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Credit constraints and R&D over the boom and bust: Firm-level evidence from Central and Eastern Europe

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ABSTRACT

This paper studies the effect of credit constraints on R&D over the recent boom and bust episode in Central and Eastern European countries (CEECs). Given that financial and venture capital markets in CEECs are thin in comparison to those in high-income economies, it is proposed that credit constraints have a significant adverse effect on R&D activity in these countries. The paper uses three waves of Business Environment and Enterprise Performance Survey (BEEPS) data between 2005 and 2013 on manufacturing firms from ten CEECs. We find that credit constraints have a substantial effect on R&D engagement, as the probability of credit constrained firms undertaking R&D activities is around 30 % lower than for other firms. The adverse effect of credit constraints for R&D emerges during the years of fast economic growth.

1. Introduction

Although financing constraints play a key role in R&D commitment (Aghion et al., 2010), the evidence on the effect of credit constraints on innovation or technological investments over the business cycle is only scattered and often conflicting. There is evidence that the financing of innovative firms suffered relatively less during and after the Great Recession (Lee et al., 2015) and that high-tech exporters and innovative firms faced stronger financing constraints during the recession (Lööf and Nabavi, 2016; Giebel and Kraft, 2018).

The countries in Central and Eastern Europe have received less attention in the literature of R&D financing, and there is very little evidence on the role of credit constraints in the low level of R&D activity in these countries. Moreover, CEECs have less developed financial and venture capital markets (Brown et al., 2011), and have had very volatile economic growth.

This paper studies the effect of credit constraints on R&D activity over the boom and bust in Central and Eastern Europe in 2005-2013. Notably, there is no consensus in the theoretical and empirical literature on the counter- or pro-cyclicality of R&D activity and the role credit constraints play in it. The paper seeks answers to two research questions: How much do credit constraints hamper manufacturing firms' R&D in CEECs and has the role of credit constraints for R&D changed over the last boom-bust episode? The contribution of the paper is twofold. First, it provides comparative firm-level evidence on the effect of credit constraints on R&D engagement in CEECs. Second, the paper seeks to reveal whether the role of credit constraints for R&D differs over periods of fast and slow growth.

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The study finds that credit constraints substantially hamper R&D activity in CEECs. Under credit constraints, the firms' probability of undertaking R&D drops by 32 %. This effect is considerably higher as compared to evidence from high-income countries. The R&D activity in CEECs is procyclical and this implies that credit constraints bind in times of economic growth, but not in times of recession. Credit constraints hampered R&D activity especially during the long period of vast economic growth before the Great Recession, and this has had a role in the low R&D activity in CEECs. Our findings corroborate the line of empirical literature that finds R&D to be procyclical and the effect of credit constraints on technological investments to be less severe during the Great Recession (Lee et al., 2015).

The paper is organised as follows. Section 2 gives some background on business R&D in CEECs and reviews literature on cyclicality, financial constraints and R&D activity with reference to the context of CEECs. Section 3 explains the data and the empirical methodology. Section 4 presents and discusses the results, and the last section concludes.

2. Background of the study and related literature

2.1. The evolution of business R&D in central and Eastern Europe

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

There are many factors, other than credit constraints, that have restrained R&D investing in CEECs, including capital account controls, industry structure and institutions.[2] Larrain and Stumpner (2017) show that capital account liberalisation has contributed to a higher demand for capital and higher productivity in firms. Only the Baltic States had a high degree of capital account liberalisation throughout the transition period; most of the other countries liberalised their capital accounts in the early 2000s, but the capital account openness index in Poland is still very low (Larrain and Stumpner, 2017). The structure of the industry also plays a role, as employment in the high technology sector is lower than in the EU15 in most of the CEECs (Eurostat series htec_emp_nat2). One important institutional factor that has contributed to poor business R&D expenditures in the national innovation system is that R&D in these countries was mostly focused on the military sector before the market reforms (Freeman, 2006).

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

The strong growth before the crisis and the sudden GDP decline in the crisis year of 2009 were similar in most of the countries, while the dynamics of the recovery have varied, with some countries facing a much more sluggish recovery.

Most of the countries have experienced notable growth in R&D expenditures, while there is hardly any evidence that R&D expenditures substantially increased or decreased in response to the recession in 2009. There is some evidence of a decline in R&D expenditure in 2009 in the Czech Republic, Latvia and Lithuania, but as the time series are in general very volatile, these developments are not necessarily related to the recession. In sum, there is strong evidence of a boom-bust growth episode in these countries, but no clear evidence of pro- or counter-cyclicality in R&D expenditure at the aggregate level.

CEE firms use bank financing much less and internal funds much more for investments (see Fig. A1 in the Appendix for the financing structure of fixed and working assets). This implies that firm investments are less dependent on the availability of external financing in CEECs and are thus likely to have been affected less by the credit crunch in 2009. Fig. 1 shows that the loan stock increased in all the CEECs during the period analysed, but the growth rate has slowed and the loan stock even declined in some countries in more recent years.

The link between R&D expenditure and research output is quite weak in Central and Eastern Europe. Aristovnik (2014) shows that CEECs have the lowest effectiveness of R&D expenditure in Europe as the number of patents produced is very low given inputs like R&D expenditure, research personnel and employment in the high-tech sector. According to the European Commission (2014) innovation scoreboard, the CEECs lag behind Western Europe in most of the innovation indicators, especially in terms of economic effects, though they perform well in research inputs like human resources.

[1] The gap in R&D expenditures stems mostly from the intensive and not from the extensive margin, according to the micro-data used in this paper. The share of companies conducting R&D is 18.3% in CEECs and 19.2% in Western and Southern European countries in the BEEPS data for 2005 (see the notes of Figure A.1 in the Appendix for the list of countries covered). However, the median level of annual spending on R&D was about 50 000 USD (mean about 170 000 USD) in CEECs and 100 000 USD (mean about 380 000 USD) in Western and Southern Europe.

[2] We are grateful to an anonymous referee for pointing out these possible reasons.

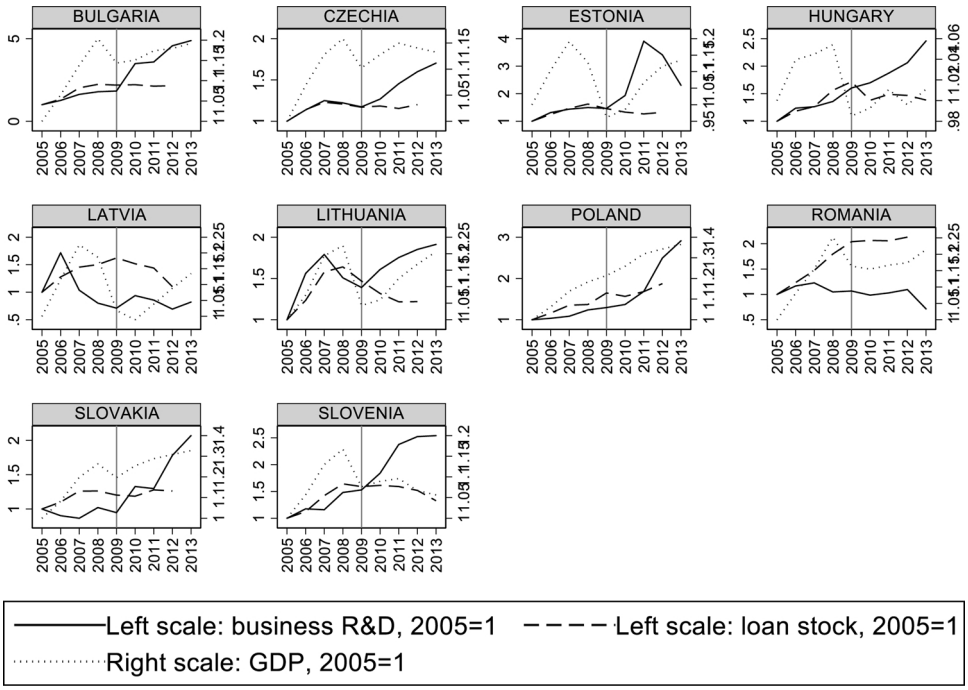

Fig. 1. Real business R&D expenditures, real business loan stock and real GDP in 2005 prices, 2005–2013.
Source: Authors' calculations from Eurostat data; R&D series name rd_e_berdindr2; loan stock of non-financial corporations name nasa_f_bs; GDP series name nama_10_gdp;.

2.2. R&D financing

There are two types of market failure that lead to R&D being underfinanced (Hall, 2002; Hall and Lerner, 2010). First, as knowledge is non-rival, firms will invest less in R&D than is socially optimal. To support R&D, governments protect intellectual property and establish tax incentives and subsidies. Second, external financing for R&D is much more costly than internal financing. Even venture capital cannot resolve market failure for projects with a highly uncertain outcome (Hall, 2002; Hall and Lerner, 2010).

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

Internal funds have been the primary financing source for R&D since the very beginning of the industrial revolution (Bakker, 2013). Small and newly established firms in particular are prone to financing constraints for R&D projects (Brown et al., 2009, 2012; Martinsson, 2010). While the financing constraints for investments in general have declined over recent decades, the R&D financing constraints remained high (Brown and Petersen, 2009). Efthyvoulou and Vahter (2014) show that financing constraints have a more pronounced negative effect on innovation performance among production firms and among non-exporters.

The structure of R&D financing varies across countries. In the US and UK, firms rely more on external equity, while continental European firms rely more on bank financing (Brown et al., 2009, 2012). Brown et al. (2012) show that external equity issues are also important sources of R&D financing and especially so for young firms. Brown and Petersen (2011) stress cash holdings as an important factor for R&D financing, since R&D investments have high adjustment costs, and so cash holdings are accumulated to ensure that finances are always available to maintain these investments irrespective of any external financing shocks. For the same reason, even large and successful high-tech firms hold substantial cash on their balance sheets (Bakker, 2013; Hall, 2002; Hall and Lerner, 2010). Brown et al. (2012) find that all the variables, stock issues, cash holdings and cash flows, are important for R&D financing.

Only a few studies address the role of financing constraints for R&D activity in transition or developing economies. Hölzl and Janger (2014) find that financing constraints are the most important barriers to innovation in Eastern Europe, while in countries close to the technological frontier, knowledge and skill barriers are more important than financing constraints.[3] Männasoo and Meriküll

[3] The Central and Eastern European countries are divided into two groups in this study. Half of the countries fit into the group of countries with

(2014) find credit constraints to be severe for R&D financing in Central and Eastern Europe. In a similar manner, Hall and Maffioli (2008) report that financing constraints have been perceived as one of the most important factors holding back R&D investments in Latin American and Caribbean countries. Coad et al. (2016) find that innovation in high productivity firms is hampered most by shortages of skilled personnel, while the availability and cost of finance affect innovation in firms across the whole productivity distribution. Czarnitzki (2006) shows that financing constraints are more severe for R&D in Western Germany than in Eastern Germany, which is a consequence of the large government subsidies for R&D in the East. According to the author, this result shows that the market for private R&D financing is dysfunctional in Eastern Germany.

This paper tests whether credit constraints hamper R&D in CEECs. The authors expect that credit constraints hold back R&D activity in CEECs for multiple reasons. The venture capital markets are less developed and firms rely on internal financing. Firms in CEECs are young, small and more distant from the technological frontier.

2.3. R&D activity over the business cycle

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

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

Barlevy (2007) model suggests that R&D expenditures are procyclical, that is, the firms concentrate their inventions in periods of economic growth because of dynamic positive externalities. The idea of this model is that the non-rivalry of inventions means that other firms also benefit from the invention, but the benefits to other firms occur with some delay, so that firms want to appropriate the benefits of the invention as much as possible by concentrating inventions in the time of economic growth. There are many country-level empirical studies that suggest that R&D is procyclical (see Ouyang (2011) for an excellent survey). However, there are also opposite results, especially when the role of credit constraints is taken into account. Aghion et al. (2010) provide empirical support for their model by using OECD country-level data. They demonstrate that the share of long-term structural investments in countries with less developed financial systems is much more dependent on exogenous commodity price shocks.

Lee and Noh (2009) set up a model for R&D intensity, which is determined by consumer preferences or demand-pull factors in quality and price, and firm technology-push factors related to technological competence and the appropriability of R&D in terms of market share. Their theoretical propositions and empirical test on the Korean manufacturing industry in 1991–1996 shows a positive correlation between R&D intensity and concentration. Taking a sample of German firms for 2001–2013, Rammer and Schubert (2016) report a sharp contraction in the number of firms conducting innovation and R&D even while there was substantial growth in overall innovation and R&D expenditures. The concentration process is mainly driven by smaller firms exiting R&D and innovation activity. Their sample period covers the years of the global financial crisis, but Rammer and Schubert (2016) do not find the recession to be the underlying cause for R&D concentration, which is a trend that has picked up more strongly in the post-crisis period.

There are only a few papers that study R&D cyclicality at the firm level.[4] Aghion et al. (2012) use French firm-level data and show R&D investments to be countercyclical for firms with no credit constraints, while R&D investments are procyclical for credit constrained firms. They measure credit constraints as reported payment incidence, the cycle as firm-level growth, and R&D as R&D investment and not total R&D expenditure. They also demonstrate that the effect of the cycle on R&D is asymmetric for credit constrained firms; the R&D investments of these firms fall proportionately more into recession times than they increase during upturns. Beneito et al. (2014) obtain a similar result using Spanish firm-level panel data. In addition, they show that credit constraints matter much less for the cyclicality of R&D in family-owned and group-affiliated firms. This result suggests that family-owned and group-affiliated firms rely much more on internal resources in their R&D financing.

Hirschey et al. (2012) investigate the evolution of corporate R&D spending in the US from 1976 to 2010 and do not find evidence of reduced R&D intensity from the two episodes of economic downturn, the tech bubble in 2000–2002 and the global financial crisis 2008-2010.

There are even fewer studies on firm R&D financing that focus on the business cycle or boom and bust episodes. Lee et al. (2015)

(*footnote continued*)
low technology intensity and severe credit constraints, while the other half fall into the group closer to the technological frontier, where financing constraints are less severe. This also illustrates the heterogeneity of R&D efforts in CEECs, which is why it is important to introduce country dummies in our R&D equation on pooled data (see the section on Data and Methodology).

[4] There are a number of papers that demonstrate a decline in firms' innovation activity during a recession (Archibugi and Filippetti, 2011; Archibugi et al., 2013), but they do not study the role of financing constraints in this decline.

show that innovative firms have impaired access to external financing in general, while the tightening of credit conditions has been stronger for non-innovative firms than for innovative firms during and after the Great Recession. Their results imply that the financing gap between innovative and non-innovative firms in general credit conditions narrowed during and after the recession.[5] Unlike in the previous study, Lööf and Nabavi (2016) find that high-tech exporters face stronger financing constraints during a recession than medium and low-tech firms. They use panel data from Sweden that cover only exporting firms. Similarly, Giebel and Kraft (2018), on a panel of German manufacturing firms, find that during the Great Recession innovative firms reduced their capital investments more than non-innovative firms and that a decline in capital investments was present only for firms using external financing for investment and not for firms using internal funds.

This paper tests whether the adverse effect of credit constraints on R&D activity has changed over the business cycle. The related literature does not give a clear indication of whether this relationship does or does not change in CEECs during a recession. The Great Recession had severe repercussions in most of the CEECs, so it can be expected that the adverse effect of credit constraints on R&D became even stronger during the recession. The internal funds for R&D financing dried up and access to financing worsened substantially during the credit crunch, which suggests that the adverse effect of credit constraints on R&D increased in the recession. However, as CEE firms rely more on internal funds in their financing, the role of the credit cycle in R&D activity can also be limited, as other factors determine the decision about whether to engage in R&D.

3. Data and methodology

This paper employs data from the Business Environment and Enterprise Performance Survey (BEEPS) run by the EBRD and the World Bank. The BEEPS data cover a wide set of countries from Eastern Europe and Central Asia (see http://ebrd-beeps.com/ for more information about the survey). Three consecutive waves of the BEEPS have been used: 2005, 2009 and 2012/2013, and the data used are from ten countries from Central and Eastern Europe: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. This group of countries was used as they shared quite a similar transitory process in fighting for their position on European and global markets. Earlier waves were not considered as they had low samples. The survey contains a representative sample of private companies in these countries.

This paper observes manufacturing firms, the main contributors to business R&D[6], and forms a more homogeneous sample than the whole business sector. The size threshold of at least five employees has been used since 2009, while there was an age threshold of at least three years before 2009. Given these changes in the methodology, only firms with at least five employees and at least three years of history in operation are used in this paper. Quota sampling was used in 2005 and random stratified sampling has been used since 2009. The probability weights have been available since 2009, but the weights have not been applied because of occasional very high weight values and because of our empirical specification where we control for strata like country, industry and firm size.

The BEEPS data collect a wide set of information about innovation, access to finance, firms' background, and the business environment. R&D activity is defined as a binary variable reflecting whether a firm is committed to R&D or not.[7] Access to finance is available as a binary variable; firms are asked whether they have applied for a loan and whether their application has been rejected. Credit constrained firms are defined as those whose application for a loan was rejected or who were discouraged from borrowing.[8] The direct measure of credit constraints is the strength of this database and, unlike the indirect cash-flow based measure, it provides a clear indication whether or not firms had problems with access to loans.

The objective of this paper is to study how credit constraints hamper R&D activity. However, as the decision to engage in R&D and the availability of finance are determined simultaneously, the credit constraints will be endogenous in the R&D equation. We address the endogeneity of credit constraints in the R&D equation by estimating a simultaneous model. Given our binary measure of these two key variables, the following recursive bivariate model is estimated (Cameron and Trivedi, 2010):

$$R\&D\ activity^{*} = x'_1\beta_1 + \gamma Credit\ constrained + \varepsilon_1$$

$$Credit\ constraints^{*} = x'_2\beta_2 + \varepsilon_2 \quad (1)$$

R&D activity* is the unobserved latent variable of R&D activity and *Credit constraints** is the unobserved latent variable of credit constraints. Instead of the latent variables, the binary variables are observed $y_i = 1$ if $y_i^{*} > 0$ and yi = 0 otherwise, for i = 1, 2 where y1 denotes R&D activity and y2 Credit constraints. The correlation between ε1 and ε2 is expected to be non-zero due to the simultaneous determination of R&D and credit constraints.

Maximum likelihood jointly estimates the two equations and pools all ten countries over three survey waves.

x'_1 and x'_2 denote the set of explanatory variables in the equations. There is a common set of firm characteristics that affect both R&D activity and credit constraints: log firm age, firm size groups, share of foreign ownership, country dummies and wave dummies. The set of x'_1 contains additional explanatory variables that affect only R&D activity, these are the competition characteristics, technology-push and demand-pull factors, which are traditionally used to explain R&D and innovation. The competition

[5] They also note that these results may be specific to their database of SMEs from the UK, and Brown et al. (2012) show that R&D firms from the UK use external equity much more and bank debt much less for financing than do firms in the rest of Europe.

[6] According to Eurostat, 53% of total business R&D expenditures were made by manufacturing companies in 2012 (Eurostat: series name rd_e_berdindr2).

[7] R&D expenditure data are available only in wave 2005, while the binary variable of R&D activity is available for all the survey rounds.

[8] Brown et al. (2011) emphasise the large share of credit-discouraged firms in CEECs.

characteristics are proxied by whether firms consider anticompetitive practices to be a serious obstacle to business; technology-push by the share of firms' employees with higher education and firms' estimation about qualified staff being the main obstacle to business; and demand-pull by sales growth at the firm level.

The set of x'_2 contains additional explanatory variables that affect only credit constraints but not R&D activity. These variables are the instruments that address the endogeneity of credit constraints in the R&D activity equation and identify the effect of credit constraints on R&D. The choice of instruments is motivated by the theory and the related literature and the validity of instruments and the exclusion restriction are also empirically evaluated. The following three variables have been used as instruments:

- The proxy for the supply of credit. It is measured as the firms' assessment whether access to finance is an obstacle to the operations of the firm. This is an ordered variable covering categories from no obstacle to very severe obstacle. All categories have been used as a separate variable to capture the non-linearity of the effect.
- Firms' financing structure measured as the share of investments financed by bank loans. The same instrument was used by Savignac (2008), who claimed that this is one of the variables that helps capture "the risk associated with the investment and the information asymmetry with the external investor" (p.559).
- Share of exports in sales. This variable performs well empirically as an instrument in our sample; it is not related to R&D, but strongly related to credit constraints. Success in foreign markets seems to be an effective signal for banks in assessing firms' potential to pay back loans.

The explanatory variables capture the main firm-level and country-level characteristics that are known to affect R&D engagement and credit constraints. Hadlock and Pierce (2010) found that the best predictors of credit constraints are firm size and age. R&D engagement is similarly related to firm size and age and, in addition, competition, technology-push and demand-pull factors (see the discussion in the previous section). The variables for the share of academically educated employees and for the concern of firms about inadequately educated staff reflect the competence push aspects driving R&D via the emergence of new technologies and complex production processes. The prevalence of anticompetitive practices are used as an indirect measure of competition characteristics; firms are expected to regard it as a problem when there is tighter competition in the market.

The growth of value added in manufacturing at the country level captures the effect of the business cycle on R&D activity. The effect of growth in value added on R&D engagement is ambiguous, as discussed in the previous subsection on the cyclicality of R&D. It is also tested whether the effect of credit constraints on R&D depends on the economic cycle; this is done by interacting the aggregate growth of manufacturing with the firm-level credit constraints. Again, the direction of this interaction effect is ambiguous.

Table 1 presents the descriptive statistics of the BEEPS data. Most of the firm-level variables analysed are binary, but there are also some continuous variables such as firm age, sales growth, share of employees with higher education and share of exports in sales. The sample firms contain quite a high share of R&D firms, as about 18 % of the firms have some R&D expenditures. The share of credit constrained firms is around 10 %, the share of employees with higher education is 19 %, the share of exports in sales is 15 %, and one tenth of the firms are majority foreign owned.

4. Results

4.1. The effect of credit constraints on R&D

As discussed in the previous section, the cash-flow sensitivity of investments is the indirect measure of credit constraints. This paper uses direct information on credit constraints reported by the firms, which is the strength of our data. However, the weakness of our data is that it is a pooled cross-section and not a panel, which complicates the identification of a causal relationship from credit constraints to R&D. We start the presentation of results by discussing methodological problems including instrumentation.

Savignac (2008) uses similar data to ours and claims that two types of biases, the endogeneity bias and the selection bias, can make the estimates of the effect of credit constraints on R&D inconsistent. The endogeneity bias originates from the simultaneous choice of financing and R&D activity of firms and we aim to address this by introducing instruments that affect only credit constraints but not R&D activity. Second, the selection bias originates from the inclusion of firms that are not potentially interested in R&D, so that credit constraints cannot hamper their R&D activity. The inclusion of such firms can create a spurious positive correlation between R&D activity and credit constraints.

Table 2 presents the results of the estimation of Eq. (1). The table presents marginal effects at averages for a simple probit model, the bivariate probit where endogeneity is addressed, and the bivariate probit where endogeneity and selection are addressed. The marginal effect of the credit constraints is always negative and turns statistically significant after addressing both endogeneity and selection. The results suggest that it is important to consider these methodological issues as the effect of credit constraints on R&D increases substantially in absolute terms after controlling for endogeneity and selection. Table A1 in the Appendix tests the quality of the instruments indirectly, that is, it controls for exclusion restrictions and shows that the instruments do not correlate with R&D in the reduced form. This raises confidence that the effect of instruments takes place through the credit constraints and does not have a direct effect on R&D. Access to finance, financing structure and export share correlate strongly with credit constraints and this confirms that they are relevant and valid instruments of the credit constraint equation. Our preferred specification is in column (3) and controls for both endogeneity and selection bias.

Our preferred specification in Table 2, column (3) estimates a sizable effect, which is that credit constrained firms have a 32 % lower probability of being engaged in R&D. Savignac (2008), the study that is methodologically closest to ours, finds a 27 % lower

Table 1
Descriptive statistics of the BEEPS data, manufacturing in 2005, 2009 and 2012/2013 (n = 2116).

Variable	Definition	Mean	Std. Dev.	Min	Max
R&D	1 if firm had R&D expenditure, either in-house or contracted, over the last three years, 0 otherwise	0.244	0.430	0	1
Credit constrained	1 if an application for a loan was rejected or the firm was discouraged from borrowing, 0 otherwise	0.090	0.287	0	1
Firm background characteristics affecting both R&D and credit constraints					
Age	Firm age in years. The beginning year is set to 1987 if reported earlier	14.9	5.3	3	27
Employment 2-49	1 if firm employment is between 2 and 49 employees, 0 otherwise	0.626	0.484	0	1
Employment 50–249	1 if firm employment is between 50 and 249 employees, 0 otherwise	0.276	0.447	0	1
Employment 250 and more	1 if firm employment is between 250 and 10000 employees, 0 otherwise	0.099	0.298	0	1
Share of foreign ownership	Percent of firm owned by foreign individuals, companies or organisations	0.121	0.313	0	1
Variables affecting only R&D					
Share of workers with higher education	Share of firm workforce with a university degree	0.155	0.189	0	1
Qualified workforce as obstacle	Inadequately qualified workforce as an obstacle for business growth: 1 – “no obstacle”; 2 – “minor obstacle”, 3 – “moderate obstacle”, 4 – “major obstacle”	2.296	1.145	1	4
Anticompetitive practices	1 if the anticompetitive practices are a serious concern for the firm, 0 otherwise	0.149	0.356	0	1
Sales growth	Real sales growth over the last three years, in percent	0.173	0.412	−0.993	1.994
Variables affecting only credit constraints					
Access to finance as no obstacle	1 if access to finance is no obstacle for business growth, 0 otherwise	0.361	0.480	0	1
Access to finance as minor obstacle	1 if access to finance is a minor obstacle for business growth, 0 otherwise	0.180	0.384	0	1
Access to finance as moderate obstacle	1 if access to finance is a moderate obstacle for business growth, 0 otherwise	0.238	0.426	0	1
Access to finance as major obstacle	1 if access to finance is a major obstacle for business growth, 0 otherwise	0.194	0.395	0	1
Access to finance as very severe obstacle	1 if access to finance is a very severe obstacle for business growth, 0 otherwise	0.028	0.165	0	1
Share of bank loans	The share of investments financed by bank loans	0.185	0.307	0	1
Share of exports in sales	Share of direct and indirect exports in firm sales	0.269	0.357	0	1
Additional variables					
Innovative firms	Firms that have introduced new or significantly improved products or services or new or significantly improved methods for the production or supply of products or services over the last three years	0.469	0.499	0	1
GDP growth	Manufacturing real annual growth of value added	0.071	0.052	−0.029	0.184

Notes: [a)] Survey 2005 covers firms with two or more employees and surveys 2009 and 2012/2013 cover firms with five or more employees. Central and Eastern Europe: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.
Source: Authors’ calculations from BEEPS data.

probability of credit constrained firms innovating in France and this negative relationship emerged only after controlling for endogeneity and selection, while the model where these issues were not addressed even showed a positive relationship between credit constraints and R&D. Our effect is negative across all models and larger in magnitude. This suggests that the effect of credit constraints is more severe in CEECs than in highly developed countries.

The controls for R&D activity are firm size, country and survey wave dummies. Firms with fewer than 50 employees engage in R&D 33 % less frequently than firms with more than 250 employees, and firms with 50–249 employees have a 13 % lower probability of doing R&D than firms with 250 and more employees. The country dummies are also mostly statistically significant, indicating that firms in Slovenia undertake R&D more frequently than firms in the rest of the sample countries. This suggests that, conditional on other firm characteristics, firms from CEECs have quite a different propensity to undertake R&D, with the difference between countries being as large as 0.26 percentage points. Wave dummies are also statistically significant, indicating that firms have been more active in R&D during the later waves of the survey.

The other factors expected to affect R&D, such as technology push and demand pull factors and competition intensity, are also mostly statistically significant. The share of workers with higher education is related to a higher propensity to undertake R&D; however, the economic size of the effect is modest. Increasing the share of workers with higher education by 10 percentage points is related to an increase in R&D activity by 2.3 percentage points. The competition intensity seems to be economically more relevant for R&D, firms that think that anticompetitive activities are a serious concern have a 13.8 percentage points lower propensity to undertake R&D. This indicates that negative competitive pressure holds R&D back. The demand pull proxy is also relevant, firms that have 10 % percentage points higher real sales growth have an 0.08 percentage points higher propensity to undertake R&D.

Access to finance, financing structure and export share are all strongly correlated with credit constraints and prove to be relevant instruments. Firms that feel access to finance to be a major or very severe obstacle to business growth have a 13–14 percentage points higher probability to be credit constrained compared to firms that find it to be no obstacle (see Table A.1). Similarly, firms that have high shares of investment finances with bank loans or export high shares of sales have a lower probability to be credit constrained. However, the indirect effect of these variables on R&D propensity is statistically insignificant (see Table 2).

Table 3 disentangles the overall effect on R&D propensity into the direct effect from the R&D equation and the indirect effect from

Table 2
R&D activity and credit constraints, 2005-2012, manufacturing, marginal effects.

	(1) Initial model	(2) Controlling for endogeneity	(3) Controlling for selection
	Propensity to conduct R&D, Probit all sample	propensity to conduct R&D, bivariate probit all sample	propensity to conduct R&D, bivariate probit innovative firms
Credit constrained	−0.038	−0.137	−0.353*
	(0.036)	(0.098)	(0.182)
Log(age)	0.102***	0.104***	0.079
	(0.027)	(0.031)	(0.052)
Employment 2–49, base 250 and more	−0.262***	−0.266***	−0.327***
	(0.032)	(0.051)	(0.082)
Employment 50–249, base 250 and more	−0.110***	−0.114***	−0.122**
	(0.032)	(0.038)	(0.061)
Share of foreign ownership	0.040	0.040	0.008
	(0.030)	(0.032)	(0.056)
Share of workers with higher education	0.223***	0.221***	0.232**
	(0.049)	(0.056)	(0.090)
Qualified workforce as obstacle	0.015*	0.016*	0.025
	(0.009)	(0.009)	(0.016)
Anticompetitive practices	−0.059**	−0.056*	−0.127***
	(0.029)	(0.029)	(0.046)
Sales growth	0.062***	0.061**	0.077**
	(0.024)	(0.025)	(0.039)
Bulgaria, base Slovenia	−0.260***	−0.254***	−0.197***
	(0.046)	(0.056)	(0.063)
Czech Republic, base Slovenia	−0.073*	−0.062	−0.090
	(0.041)	(0.042)	(0.066)
Estonia, base Slovenia	−0.172***	−0.191***	−0.186**
	(0.045)	(0.060)	(0.079)
Hungary, base Slovenia	−0.271***	−0.255***	−0.226***
	(0.040)	(0.048)	(0.059)
Latvia, base Slovenia	−0.267***	−0.274***	−0.257***
	(0.053)	(0.068)	(0.077)
Lithuania, base Slovenia	−0.216***	−0.219***	−0.211***
	(0.050)	(0.059)	(0.063)
Poland, base Slovenia	−0.209***	−0.208***	−0.217***
	(0.037)	(0.047)	(0.067)
Romania, base Slovenia	−0.252***	−0.247***	−0.241***
	(0.040)	(0.051)	(0.067)
Slovakia, base Slovenia	−0.231***	−0.228***	−0.230***
	(0.051)	(0.060)	(0.066)
Wave 2009, base 2005	0.062**	0.061**	0.107**
	(0.028)	(0.029)	(0.051)
Wave 2012, base 2005	−0.031	−0.021	0.182*
	(0.026)	(0.028)	(0.099)
Access to finance as a minor obstacle		−0.029	−0.045
		(0.029)	(0.047)
Access to finance as a moderate obstacle		−0.041	−0.069
		(0.039)	(0.060)
Access to finance as a major obstacle		−0.063	−0.114
		(0.059)	(0.091)
Access to finance as a very severe obstacle		−0.067	−0.120
		(0.065)	(0.098)
Share of bank loans		0.067	0.109
		(0.064)	(0.094)
Share of exports in sales		0.021	0.066
		(0.022)	(0.061)
No of obs.	2116	2116	993
Pseudo R^2	0.145		
Rho		0.201	0.327
Wald test of rho = 0		1.231	1.627
R&D activity in sample	0.244	0.244	0.368

Notes: The table presents marginal effects at averages. ***, ** and * show statistical significance at the 1, 5 and 10 % level.
Source: Authors' calculations from BEEPS data.

Table 3
R&D activity and credit constraints, 2005-2012, manufacturing, marginal effects, direct and indirect effects.

	Overall effect	Direct effect from R&D	Indirect effect from credit constraints
Credit constrained	−0.353*		
	(0.182)		
Log(age)	0.079	0.115**	−0.036*
	(0.052)	(0.009)	(0.022)
Employment 2–49, base 250 and more	−0.327***	−0.297***	−0.030
	(0.082)	(0.043)	(0.169)
Employment 50–249, base 250 and more	−0.122**	−0.110**	−0.012
	(0.061)	(0.047)	(0.146)
Share of foreign ownership	0.008	0.009	−0.001
	(0.056)	(0.050)	(0.029)
Bulgaria, base Slovenia	−0.197***	−0.213***	0.016
	(0.063)	(0.045)	(0.195)
Czechia, base Slovenia	−0.090	−0.101*	0.011
	(0.066)	(0.058)	(0.188)
Estonia, base Slovenia	−0.186**	−0.136***	−0.050
	(0.079)	(0.051)	(0.098)
Hungary, base Slovenia	−0.226***	−0.260***	0.034
	(0.059)	(0.037)	(0.195)
Latvia, base Slovenia	−0.257***	−0.221***	−0.035
	(0.077)	(0.038)	(0.089)
Lithuania, base Slovenia	−0.211***	−0.225***	0.014
	(0.063)	(0.043)	(0.181)
Poland, base Slovenia	−0.217***	−0.201***	−0.016
	(0.067)	(0.044)	(0.131)
Romania, base Slovenia	−0.241***	−0.236***	−0.005
	(0.067)	(0.037)	(0.135)
Slovakia, base Slovenia	−0.230***	−0.236***	0.005
	(0.066)	(0.040)	(0.161)
Wave 2009, base 2005	0.107**	0.120**	−0.013
	(0.051)	(0.050)	(0.115)
Wave 2012, base 2005	0.182*	0.085	0.098
	(0.099)	(0.054)	(0.273)
No of obs.	993		

Notes: The table presents marginal effects at averages. ***, ** and * show statistical significance at the 1, 5 and 10 % level.
Source: Authors' calculations from BEEPS data.

the credit constraints equation. The indirect effect shows how factors that affect credit constraints also affect R&D activity through the availability of credit. The direct and indirect effects are only calculated for variables that enter both the credit constraints and R&D equations, and are disentangled based on the correlation of errors of both equations, the rho reported in Table 2. Given that the rho is statistically insignificant, this implies that the indirect effects are mostly statistically insignificant. The only variable that has a statistically significant indirect effect on R&D is firm age. Older firms are more likely credit constrained, which affects R&D propensity negatively, and more likely to undertake R&D, which positively affects R&D propensity as a direct effect. The overall effect of age on R&D propensity is statistically insignificant as the negative and positive effects offset each other. The positive effect of age on credit constraints is opposite to the findings in the literature (Hadlock and Pierce, 2010) and can be specific to the sample of CEEC firms or our set of other control variables.

In sum, credit constraints seem to have a significant negative effect on the probability to engage in R&D in CEECs. There are more factors that explain R&D activity in these countries, such as firm size, skilled workforce, technology push and demand pull factors, and anticompetitive practices. Country dummies are also statistically and economically significant, indicating a large variation in firms' R&D activity over CEECs.

4.2. Credit constraints and R&D over the boom and bust

As demonstrated in Fig. 1, most of the sample countries experienced strong boom-bust episodes during the sample years and it is expected that credit constraints had a different effect on R&D activity during the boom and the recession years. We test whether the effect of credit constraints on R&D has changed over time by estimating Eq. (1) and introducing an additional variable, manufacturing GDP growth, and its interaction term with credit constraints. This test employs pooled data and studies whether the effect of credit constraints has changed over time, while it is assumed that the coefficients of the rest of the variables are unchanged over time.

Table 4 presents the results where, first, GDP growth enters the preferred model, and then the interaction term of GDP growth with credit constraints is added to the model. GDP growth is statistically significant and positively related to R&D activity, while the interaction term of GDP and credit constraints is statistically insignificant. So our results hint at the procyclicality of R&D investments, though the effect is estimated with relatively low precision.

Table 4
R&D activity and credit constraints, 2005-2012, manufacturing, marginal effects, direct and indirect effects.

	(1) Final model with aggregate GDP	(2) Final model with aggregate GDP and interaction of credit constraints and GDP
Credit constrained	−0.325*	−0.146
	(0.187)	(0.256)
Log(age)	0.085	0.102*
	(0.053)	(0.058)
Employment 2–49, base 250 and more	−0.334***	−0.359***
	(0.088)	(0.077)
Employment 50–249, base 250 and more	−0.125*	−0.131**
	(0.066)	(0.065)
Share of foreign ownership	0.019	0.017
	(0.057)	(0.059)
Share of workers with higher education	0.229**	0.255***
	(0.090)	(0.095)
Qualified workforce as obstacle	0.026*	0.029*
	(0.016)	(0.017)
Anticompetitive practices	−0.144***	−0.158***
	(0.054)	(0.057)
Sales growth	0.081**	0.091**
	(0.039)	(0.042)
Bulgaria, base Slovenia	−0.293***	−0.321***
	(0.097)	(0.096)
Czechia, base Slovenia	−0.140*	−0.158*
	(0.079)	(0.083)
Estonia, base Slovenia	−0.214**	−0.224**
	(0.106)	(0.105)
Hungary, base Slovenia	−0.269***	−0.304***
	(0.083)	(0.087)
Latvia, base Slovenia	−0.363***	−0.394***
	(0.125)	(0.119)
Lithuania, base Slovenia	−0.305***	−0.342***
	(0.095)	(0.096)
Poland, base Slovenia	−0.318***	−0.344***
	(0.093)	(0.086)
Romania, base Slovenia	−0.327***	−0.357***
	(0.092)	(0.086)
Slovakia, base Slovenia	−0.429***	−0.478***
	(0.123)	(0.122)
Wave 2009, base 2005	0.111**	0.122**
	(0.050)	(0.052)
Wave 2012, base 2005	0.282**	0.291***
	(0.118)	(0.112)
Access to finance as a minor obstacle	−0.048	−0.039
	(0.050)	(0.049)
Access to finance as a moderate obstacle	−0.074	−0.062
	(0.065)	(0.068)
Access to finance as a major obstacle	−0.130	−0.109
	(0.107)	(0.116)
Access to finance as a very severe obstacle	−0.151	−0.124
	(0.134)	(0.139)
Share of bank loans	0.112	0.094
	(0.094)	(0.100)
Share of exports in sales	0.067	0.056
	(0.060)	(0.063)
Manufacturing GDP	1.298**	1.534**
	(0.618)	(0.664)
Credit constrained*manufacturing GDP		−1.811
		(1.569)
No of obs.	993	993
Rho	0.333	0.259
Wald test of rho = 0	1.749	0.875
R&D activity in sample	0.368	0.368

Notes: The table presents marginal effects at averages. ***, ** and * show statistical significance at the 1, 5 and 10 % level.
Source: Authors' calculations from BEEPS data.

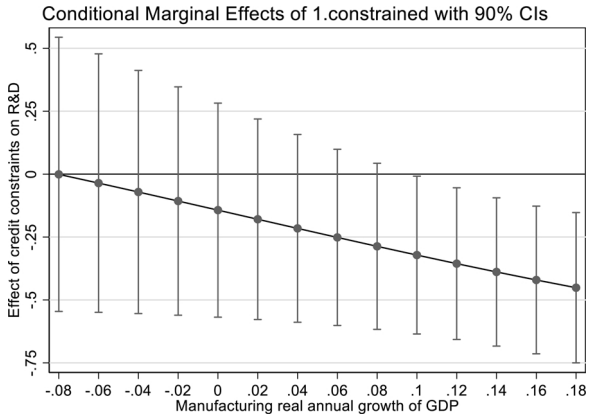

Fig. 2. The effect of credit constraints on R&D activity over different growth periods.
Source: Authors' calculations from BEEPS data

Our results in Table 4 do not show that the effect of credit constraints on R&D varies over economic fluctuations, as the interaction term of GDP and credit constraints is statistically insignificant. However, the table presents the marginal effect at averages. Fig. 2 indicates that the negative effect of credit constraints on R&D emerges during the period of fast economic growth. The effect becomes statistically significant slightly above the average, the average growth is 7% in the sample and the effect of credit constraints becomes statistically significant over 10 % of growth (which is more than 30 % of cases in our sample). The effect of credit constraints on R&D can be as large as -45 percentage points during the period of very fast economic growth.

We conclude that despite the negative effect of credit constraints on R&D in CEECs, there is no evidence that credit constraints tightened for R&D during the recession. As we cannot control for firm-specific effects in a cross-sectional setting, the effect of credit constraints on R&D over the boom and bust periods is estimated using the cross-sectional variation in the manufacturing industry. Panel data estimates would be more suitable for such testing. Panel data have been employed by Männasoo and Meriküll (2015) for similar testing and they find the same result; the effect of credit constraints on R&D did not increase during the recession. They use data from one of our BEEPS sample countries, Estonia.

Lööf and Nabavi (2016) and Giebel and Kraft (2018) show evidence that in some countries innovative firms have faced increased financing constraints during recession and in some countries credit constraints have been revealed compared to non-innovative firms (Lee et al., 2015). So there is conflicting evidence on whether the financing of high-tech or innovative projects became worse during the crisis. Our results complement these findings by suggesting that in an environment of tight financing constraints for innovative firms, where firms rely mostly on internal funds for financing R&D, the negative effect of credit constraints on R&D is mostly concentrated in periods of strong economic growth and high demand for R&D financing rather than in periods of recession.

5. Summary

This paper studied the effect of credit constraints on R&D activity in Central and Eastern Europe over the boom and bust cycle. There is evidence that credit constraints have an endogenous impeding effect on R&D for innovative firms The analysis of the BEEPS dataset from ten new EU member states suggests that credit constraints lower the probability of an innovative firm engaging in R&D by about 32 %.

It is found that R&D has no clear cyclical pattern in CEECs aside from a modest positive association with GDP growth. Despite the deep recession and the credit crunch in 2009, in most of the sample countries there is no evidence that the effect of credit constraints on R&D became more severe during the recession. A potential explanation for this result is that firms in Central and Eastern Europe perceive strong credit constraints and accumulate internal funding for their R&D. Our results suggest that credit constraints hampered R&D only in times of solid economic growth and that the credit constraints were binding during periods of high demand for R&D investment. These findings imply that credit constraints have contributed to the low R&D activity in CEECs and the effect emerged during the long period of strong economic growth.

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Appendix A

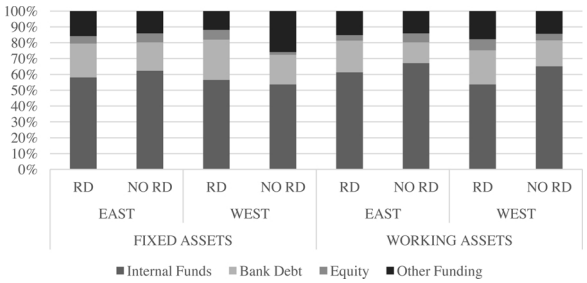

Fig. A1. Firm financing structure of fixed and working assets in European countries, manufacturing, BEEPS data 2005.
Notes: Central and Eastern Europe: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia; sample size is 301 R&D firms and 1397 non-R&D firms. Western and Southern Europe: Germany, Portugal, Greece, Spain and Ireland; The sample size is 248 R&D firms and 445 non-R&D firms.
Source: Authors' calculations from BEEPS data.

Table A1
Probability to undertake R&D and credit constraints.

	Propensity to conduct R&D, probit reduced form	Propensity to be credit constrained, all explanatory variables	Propensity to be credit constrained, explanatory variables used as instruments
Credit constrained	−0.035		
	(0.037)		
Log(age)	0.106***	−0.014	
	(0.027)	(0.012)	
Employment 2–49, base 250 and more	−0.258***	0.021	
	(0.033)	(0.022)	
Employment 50–249, base 250 and more	−0.109***	0.012	
	(0.032)	(0.022)	
Share of foreign ownership	0.039	−0.008	
	(0.031)	(0.020)	
Share of workers with higher education	0.227***	−0.000	
	(0.049)	(0.022)	
Qualified workforce as obstacle	0.014	−0.005	
	(0.009)	(0.004)	
Anticompetitive practices	−0.061**	0.009	
	(0.029)	(0.011)	
Sales growth	0.061***	−0.016	
	(0.024)	(0.012)	
Bulgaria, base Slovenia	−0.258***	−0.009	
	(0.046)	(0.027)	
Czechia, base Slovenia	−0.069*	−0.019	
	(0.041)	(0.025)	
Estonia, base Slovenia	−0.172***	0.045*	
	(0.046)	(0.026)	
Hungary, base Slovenia	−0.267***	−0.034	
	(0.040)	(0.023)	
Latvia, base Slovenia	−0.264***	0.027	
	(0.053)	(0.026)	
Lithuania, base Slovenia	−0.210***	0.019	
	(0.050)	(0.026)	
Poland, base Slovenia	−0.205***	0.013	
	(0.038)	(0.021)	
Romania, base Slovenia	−0.245***	0.001	
	(0.040)	(0.022)	
Slovakia, base Slovenia	−0.229***	−0.002	
	(0.052)	(0.029)	

(*continued on next page*)

Table A1 (*continued*)

	Propensity to conduct R&D, probit reduced form	Propensity to be credit constrained, all explanatory variables	Propensity to be credit constrained, explanatory variables used as instruments
Wave 2009, base 2005	0.065**	0.005	
	(0.028)	(0.015)	
Wave 2012, base 2005	−0.025	−0.027*	
	(0.027)	(0.014)	
Access to finance as minor obstacle	−0.004	0.056***	0.064***
	(0.028)	(0.015)	(0.015)
Access to finance as moderate obstacle	0.004	0.082***	0.091***
	(0.026)	(0.014)	(0.014)
Access to finance as major obstacle	0.021	0.128***	0.144***
	(0.029)	(0.015)	(0.014)
Access to finance as very severe obstacle	−0.055	0.132***	0.131***
	(0.059)	(0.024)	(0.025)
Share of bank loans	0.042	−0.132***	−0.144***
	(0.031)	(0.020)	(0.021)
Share of exports in sales	0.014	−0.039**	−0.054***
	(0.030)	(0.016)	(0.015)
Country dummies	yes	yes	no
No of obs.	2116	2116	2116
Pseudo R^2	0.147	0.193	0.169

Notes: The table presents marginal effects at averages. ***, ** and * show statistical significance at the 1, 5 and 10 % level.
Source: Authors' calculations from BEEPS data.

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