EUROSÜSTEEM

R&D, Demand Fluctuations and Credit Constraints: Comparative Evidence from Europe

Kadri Männasoo and Jaanika Meriküll

Working Paper Series
5/2011

The Working Paper is available on the Eesti Pank web site at:
www.bankofestonia.ee/pub/en/dokumendid/publikatsioonid/seeriad/uuringud/

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

ISBN 978-9949-404-95-7
Eesti Pank. Working Paper Series, ISSN 1406-7161; 5

R&D, demand fluctuations and credit constraints: comparative evidence from Europe

Kadri Männasoo and Jaanika Meriküll*

Abstract

This paper contributes to the literature by investigating whether the cyclicality of R&D differs across countries with different levels of development. The paper uses micro-data from the World Bank/EBRD Business Environment and Enterprise Performance survey from 2001–2007 and estimates bivariate probit model of firms' R&D conditioned on credit constraints. The main results are: (1) The likelihood of a firm conducting R&D increases with sales growth and decreases with credit constraints. (2) R&D by firms is counter-cyclical to exogenous industry output and a negative industry demand shock has a stronger counter-cyclical effect on R&D than a positive industry demand shock does. (3) R&D is more counter-cyclical to demand shocks the further the country is from the technological frontier.

JEL Code: G31, E32, O30, O52

Keywords: R&D cyclicality, demand fluctuations, credit constraints, comparative study

Authors' e-mail addresses: kadri.mannasoo@eestipank.ee,
jaanika.merikyll@eestipank.ee

---

*Kadri Männasoo is a senior researcher at Tallinn University of Technology and a visitor researcher at Eesti Pank. Jaanika Meriküll is a researcher at Eesti Pank. The research was supported by Estonian Science Foundation grant project ETF8796. The authors thank Dmitri Kulikov, Martti Randveer, Karsten Staehr and participants in Eesti Pank seminars for their valuable comments. All remaining errors are the author's own.

Non-technical summary

European integration has led to a large, but heterogeneous market. Despite the on-going convergence process, discrepancies between the mature part of Europe and the emerging regions have remained significant. In particular, the volatility in economic growth in Central, Southern and Eastern Europe (CSEE) has been markedly stronger than that in "old Europe" over the last decade.

Economic theory has shown that investments that enhance productivity, such as R&D (Research and Development), are crucial for economic growth. The social return from R&D outweighs the private benefit, which is why government involvement is needed for the optimal level of R&D to be achieved. However, private incentives still remain dominant in how, when and to what extent firms devote funding and effort to their R&D.

In view of the recent macroeconomic turbulence, research on growth and volatility issues is highly valued. Theoretical contributions suggest that temporary fluctuations have further implications for a country's long-term growth. R&D plays a crucial role here in providing a link between short-term fluctuations and long-term growth. The opportunity cost argument states that investors face a choice between short-term liquid investments and long-term investments that enhance productivity with lagged returns. Since the opportunity costs of productivity-enhancing R&D are high when the economy is at its peak, investors then prefer liquid, short-term investments. The opposite happens when opportunity costs are suppressed in times of low demand as firms focus on R&D and on productivity improvement in general. In total this means a counter-cyclical pattern emerges between cyclical fluctuations in the economy and R&D. However, R&D is counter-cyclical to low demand only as long as the financial constraints remain unbinding. In imperfect credit markets firms have to reduce R&D even when there are low opportunity costs. There is however no agreement about R&D cyclicality on the theoretical front or in the empirical literature. The country, industry or firm-level analyses reveal mixed evidence.

The aim of this research is to compare how demand fluctuations and credit constraints affect R&D in mature economies in Europe and in the newly integrated Central, and South-East European (CSEE) countries. For this purpose we assemble 11 CSEE countries: Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia into the "East" sample and 5 Western and Southern European countries: Germany, Ireland, Spain, Portugal and Greece into the "West" sample. The distinction between these country groups enables us to control for the impact of the economy's level of development on whether the R&D strategies of firms are conditioned on demand fluctuations and credit constraints.

The World Bank/EBRD Business Environment and Enterprise Performance survey (BEEPs) rounds 2002, 2004, 2005 and 2008/09 have been employed for the empirical analysis. This multiple cross-section provides direct self-reported measures of firms' credit frictions and R&D along with a number of indicators on the demographics and performance of firms. Eurostat industry-level statistics have been used for compiling exogenous demand fluctuation variables and a panel for the robustness study. We control for three different demand proxies, using annual growth in real value added, in number of employees and in real turnover. The main variables of interest, R&D by firm and credit constraints, are defined as the likelihood of a firm conducting R&D and its propensity to be credit constrained respectively. All firms that are dependent on external funding but that have been rejected by lenders or discouraged from borrowing are defined as credit constrained. The rest of the firms, those 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 findings imply that R&D investments respond more counter-cyclically to demand fluctuations in the less mature countries of the CSEE region than in the West-European countries. This departs from the model of marginal opportunity cost and marginal expected return from R&D. Western European countries, being closer to the technological frontier, show stronger persistence and expect higher returns from R&D, whilst the opportunity costs outweigh the expected return from R&D in Eastern European countries. It can be assumed that in less advanced markets a competitive edge can also be pursued through imitation or market expansion.

The overall conclusion is that the importance of R&D increases with a country's level of technological and economic advancement, whilst fluctuations in demand have less impact on enhancing productivity in firms. Nevertheless, R&D incentives deserve to be encouraged by stable access to credit and mechanisms that promote far-sighted R&D strategies over volatile opportunity cost driven behaviour.

Contents

1. Introduction

Theoretical models predict that pro-cyclical R&D should lead to higher volatility and lower long-term growth. The so-called cleansing mechanism or "virtue of bad times" in the Schumpeterian view of business cycles suggests that recessions help to correct for inefficiencies while forcing firms to focus on an agenda to enhance productivity. This is the cause of the cyclicality of productivity-enhancing investments as R&D acts as a potential link between the business cycles and long-run growth; so it is suggested by Schumpeter that we should observe R&D to be counter-cyclical.

However, the empirical evidence has not given consistent support to the counter-cyclicality of R&D. The influential model proposed by Aghion, Angeletos, Banerjee, Manova, or AABM (see Aghion et al., 2005, 2010), explains the pro-cyclical nature of R&D through credit market frictions. The starting point for the argument in the AABM model is again that investments that can enhance long-term growth behave in a counter-cyclical manner, implying that when the economy is at its peak (facing positive demand) it is more profitable to invest in short-term production with high-level productivity than in long-term investments, as these involve an uncertainty component and a delay in returns. An adverse productivity shock in contrast encourages business leaders to make long-term investments as the opportunity cost of forgone current production is low. But this cyclical pattern of long-term investments or R&D turns pro-cyclical when firms face credit constraints. The implication is that there is a higher risk that these long-lasting investments will be cut off in the future by a liquidity shock. As a result of credit constraints firms tend to make less long-term investments relative to short-term investments and the cut in long-term investments becomes especially severe during a recession.

Barlevy (2007) models another mechanism for how R&D is not concentrated in recessions as predicted by the idea of the virtue of bad times. According to Barlevy (2007) the pro-cyclicality of R&D expenditures comes from the non-excludability of its nature. Innovating firms cannot always exclude other firms from the benefits from their innovations, while the positive externalities usually appear to other firms with a time-lag, for example after the expiration of patent protection. This dynamic externality makes firms do less R&D than is socially optimal during recessions as their competitors will benefit from their innovation during the following period of high demand. Pro-cyclical R&D will be more costly for society, making recessions more persistent and the return to growth more costly.

There is quite a lot of empirical evidence on the cyclicality of R&D and as already seen it finds R&D to be quite pro-cyclical. Barlevy (2007) tests his model empirically and concludes that US R&D expenditures are historically pro-cyclical at the firm and aggregated levels. Studying long-term relationships in aggregate data from the USA, Rafferty (2003) demonstrates pro-cyclical and asymmetric patterns of firm-financed R&D. Walde and Woitek (2004) find that R&D expenditures are fairly pro-cyclical in the majority of G7 countries over the period 1973–2000. Ouyang (2011) finds that R&D reacts asymmetrically to demand shocks, responding pro-cyclically to negative demand shocks and counter-cyclically to positive demand shocks. She makes use of an annual panel of 20 US manufacturing industries over 1957–1998 and finds that the pro-cyclicality of R&D expenditures is much milder at the industry level than it is in the country level estimations.

Regarding the inference of credit constraints, empirical studies usually find that R&D expenditures are more pro-cyclical in more credit-constrained firms or countries. Using an annual panel of 21 OECD countries over the period 1960–2000 Aghion et al. (2005, 2010) show that long-term growth-enhancing investments respond less to positive 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. They 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 during downturns than they are encouraged in booms.

The direct impact of credit constraints on firms' performance is predominantly negative. Recent evidence presented by Campello et al. (2010) on the global financial crisis of 2008/09 shows that constrained firms in the USA, Europe, and Asia witnessed deeper cuts in employment, technology and capital spending. Their study also interestingly identifies 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. Savignac (2008), Aghion et al. (2008), Ouyang (2007) and others have found strong support for the evidence that financial and credit constraints have an adverse effect upon R&D and innovation. The study by Badia and Slootmaekers (2008) on the relationship between productivity and financial constraints in Estonia, concluded that of all industries financial constraints had a large negative impact on productivity in the R&D sector.

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. To the best of our knowledge, this is the only study on the cyclicality of R&D investments in a transitional country with a centrally planned background. The empirical papers studying R&D cyclicality use a different methodological approach, proceed from different measures of credit constraints, and employ different econometric techniques. To the best of our knowledge there is no cross-country comparative study of this issue that would use similar data sets and a similar methodological approach. We seek to fill this gap in the literature.

The aim of this paper is to investigate the relationship between the likelihood of a firm undertaking R&D and demand fluctuations, conditioned on the presence of credit constraints. We seek to uncover whether this relationship differs across countries with different levels of development. Our main hypothesis is that as predicted by the theory of Aghion et al. (2005, 2010), countries with a less developed financial intermediation sector and a lower level of development should have more pro-cyclical R&D expenditures than countries with well developed financial markets. We make use of the cross-country comparable micro-data from 11 Central and South-East European countries and five Western and Southern European countries with diverse levels of development. We test for the robustness of our findings using the industry level panel data for the same set of European countries.

The paper is organised as follows: Section 2 presents the relevant economic background of the countries investigated; Section 3 presents the methodology of the study; Section 4 describes the data; Section 5 presents the results of the main study based on micro-data and Section 6 a robustness study based on macro or industry level data; and finally Section 7 provides conclusions.

2. Background

This section provides some stylised facts about the aggregated data from the set of countries analysed in the following sections. We start by investigating the cross-country comparison of relations between R&D expenditures, productivity and financial deepening. The R&D expenditures in transitional countries are significantly lower than in their counterparts in mature Europe, see Figure 1. The graph also reveals a generally positive relationship between R&D expenditures and labour productivity, although this relationship diminishes at very high levels of R&D expenditures. The empirical studies have usually found a positive relationship between productivity and innovation[1] (see literature survey by Verspagen (2006), Ulku (2004) and Masso and Vahter (2008), Damijan et al. (2008) on the evidence on CSEE countries).

[1]The linkage between R&D and innovation is stronger for leading-edge technologies and novel innovations. The follower-type, imitative innovations have more in common with regu-

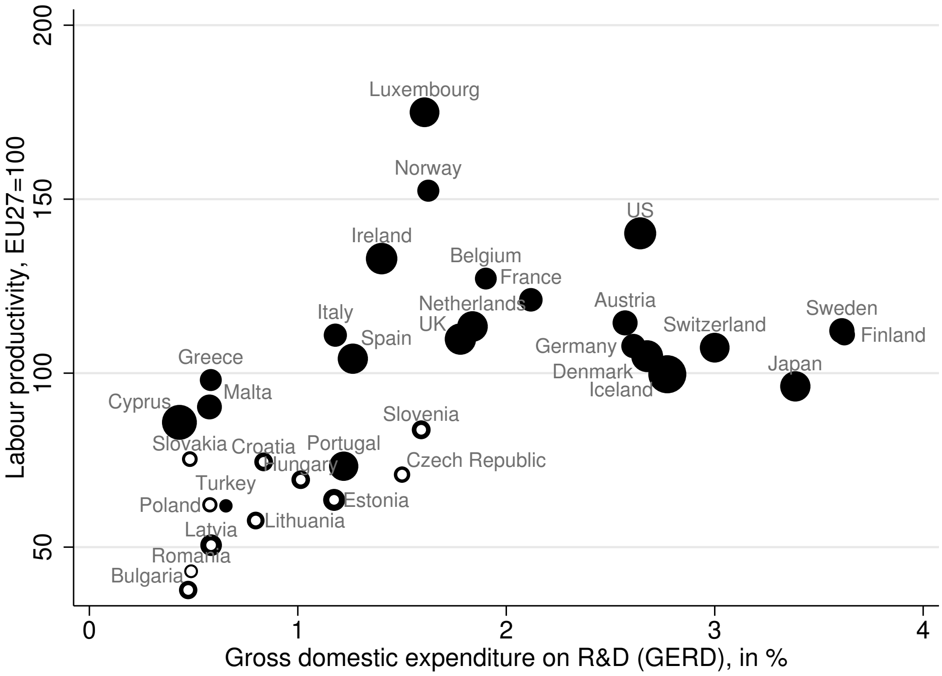

Figure 1: R&D expenditures in GDP and labour productivity, markers weighted by financial deepening, average of 2005–2009 (Post-Communist countries noted by hollow circle

Note: R&D expenditures from 2005–2008 for Iceland, Turkey and US; 2005–2007 for Japan; and only 2008 for Switzerland. Financial deepening is averaged over 2005–2008 except for 2005–2007 for Malta; 2005–2006 for Slovenia and Iceland; and 2003 for Norway.
Source: R&D expenditures and productivity from Eurostat; financial deepening is measured as domestic credit to private sector (% of GDP) and is derived from the World Bank.

There is also ample diversity in financial sector development within the group of transitional countries and the group of developed countries (markers are weighted by financial deepening in Figure 1). The financial development is measured in Figure 1 by domestic credit to the private sector in GDP. In general, the transitional countries or countries with lower levels of development also have lower levels of financial sector development, meaning that firms in transition economies tend to face tighter credit constraints and more limited access to venture capital relative to firms operating in mature markets[2]. This

lar investments in the firm.

[2]Groh and von Liechtenstein (2009) demonstrate that venture capitalists find markets in formerly centrally planned EU countries less attractive than those in older EU members. The only advantage of centrally planned economies for venture capitalists is their lower capital

regularity motivates our research question of whether the countries with lower levels of development and less financial deepening face more pro-cyclicality in their R&D investments and as a result see a more adverse effect of economic downturns on long-term growth.

3. 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. Masso and Vahter (2008), and Masso et al. (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) private bank funding in the firm's total fixed investments funding, (6) a dummy variable for the presence of 90-day overdue loans; (7) the share of sales sold on credit; (8) an indicator for whether the firm is audited; and finally (9) the dummy variable for the existence of state subsidies. 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.

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 inten-

taxation; but the disadvantages are the small size of their capital markets, low liquidity, bribery and corruption, and low levels of innovativeness.

sity 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 Monfardini and Radice (2008).

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 decision. The errors ϵ_1 and ϵ_2 are jointly normally distributed with zero mean, unit variance and correlation of ρ where $|\rho| > 0$[3]. 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

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

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. Data

This paper employs the data from the Business Environment and Enterprise Performance survey (BEEPs) conducted jointly by the EBRD and the World Bank. Three consecutive rounds of BEEPs, 2002, 2005 and 2008/2009, have been used. The survey covers firm-level data from a wide set of transition countries, but to reduce the heterogeneity of the sample the 11 more advanced CEE countries, the Czech Republic, Bulgaria, Croatia, Hungary, Poland, Slovakia, Slovenia, Romania, Estonia, Latvia and Lithuania, have been selected for the empirical analysis. In 2004 a benchmark survey was conducted on a sample of seven non-transition countries. We use this data from five non-transition European countries: Germany, Spain, Portugal, Greece and Ireland.

The sample structure of BEEPs has been designed to be representative of the population of firms in each country surveyed[4]. The surveys leave out firms operating in sectors under government regulation and prudential supervision such as banking, electric power, rail transport and water supply, and firms with only one employee or with more than 10,000 employees were excluded from the sample. We excluded firms with yearly sales below 50,000 euros and firms with less than three years in operation[5].

BEEPs contains information about such firm-specific characteristics as the age, size measured by number of employees, ownership, sales growth, and share of exports of the firm, and also its dependence on and access to external finances. The likelihood of the firm conducting R&D has been defined as a dummy variable based on BEEPs, where the variable takes the value 1 if

[4]For more details on the survey design, see BEEPs reports on methodology at http://www.ebrd.com/pages/research/analysis/surveys/beeps.shtml.

[5]Starting businesses might exhibit dynamics which are not fully in line with the general patterns of the other firms or the industry.

the firm is doing R&D and 0 otherwise. The data is collected for the year preceding the survey, i.e. for 2001 in the 2002 survey, for 2004 in the 2005 survey and for 2007 in the 2008 survey. The data on non-transitional countries was collected in 2004 and the reference period is also 2004. All the data is collected on a yearly basis, except for firms' sales growth, which is collected for a period of three years. See Table 1 for a description of the variables.

The credit constraint variable is conditioned on two terms, first the firm's dependency on external finance and secondly its access to finance. Those firms which state that they don't need any loan are defined as not dependent on external finance because access to finance is irrelevant for them. On the other hand those 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 discouraged firms, firms which have applied for credit but been turned down by the bank are put in the credit constrained group.

The demand shock has been proxied by three industry level output variables of year-on-year growth in real value added, employment and real turnover. The set of industries considered comprises: mining and quarrying, manufacturing, energy, construction, 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 output aggregates are quite broad and presumably individual firms do not have any significant influence on setting the industry's output, which makes them a good proxy for the exogenous demand shocks[6]. We include cycle variables in our regressions from the contemporaneous period to R&D as there is empirical evidence that the correlation between R&D and economic growth is strongest at the same period of time (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.

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

[6]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 demand shocks have been disentangled from supply shocks. Without this treatment, industry level output growth and R&D growth were clearly positively correlated. The distinction between supply and demand shocks is of less 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 the R&D efforts of firms are not material to industry supply shocks within a year, we find that the influence of supply shocks on our R&D and demand proxies is minimal.

Table 1: Description of variables

NAME	UNIT	DESCRIPTION
RD	[0;1]	1 if firm conducts R&D, 0 otherwise
constrained	[0;1]	1 if firm is constrained, 0 otherwise
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
size	[0;1]	dummy variable on wheter the company belongs to one of the three size categories: 1–49 employees; 50–250 employees or 250–10 000 employees
dsales	%	Percent change in sales over last three years in real terms
UniGrade	%	A percent of firm workforce having university degree or higher
ExSale	%	share of direct and indirect exports in firm total sales
BankFin	%	Proportion of fixed assets (land, buildings, machinery, equipment) financed with private bank borrowing
CredSale	%	Proportion of sales sold on credit i.e. paid after delivery
foreign	%	Percent of foreign ownership if foreign share $\geq$50%, zero otherwise
Overdue	[0;1]	1 if the firm has 90 day overdue payment (includes tax overdues and overdues on utilities), 0 otherwise
audit	[0;1]	1 if the financial statements reviewed by external auditor, 0 otherwise
subsidies	[0;1]	1 if the firm has been subject to public subsidies from local, national or EU sources
VA	%	Industry-level annual real growth of value added (source: Eurostat)
LAB	%	Industry-level annual growth of workforce (source: Eurostat)
TURN	%	Industry-level annual real sales growth (source: Eurostat)
WSEC	[0;1]	1 if firm located in Western and Southern Europe (Old EU members), 0 otherwise
GDP	PPS	Country-level annual GDP per capita in thousands of purchasing power parity standard units (source: Eurostat)

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:

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

Throughout the paper we present our analysis separately for two groups of countries: those from Central and South-Eastern Europe and those from the Western and Southern Europe. We denote these groups using the abbreviations CSEE and WSE respectively. The distinction between these two groups is based on the political and economic backgrounds of the countries, with the CSEE group consisting of formerly centrally planned economies[7]. The summary statistics of all the variables engaged in the analysis and across the CSEE and WSE groups is presented in Table 8 in the Appendix.

5. Results

5.1. The cyclicality of R&D in emerging markets

Our econometric analysis seeks to reveal how R&D responds to demand shocks, and the extent to which credit constraints matter for firms' R&D decisions. We estimate bivariate probit models presenting the conditional marginal effects of factors that affect directly and indirectly (i.e. via credit constraints) the propensity of firms to be engaged in R&D. We present the estimation results of bivariate probit models on two categories of firms: all of the firms in the sample and only those firms that are dependent on external finance. This division is made to differentiate between the general R&D cyclicality and the

[7]We also undertake robustness tests based on a more flexible measure of the country's level of development — the purchasing power standard GDP per capita. For this robustness test we do not estimate R&D equations separately for the CSEE and WSE groups, but we interact all the explanatory variables with country-level purchasing power standard GDP per capita.

R&D cyclicality of those firms for which the credit constraints are particularly relevant. This section presents the results for the firms from the CSEE countries, also denoted as emerging markets, the next section presents the results for the firms from WSE countries, denoted as mature markets, and compares the results from the CSEE and WSE countries.

The estimations for all the firms from the CSEE countries are presented in Table 2 and the estimations for the firms that are dependent on external finance in Table 3. The implementation of bivariate probit seems to be justified here as there is a statistically significant correlation between the residuals from both simultaneous equations (engagement in R&D and existence of credit constraints), see the correlation rho and Wald test of rho=0 in Table 2 and Table 3.

The results indicate that credit constraints have a significant effect on the R&D initiative of firms, as the probability of credit constrained firms being engaged in R&D is around 70% points lower. An important factor for accelerating R&D is the sales of the firm or its capacity to generate internal funds. Firm sales growth increase by 1%-point is related to R&D propensity increase by 0.12–0.15%. Interestingly, a large share of sales effect on R&D takes effect via credit constraints, faster sales growth reduces propensity to be credit constrained and via this increases propensity to be engaged with R&D. Internal funds reduce the firm's need to borrow or even annul it. R&D is also more frequent in firms of middle size, in listed firms, in firms where the loan burden is high and there are no overdue payments, in firms where sales are sold on credit, in audited firms and in firms subject to public subsidies. All these variables have an intuitively reasonable impact on credit constraints and also have, indirectly via credit constraints, a substantial effect on R&D activity. Interestingly, foreign ownership has no statistically significant effect on the propensity of a firm to undertake R&D.

The results are fairly similar across the sample of external finance dependent firms and the sample of all the firms. However, there is evidence that the firm's own sales are more important for R&D in firms that do not rely on external finance. This result is logical, because for credit dependent firms, access to external finance is more important for R&D investments than revenue generated from sales growth. There is also evidence that credit constraints have smaller effect on R&D in firms that are dependent on external finance.

Industry level demand fluctuations have a significant impact upon R&D. Whilst the firm's own sales have a positive effect on R&D and credit constraints have a negative effect, the exogenous demand indicators have a counter-cyclical effect on R&D. Falling industry-level demand is counter-cyclical to R&D, providing support to the opportunity cost theory. In consequence, the 'virtue of bad times' proves to be true in CSEE countries. On the positive side

Table 2: R&D and credit constraints in CSEEC, 2001–2007, total sample

	Industry demand proxy:				
		Value added		Employment	Turnover
	Overall effect	Direct effect	Indirect effect	Overall effect	Overall effect
constrained (d)	–0.707***	–0.707		–0.686***	–0.490
	(0.122)			(0.182)	(0.401)
lnage	0.044	–0.020	0.064	0.052*	0.020
	(0.029)			(0.027)	(0.026)
empl2to49 (d)	–0.309***	–0.323	0.014	–0.305***	–0.313***
	(0.052)			(0.048)	(0.045)
empl50to250 (d)	–0.113***	–0.122	0.009	–0.116***	–0.113***
	(0.034)			(0.032)	(0.032)
listed (d)	0.087*	0.166	–0.079	0.092*	0.111**
	(0.049)			(0.048)	(0.046)
ExSale	0.049	0.049		0.058	0.058
	(0.041)			(0.041)	(0.038)
foreign	0.041	–0.009	0.049	0.041	0.047
	(0.029)			(0.031)	(0.033)
UniGrade	0.044	0.044		0.042	0.055
	(0.038)			(0.037)	(0.039)
dsales	0.157***	0.069	0.088	0.152***	0.120***
	(0.035)			(0.038)	(0.038)
Industry demand$^-$	–2.209**	–2.209		–2.255***	–0.970***
	(1.044)			(0.797)	(0.344)
Industry demand$^+$	–0.621	–0.621		–0.128	0.042
	(0.402)			(0.140)	(0.122)
BankFin	0.094**		0.094	0.087**	0.067
	(0.045)			(0.044)	(0.044)
overdue (d)	–0.096***		–0.096	–0.094***	–0.087**
	(0.020)			(0.018)	(0.038)
CredSale	0.052**		0.052	0.047*	0.028
	(0.025)			(0.025)	(0.026)
audit (d)	0.043**		0.043	0.040*	0.021
	(0.020)			(0.023)	(0.026)
subsidies (d)	0.102***		0.102	0.106***	0.090
	(0.032)			(0.039)	(0.069)
No of obs.	5330			5226	4924
Log likelihood	–4252.7			–4128.4	–3860.8
Rho	0.879			0.857	0.700
Wald test of rho=0	7.603***			4.521**	1.505

Note: Conditional marginal effects of R&D, reported at constrained=1. Country and industry dummies are not reported. Robust standard errors clustered by country, industry and year in parenthesis. ***, **, * denote statistical significance at 1%, 5% and 10% level respectively.
Source: Authors' calculations from BEEPs data.

Table 3: R&D and credit constraints in CSEEC, 2001–2007, financially dependent firms

	Industry demand proxy:				
		Value added		Employment	Turnover
	Overall effect	Direct effect	Indirect effect	Overall effect	Overall effect
constrained (d)	–0.402**	–0.402		–0.365*	–0.184
	(0.193)			(0.194)	(0.205)
lnage	0.063**	–0.009	0.072	0.072**	0.029
	(0.030)			(0.032)	(0.026)
empl2to49 (d)	–0.291***	–0.257	–0.035	–0.279***	–0.282***
	(0.046)			(0.043)	(0.043)
empl50to250 (d)	–0.107***	–0.097	–0.010	–0.107***	–0.098***
	(0.037)			(0.035)	(0.033)
listed (d)	0.092*	0.145	–0.054	0.093*	0.120**
	(0.054)			(0.051)	(0.053)
ExSale	0.068*	0.068		0.074*	0.070*
	(0.041)			(0.041)	(0.040)
foreign	0.034	0.029	0.005	0.038	0.049
	(0.032)			(0.034)	(0.032)
UniGrade	0.099**	0.099		0.092**	0.113***
	(0.040)			(0.039)	(0.040)
dsales	0.096***	0.031	0.066	0.093***	0.083**
	(0.035)			(0.035)	(0.033)
Industry demand^{-}	–3.517***	–3.517		–1.987**	–1.531***
	(1.225)			(0.831)	(0.405)
Industry demand^{+}	–0.507	–0.507		–0.118	0.097
	(0.408)			(0.124)	(0.121)
BankFin	0.161***		0.161	0.147**	0.093
	(0.056)			(0.057)	(0.069)
overdue (d)	–0.077***		–0.077	–0.073**	–0.048
	(0.029)			(0.030)	(0.036)
CredSale	0.072*		0.072	0.063*	0.036
	(0.037)			(0.034)	(0.030)
audit (d)	0.028		0.028	0.026	0.012
	(0.020)			(0.020)	(0.014)
subsidies (d)	0.084**		0.084	0.079**	0.054
	(0.037)			(0.039)	(0.044)
No of obs.	3627			3556	3317
Log likelihood	–3138.3			–3057.0	–2825.8
Rho	0.619			0.581	0.388
Wald test of rho=0	5.050**			4.557**	1.665

Note: Conditional marginal effects of R&D, reported at constrained=1.
Country and industry dummies are not reported. Robust standard errors clustered by country, industry and year in parenthesis. ***, **, * denote statistical significance at 1%, 5% and 10% level respectively.
Source: Authors' calculations from BEEPs data.

of the demand shock, the evidence for the opportunity cost arguments is quite weak, with mixed signs and insignificant coefficients across the three demand proxies. Omitting the asymmetric effects of industry demand and investigating the impact of simple demand growth on R&D reveals that the overall relation is counter-cyclical and mostly statistically significant, see Table 9 in the Appendix.

5.2. The cyclicality of R&D in mature markets

Table 4 and Table 5 show that smaller set of variables have statistically significant effect on R&D in the sample of WSE countries. Similarly to CSEEC sample credit constrained and small firms have lower propensity to conduct R&D, while exporting and more skilled workforce is related to higher propensity to conduct R&D. Sales and industry demand proxies have in economic terms strong but statistically insignificant effect on R&D. As in the results from the CSEE countries, R&D is pro-cyclical for firms' sales. The sales variable measured as a firm's turnover growth over the last three years shows the firm's capacity to generate internal funding. Higher sales growth by 1% points leads to a higher probability by around 0.2%–0.4%-point of a firm conducting R&D, which is a stronger effect than that observed for firms in the CEE countries. Again, the direct effect from R&D equation and the indirect effect from constraint equation have equally important role on the overall effect of sales.

Industry cycle proxies have a mixed effect on firms' R&D investment decisions. A positive and significant correlation prevails between R&D and positive turnover and value added growth for an industry, indicating that more firms conduct R&D in industries with growing turnover and value added. However, the results for negative demand shocks are the opposite, however statistically insignificant, as negative industry demand shock coincides with more firms conducting R&D in that sector. This means that unlike in the CSEE group, we observe more pro-cyclicality of R&D during the booms in the WSE group, but similarly to the CSEE group we observe counter-cyclicality in R&D during recessions. Table 10 in the Appendix presents the industry demand effect on R&D without asymmetric industry growth measures, giving inconclusive results for the overall cyclicality of R&D in the WSE countries.

The exercise with developed countries in this section confirms our results from the catching-up countries that the demand effect on R&D is asymmetric, with quite a mixed effect on the industry's business cycle being manifested at the peak in demand, but a counter-cyclical effect following contraction in demand. However, the results are somewhat mixed, with R&D clearly much less counter-cyclical in the WSE countries than it is in the CSEE countries[8].

[8]It should also be remembered that the estimations in the WSE sample are based on a

Table 4: R&D and credit constraints in WSEC, 2004, total sample

	Industry demand proxy:				
		Value added		Employment	Turnover
	Overall effect	Direct effect	Indirect effect	Overall effect	Overall effect
constrained (d)	–0.220	–0.220		–0.426*	–0.229
	(0.296)			(0.240)	(0.301)
lnage	0.074	0.062	0.012	0.106*	0.072
	(0.050)			(0.059)	(0.050)
empl2to49 (d)	–0.407**	–0.367	–0.040	–0.513***	–0.420**
	(0.167)			(0.146)	(0.174)
empl50to250 (d)	–0.095	–0.049	–0.045	–0.149	–0.098
	(0.077)			(0.097)	(0.081)
listed (d)	–0.108	–0.046	–0.062	–0.181	–0.116
	(0.103)			(0.124)	(0.105)
ExSale	0.216*	0.216		0.284**	0.194
	(0.127)			(0.131)	(0.126)
foreign	–0.038	–0.065	0.027	–0.034	–0.037
	(0.058)			(0.085)	(0.057)
UniGrade	0.150*	0.150		0.218**	0.150*
	(0.091)			(0.107)	(0.088)
dsales	0.218	0.144	0.074	0.378	0.205
	(0.192)			(0.265)	(0.189)
Industry demand^{-}	–1.496	–1.496		–1.634	–1.418
	(1.668)			(1.259)	(1.644)
Industry demand^{+}	1.169	1.169		–0.250	0.869*
	(0.803)			(0.696)	(0.488)
BankFin	0.484		0.484	1.040	0.502
	(0.690)			(0.930)	(0.711)
overdue (d)	–0.055		–0.055	–0.112	–0.057
	(0.066)			(0.083)	(0.068)
CredSale	0.012		0.012	0.028	0.013
	(0.020)			(0.031)	(0.021)
audit (d)	0.021		0.021	0.047	0.022
	(0.032)			(0.048)	(0.033)
subsidies (d)	0.043		0.043	0.102	0.045
	(0.069)			(0.104)	(0.073)
No of obs.	2423			2423	2419
Log likelihood	–945.4			–947.0	–942.0
Rho	0.338			0.528	0.348
Wald test of rho=0	1.190			3.931**	1.219

Note: Conditional marginal effects of R&D, reported at constrained=1. Country and industry dummies are not reported. Robust standard errors clustered by country, industry and year in parenthesis. ***, **, * denote statistical significance at 1%, 5% and 10% level respectively.
Source: Authors' calculations from BEEPs data.

Table 5: R&D and credit constraints in WSEC, 2004, financially dependent firms

	Industry demand proxy:				
		Value added		Employment	Turnover
	Overall effect	Direct effect	Indirect effect	Overall effect	Overall effect
constrained (d)	–0.339*	–0.339		–0.373***	–0.322
	(0.185)			(0.142)	(0.206)
lnage	0.143**	0.115	0.028	0.158***	0.133**
	(0.061)			(0.057)	(0.063)
empl2to49 (d)	–0.484***	–0.397	–0.086	–0.501***	–0.482***
	(0.126)			(0.105)	(0.138)
empl50to250 (d)	–0.166	–0.051	–0.115	–0.190	–0.162
	(0.119)			(0.123)	(0.126)
listed (d)	–0.160	0.008	–0.168	–0.207	–0.146
	(0.174)			(0.191)	(0.173)
ExSale	0.319**	0.319		0.329	0.282
	(0.161)			(0.249)	(0.177)
foreign	0.019	–0.041	0.060	0.034	0.020
	(0.081)			(0.093)	(0.075)
UniGrade	0.319**	0.319		0.360**	0.307*
	(0.159)			(0.155)	(0.176)
dsales	0.322	0.163	0.159	0.390	0.271
	(0.255)			(0.621)	(0.251)
Industry demand^{-}	–3.248	–3.248		–1.739	–1.229
	(2.653)			(1.676)	(2.324)
Industry demand^{+}	2.215	2.215		0.319	1.424**
	(1.435)			(0.883)	(0.558)
BankFin	1.265		1.265	1.551	1.175
	(1.044)			(1.050)	(1.081)
overdue (d)	–0.101		–0.101	–0.126	–0.095
	(0.085)			(0.091)	(0.088)
CredSale	0.044		0.044	0.054	0.041
	(0.047)			(0.104)	(0.039)
audit (d)	0.043		0.043	0.054	0.040
	(0.048)			(0.052)	(0.048)
subsidies (d)	0.118		0.118	0.146	0.110
	(0.116)			(0.120)	(0.121)
No of obs.	1610			1610	1608
Log likelihood	–719.4			–722.3	–718.0
Rho	0.411			0.465	0.392
Wald test of rho=0	2.735*			3.509*	2.237

Note: Conditional marginal effects of R&D, reported at constrained=1. Country and industry dummies are not reported. Robust standard errors clustered by country, industry and year in parenthesis. ***, **, * denote statistical significance at 1%, 5% and 10% level respectively.
Source: Authors' calculations from BEEPs data.

We observe a very small share of credit constrained firms in the WSE countries, as only 3.5% of firms in 2004 did not qualify or were discouraged from taking a loan (the share in CSEE firms was 12.6%). It is clear that 2004 was a year with a generous credit market. Our small number of credit constrained firms destroys the explanatory power in the reduced form equation. Even the conventional features that capture creditworthiness, such as firm size and age, remain insignificant. As a result of this we find there is not much simultaneity between credit constraints and R&D, as can be seen from the rho coefficients.

The empirical evidence supports the opportunity cost theory, as the counter-cyclical R&D indicates that the opportunity cost effect of R&D dominates over the expected return effect of R&D. As there is less evidence of the counter-cyclicality of R&D investments in developed countries, it could be assumed that the opportunity cost argument is less relevant and the expected return argument more relevant for mature markets closer to technological frontier.

We test this argument by pooling the datasets on Eastern and Western European firms together and testing whether there are any statistically significant effects in the explanatory variables across countries with different levels of development. Regarding the aim of this paper the most important interactions for a country's level of development and explanatory variables are those with credit constraint and exogenous industry demand. Table 11 and Table 12 in the Appendix present the results. There is evidence that the effect of credit constraints on R&D is not significantly different across WSE or CSEE countries, but is statistically significantly different across countries with higher or lower levels of GDP per capita. However, while R&D is counter-cyclical to industry demand, this counter-cyclicality is often more pronounced in CSEE countries or countries with lower GDP per capita. These results confirm our earlier findings from the separate samples of firms from Eastern and Western Europe that the effect of credit constraints on R&D is more severe and R&D more counter-cyclical in Eastern Europe.

6. Robustness study: cyclicality of R&D at the industry level

What the model of Aghion et al. (2005, 2010) together with extensions for credit frictions predicts is that we should observe more pro-cyclicality in R&D in countries with less developed credit markets. However, our firm-level analysis revealed more counter-cyclicality in R&D in CSEE countries (with lower financial deepening, see Figure 1 than in WSE countries. As a next

single year, unlike the data for the CSEE countries which are spread over three consecutive rounds of survey and allow much richer variation in industry demand variables.

exercise we seek to test for this regularity in a simple industry level panel data framework. We make use of the Eurostat public database and collect data on the same range of countries and industries that were analysed in the previous sections at company level. The timespan of the data is from 1996–2007.

The proxy for R&D expenditures is calculated as a ratio where the industry's R&D expenditures are divided by the industry's investments. This means we can investigate the ratio of R&D investments that usually have a long-term nature and conventional investments in physical capital[9]. We use three different industry demand proxies: real growth in value added, real growth in turnover, and employment growth. The same industry level growth proxies were used in firm-level analysis.

Table 6 presents the descriptive statistics of the industry level data. While R&D expenditures are almost twice as high in the WSE countries as they are in the CSEE countries, value added and turnover growth have been much faster in the catching-up part of Europe. Interestingly, employment growth shows approximately the same average value in WSE and CSEE. We go on with the industry level analysis by regressing the share of R&D expenditures in investment with industry growth indicators and we control for industry and country level fixed effects. Table 7 presents the results of this industry-level analysis.

Table 6: Descriptive statistics of R&D expenditures, value added, turnover and employment growth, 1996–2007

	CSEEC		WSEC	
	Mean	Std. Dev.	Mean	Std. Dev.
R&D expenditures in investment	0.031	0.111	0.056	0.128
Real value added growth	0.071	0.190	0.014	0.111
Real turnover growth	0.071	0.115	0.029	0.103
Real employment growth	0.020	0.096	0.020	0.074

Source: Authors' calculations from Eurostat data.

The industry level analysis confirms the previous firm-level results. The relation between R&D expenditures and industry demand is negative and also sometimes statistically significant for the CSEE countries. The magnitude of this effect across demand indicators is quite large, as for example a 10%-point increase in industry level growth is related to a 0.2 to 0.7%-point fall in the ra-

[9]These two types of investment are not directly comparable as R&D expenditures also include labour costs and some of the R&D expenditures may be taken into account in the investment side, but their ratio still provides a valuable proxy for the trade-off between long- and short- term investments.

Table 7: R&D expenditures in investment explained by real value added, real turnover and employment growth, industry level 1996–2007

	Value added		Employment		Turnover	
	CSEEC	WSEC	CSEEC	WSEC	CSEEC	WSEC
AR(1)	0.228**	0.438***	-0.081***	0.420***	0.187	0.439***
	(0.103)	(0.128)	(0.027)	(0.079)	(0.132)	(0.129)
Industry demand	–0.019	–0.014	–0.024*	0.031	–0.066*	–0.017
	(0.014)	(0.019)	(0.014)	(0.046)	(0.037)	(0.015)
Constant	0.026***	0.034***	0.024***	0.038***	0.033***	0.034***
	(0.003)	(0.007)	(0.001)	(0.005)	(0.005)	(0.007)
No of obs	460	130	449	156	489	130
No of objects	70	22	70	29	70	22
Within group R2	0.083	0.108	0.007	0.117	0.041	0.109

Note: Country and industry level fixed effects estimates, robust standard errors in parenthesis. ***, **, * denote statistical significance at the 1%, 5% and 10% levels respectively.
Source: Authors' calculations from Eurostat data.

tio of R&D expenditures to investments in the CSEE groups[10]. The economic effect of the demand cycle for R&D on the mean value of the R&D ratio is notable, moving it from the average of 3.1% to 2.9–2.4% as a result of a 10%-point increase in industry growth. The results on WSE countries are mixed and statistically insignificant, but the evidence of R&D expenditures that emerges is rather counter-cyclical. Although we cannot test for the relevance of credit constraints at the industry-level due to the lack of cross-country comparable data, the results are robust to the earlier firm-level estimations.

Coming back to the argument of Aghion et al. (2005, 2010) for pro-cyclicality in R&D under credit constraints, we find conflicting evidence for this theory from the European sample. Given that the share of credit constrained companies is more than three times higher in Eastern Europe than in Western Europe (see Table 8 in Appendix) and that there is no statistically significant difference in how credit constraints hinder R&D in these regions (see Table 11 and 12), then according to the model of Aghion et al. (2005, 2010) we should have observed more pro-cyclicality of R&D in Western Europe than in Eastern Europe. However our results indicate exactly the opposite. This means the credit constraint argument seems not to be a relevant factor behind the cyclicality of R&D in Europe. The observed extensive R&D counter-cyclicality in Eastern Europe could arise from the high R&D opportunity costs there, as more conventional investments also have high returns (technology transfer via imitation). The less counter-cyclical R&D in Western Europe could arise from the timing of innovations for the period of high demand as predicted by the dynamic externalities argument in the model of

[10]Ouyang (2011) finds from industry level US data that a 10% point increase in output growth is related to a 2.6% decrease in R&D. Our elasticities are of a similar magnitude, although our dependent variable is not measured as R&D growth but as a ratio of R&D expenditures and total investments.

Barlevy (2007).

Another interesting result from this industry level exercise is that R&D expenditures seem to be much more persistent in Western than in Eastern Europe. Table 7 shows that R&D AR(1) terms differ by around two times across these country groups. There could be various explanations for the persistence of this difference in R&D. First, it may be assumed that the R&D projects in Western Europe are more long-term[11]. Second, R&D is something that must be done at any time in mature markets close to the technological frontier, whilst R&D investments have a lower priority in Eastern Europe where there is more room for productivity gain through imitation or market expansion. Keller (2004) surveys the empirical literature stating that foreign sources of technology are, relative to domestic knowledge creation, more important for poorer countries. Third, as a large amount of R&D expenditures go on employment costs, the tighter labour market regulation and higher lay-off costs in Western Europe contribute to the higher persistence of total R&D expenditures in these countries.

7. Conclusions

This paper sought to contribute to the discussion of the inference between business cycles and long-term growth by investigating the cyclicality of business sector R&D. The focus of the study has been on cross-country differences, investigating whether there are any regularities in the cyclicality of R&D activity across countries with different levels of development.

We have accounted for the financial frictions of R&D investments with a simultaneous estimation procedure, estimating a recursive probit model on firms' R&D and credit constraints. Our main empirical study made use of cross-sectional micro-data from the Business Environment and Enterprise Performance survey. The study proxied demand shocks with yearly industry output growth. However, we also performed an industry level panel data estimation of R&D cyclicality as a robustness test.

We find evidence of a negative relationship between R&D and industry demand fluctuations. This result is not in accordance with the effect of a firm's own sales on its R&D activity. Firms' sales growth has a positive and statistically significant effect on R&D, while this effect materialises equally impor-

[11] The industry decomposition of R&D could have a significant role here as well. Barlevy (2007) demonstrates that the cyclicality of R&D differs substantially across industries. For example there is little cyclicality of R&D in pharmaceuticals where the diffusion lags between discovery and implementation are long; but in contrast R&D is very cyclical in software and the computer equipment industry where diffusion lags are short.

tantly through indirectly lessening credit constraints and through directly creating more incentives or/and funds for R&D. However, this idiosyncratic demand proxy is probably endogenous to firms' R&D and should be interpreted as a firm's revenue generating power rather than as a proxy for exogenous demand shocks. We also find an intuitive effect of credit constraints on the R&D activity of firms, so that credit constraints directly decrease the propensity of a firm to be engaged in R&D and that indirectly the firm's sales, age, size and historically good credit records decrease its exposure to credit constraints, and this supports R&D.

Regarding the R&D cyclicality across countries with different levels of development, we find that R&D activities respond more counter-cyclically to demand shocks in less developed countries. The explanation behind this finding does not arise from the different level of financial deepening or financial constraints (as predicted by the model of Aghion et al. (2005, 2010), but presumably rather from the differences in the quality of R&D being done and the lower relevance of R&D investments for productivity growth in less developed countries. The R&D in high-income countries results in output that has higher potential in terms of market value, which makes the pro-cyclical timing of R&D investments (as modelled by Barlevy (2007)) more important in developed countries. The opportunity cost argument makes R&D in the less developed countries less relevant as the quality of the firms' own R&D is low and the imitative innovations like investments in new machinery and equipment also provide substantial productivity enhancing returns.

Another finding of our paper is that the effect of the business cycle on R&D is asymmetric — the response to negative demand shocks is stronger and more counter-cyclical than the response to positive demand shocks. The firms, particularly in CSEE countries, proved to be more inclined to conduct R&D at times of low demand. This evidence is in line with the opportunity cost argument, suggesting that recessions force firms to focus on a productivity enhancing agenda and in this way contribute to long-term economic growth.

References

Aghion, P.,Angeletos, G.-M., Banerjee, A., Manova, K., (2005). Volatility and Growth: Credit Constraints and Productivity-Enhancing Investment. NBER Working Papers, No. 11349, National Bureau of Economic Research, Inc.

Aghion, P.,Angeletos, G.-M., Banerjee, A., Manova, K., (2010). Volatility and growth: Credit constraints and the composition of investment. Journal of Monetary Economics, No. 57, 246–265.

Aghion, P., Ghion, P., Askenazy, P., Berman, N., Cette, G., Eymard, L., (2008). Credit Constraints and the Cyclicality of RD Investment: Evidence from France. Documents de Travail, No. 198, Banque de France.

Badia, M. M., Slootmaekers, V., (2008). The Missing Link Between Financial Constraints and Productivity. LICOS Discussion Papers 20808, LICOS - Centre for Institutions and Economic Performance, K.U.Leuven.

Barlevy, G., (2007). On the Cyclicality of Research and Development. American Economic Review, No. 97, 1131–1164.

Bovha-Padilla, S., Damijan, J. P., Konings, J., (2009). Financial Constraints and the Cyclicality of RD Investment: Evidence from Slovenia. LICOS Discussion Papers 23909, LICOS - Centre for Institutions and Economic Performance, K.U.Leuven.

Campello, M., Graham, J. R., Harvey, C. R., (2010). The real effects of financial constraints: Evidence from a financial crisis. Journal of Financial Economics, No. 97, 470–487.

Damijan, J. P., Kostevc, C., Rojec, M., (2008). Innovation and Firms Productivity Growth in Slovenia: Sensitivity of Results to Sectoral Heterogeneity and to Estimation Method. LICOS Discussion Papers, No. 20308, LICOS - Centre for Institutions and Economic Performance, K.U.Leuven.

Greene, W., (1998). Gender Economic Courses in Liberal Arts Colleges: Further Results. Journal of Economic Education, 291–300.

Groh, A. P., von Liechtenstein, H., (2009). How attractive is central Eastern Europe for risk capital investors? Journal of International Money and Finance, No. 28, 625–647.

Keller, W., (2004). International Technology Diffusion. Journal of Economic Literature, No. 42, 752–782.

Lee, M.-J., (2010). Micro-Econometrics: Methods of Moments and Limited Dependent Variables, Springer.

Maddala, G., (1983). Limited Dependent and Qualitative Variables in Econo, Cambridge University Press.

Masso, J., Vahter, P., (2008). Technological innovation and productivity in late-transition Estonia: econometric evidence from innovation surveys. European Journal of Development Research, No. 20, 240–261.

Monfardini, C., Radice, R., (2008). Testing Exogeneity in the Bivariate Probit Model: A Monte Carlo Study. Oxford Bulletin of Economics and Statistics, No. 70, 271–282.

Moulton, B. R., (1990). An Illustration of a Pitfall in Estimating the Effects of Aggregate Variables on Micro Unit. The Review of Economics and Statistics, No. 72, 334Ű-338.

Ouyang, M., (2007). On the cyclicality of RD: disaggregated evidence. Working Paper, No. 0707, Federal Reserve Bank of Cleveland.

Ouyang, M., (2011). On the cyclicality of RD. The Review of Economics and Statistics, No. 93.

Piga, C. A., Atzeni, G., (2007). RD Investment, Credit Rationing And Sample Selection. Bulletin of Economic Research, No. 59, 149–178.

Rafferty, M.C., (2003). Do Business Cycles Influence Long-Run Growth? The Effect of Aggregate Demand on Firm-Financed RD Expenditures. Eastern Economic Journal, No. 29, 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, No. 17, 553–569.

Ulku, H., (2004). RD, Innovation, and Economic Growth: An Empirical Analysis. IMF Working Papers, No. 04/185. International Monetary Fund.

Verspagen, B., (2006). Innovation and economic growth. In The Oxford Handbook of Innovation, ed. by J. Fagerberg, D. C. Mowery, and R. R. Nelson, Oxford University Press, Chap. 18, 487–513.

Walde, K., Woitek, U., (2004). RD expenditure in G7 countries and the implications for endogenous fluctuations and growth. Economics Letters, No. 82, 91–97.

Wilde, J., (2000). Identification of multiple equation probit models with endogenous dummy regressors. Economics Letters, No. 69, 309–312.

Appendices

Table 8: Summary statistics, 2001–2007

Variable	CSEEC			WSEC		
	Mean	Std.Dev.	N	Mean	Std.Dev.	N
RD	0.215	0.411	7127	0.143	0.35	2900
product innovation	0.408	0.491	7127	0.233	0.423	3177
constrained	0.126	0.332	7127	0.035	0.184	3177
age	12.527	4.537	7127	20.483	19.133	3177
empl2to49	0.678	0.467	7122	0.786	0.41	3177
empl50to250	0.229	0.42	7122	0.127	0.334	3177
empl250to10000	0.093	0.291	7122	0.086	0.281	3177
dsales	0.16	0.402	7127	0.04	0.193	3177
UniGrade	0.189	0.248	6963	0.154	0.247	3136
listed	0.053	0.224	7127	0.011	0.104	3177
ExSale	0.144	0.282	7114	0.072	0.194	3175
ForOwned	0.133	0.339	7127	0.09	0.286	3177
ForCapShare	0.123	0.309	7110	0.079	0.254	3177
BankFin	0.143	0.29	5478	0.179	0.314	2462
overdue	0.072	0.258	7127	0.034	0.181	3177
CredSale	0.497	0.409	7090	0.481	0.405	3166
audit	0.508	0.5	7127	0.628	0.483	3177
subsidies	0.119	0.324	7127	0.133	0.34	3177
dsales	0.16	0.402	7127	0.04	0.193	3177
VA	0.072	0.055	7127	0.02	0.033	3177
VA^+	0.082	0.047	6534	0.032	0.028	2429
VA^-	-0.033	0.028	593	-0.018	0.019	748
LAB	0.027	0.059	6993	0.018	0.033	3177
LAB^+	0.049	0.048	4998	0.02	0.047	2283
LAB^-	-0.031	0.043	1970	-0.021	0.009	894
TURN	0.098	0.13	6549	0.037	0.053	3171
$TURN^+$	0.116	0.123	5856	0.061	0.041	2311
$TURN^-$	-0.056	0.066	693	-0.026	0.017	860

Note: CSEE countries are the Czech Republic, Estonia, Hungary, Poland, Slovakia, Slovenia, Latvia, Lithuania, Bulgaria, Romania and Croatia; WSE countries are Germany, Ireland, Spain, Portugal and Greece.
Source: Authors' calculations from BEEPs data.

Table 9: R&D and credit constraints without asymmetric demand effects in CSEEC, 2001–2007

	Total sample			Financially dependent firms		
Industry demand proxy:	Value added	Employment	Turnover	Value added	Employment	Turnover
Rconstrained (d)	–0.707***	–0.494*	–0.472	–0.390**	–0.307*	–0.199
	(0.120)	(0.264)	(0.381)	(0.197)	(0.179)	(0.194)
lnage	0.045	0.046*	0.016	0.064**	0.066**	0.027
	(0.029)	(0.026)	(0.025)	(0.031)	(0.031)	(0.025)
empl2to49 (d)	–0.308***	–0.294***	–0.314***	–0.286***	–0.276***	–0.290***
	(0.052)	(0.042)	(0.045)	(0.045)	(0.042)	(0.042)
empl50to250 (d)	–0.114***	–0.113***	–0.116***	–0.106***	–0.104***	–0.105***
	(0.035)	(0.031)	(0.031)	(0.037)	(0.034)	(0.033)
listed (d)	0.088*	0.098**	0.107**	0.094*	0.101*	0.111**
	(0.049)	(0.043)	(0.046)	(0.054)	(0.052)	(0.053)
ExSale	0.048	0.061	0.058	0.068*	0.074*	0.070*
	(0.041)	(0.037)	(0.038)	(0.041)	(0.041)	(0.040)
foreign	0.041	0.047	0.050	0.036	0.045	0.050
	(0.030)	(0.031)	(0.034)	(0.033)	(0.034)	(0.033)
UniGrade	0.042	0.032	0.045	0.093**	0.082**	0.101**
	(0.038)	(0.036)	(0.038)	(0.040)	(0.040)	(0.040)
dsales	0.157***	0.139***	0.122***	0.097***	0.087**	0.087***
	(0.035)	(0.040)	(0.038)	(0.035)	(0.034)	(0.033)
Industry demand	–0.824**	–0.404**	–0.068	–0.880**	–0.371*	–0.082
	(0.336)	(0.204)	(0.102)	(0.389)	(0.206)	(0.132)
BankFin	0.096**	0.073*	0.066	0.160***	0.135**	0.101
	(0.045)	(0.043)	(0.044)	(0.059)	(0.059)	(0.065)
overdue (d)	–0.097***	–0.087***	–0.085**	–0.077**	–0.068**	–0.052
	(0.020)	(0.028)	(0.037)	(0.031)	(0.030)	(0.033)
CredSale	0.052**	0.034	0.028	0.070*	0.056*	0.039
	(0.025)	(0.024)	(0.025)	(0.037)	(0.031)	(0.029)
audit (d)	0.043**	0.025	0.020	0.028	0.023	0.014
	(0.019)	(0.023)	(0.025)	(0.020)	(0.018)	(0.014)
subsidies (d)	0.104***	0.079*	0.088	0.083**	0.071*	0.059
	(0.032)	(0.045)	(0.066)	(0.038)	(0.037)	(0.042)
No of obs.	5330	5226	4924	3627	3556	3317
Log likelihood	–4255.0	–4142.2	–3868.4	–3144.1	–3065.5	–2837.8
Rho	0.879	0.693	0.685	0.609	0.528	0.414
Wald test of rho=0	7.786***	3.375*	1.647	4.687**	4.474**	2.185

Note: Conditional marginal effects of R&D, reported at constrained=1. See Data section for the set of variables included in R&D and constrained equation. Country and industry dummies are not reported. Robust standard errors clustered by country, industry and year in parenthesis. ***, **, * denote statistical significance at 1%, 5% and 10% level respectively.
Source: Authors' calculations from BEEPs data.

Table 10: R&D and credit constraints without asymmetric demand effects in WSEC, 2004

	Total sample			Financially dependent firms		
Industry demand proxy:	Value added	Employment	Turnover	Value added	Employment	Turnover
constrained (d)	–0.229	–0.437**	–0.125	–0.332*	–0.375***	–0.286
	(0.296)	(0.217)	(0.327)	(0.186)	(0.137)	(0.232)
lnage	0.077	0.110*	0.059	0.145**	0.160***	0.125*
	(0.052)	(0.057)	(0.053)	(0.061)	(0.054)	(0.066)
empl2to49 (d)	–0.411**	–0.519***	–0.358*	–0.474***	–0.501***	–0.457***
	(0.160)	(0.136)	(0.210)	(0.122)	(0.103)	(0.153)
empl50to250 (d)	–0.099	–0.155*	–0.072	–0.165	–0.195	–0.142
	(0.078)	(0.094)	(0.086)	(0.116)	(0.120)	(0.120)
listed (d)	–0.114	–0.190	–0.085	–0.175	–0.218	–0.134
	(0.107)	(0.119)	(0.113)	(0.177)	(0.188)	(0.170)
ExSale	0.221*	0.296**	0.164	0.316*	0.341**	0.265
	(0.124)	(0.124)	(0.134)	(0.185)	(0.146)	(0.639)
foreign	–0.032	-0.032	-0.036	0.026	0.036	0.015
	(0.059)	(0.088)	(0.047)	(0.085)	(0.100)	(0.076)
UniGrade	0.157*	0.224**	0.128	0.319**	0.361**	0.289
	(0.093)	(0.104)	(0.096)	(0.137)	(0.148)	(0.418)
dsales	0.229	0.386	0.151	0.316	0.394	0.238
	(0.200)	(0.255)	(0.188)	(0.245)	(0.640)	(0.250)
Industry demand	0.555	–0.619	0.591	0.965	–0.233	1.126
	(0.532)	(0.614)	(0.412)	(0.781)	(0.650)	(0.835)
BankFin	0.517	1.087	0.288	1.245	1.583	1.001
	(0.717)	(0.896)	(0.694)	(1.023)	(1.003)	(1.056)
overdue (d)	–0.058	–0.116	–0.034	–0.100	–0.129	–0.081
	(0.068)	(0.080)	(0.073)	(0.083)	(0.089)	(0.083)
CredSale	0.013	0.029	0.007	0.043	0.055	0.035
	(0.021)	(0.031)	(0.018)	(0.042)	(0.074)	(0.048)
audit (d)	0.022	0.049	0.012	0.042	0.055	0.034
	(0.033)	(0.047)	(0.031)	(0.047)	(0.052)	(0.044)
subsidies (d)	0.047	0.108	0.025	0.116	0.149	0.093
	(0.072)	(0.099)	(0.066)	(0.114)	(0.117)	(0.116)
No of obs.	2423	2423	2419	1610	1610	1608
Log likelihood	–947.6	–947.6	–943.5	–721.7	–722.9	–718.7
Rho	0.349	0.539	0.237	0.405	0.470	0.355
Wald test of rho=0	1.303	4.803**	0.325	2.752*	3.774*	1.788

Note: See note and source in Table 9.

Table 11: R&D and credit constraints, interactions with country group dummy (WSEC=1, CSEEC=0), 2001–2007, total sample

	Industry demand proxy:		
	Value added	Employment	Turnover
Constrained (d)	–0.233	–0.258	–0.138
	(0.205)	(0.216)	(0.152)
WSEC (d)	–0.207**	–0.145	–0.235**
	(0.094)	(0.116)	(0.092)
Constrained*WSEC (d)	–0.052	–0.065	–0.056
	(0.047)	(0.046)	(0.049)
lnage	0.038	0.045*	0.008
	(0.025)	(0.025)	(0.021)
lnage*WSEC	0.065**	0.061*	0.085***
	(0.033)	(0.033)	(0.033)
empl2to49 (d)	–0.268***	–0.269***	–0.284***
	(0.043)	(0.042)	(0.041)
empl2to49*WSEC (d)	–0.127*	–0.134*	–0.104*
	(0.069)	(0.075)	(0.059)
empl50to250 (d)	–0.097***	–0.101***	–0.100***
	(0.026)	(0.026)	(0.025)
empl50to250*WSEC (d)	–0.014	–0.008	0.005
	(0.064)	(0.069)	(0.057)
listed (d)	0.089**	0.091**	0.105***
	(0.038)	(0.038)	(0.039)
listed*WSEC (d)	–0.158***	–0.167***	–0.160***
	(0.054)	(0.054)	(0.048)
ExSale	0.034	0.040	0.037
	(0.032)	(0.033)	(0.033)
ExSale*WSEC	0.363***	0.369***	0.301***
	(0.122)	(0.131)	(0.113)
foreign	0.032	0.033	0.031
	(0.026)	(0.029)	(0.027)
foreign*WSEC	–0.085	–0.089	–0.087
	(0.071)	(0.076)	(0.068)
UniGrade	0.058*	0.052*	0.070**
	(0.030)	(0.030)	(0.033)
UniGrade*WSEC	0.097	0.117*	0.051
	(0.063)	(0.065)	(0.056)
dsales	0.136***	0.134***	0.104***
	(0.042)	(0.044)	(0.034)
dsales*WSEC	0.162	0.207*	0.120
	(0.104)	(0.114)	(0.085)
Industry demand negative	–2.016**	–1.608**	–0.866**
	(0.964)	(0.652)	(0.340)
Industry demand positive	–0.497	–0.164	0.048
	(0.359)	(0.125)	(0.113)
(Industry demand negative)*WSEC	0.983	1.832	1.831
	(0.858)	(1.369)	(1.414)
(Industry demand positive)*WSEC	2.587*	–0.967	0.948***
	(1.326)	(0.780)	(0.330)
BankFin	0.044	0.046	0.028
	(0.039)	(0.040)	(0.027)
BankFin*WSEC	0.478	0.520	0.354
	(0.384)	(0.398)	(0.301)
overdue (d)	–0.048	–0.052	–0.038
	(0.031)	(0.032)	(0.027)
overdue*WSEC (d)	–0.021	–0.023	–0.015
	(0.025)	(0.027)	(0.019)
CredSale	0.020	0.021	0.011
	(0.017)	(0.017)	(0.011)
CredSale*WSEC	–0.020	–0.021	–0.012
	(0.021)	(0.023)	(0.015)
audit (d)	0.008	0.009	0.004
	(0.011)	(0.013)	(0.007)
audit*WSEC (d)	0.031	0.033	0.023
	(0.026)	(0.027)	(0.020)
subsidies (d)	0.036	0.042	0.031
	(0.030)	(0.035)	(0.028)
subsidies*WSEC (d)	0.014	0.014	0.004
	(0.026)	(0.028)	(0.015)
No of obs.	7753	7649	7343
Log likelihood	–5289.1	–5169.1	–4877.1
Rho	0.410	0.441	0.318
Wald test of rho=0	2.409	2.570	2.100

Note: See note and source in Table 9.

Table 12: R&D and credit constraints, interactions with country's GDP per capita in PPS (in thousands of PPS units), total sample

	Industry demand proxy:		
	Value added	Employment	Turnover
Constrained (d)	0.006	–0.012	0.045
	(0.110)	(0.116)	(0.090)
GDP	0.433	1.476	0.213
	(0.464)	(0.943)	(0.974)
Constrained*GDP	–1.407***	–1.179***	–1.265***
	(0.405)	(0.367)	(0.421)
lnage	0.072***	0.078***	0.063***
	(0.024)	(0.022)	(0.020)
lnage*GDP	–0.255	–0.353	–0.301
	(0.308)	(0.284)	(0.274)
empl2to49 (d)	–0.328***	–0.314***	–0.335***
	(0.044)	(0.044)	(0.042)
empl2to49*GDP	0.126	–0.013	0.033
	(0.492)	(0.488)	(0.462)
empl50to250 (d)	–0.107***	–0.097***	–0.091***
	(0.032)	(0.031)	(0.031)
empl50to250*GDP	0.043	–0.103	–0.284
	(0.414)	(0.430)	(0.457)
listed (d)	0.098*	0.112**	0.120**
	(0.057)	(0.052)	(0.058)
listed*GDP	–0.222	–0.512	–0.541
	(0.573)	(0.602)	(0.698)
ExSale	0.132**	0.127**	0.083
	(0.061)	(0.060)	(0.061)
ExSale*GDP	–0.438	–0.340	0.242
	(0.695)	(0.705)	(0.692)
foreign	0.017	0.015	0.022
	(0.035)	(0.034)	(0.037)
foreign*GDP	0.027	–0.071	–0.226
	(0.495)	(0.520)	(0.576)
UniGrade	0.101**	0.108***	0.117***
	(0.043)	(0.041)	(0.040)
UniGrade*GDP	0.057	–0.130	0.092
	(0.553)	(0.529)	(0.560)
dsales	0.218***	0.221***	0.171***
	(0.051)	(0.054)	(0.040)
dsales*GDP	–0.789*	–0.912**	–0.528
	(0.410)	(0.420)	(0.348)
Industry demand negative	–2.468	–1.904***	–0.033
	(2.973)	(0.737)	(0.990)
Industry demand positive	0.536	–0.118	0.053
	(1.272)	(0.237)	(0.161)
(Industry demand negative)*GDP	–0.643	15.023**	–13.692
	(3.213)	(7.279)	(12.713)
(Industry demand positive)*GDP	–17.287	0.551	3.256
	(31.331)	(3.426)	(2.141)
BankFin	0.029	0.027	0.020
	(0.027)	(0.026)	(0.023)
BankFin*GDP	0.097	0.105	0.036
	(0.225)	(0.227)	(0.157)
overdue (d)	–0.027	–0.024	–0.017
	(0.024)	(0.022)	(0.019)
overdue*GDP	–0.116	–0.142	–0.109
	(0.114)	(0.136)	(0.132)
CredSale	0.011	0.011	0.007
	(0.012)	(0.012)	(0.009)
CredSale*GDP	–0.020	–0.026	–0.025
	(0.079)	(0.078)	(0.057)
audit (d)	0.014	0.014	0.011
	(0.014)	(0.014)	(0.013)
audit*GDP	–0.078	–0.078	–0.078
	(0.081)	(0.081)	(0.092)
subsidies (d)	0.020	0.019	0.014
	(0.021)	(0.021)	(0.018)
subsidies*GDP	0.020	0.043	0.047
	(0.083)	(0.084)	(0.073)
No of obs.	7753	7649	7343
Log likelihood	–5435.4	–5300.5	–5001.7
Rho	0.219	0.222	0.154
Wald test of rho=0	1.416	1.315	0.811

Note: See note and source in Table 9.

Working Papers of Eesti Pank 2011

No 1
Jaanika Meriküll
Labour Market Mobility During a Recession: the Case of Estonia

No 2
Jaan Masso, Jaanika Meriküll, Priit Vahter
Gross Profit Taxation Versus Distributed Profit Taxation and Firm Performance: Effects of Estonia's Corporate Income Tax Reform

No 3
Karin Kondor, Karsten Staehr
The Impact of the Global Financial Crisis on Output Performance Across the European Union: Vulnerability and Resilience

No 4
Tairi Rõõm, Aurelijus Dabušinskas
How Wages Respond to Shocks: Asymmetry in the Speed of Adjustment