necessary to adopt the standard normalisation of the variance of the errors. Given $\sigma_1 = SD(\varepsilon_1)$ and $\sigma_2 = SD(\varepsilon_2)$ the respective standardised probabilities are obtained as functions of $\beta_1/\sigma_1, \gamma_1/\sigma_1, \beta_2/\sigma_2, \rho$ where the last term ρ denotes the correlation between the standardised error terms.

$$\begin{aligned} Pr(-\tfrac{\varepsilon_1}{\sigma_1} < \tfrac{\beta_1}{\sigma_1} x_1, -\tfrac{\varepsilon_2}{\sigma_2} < \tfrac{\gamma_2}{\sigma_2} + \tfrac{\beta_2}{\sigma_2} x_2) &= \Psi(\tfrac{\beta_1}{\sigma_1} x_1, \tfrac{\gamma_2}{\sigma_2} + \tfrac{\beta_2}{\sigma_2} x_2; \rho) \\ Pr(-\tfrac{\varepsilon_1}{\sigma_1} < \tfrac{\beta_1}{\sigma_1} x_1, \tfrac{\varepsilon_2}{\sigma_2} < -\tfrac{\gamma_2}{\sigma_2} - \tfrac{\beta_2}{\sigma_2} x_2) &= \Psi(\tfrac{\beta_1}{\sigma_1} x_1, \tfrac{-\gamma_2}{\sigma_2} - \tfrac{\beta_2}{\sigma_2} x_2; -\rho) \\ Pr(\tfrac{\varepsilon_1}{\sigma_1} < -\tfrac{\beta_1}{\sigma_1} x_1, -\tfrac{\varepsilon_2}{\sigma_2} < \tfrac{\beta_2}{\sigma_2} x_2) &= \Psi(-\tfrac{\beta_1}{\sigma_1} x_1, \tfrac{\beta_2}{\sigma_2} x_2; -\rho) \\ Pr(\tfrac{\varepsilon_1}{\sigma_1} < -\tfrac{\beta_1}{\sigma_1} x_1, \tfrac{\varepsilon_2}{\sigma_2} < -\tfrac{\beta_2}{\sigma_2} x_2) &= \Psi(-\tfrac{\beta_1}{\sigma_1} x_1, -\tfrac{\beta_2}{\sigma_2} x_2; \rho) \end{aligned}$$

From here the maximum likelihood is derived by maximising the following likelihood function:

$$\sum [y_{1i} y_{2i} ln(\Psi(\tfrac{\beta_1}{\sigma_1} x_1, \tfrac{\gamma_2}{\sigma_2} + \tfrac{\beta_2}{\sigma_2} x_2; \rho) + y_{1i}(1 - y_{2i}) ln(\Psi(\tfrac{\beta_1}{\sigma_1} x_1, \tfrac{-\gamma_2}{\sigma_2} - \tfrac{\beta_2}{\sigma_2} x_2; -\rho)$$
$$+ (1 - y_{1i}) y_{2i} ln\Psi(-\tfrac{\beta_1}{\sigma_1} x_1, \tfrac{\beta_2}{\sigma_2} x_2; -\rho) + (1 - y_{1i}) 1 - y_{2i}) ln\Psi(-\tfrac{\beta_1}{\sigma_1} x_1, -\tfrac{\beta_2}{\sigma_2} x_2; \rho)]$$

4.2. Data

This paper employs data from the World Bank Financial Crisis Survey (FCS) and from the Business Environment and Enterprise Performance survey (BEEPs) conducted jointly by the EBRD and the World Bank. The Financial Crisis Survey (FCS) was undertaken in 2009–2010 and covered six countries:

[7] If $\rho = 0$ two separate probit models can be estimated implying that y_1 is exogenous for the structural form equation.

Bulgaria, Hungary, Latvia, Lithuania, Romania and Turkey. The sample of firms interviewed was a sub-selection from the 2009 round of BEEPs. The BEEPs contains three separate rounds, 2002, 2005 and 2009, that cover firm-level data from a wide set of transition countries collected retrospectively for the years 2001, 2004 and 2007.

Both surveys, BEEPs and FCS, contain valuable information about firm-specific factors, including the firms' age, size measured by the number of employees, ownership, growth in real sales, share of export, and dependence on and access to external finances. The data relevant for the current study concern the years 2001, 2004 and 2007 from BEEPs and 2010 from FCS. For a description of the variables see Table 1 below.

The sample structure has been designed to be representative of the population of firms in each country. The survey does not cover firms operating in sectors under government regulation or prudential supervision such as banking, electric power, rail transport and water supply. Firms with only one employee or with more than 10,000 employees were also not included[8]. In addition, we exclude firms with yearly sales below 50,000 euros and firms with less than three years of operation[9].

The likelihood of a firm conducting R&D has been defined as a dummy variable based on the BEEPs, where the variable takes the value 1 if the firm is doing R&D and 0 otherwise. The dataset in the Financial Crisis Survey differs in regard to the R&D variable. For this reason, a dummy variable is compiled which takes the value 1 if there has been an increase in R&D spending in the firm over the last 12 months and 0 otherwise.

The credit constraint variable is conditioned on two terms, first the firm's dependence on external finance and secondly its access to finance. Firms which state that they don't need a loan are defined as not dependent on external finance, so access to finance is irrelevant for them. In contrast, firms which do not have a loan because they claim not to be eligible for one can be treated as discouraged and hence credit constrained. In addition to the discouraged firms, firms which have applied for credit but been turned down by the bank are attached to the credit constrained group. See the Table 2.

The demand shock has been proxied by two industry level variables of year-on-year growth in employment and in real value added. The set of industries considered comprises: mining and quarrying, manufacturing, energy, con-

[8]See BEEPs reports on methodology and observations at http://www.ebrd.com/pages/research/analysis/surveys/beeps.shtml for more details on survey design.

[9]Starting businesses might exhibit dynamics, which are not well in line with general patterns on firm or industry level.

Table 1: Variables Description

NAME	UNIT	DESCRIPTION	SOURCE
dRD	[0;1]	1 if firm increased R&D spending over last 12 months, 0 otherwise	FCS
RD	[0;1]	1 if firm conducts R&D, 0 otherwise	BEEPs
constrained	[0;1]	1 if firm is constrained, 0 otherwise	BEEPs/FCS
age	ln(year)	age in years since company started operations in particular country. For transition countries the beginning year is set to 1987 if reported earlier	BEEPs
size	[0;1]	dummy variable on wheter the company belongs to one of the three size categories: 2–49 employees; 50–250 employees or 250–10 000 employees	BEEPs
size	[0;1]	dummy variable on wheter the company belongs to one of the three size categories: 5–19 employees; 20–99 employees or 100–10 000 employees	FCS
dsales	%	Percent change in sales over last three years in real terms	BEEPs
dsale	%	Percent change in sales over the last year	FCS
UniGrade	%	A percent of firm workforce having university degree or higher	BEEPs
ExSale	%	share of direct and indirect exports in firm total sales	BEEPs/FCS
BankFin	%	Proportion of fixed assets (land, buildings, machinery, equipment) financed with private bank borrowing	BEEPs/FCS
CredSale	%	Proportion of sales sold on credit i.e. paid after delivery	BEEPs
foreign	%	Percent of foreign ownership if foreign share $\geq$50%, zero otherwise	BEEPs
overdue	[0;1]	1 if the firm has 90 day overdue payment (includes tax overdues and overdues on utilities), 0 otherwise	BEEPs/FCS
audit	[0;1]	1 if the financial statements reviewed by external auditor, 0 otherwise	BEEPs
subsidies	[0;1]	1 if the firm has been subject to public subsidies from local, national or EU sources, 0 otherwise	BEEPs/FCS
value added	%	Industry level annual growth in real value added	Eurostat
employment	%	Industry level annual growth of workforce	Eurostat

Table 2: Variable definitions

	DEPENDENT	INDEPENDENT
CONSTRAINED	Loan rejected OR discouraged from applying a loan	Not applicable
UNCONSTRAINED	Has got a loan	Does not need a loan

struction, sales, hotels and restaurants, transport and communication, real estate, and business services. The aggregation level of industries corresponds to

the NACE Rev.1.1 one-digit level of industries. This means that the industry-level demand aggregates are relatively broadly defined, which implies that firms are not likely to have any significant influence on setting demand. Therefore the industry demand variables serve as good proxies for the exogenous demand shocks[10]. We include cycle variables in our regressions from the contemporaneous year for R&D and demand growth as there is empirical evidence that the correlation between R&D and economic growth is strongest when both indicators origin from the same year (see Walde and Woitek, 2004). Asymmetric demand shock effects are accounted for by decomposing the demand variables into separate variables for positive values, i.e. growth, and negative values, i.e. decline. (For the full set of variables used in the current analysis from the data description table, see Table 1, above).

$$Demand^{+} = \Delta Demand \textit{ if } \Delta Demand > 0, \quad 0 \textit{ otherwise}$$
$$Demand^{-} = \Delta Demand \textit{ if } \Delta Demand < 0, \quad 0 \textit{ otherwise}$$

The econometric analysis in the next section clusters standard errors by country, industry and year. The need for clustering arises because the performance of firms within a particular country and/or industry may be correlated in some way and we are not able to capture all of this correlation with any available set of explanatory variables. Another reason for clustering rises from the inclusion of group level variables (i.e. industry demand measured at the level of country, industry and year) together with firm-level variables in the same regressions. As shown by Moulton (1990) the inclusion of higher level measured variables in the analysis of lower level measured variables may lead to serious underestimation of the standard errors of coefficients. Hence, to account for the possible correlation of disturbances within groups, we use robust country-industry-year-level clustered standard errors in our econometric analysis.

Coming back to the recursive system with binary endogenous variables introduced in the methodology section, we use following list of explanatory variables for credit constraint and R&D equations:

[10]The exclusion of the impact of supply shocks from the output variable is found to be an important matter in this type of empirical literature investigating R&D cyclicality. Ouyang (2011) finds that US R&D is counter-cyclical only after disentangling demand shocks from a supply one. While without this treatment industry level output growth and R&D growth were clearly positively correlated. The distinction between supply and demand shocks is of a smaller relevance in our study, as we analyse a firm-level cross-sectional dataset proxying industry demand by industry's yearly output growth. As supply shocks have been found to be much more persistent than demand shocks and firms R&D efforts do not materialise to industry supply shock within a year, we find that the inference of supply shocks on our R&D and demand proxies relation is minimal.

$$\begin{cases} constrained = f_1(lnage, empl2to49, empl50to250, listed, foreign, dsales, \\ BankFin, overdue, CredSale, audit, subsidies, country\ and\ industry\ dummies) \\ R\&D = f_2(constrained, lnage, empl2to49, empl50to250, listed, ExSale, \\ foreign, UniGrade, dsales, Dneg, Dpos, country\ and\ industry\ dummies) \end{cases}$$

4.3. Implications of the global financial crisis

Aghion et al. (2010) have claimed that extremely severe demand shocks may signal structural changes and exhibit non-linearities. These patterns cannot be explained by opportunity cost arguments. Departing from this theory we have looked at the R&D and credit constraint patterns during the pre-crisis period of 2001–2007 and in the aftermath of the global financial crisis 2009–2010. The World Bank Financial Crisis Survey enables us to conduct this exercise on six countries: Bulgaria, Hungary, Latvia, Lithuania, Romania and Turkey.

It must be remembered that the dependent variables have different definitions in the FCS and BEEPs data. Firms were asked about their response to the crisis in terms of R&D spending in FCS and a binary variable was constructed where the value is 1 if firm has increased its R&D spending over the last year and 0 otherwise. In BEEPs data the dependent variable is measured by the binary category of whether the firm is engaged in R&D or not. The descriptive statistics of the analysis variables can be found in Table 5 in the Appendixes.

Interestingly, the credit constraints have no significant negative effect on firm likelihood to conduct R&D in pre-crisis period (Table 3). The missing link remains present when controlling for the selection bias i.e. removing the non-innovative and financially unconstrained firms as suggested by Savignac (2008) and Mancusi and Vezzulli (2010) (see Table 6 in Appendix).[11] Including the financially dependent firms (NoCredNeed=0) only renders the negative coefficients on financial constraint significant at 10–15% level.[12] The weak relationship between firm R&D participation and credit constraints might seem counter-intutitive, but in the context of emerging credit markets the access firms have to long-term credit and venture capital (Groh and von Liechtenstein, 2009) might be quite poor, which implies that R&D is often financed from internal resources. This conclusion is supported by the positive impact of sales growth on R&D in pre-crisis period. Direct and indirect positive effects of firm sales growth are of similar magnitude suggesting that firm sales is important in supporting firm R&D engagements directly as well as in decreasing R&D impeding liquidity constraints.

[11] The firms not conducting R&D or any type of innovation and which perceive no credit constraints were excluded from the estimation.

[12] The results are available from the authors upon request.

Table 3: Likelihood to conduct R&D conditional on credit constraints, 2001–2007

constrained=1	Industry demand proxy: Value added			Employment		
	Overall	Direct	Indirect	Overall	Direct	Indirect
constrained (d)	–0.615	–0.615		–0.476	–0.476	
	(1.596)			(0.445)		
lnage	0.059**	0.029	0.030	0.066***	0.041	0.025
	(0.025)			(0.021)		
small (d)	–0.200***	–0.219	0.019	–0.203***	–0.216	0.013
	(0.046)			(0.043)		
medium (d)	–0.083***	–0.076	–0.007	–0.081***	–0.073	–0.008
	(0.025)			(0.026)		
listed (d)	0.055	0.031	0.024	0.060	0.039	0.021
	(0.087)			(0.061)		
ExSale	–0.010	–0.010		–0.009	–0.009	
	(0.036)			(0.038)		
foreign	0.041*	0.011	0.030	0.050*	0.023	0.027
	(0.023)			(0.027)		
UniGrade	0.077**	0.077		0.075**	0.075	
	(0.038)			(0.038)		
dsales	0.096***	0.038	0.058	0.099***	0.050	0.049
	(0.031)			(0.036)		
$demand^{-}$	0.174			–0.812		
	(0.696)			(0.820)		
$demand^{+}$	–1.249**			–0.899*		
	(0.560)			(0.480)		
BankFin	0.038		0.038	0.034		0.034
	(0.064)			(0.034)		
overdue (d)	–0.057**		–0.057	–0.057**		–0.057
	(0.024)			(0.028)		
CredSale	0.036		0.036	0.032		0.032
	(0.064)			(0.033)		
audit (d)	0.022		0.022	0.018		0.018
	(0.053)			(0.019)		
subsidies (d)	0.049		0.049	0.041		0.041
	(0.077)			(0.033)		
Log likelihood	–2.4e+03			–2.4e+03		
No of obs.	3595			3595		
rho	0.806			0.707		
Wald test of rho=0	0.125			1.488		

Source: authors' calculations on BEEPs data.

Note: Bivariate probit conditional marginal effects of R&D, reported at constrained=1. Robust, country-sector-survey clustered standard errors in parenthesis. Country, sector dummies included. ***, **, * stand for 1%, 5% and 10% level statistical significance respectively.

There is also no negative effect found between credit constraints and R&D spending at the time of the crisis. On the contrary, an unexpected positive, at 10% level significant, effect emerged in one of the crisis-period regressions (Table 4). The sign is also not reversed when controlling for the selection bias possibly introduced by non-innovative and financially non-constrained firms as brought out by Savignac (2008) and Mancusi and Vezzulli (2010) (see Table 6 in Appendix). This abnormal evidence stems from the crisis context. An extreme slump in demand dried-up the firms' need for external finances whereas the share of credit dependent firms dropped from 65% in pre-crisis period down to 30% during the crisis (see Table 5 in Appendix).[13] Instead, the direct effect of sales growth turns out to be key in explaining the increase in R&D spending in the crisis period 2009–2010, whilst the indirect effect via decrease in credit constraints remains absent.

Some evidence was found that listed firms were less likely to focus on R&D spending in the aftermath of the crisis. This might be a consequence of frozen capital markets at the time of the crisis. The managerial myopia arguments of Bushee (1998) are also well aligned with this result, confirming that the managerial incentive to cut R&D in order to reverse an earnings decline during a cycle downturn is manifested more strongly in traded firms.

It is also striking that firms with a lower number of employees turned out to be more prone to raising their R&D budgets after the crisis, whereas foreign ownership or share of university degree employees had no effect on R&D spending. The estimations from the pre-crisis period of 2001–2007 show the contrary. Foreign owned firms and firms with larger share of highly-educated employees were more ready to conduct R&D.

The counter-cyclical pattern of R&D is clearly evident during the period 2001–2007, suggesting that firms facing increasing industry demand were less likely to conduct R&D. This relation was significant for both of the industry demand proxies, growth in real value added and in the number of employees. An increase of one percentage point in value added reduced the probability of the firm conducting R&D by 1.2%, while the similar effect for a 1% increase in the number of people employed was –0.9%. However, during the crisis period of 2010 this counter-cyclical pattern vanishes. On the contrary, a one percentage point decrease in a firm's value added leads to a 0.4% drop in the probability of the firm increasing R&D spending. It seems that firms in those industries which witnessed a harsher demand contraction were not able to increase their R&D spending. With a closer look it becomes clear that at the time of the financial crisis a vast majority of firms faced a decline in demand which

[13] Most of the surveyed firms confirmed, that the abrupt fall in demand was a substantially more important concern for their business than limited access to finance (Correa, 2010).

Table 4: Likelihood to increase R&D spending conditional on credit constraints, 2010

constrained=1	Industry demand proxy: Value added			Employment		
	Overall	Direct	Indirect	Overall	Direct	Indirect
constrained (d)	0.072*	0.072		0.031	0.031	
	(0.037)			(0.050)		
lnage	–0.012	0.000	–0.012	0.024	0.026	–0.002
	(0.028)			(0.022)		
small (d)	0.043**	0.055	–0.012	0.048**	0.051	–0.003
	(0.017)			(0.021)		
medium (d)	0.019	0.019		0.029	0.029	
	(0.019)			(0.024)		
listed (d)	–0.070**	–0.066	–0.004	–0.066*	–0.064	–0.002
	(0.030)			(0.039)		
foreign	0.000	0.000	–0.000	0.000	0.000	–0.000
	(0.000)			(0.000)		
ExSale	0.046	0.046		0.027	0.027	
	(0.029)			(0.028)		
UniGrade	–0.000	–0.000		0.055	0.055	
	(0.055)			(0.037)		
dsale	0.134***	0.148	–0.014	0.067	0.075	–0.008
	(0.047)			(0.043)		
demand$^-$	0.422**	0.422		–0.068	–0.068	
	(0.194)			(0.156)		
demand$^+$	–3.399**	–3.399		1.380	1.380	
	(1.494)			(1.436)		
BankFin	–0.009		–0.009	–0.003		–0.003
	(0.011)			(0.007)		
overdue (d)	0.064		0.064	0.021		0.021
	(0.050)			(0.031)		
CredSale	0.009		0.009	0.004		0.004
	(0.009)			(0.007)		
audit (d)	0.007		0.007	0.002		0.002
	(0.005)			(0.002)		
subsidies (d)	0.020		0.020	0.006		0.006
	(0.017)			(0.010)		
Log likelihood	–1.7e+05			–1.2e+05		
No of obs.	2218			1670		
rho	–0.238			–0.102		
Wald test of rho=0	1.917			0.574		

Source: authors' calculations on FCSs data.

Note: Bivariate probit conditional marginal effects of dR&D, reported at constrained=1. Robust, country-sector-survey clustered standard errors in parenthesis. Country, sector dummies included. ***, **, * stand for 1%, 5% and 10% level statistical significance respectively.

was of extreme magnitude[14]. Therefore the statistically significant countercyclical result as for the positive value added reflects only about 1% of firms, which managed to grow despite of the crisis. Figure 1 illustrates the differences in the distribution of industry value added during the pre-crisis period of 2001–2007 and during the crisis period 2009–2010. The presence of two

[14]See Table 5 in Appendix.

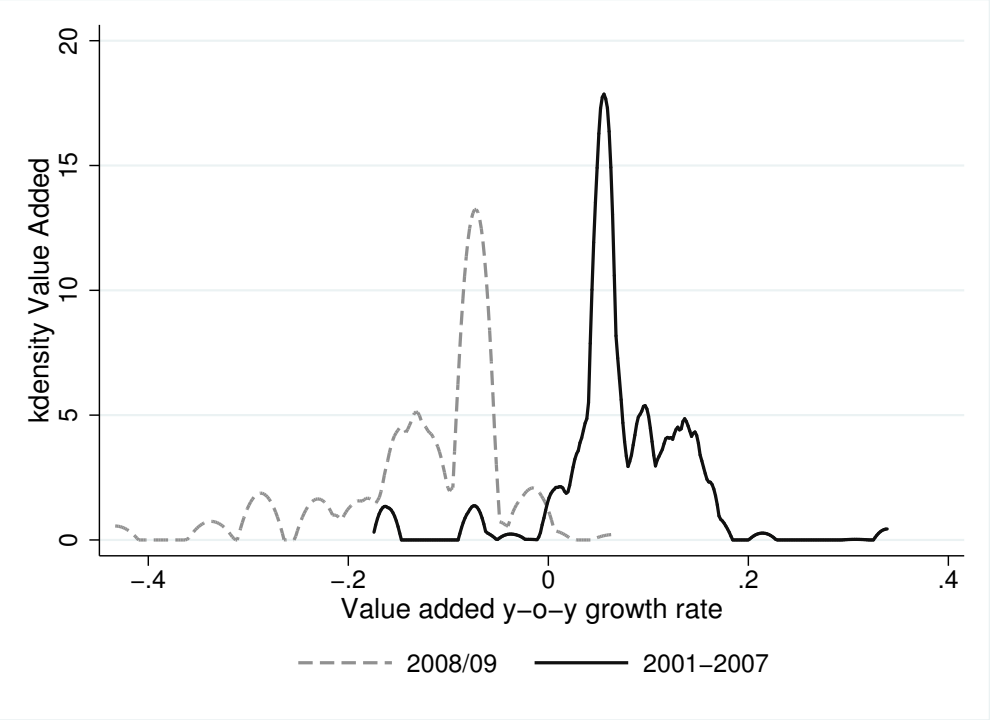

Figure 1: Kernel density estimation of sample companiest' value added in 2001–2007 and during the crisis period of 2008–2009.

Source: Eurostat.

drastically different regimes appears to be the reason why we observe a paradigm shift over the two periods. Facing a huge demand drop, the firms start to focus on acute issues instead of long-term strategic objectives such as R&D. Eventually, companies cease to focus on R&D at times of severe contraction. Hence, the opportunity cost considerations are outweighed by countervailing factors at the lowest tail of demand distribution. Encountering an abnormal fall in demand, the companies consolidate for survival.

5. Summary

In our study we have sought to fill the gap between macroeconomic understanding of volatility and long-term growth on the one hand and the firm-level evidence of productivity-enhancing R&D on the other. The analysis has provided solid support for the existing literature, highlighting the link between short-term demand fluctuations and long-term growth through incentives generated in R&D investors. The firms proved to be less inclined to conduct R&D at times of strong demand. This evidence is in line with the opportunity cost argument that suggests that high opportunity costs at a time of positive demand shock divert firms from a long-term productivity-enhancing agenda.

The financial frictions were accounted for by a simultaneous estimation procedure of a recursive probit model on firm R&D and credit constraints. Interestingly the effect of credit constraints on R&D remained absent. This might seem counter-intuitive, but in the context of underdeveloped credit markets firms reliance on external funds is low. In the crisis environment however the firms' need for external finances has dried-up dramatically due to an extreme drop in demand. The sales growth of the firms, however, remained highly significant in explaining likelihood to conduct R&D during the pre-crisis period 2001–2007 as well as in supporting R&D spending during the crisis years 2009–2010. Though the indirect effect of sales growth on R&D via lower credit constraints was significant only in pre-crisis period.

The years of robust growth in 2001–2007 stand in sharp contrast to the crisis period of 2009–2010 in regard to industry demand. For example the average growth in industry value added was 6.7% over the former and –12.4% over the latter period. The evidence from two episodes proves that the "virtue of bad times" argument is valid only when the sustainability of the firm is not under threat, i.e. in the period 2001–2007. Although R&D behaved counter-cyclically over the pre-crisis period, the relationship became pro-cyclical during the crisis. This is in line with Aghion et al. (2010) postulate that extremely severe demand shocks encompass structural changes which can not be explained by opportunity cost arguments.

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Appendix

Table 5: Summary statistics

	BEEPs 2001–2007			FCS 2010		
	Mean	Std. Dev.	N	Mean	Std. Dev.	N
RD BEEPs	0.174	0.379	4503			
dRD FCS				0.142	0.349	2920
constrained BEEPs	0.118	0.322	4503			
constrained FCS				0.171	0.376	2920
NoCredNeed	0.352	0.478	4503	0.691	0.462	2920
age	12.54	4.772	4503	14.043	5.24	2562
small: 2-49 employees	0.652	0.477	4501			
medium: 50-250 employees	0.246	0.431	4501			
large: 250-10000 employees	0.102	0.303	4501			
small: 5-19 employees				0.336	0.472	2920
medium: 20-99 employees				0.356	0.479	2920
large: 100-10000 employees				0.285	0.451	2920
dsales	0.177	0.46	4503			
dsale				–0.154	0.316	2920
UniGrade	0.185	0.242	4407	0.178	0.228	2422
listed	0.026	0.158	4503	0.028	0.164	2562
ExSale	0.16	0.3	4500	0.187	0.322	2897
foreign	0.109	0.291	4503	0.092	0.289	2920
BankFin	0.141	0.297	3685	0.121	0.224	2744
overdue	0.084	0.278	4503	0.062	0.242	2920
CredSale	0.533	0.393	4488	0.651	0.365	2488
audit	0.583	0.493	4503	0.527	0.499	2562
subsidies	0.099	0.298	4503	0.049	0.215	2920
value added	0.067	0.068	4503	–0.124	0.085	2920
value added^{+}	0.081	0.046	4175	0.041	0.031	34
value added^{-}	–0.112	0.047	328	–0.126	0.084	2886
employment	0.02	0.057	4503	–0.068	0.085	1963
employment^{+}	0.049	0.049	2850	0.027	0.001	432
employment^{-}	–0.03	0.029	1653	–0.095	0.077	1531

Table 6: Likelihood to conduct R&D and likelihood to increase R&D spending conditional on credit constraints, restricted sample of innovative firms only, 2001–2007 and 2010 respectively

constrained=1	R&D: 2001-07		dR&D: 2010	
	value added	employment	value added	employment
constrained (d)	–0.232	–0.249	0.072*	0.031
	(0.324)	(0.276)	(0.038)	(0.051)
lnage	0.053**	0.061***	–0.010	0.027
	(0.021)	(0.021)	(0.029)	(0.022)
small(d)	–0.185***	–0.189***	0.043**	0.047**
	(0.040)	(0.040)	(0.019)	(0.024)
medium (d)	–0.077***	–0.076***	0.020	0.028
	(0.024)	(0.024)	(0.022)	(0.029)
listed (d)	0.035	0.042	–0.068**	–0.066*
	(0.050)	(0.052)	(0.029)	(0.038)
ExSale	–0.025	–0.024	0.048	0.030
	(0.034)	(0.036)	(0.030)	(0.030)
foreign	0.049**	0.060**	0.000	0.000
	(0.024)	(0.026)	(0.000)	(0.000)
UniGrade	0.064*	0.061	0.002	0.058
	(0.036)	(0.038)	(0.058)	(0.039)
dsales	0.073**	0.077**	0.135***	0.067
	(0.034)	(0.034)	(0.049)	(0.043)
$demand^{-}$	0.080	–0.697	0.431**	–0.064
	(0.644)	(0.833)	(0.200)	(0.160)
$demand^{+}$	–1.218**	–0.947**	–3.442**	1.490
	(0.565)	(0.480)	(1.531)	(1.471)
BankFin	0.025	0.028	–0.009	–0.003
	(0.025)	(0.022)	(0.011)	(0.007)
overdue (d)	–0.033	–0.037	0.063	0.021
	(0.033)	(0.031)	(0.050)	(0.032)
CredSale	0.022	0.025	0.008	0.003
	(0.029)	(0.026)	(0.009)	(0.006)
audit (d)	0.008	0.010	0.008	0.003
	(0.013)	(0.012)	(0.005)	(0.003)
subsidies (d)	0.025	0.027	0.020	0.006
	(0.029)	(0.026)	(0.017)	(0.010)
Log likelihood	–2.2e+03	–2.2e+03	–1.7e+05	–1.2e+05
No of obs.	3084	3084	2183	1635
rho	0.411	0.439	–0.232	–0.101
Wald test of rho=0	0.811	1.308	1.909	0.540

Source: authors' calculations on BEEPs and FCS data.
Note: Bivariate probit conditional marginal effects of R&D and dR&D, reported at constrained=1. Robust, country-sector-survey clustered standard errors in parenthesis. Country, sector dummies included. ***, **, * stand for 1%, 5% and 10% level statistical significance respectively.

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