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R&D Investments and Credit Lines

Abstract
Using data for 939 publicly listed firms from 17 European countries over the period from 2004 to 2013, we investigate the effect of used credit lines on R&D investments, controlling for other determinants of R&D investments, i.e., cash flows, cash holdings, sales growth, equity financing, and Tobin's Q. Our estimation results, based on the system-GMM method, show that used credit lines have a positive and significant impact on R&D investments. In addition, we find that this impact is more pronounced for small and young firms than for large and mature firms. These results show that firms use credit lines as part of their liquidity management tools for supporting their R&D investments. Finally, we provide evidence that European firms in bank-based countries increased their use of credit lines for financing their R&D investments during the financial crisis of 2007-2009, while the link between R&D investments and used credit lines became weaker during the European sovereign debt crisis of 2010-2013.

Keywords: R&D investment, credit lines, financial crises, debt types

JEL Classification: O32, G32

1. Introduction

It has long been viewed that research and development (R&D) investments are the 'engine of economic growth' determining the long-run economic growth rate (e.g., Romer, 1990; Akcigit and Kerr, 2015). Recently, one of the major objectives of the European Commission has been to increase R&D investments as an important stimulus for fostering Europe's competitiveness (Bilbao-Osorio, 2014).[1] In this paper, we aim to improve our understanding of financing R&D investments by examining how the components of bank debt could influence firms' R&D investment decisions. In particular, we focus on the role of credit lines (i.e., revolving credit facilities) in determining the level of R&D investments for a sample of European firms. In the extant literature, credit lines have been viewed as a component of bank debt, which can help firms with their liquidity management, mitigating financial market frictions (e.g., Lins et al., 2010; Sufi, 2009).

Firms can use three main sources of financing for their R&D investments: internally generated cash as an internal source, and net stock issues and/or debt as external sources (e.g., Ozkan, 2002; Brown et al., 2009; Hall and Lerner, 2010). There have been mixed findings on the impact of these sources of financing on R&D investments. Prior studies have mainly treated debt as a uniform variable and do not consider the role of different debt components, i.e., bank debt, including used credit lines and term loans, in determining the level of R&D investments. Bank debt, which is a common source of financing for European firms (Demirguc-Kunt and Levine, 2001), could be important for financing R&D investments. A recent survey by Campello et al.

[1] European countries constitute a considerable portion (around a quarter) of global R&D spending. The Lisbon strategy set for the European Union an objective of devoting 3 % of its GDP to R&D investments by 2010. However, the target was not reached, and subsequently, the European Commission decided to maintain the 3 % target. Currently 2 % of the GDP in Europe is devoted to R&D investments, lagging behind Japan (3.4 %) and the US (2.8 %). See the article, 'EU must spend more on research and development', *Financial Times*, May 19, 2014, and 'Europe continues to fall behind in race to innovate', *Financial Times*, December 16, 2014.

(2012) also highlights the role of bank financing for European firms. They argue that the use of credit lines can be important in understanding how firms manage their liquidity, particularly during financial crises. Differently from prior studies, our paper investigates the impact of used credit lines, which is a component of bank debt, on R&D investments. Further, we explore whether our sample of European firms relied on credit lines for financing their R&D investments during the recent financial crisis and the Euro area sovereign debt crisis.

Our approach is motivated by Chava et al. (2013) and Amore et al. (2013), who emphasize the role of bank lending in determining corporate innovation outcomes, i.e., the number and quality of patents.[2] Amore et al. (2013) document that interstate bank deregulation had a positive effect on the innovation of public firms, while Chava et al. (2013) report that interstate bank deregulation fostered the innovation of young and private firms. However, these studies do not establish whether the increase in innovation stems directly from bank financing for firms' R&D investment. Given their empirical evidence of a significant relationship between bank lending and innovation, one can argue that R&D investments, which have been viewed as one of the inputs for innovation, can be associated with firms' access to bank debt.[3] In fact, anecdotal evidence from Europe shows that some firms rely on bank financing to fund their R&D investments. For instance, recently, Konecranes, a Finnish firm, signed a €50 million loan for R&D purposes with Nordic Investment Bank. This loan will be used for funding R&D activities in the fields of machine artificial intelligence and new mid-market equipment until 2017. Further, this loan agreement follows the borrower's €100m five-year credit line facility refinancing, signed in February 2014.[4]

[2] More recently, Atanassov (2016) investigates the impact of various forms of financing sources on innovation for a sample of US firms, including bank debt, equity financing and public debt.
[3] See Knott (2008) about inputs of innovation.
[4] Commerzbank, Danske Bank, Nordea, Pohjola Bank and SEB were mandated lead arrangers and book-runners on the credit lines. Danske Bank was the facility agent. See *Global Capital* (2014) magazine.

The extant literature provides ambiguous predictions about the relationship between bank financing and R&D investments. On the one hand, the nature of debt contracts, particularly bank financing, may not be well suited for R&D investments for various reasons (e.g., Carpenter and Petersen, 2002). For instance, lenders do not share gains from R&D projects, while they are subject to losses from a potential downside.[5] Thus, banks could be reluctant to lend to firms involved in R&D activities. On the other hand, bank debt can have considerable advantages over public debt for firms involved in R&D activities. Prior studies have highlighted banks' role of effective monitoring, as they have access to private information about the firms with whom they have lending relationships (e.g., Bolton et al., 2016). Therefore, they could reduce potential moral hazard problems and provide firms with strong incentives to make appropriate corporate decisions. Specifically, for R&D investments, which involve a high degree of information asymmetry between insiders and outside investors, bank debt could be considerably helpful in reducing potential information asymmetries.[6]

Furthermore, credit lines, which are a component of bank debt, can provide liquidity insurance for firms, i.e., firms can draw on their credit lines when accessing external capital markets becomes more restricted (e.g., Almeida et al., 2014). Hence, firms involved in R&D activities may use credit lines to smooth their R&D investments, which could involve a considerably high level of adjustment costs (Bernstein and Nadiri, 1989). In particular, credit lines can play an important role in firms' financing of their R&D investments during a period of exogenous shock, e.g., a financial crisis. We can view credit lines as a put option, since firms can

[5] Moreover, firms with R&D projects may not offer good collateral value and may suffer from credit rationing arising from the adverse selection problem (Stiglitz and Weiss, 1981; Hall, 2002).
[6] Chava et al. (2015) provide empirical evidence that bank financing can be an important source of financing for innovative firms, and banks price their loans to innovative firms considering these firms' intellectual property, i.e., patent stock. However, they do not explore whether bank financing influences R&D investments.

use them at pre-arranged low rates if the spot-market interest rates are high (e.g., Berg et al., 2016).

For our empirical analysis, we use a sample of 939 European firms for the period 2004 to 2013. To estimate the impact of bank debt components on R&D investments, we employ the system-GMM estimation method developed for dynamic panel models, which provides a joint estimation of a regression model in differences and levels (e.g., Flannery and Hankins, 2013).[7] The system-GMM method addresses the potential endogeneity problems in our regression model, where R&D investments, bank debt components and other financial variables could be simultaneously determined (e.g., Brown et al., 2012; Brown and Petersen, 2011). Alternatively, the relation between R&D investments and bank debt components can suffer from reverse causality. Further, we use a difference-in-differences approach to examine the impact of the 2007-2009 financial crisis and the Euro area sovereign debt crisis on firms' financing of R&D investments.

Our results support the view that banks can play an important role in determining the level of R&D investments in European firms. We find that used credit lines have a positive and significant impact on R&D investments, while the coefficient estimate for term loans is not statistically significant. This result is consistent with the view that credit lines are more flexible than term loans and provide financing for smoothing R&D investments. Further tests show that our sample of European firms draw funds from their credit lines to finance their R&D investments when they are faced with a cash shortage, or their access to equity financing is more limited. Our finding for used credit lines is also economically significant: a one-standard deviation increase in the used credit lines-to-total assets ratio is associated with a 65.64 basis point increase in the

[7] That is, lagged levels are used as instruments for the equations in differences, while lagged differences are used as instruments for the equations in levels.

R&D-to-total assets ratio. These results provide support for the survey findings from Lins et al. (2010), showing that firms with growth opportunities, i.e., R&D activities, rely on credit lines as part of their liquidity management tools. Similar to the results from Brown and Petersen (2011), we also find that our sample of European firms relies on their cash holdings in financing their R&D investments. Notably, our results show that firms most likely to be financially constrained, i.e., small and young firms, rely relatively more on credit lines as a source of financing for their R&D investments than mature and large firms. Further, we observe that the link between R&D investment and used credit lines stays positive and significant during the 2007-2009 financial crisis and the European sovereign debt crisis. This finding is consistent with the view that the European banking system is mainly a relationship-based banking system, which can help firms weather crisis times better, given that they can continue to borrow from their banks (e.g., Ongena and Smith, 2000; Bolton et al., 2016). Thus, credit lines help firms protect their R&D investments during a period when access to alternative sources of financing becomes more limited.

We conduct further tests by incorporating country-level financial structure characteristics, i.e., the ratio of credit market development to stock market development, into our analysis. Following Demirguc-Kunt and Levine (2001) and Didier et al. (2014), we split our sample of European countries into bank-based and market-based countries, considering their ratio of credit market development to stock market development. Firms in market-based countries with relatively easy access to equity markets would not be expected to rely as much on credit lines as a source of financing for their R&D investments as firms in bank-based countries would. Our results provide evidence consistent with this prediction. We find that the link between R&D investments and used credit lines is stronger in bank-based countries than market-based countries.

Additionally, our results show that firms in bank-based countries increased their use of credit lines during the 2007-2009 crisis. This finding suggests that relationship banking, which is more likely to be prevalent in bank-based countries, can help firms weather crises more smoothly. However, these firms in bank-based countries reduced their reliance on credit lines as a source of financing for their R&D investments during the Euro area sovereign debt crisis. This finding is consistent with prior studies reporting that banks in Europe reduced their lending considerably more during the sovereign debt crisis than the 2007-2009 financial crisis (e.g., Becker and Ivashina, 2016).

Our paper makes a number of contributions to the literature. First, while Chava et al. (2013), Amore et al. (2013) and Atanassov (2016) document that bank lending can influence innovation, we are the first (to our knowledge) to investigate the relation between bank debt, i.e., used credit lines and term loans, and a firm's R&D investment decisions. Second, we extend the literature on the real effects of financial crises by providing evidence that European firms in bank-based countries increased their use of credit lines as a source of financing for their R&D during the financial crisis of 2007-2009, while they reduced their reliance on credit lines for financing their R&D investments during the Euro area sovereign debt crisis of 2010-2013. To our best knowledge, this is the first study investigating the effect of the recent financial crises on the financing of R&D investment for European firms. Our findings complement the results from prior surveys that reported an increased use of credit lines during the recent financial crisis (e.g., Campello et al., 2012; Campello et al., 2010).

The rest of the paper proceeds as follows. The next section provides the literature review and hypotheses development. Section 3 discusses our regression model and estimation method. Section 4 reports the data characteristics. Section 5 discusses our findings, and Section 6 concludes.

2. Literature review and hypotheses development

R&D investments have some specific characteristics, which may have direct implications about how they are financed. Notably, R&D activities involve a great degree of uncertainty, intangible capital and information asymmetry between insiders and outside investors about their potential output and financial return (see e.g., Aboody and Lev, 2000; Knott, 2008). Given these characteristics of R&D investments, firms are less likely to rely on debt as a source of financing for their R&D activities (e.g., Hall and Lerner, 2010). For instance, Brown et al. (2012) and Hall (1992) provide empirical evidence that European and US firms do not rely on debt financing for funding their R&D investments.

Previous studies have mainly highlighted the role of internal financing, i.e., cash flows and cash holdings, and equity issuance in financing R&D investments. Equity financing has several advantages as a source of financing for R&D investments (e.g., Carpenter and Petersen, 2002). It does not require collateral, and upside returns for investors are not bounded. Further, it does not lead to an increase in the likelihood of financial distress. For a sample of 16 major European countries over the period 1995-2007, Brown et al. (2012) find that equity financing could be an important source of financing for R&D investments. Carpenter and Petersen (2002) also investigate the importance of equity financing for US high-tech companies over the period 1981-1998. They find that equity finance plays a crucial role for firms. In addition, Brown et al. (2012) show that cash flows have a positive and significant effect on R&D investment for European firms. Brown and Petersen (2015) also find a positive relation between cash flows and R&D investments for US firms. Further, Brown and Petersen (2011) show that cash holdings can be used as a buffer for smoothing R&D investments, which involve relatively high adjustment costs.[8]

[8] Researchers previously reported that the salaries of scientists and engineers constituted a major part of R&D investments (Hall, 2002; Brown and Petersen, 2011). Therefore, R&D investments can have major adjustment costs

Prior studies have mainly provided evidence about the role of cash flows, cash holdings, equity issuance and debt in determining R&D investments. However, there has been no study, to our knowledge, which examines whether bank debt and its components can play a role in financing R&D investments. In the next subsection, we discuss whether bank debt, especially credit lines, can provide a source of financing for R&D investments.

2.1. Bank debt, credit lines and R&D investment

Recently researchers have documented that there is a significant relationship between bank deregulation and innovation, suggesting that bank financing can play an important role in determining corporate innovation activity.[9] Further, Atanassov (2016) reports that credit lines have a positive impact on the novelty of US firms' innovations. In this paper, we aim to extend this literature by investigating whether R&D investment, as an input of innovation, can be influenced by bank financing.

The extant literature does not offer a distinct explanation about whether bank financing can be a possible source of funding for R&D investments. On the one hand, banks are unlikely to extend financing to firms with R&D investments, as these investments have a high degree of uncertainty, information asymmetry and risk. On the other hand, banks can alleviate information asymmetry problems through their monitoring and screening technologies, and can therefore reduce the costs of moral hazard and adverse selection (e.g., Diamond, 1991). Further, firms can renegotiate and re-contract with their banks when they are in financial distress. In particular, bank loans can be part of a long-term relation between banks and firms (e.g., Petersen and Rajan, 1994; Hadlock and James, 2002). Thus, firms may be willing to use bank debt for their R&D activities,

(e.g., Bernstein and Nadiri, 1989). Firms spend resources investing in the knowledge capital of their R&D employees, i.e., scientists. Hence, they would be reluctant to fire them unless there is considerable pressure to do so.

[9] See Chava et al. (2013), and Amore et al. (2013).

since banks as relational lenders facilitate the continuity of R&D investments when firms are financially distressed (Hoshi et al., 1990).

Moreover, credit lines, which are a component of bank debt and are more flexible than terms loans, can help firms smooth their R&D investments. Given the relatively high adjustment costs involved in R&D investments, firms are likely to rely on both their cash holdings and credit lines when access to external capital markets becomes limited. Credit lines allow firms to have access to pre-committed financing at a pre-set interest rate. For this access right, these firms pay an additional commitment fee for the unused part of the loan in exchange. Berg et al. (2016) argue that credit lines and term loans are different, considering the options embedded in each one and their pricing structure. For instance, they identify five different types of fees for credit lines, while they find only two fee types for term loan contracts. Further, Sufi (2009) and Atanassov (2016) argue that credit lines are more flexible than term loans.

Credit lines, hence, can be viewed as a liquidity insurance for firms, as long as banks can provide the credit (e.g., Campello et al., 2011). Prior research on the theory of credit lines has considered credit line commitments as insurance against the decline in a firm's creditworthiness, since these commitments offer borrowing firms the option to use credit lines in the case of economic deterioration. A borrowing firm will draw down a line of credit, i.e., exercise the option, if it is more expensive to borrow in the spot market (e.g., Thakor et al., 1981; Thakor, 1982).

Theoretically, firms hold liquid reserves (cash holdings) and/or credit lines to protect themselves against liquidity shocks (Holmstrom and Tirole, 1998). Thus, cash holdings and credit lines could help firms hedge against liquidity shocks, which could otherwise potentially force them to give up projects with positive net present value. Bolton et al. (2011)'s theoretical model shows that there is a pecking order of financing, in the order of internal funds, credit lines, and external equity financing. In their model, credit lines help firms mitigate their underinvestment problem when they run out of cash. Sufi (2009) analyzes a sample of 300 US public firms over 1996-2003 and shows bank lines of credit are an important financial source, but firms with low cash flows are less likely to obtain such lines of credit. The reason is that these firms cannot satisfy the loan covenants. Further, Lins et al. (2010) use survey data from 29 countries and report that managers use cash holdings as a way to hedge against negative shocks, while credit lines are used to improve firms' ability to take up future growth opportunities.

Overall, the current literature highlights two important distinctive characteristics of credit lines that separate them from term loans: flexibility and the liquidity insurance role of credit lines. We therefore predict that as a form of bank financing, credit lines rather than term loans play an important role in determining R&D investments. Firms can rely on drawn (used) credit lines, as well as other external and internal sources of financing to fund their R&D investments. The relationship between R&D investments and used credit lines could be even stronger for financially constrained firms, since these firms are more likely to face liquidity shortages, and therefore need more liquidity insurance.

In this context, we have the following main hypotheses about how credit lines, as part of bank financing, can influence R&D investments:

H1. Credit lines, which are more flexible than term loans, can provide liquidity to smooth firms' R&D investments. Thus, used credit lines have a positive impact on R&D investments.

H2. The positive impact of used credit lines on R&D investments is more pronounced for financially constrained firms, as their access to alternative sources of financing is more limited than that for financially unconstrained firms.

2.2. Credit lines and R&D investment during crises

Recently, Campello et al. (2012) used survey data from CFOs in European firms to investigate credit line withdrawals over the period 2008-2009. They find that firms that cannot access credit, i.e., firms that are unprofitable, small, private, and non-investment grade, used more credit lines than their counterparts, i.e., firms that are large, public, profitable, and investment-grade, during the recent financial crises. Their results suggest that firms drew credit lines for their liquidity needs to invest during the crises. They also show that large, public, profitable and investment-grade European firms used 30%-44% of their available credit lines during the 2008-2009 crisis period. The use of credit lines was relatively higher among small and less profitable firms. On average, they withdrew between 48% and 68% of their available credit during the same period. These findings show that firms can use credit lines during a time of crisis, as long as banks can honor these credit line drawdowns.[10] Berg et al. (2017) provide further evidence that firms are more likely to use credit lines as their economic situation worsens, i.e., their equity returns decline. Jiménez et al. (2009) show that various factors, including firm-specific and lender-specific characteristics, and the macroeconomic situation can influence corporate credit line usage for their sample of Spanish firms.

Moreover, Ivashina and Scharfstein (2010) report that there was a significant increase in credit line drawdowns by US firms following the collapse of Lehman Brothers in 2008. In particular, firms with low credit quality increased their drawdowns substantially. Our summary statistics in Table 1a also show that from 2006 to 2008, on average, there is around a 35% increase in the ratio of used credit lines-to-total assets, which is consistent with Campello et al. (2012)'s findings for European firms.[11] Prior studies have also used credit register data from various

[10] As Almeida et al. (2014) argue, firms' access to existing credit lines depends on banks' health. Banks, which are exposed to liquidity shocks, can restrict access to existing credit lines.
[11] We also observe a similar pattern in the ratio of used credit lines to total debt in Table A3 of the Appendix.

European countries to investigate how bank lending changed during the recent financial crises. They document that banks continued to extend credit to their long-term clients after the collapse of Lehman Brothers (e.g., Beck et al., 2017; Bolton et al., 2016). This finding suggests that relationship lending, which is relatively more common in Europe than in the US, may have relaxed the financial constraints faced by European firms during the recent financial crises. Further, Berger and Udell (1995) argue that credit lines can be an important part of relationship lending, since they represent a forward commitment to provide financing under some pre-specified terms.

We would therefore expect our sample of European firms to continue relying on used credit lines to manage their liquidity and fund their R&D investments when there is an exogenous shock, e.g., the 2007-2009 financial crisis and Euro area sovereign debt crisis, which makes access to alternative financing more difficult. However, firms' access to their existing credit lines can be limited if banks do not fulfill their commitment to provide these funds (e.g., Jiménez et al., 2009). Thus, we posit the following hypothesis:

H3. As long as banks fulfill their commitments for credit line agreements, firms (particularly financially constrained firms) can continue to rely on credit lines as a source of financing for R&D investments during a time of exogenous shock, when access to alternative sources of financing is limited.

3. Estimation Method

To test the impact of bank debt on R&D investment, we use a dynamic model derived from an Euler equation. Bond and Meghir (1994) developed this model to study fixed investment under the assumption of quadratic adjustment costs. Further, this model incorporates expectations that are formed in line with a dynamic optimization approach. Following Brown and Petersen (2015), we augment the baseline Euler specification and add *Tobin's Q* and *Sales growth* to control for investment demand.[12] We also include *Cash flow*, *Stock issues*, Δ*Cash*, and *Debt type*, which represent either *Leverage* or *Bank debt*, i.e., *Used credit lines* and/or *Term loans*, to account for different sources of financing.[13] Our specification of the dynamic panel model is as follows:

$$R\&D_{i,t} = b_1 R\&D_{i,t-1} + b_2 R\&D^2_{i,t-1} + b_3 Q_{i,t} + b_4 Q_{i,t-1} + b_5 Sales\ growth_{i,t} + b_6 Sales\ growth_{i,t-1} + b_7 Cash\ flow_{i,t} + b_8 Cash\ flow_{i,t-1} + b_9 Stock\ issues_{i,t} + b_{10} Stock\ issues_{i,t-1} + b_{11} \Delta Cash_{i,t} + b_{12} \Delta Cash_{i,t-1} + b_{13} Debt\ type_{i,t} + b_{14} Debt\ type_{i,t-1} + f_i + d_t + e_{i,t} \quad (1)$$

where $R\&D_{i,t}$ is the ratio of research and development investment to lagged total assets for firm *i* in year *t.* Table A1 in the Appendix provides a definition for each variable used in our empirical analysis.

In our model, we also control for year fixed effects (d_t) and firm-specific fixed effects (f_i), and $e_{i,t}$ represents the error term. All variables, including $R\&D_{i,t}$, are scaled by firms' beginning-of-period total assets to maintain a common scale factor. There are several econometric problems in the dynamic panel model above. First, in the presence of unobserved firm-specific fixed effects, the OLS estimation method will produce biased estimates due to the correlation between the lagged dependent variable and unobserved firm-specific fixed effects. Taking the first-differences will remove firm-specific fixed effects. However, OLS estimation still will not yield consistent estimates, since the first-difference transformation will produce a correlation between $\Delta R\&D_{i,t-1}$

[12] By following the literature, we control for both lagged and contemporaneous values of the explanatory variables (Bond et al., 2003; Brown and Petersen, 2015), but our results remain the same if we control for only the contemporaneous values of the explanatory variables in our dynamic regressions, including lagged and quadratic R&D variables.
[13] In this model, we alternatively consider the flow form of debt type, i.e., net debt issuance, change in bank debt, change in used credit lines, and change in term loans. Our results do not change if we use these variables.

and $\Delta e_{i,t}$ through the terms $R\&D_{i,t-1}$ and $e_{i,t-1}$. Instead of the first-differencing transformation, we can use within transformation, but this will then introduce a correlation between the lagged dependent variable and time-averaged idiosyncratic error term, which would yield biased coefficient estimates. This bias falls with the number of years, T, but this is not the case in our empirical analysis, since T in our sample is relatively small.[14]

Second, some of our explanatory variables, e.g., *Cash flow* and *Cash*, are not strictly exogenous. That is, shocks affecting R&D investment decisions of the firms are also likely to affect such regressors. Additionally, it is likely that there will be a correlation between some of the regressors and the idiosyncratic component of the disturbances' past and current values.

To address these econometric problems, we employ the system-GMM dynamic panel data estimator (Arellano and Bover, 1995; Blundell and Bond, 1998). One advantage of the system-GMM estimation is that all variables, including lagged and differenced variables, are potentially valid instruments as long as they are not correlated with the error term. The system-GMM estimator tackles the potential endogeneity of all variables by jointly estimating the equations in differences (i.e., first-difference transformation) and in levels. It also addresses dynamic panel bias due to the correlation between the lagged dependent variable and firm-specific fixed effects (e.g., Bond et al., 2003; Flannery and Hankins, 2013; Brown and Petersen, 2015).

The system-GMM method uses lagged levels as instruments for the equation in differences and lagged differences as instruments for the equation in levels. In section 5, we report the one-step system-GMM estimation results employing lagged levels dated t-3 and t-4 as instruments for the equation in differences, and lagged differences dated t-2 as instruments for the equation in

[14] See, for instance, Judson and Owen (1999).

levels.[15, 16] In order to ensure the reliability of our econometric methodology, we should have an appropriate selection of instruments and no second-order serial correlation. Thus, we implement Hansen's J-test, the difference-in-Hansen test, and the m2 test to confirm the validity of our instruments. In a dynamic panel data regression, we expect to have a first-order serial correlation (i.e., m1), but there should be no second-order serial correlation. In Hansen's J-test of over-identifying restrictions, the null hypothesis is that the instruments are orthogonal to the error process. Therefore, a rejection of the null hypothesis would confirm that the estimates are not consistent. The difference-in-Hansen test assesses the validity of additional instruments for the levels equation. We report Hansen's J-test, the difference-in-Hansen test, and the m2 test statistics for diagnostic checks.

4. Data and descriptive statistics

4.1. Data

We obtain our firm-level data from Worldscope and Capital IQ databases over the period 2004 to 2013. Our sample covers 939 firms from 17 major European countries. We remove firms with missing SIC codes (N/As), and firms from utilities (SIC codes 4900-4949) and financials (SIC codes 6000-6999). We combine our list of firms from Worldscope with those from the Capital IQ database, which provides bank debt, credit lines and term loan data.[17] We keep only

[15] We also used alternative instrument sets, such as lagged levels dated t-2 and t-4 and lagged differences dated t-1; and lagged levels t-3 and t-5 and lagged differences dated t-2. The results from these alternative instrument sets suggest that our findings are consistent.

[16] Since the standard errors from the two-step GMM are downward biased for small samples (Arellano and Bond, 1991), we use the one-step GMM, as in Brown et al. (2009) and Brown and Petersen (2015). We also tried the two-step GMM with Windmeijer (2005) corrected standard errors, and the results were still consistent with the one-step GMM estimation results. For brevity, we do not tabulate these results.

[17] Lin et al. (2013) also extract bank debt, term loan, and credit line data for European countries from the Capital IQ database, while Colla et al. (2013) use Capital IQ to obtain debt structure variables for US firms. In our empirical analysis, we also test the impact of public debt and its components on R&D investments. However, the sample size is reduced by half for the public debt components; in untabulated tests, we find that the coefficient estimates for the public debt components are statistically insignificant.

those firms with positive R&D spending and at least three consecutive observations in all of the variables (firms with fewer than three consecutive variable observations do not contribute observations to our regressions) in our sample period. Then, we trim our sample at the 1% level and end up with 4,246 firm-year observations involving 939 unique firms. Table A2 in the Appendix reports the list of the countries and the number of firms from each country, while Table A1 presents the list of the variable definitions and their corresponding Worldscope codes.

4.2. Descriptive statistics

Table 1a reports the summary statistics for the *Leverage*, *Bank debt*, *Used* and *Unused credit lines*, and *Term loans* for our sample period. All variables are scaled by total assets. In Panel A, we observe that, on average, *Term loans* (11.7%) is larger than *Used credit lines* (3.6%) for the whole period, considering all firms. Our sample size for unused credit lines is 477, which is considerably smaller than our full sample size. Thus, we do not include the unused credit line variable in our regression analysis, but still report the descriptive statistics for comparison purposes.

Panel B of Table 1a shows that *Bank debt* and *Used credit lines* obtain their highest mean values in 2008, suggesting that firms used term loans and credit lines when the financial crisis started, and their access to external capital markets became relatively more limited. Also, average bank debt increases by 17.5% from 2006 to 2008. Further, on average, there is a 35% (13%) increase in *Used credit lines* (*Term loan*) between 2006 and 2008. We also observe that for most of the years, the average *Unused credit lines* is greater than the average *Term loans* with respect to their mean values.

[Insert Table 1a here]

Table 1b presents the summary statistics for *R&D*, *Cash flow*, *Stock issues*, *Tobin's Q*, *Sales growth*, *Cash*, Δ*Cash* and *Employee* (number of employees as a firm size proxy), for our sample of European firms over the period 2004-2013. In Panel A, we observe that the mean (median) *R&D* is 4% (2.1%); the mean (median) *Cash* is 12.6% (9.1%); and the median value for *Employee* is 2,841, while its average is 15,860.

Panel B of Table 1b reports the average value of firm-specific variables from 2004 to 2013. Notably, the average *R&D* does not change considerably during our sample period, which is consistent with Brown and Petersen (2015), who show that US firms try to protect their R&D investments during the financial crisis.[18] Further, we can observe that there is a decline in the mean *Cash flow* and *Stock issues* from 2006 to 2013. When we consider Table 1a and Table 1b together, we can say that our sample firms may be substituting credit lines for cash flow and stock issuance, as alternative ways of financing R&D investments. Further, mean cash holdings (*Cash*) decline from 2007 to 2008, which could be viewed as the initial years of the financial crisis, but firms seem to build up their cash holdings from 2009 to 2013, with an increase of 6.7%.

[Insert Table 1b here]

In Table 1c, we split firms into young (small) and mature (large) categories and test whether there are significant differences in the mean and median of our firm-specific characteristics between those subsamples, which could be classified as financially constrained or financially unconstrained, respectively. Consistent with previous studies, we use firm age and firm size for proxies to classify firms as being financially constrained or unconstrained. Following Brown et al. (2009) and Brown and Petersen (2015), we compute firms' age as the number of years since their IPO years and classify them as "young" if their age is 15 or less over the period 2004-2006, and "mature" otherwise. Firm size is another commonly used proxy for being financially constrained or financially unconstrained (Farre-Mensa and Ljungqvist, 2016). We

[18] Survey results by McKinsey show that European firms were able to maintain their R&D activities during the recent financial crisis years. See "R&D in the downturn: McKinsey Global Survey Results", April, 2009.

classify our sample firms as “small” if their average number of employees over the sample period is less than the 70th percentile, and “large” otherwise.[19]

We observe that, on average, R&D investment ratios for young and small firms are much higher than mature and large firms’ corresponding ratios. We also test whether these means (medians) are statistically different: the *t*-test (Wilcoxon) results in columns (4) and (7) strongly reject the null hypothesis at the 1% level that the differences between the mean (median) R&D ratios are zero. The difference between the mean used credit line ratios for young and mature firms are not significant, but the *t*-test in column (7) for the difference between the mean used credit line ratios for small and large firms strongly reject the hypothesis that there is no difference between these means. We observe that, on average, small and young firms have statistically significantly higher bank debt and term loan ratios than large and mature firms. In addition, the mean stock issue ratio shows that young and small firms’ reliance on stock issues is higher than in the case of mature and large firms, which is consistent with the literature (e.g., Brown et al., 2012), and the *t*-tests for their means also support this finding. Further, young and small firms hold significantly more cash than do mature and large firms, which is consistent with the view that mature and large firms have relatively easy access to external capital markets. Consequently, they tend to hold less cash than small and young firms.

[Insert Table 1c here]

5. Estimation results

5.1. GMM estimations

Table 2 reports the system-GMM estimation results investigating the impact of bank debt and its components, including credit lines and term loans on R&D investment.[20] In column (1), we

[19] Brown et al. (2012) use a similar classification.

[20] In our estimation, we employ ‘used’ credit lines rather than ‘unused’ credit lines, since ‘unused’ credit line data are not available for our full sample of firms, i.e., unused credit line data are available only for 477 firms out of our

run R&D investment regressions, controlling for *Cash flow*, *Stock issues*, *Tobin's Q, Sales growth*, and Δ*Cash*. We also control for lagged *R&D* to account for the presence of the potential adjustment costs of R&D investments.

Consistent with the results from Brown et al. (2012), we find that the coefficient for $R\&D_{i,t-1}$ is positive and statistically significant, while $R\&D_{i,t-1}^{2}$ has negative and statistically significant coefficient estimates. These findings confirm that R&D investments are persistent and involve adjustment costs for our sample of European firms. The coefficients for $Cash\ flow_{i,t}$ and $Stock\ issues_{i,t}$ are both positive and statistically significant, suggesting that European firms rely on internal financing and equity financing to fund their R&D investments.

We also test whether the sum of coefficients for contemporaneous and lagged values of *Cash flow* and *Stock issues* is statistically significant.[21] At the bottom of Table 2, we report the *p*-values for the $\chi 2$ test with a null hypothesis that the sum of the current and lagged coefficients is equal to zero. Our results show that the *p*-value for the sum of $Cash\ flow_{i,t}$ and $Cash\ flow_{i,t-1}$ is 0.59, which implies that the long-term effect of cash flow on R&D investment is statistically insignificant. This finding is consistent with the results from Bond et al. (2003) and Bhagat and Welch (1995). For stock issuance in column (1), we find that the *p*-value for the sum of $Stock\ issues_{i,t}$ and $Stock\ issues_{i,t-1}$ is 0.20, which indicates that the long-term effect of stock issuance on R&D investment is positive, but statistically insignificant. We further observe that *Sales growth* does not have a statistically significant effect on R&D investment. Consistent with

sample of 939 firms. When we regress R&D investment on unused credit lines, we find that the coefficient for unused credit lines is positive, but insignificant. As Campello et al. (2011) argue, the size of available credit lines may be a proxy for investment opportunities, and therefore, the credit line facilities themselves need not be used to finance the R&D spending. Hence, used credit lines rather than unused credit lines can be more informative about the extent to which firms rely on their credit lines as a source of external financing for their R&D investments. However, our result of an insignificant coefficient for unused credit lines might not be reliable, since we lose more than 50% of the firm-year observations when we employ unused (or available) credit lines in our regression model.

[21] The sum of the current and lagged values of these coefficients can be interpreted as the *overall effect* or *long-term effect*. We follow Bond et al. (2003) and interpret these sums as the long-term effects.

the prior studies, we find that firms rely on their cash holdings as a source of financing their R&D investments. In column (1), the p-value for the sum of coefficients for $\Delta Cash_{i,t}$ and $\Delta Cash_{i,t-1}$ is 0.02, which shows that cash holdings have a long-term effect on R&D investments. The negative coefficient on $\Delta Cash$ shows that reductions in cash holdings provide liquidity for financing R&D investments. Our findings suggest that firms use cash holdings to smooth their R&D investments. This finding is consistent with Brown et al. (2012) and Brown and Petersen (2015).

We also report the test statistic for testing second-order correlations in the first-differenced residuals. If there is a second-order correlation, this will make our GMM estimates inconsistent. Hansen's J-test statistic is for testing over-identifying restrictions, while the difference-in-Hansen test statistic is for testing the validity of the additional differenced instruments required for systems estimation and is used in the levels equation. A low *p*-value for the J-test and difference-in-Hansen test would indicate potential problems with instrument validity. Given these explanations, we confirm that our results pass the diagnostic tests, and hence, our instruments are valid.

In columns (2) and (3), we add *Leverage* and *Bank debt* to our regression model, respectively. We observe that in column (2) the sum of the leverage coefficients is near zero, and the *p*-value of 0.75 fails to reject the null hypothesis that the sum is zero. Further, in column (3), the sum of the bank debt coefficients is 0.011, but the *p*-value of 0.41 shows that the sum is again statistically insignificant, suggesting that bank debt is not used for financing R&D investments.

Next, we examine whether the components of bank debt, i.e., *Used credit lines* and *Term loans*, could have a significant effect on R&D investments. Previous studies have shown that credit lines could provide liquidity insurance and act as a substitute for cash holdings. Hence, we expect that firms facing high adjustment costs of R&D investments can rely on credit lines as a way of managing their liquidity to maintain a smooth R&D profile. In column (4), we observe that the contemporaneous coefficient for used credit lines (0.096) is positive and significant. A one-standard deviation increase in the ratio of used credit lines-to-total assets is associated with a 65.64 basis point increase in the ratio of R&D-to-total assets, showing that our finding is also economically significant. Further, the sum of coefficients for the lagged and contemporaneous value of *Used credit lines* is 0.05 and is statistically significant (*p*-value of 0.04). For *Term loan* in column (5), the sum of the coefficients is -0.006, and it is statistically insignificant (*p*-value = 0.64). Our findings suggest that even if leverage or bank debt does not have any significant effect on R&D investments, once the debt structure is decomposed, used credit lines as a component of bank debt is a significant determinant of the R&D investments of European firms. We can interpret this finding as firms using credit lines as a tool for liquidity management (e.g., Sufi, 2009; Acharya et al., 2013). They can draw on their credit lines and smooth their R&D investments, reducing their adjustment costs.[22] Thus, credit lines, which are more flexible than term loans, could provide firms with liquidity insurance. In column (6), we include both *Term loans* and *Used credit lines* as components of bank financing, and we still find that the impact of used credit lines on R&D investment is positive and statistically significant (*p*-value =0.02). However, the sum of coefficient estimates for the lagged and contemporaneous value of *Term loans* is again statistically insignificant (*p*-value =0.96).

[Insert Table 2 here]

5.2. Sample splits for financially constrained and unconstrained firms

In this subsection, we investigate whether there are differences between financially constrained and unconstrained firms in terms of their reliance on credit lines as a source of

[22] We also analysed the effect of used credit lines on capital expenditures, but could not find a significant effect. Given that R&D investments are likely to have relatively high adjustment costs, compared to capital expenditures (e.g., Brown et al., 2012), firms would be expected to rely on credit lines as liquidity insurance to smooth their R&D investments rather than physical investment.

financing for their R&D investments. There has been a debate about the relative merits of various methods for measuring financial constraints. Firm age and firm size are commonly used as proxies for measuring whether a firm is financially constrained or unconstrained. Previous researchers have argued that firm size and firm age appear to be closely related to financial constraints, and they are much less endogenous than most other sorting variables (e.g., Farre-Mensa and Ljungqvist, 2016; Hadlock and Pierce, 2010). Thus, in our analysis, we follow the recent extant literature and use firm age and firm size as our proxies for measuring financial constraints.[23]

In Table 3, we classify our sample of firms into groups of young, mature, small and large firms. We expect a stronger relation between R&D investment and used credit lines in the groups of young and small firms. As Table 1c reveals, on average, small and young firms have a higher ratio of R&D than large and mature firms. These firms are more likely to experience liquidity shortages, and are thus more likely to require more liquidity insurance to smooth their R&D investments. Since credit lines can provide firms with liquidity insurance, young and small firms can rely more on credit lines than mature and large firms.

[Insert Table 3 here]

Table 3 reports the GMM estimation results for our subsamples of financially constrained firms, i.e., young and small firms, and financially unconstrained firms, i.e., mature and large firms. The coefficient estimates for $R\&D_{t-1}$, for both financially constrained and unconstrained groups, are close to 1, showing that R&D investment is persistent. The coefficient for $R\&D^2_{t-1}$ for financially unconstrained firms is smaller than that for constrained firms, suggesting that the financially constrained firms' adjustment costs of R&D are less than those of unconstrained firms. The sums of coefficients for used credit lines are positive and statistically significant for the young

[23] Additionally, we use the dividend payout ratio, the HP (Hadlock-Pierce) index, and the KZ (Kaplan-Zingales) index as alternative measures for classifying our sample of firms into financially constrained and unconstrained groups. Our results remain the same. For brevity, we do not tabulate these results.

and small firms (columns 1 and 3). However, the sums of used credit line coefficients for mature and large firms are statistically insignificant. These findings support our expectation that financially constrained firms are more likely to use credit lines for financing their R&D investments. The sum of the *Cash flow* coefficients is positive and statistically significant for large firms (p-value = 0.01), consistent with the literature (Hall, 2002), while the sum of the *Stock issues* coefficients is positive and statistically insignificant (p-value =0.12) for mature firms. Further, for young and small firms, only the coefficient on lagged cash holdings is statistically significant, while for mature and large firms, both the lagged cash holdings and the sum of lagged and contemporaneous cash holdings are statistically significant. These results suggest that cash holdings affect young and small firms' R&D investments only in the short term, while this effect exists both in the short and long term for mature and large firms.

5.3. Sample splits for high and low R&D firms and alternative sources of financing

In this section, we classify our sample into high and low R&D subgroups to explore whether we observe any differences between these subgroups in terms of relying on credit lines for financing R&D activities. Firms with a ratio of R&D investment above (below) the sample median are classified into high (low) R&D subgroups. If credit lines provide liquidity insurance for firms to smooth their R&D investments, which involve high adjustment costs, then we would expect to see a stronger impact of credit lines on R&D investment for the subgroup of firms with high R&D in column (2) than firms with low R&D in column (1) of Table 4. Our findings in columns (1) and (2) support this prediction. The sum of the coefficient estimates for used credit lines in column (1) is positive and statistically insignificant, while it is positive and statistically significant in column (2). Thus, firms with high R&D rely on credit lines more than those with low R&D as a source of financing.

In column (3) and column (4) of Table 4, we examine whether there are differences between high and low cash holding groups of firms with high R&D. High R&D firms with a ratio of cash holdings above (below) the sample median are classified into high R&D and high (low) cash holding groups. Firms with high R&D and high cash holdings are more likely to use their internal financing rather than credit lines, which could involve monitoring from lenders. However, firms with high R&D and low cash holdings would use credit lines, as they lack alternative sources of internal financing. Our results in column (3) and (4) support this prediction. In column (3), the sum of the coefficient estimates for used credit lines is positive and significant, while there is no statistically significant impact of used credit lines on R&D investment in the subgroup of firms with high R&D and high cash in column (4).

Next, in columns (5) and (6), we classify our sample into subgroups of firms with high R&D and high stock issuances, and those with high R&D, but low stock issuances. High R&D firms with a ratio of stock issuances-to-total assets above (below) the sample median are classified into high R&D and high (low) stock issuance groups. As a further test of whether access to alternative sources of financing influences firms' use of credit lines in funding their R&D investments, we examine whether firms with access to equity financing would rely less on credit lines as a source of financing, since they would not prefer to expose themselves to monitoring by lenders. Our results in Table 4 show that firms with high R&D and low stock issuances, i.e., column (5), use credit lines as source of funding their R&D activities, but we do not observe a similar significant impact of credit lines for firms in column (6).

In columns (7) and (8), we focus on subgroups of firms with high R&D and low cash flows, and firms with high R&D and high cash flows. High R&D firms with a ratio of cash flows-to-total assets above (below) the sample median are classified into high R&D and high (low) cash flow groups. Sufi (2009) argues that credit lines, which provide firms with liquidity insurance, are accessible for firms with high cash flows, as such firms are more likely to fulfill the covenant requirements than those with low cash flows. We would therefore expect those firms in column (8) to have a stronger relationship between used credit lines and R&D investments than firms in column (7), which have high R&D and low cash flows. Consistent with this expectation, we observe that in column (8) the sum of the coefficient estimates for *Used credit lines* is positive and statistically significant, while we do not observe a significant relationship between used credit lines and R&D investments in column (7). Overall, these results provide further evidence that firms use credit lines to fund their R&D investments when their access to alternative sources of funding is limited.[24]

[Insert Table 4]

5.4. Difference-in-differences estimation results: The 2007-2009 financial crisis and European sovereign debt crisis

The 2007-2009 financial crisis has been viewed as an external shock for European firms, and several studies have investigated its impact on corporate financial policies (see, for instance, Campello et al., 2012; Beuselinck et al., 2017; Gilchrist and Mojon, 2017). Table 5 reports difference-in-differences estimation results for R&D investments. For brevity, we report only the coefficient estimates for *Used credit lines*, Δ*Cash* and their interaction variables with the crisis dummies. We test whether firms' use of credit lines and cash reserves for financing their R&D investments changed during the 2007-2009 crisis and the European sovereign debt crisis period. Following previous studies, we create a dummy variable, *Crisis*, which is equal to 1 if a year is

[24] We also considered whether firms with access to public debt markets would still use credit lines for financing their R&D investments. Following Faulkender and Petersen (2006), we use a corporate credit rating by the S&P as a measure of whether firms have access to public debt. We collected S&P ratings data from Thomson Reuters EIKON. In untabulated results, we find that our sample of European firms with public debt access (approximately 10% of our sample firms) use credit lines for financing their R&D investments similar to those firms with no public debt access. For brevity, we do not report these findings.

between the 2007-2009 period, and 0 otherwise (e.g., Beuselinck et al., 2017). Additionally, we define another *Crisis* dummy for the sovereign debt crisis period. Previous researchers have argued that the European sovereign debt crisis period started in 2010 and still continues (e.g., Gilchrist and Mojon, 2017). We follow the literature and define the European sovereign debt crisis period as 2010 and following years in our sample, i.e., 2010-2013. Next, we interact our crisis dummy variables with cash holdings and used credit lines to investigate whether firms continued to rely on their cash holdings and credit lines during the crisis period. As documented by prior studies, the 2007-2009 crisis and European sovereign debt crisis differ in terms of a substantial decline in the corporate lending of European banks during the European sovereign debt crisis (e.g., Becker and Ivashina, 2016).

[Insert Table 5 here]

In column (1), we test the impact of used credit lines on R&D investment during the financial crisis of 2007-2009. Firms can rely more on their credit lines if their access to external capital markets becomes relatively more limited. However, their use of credit lines during a time of crisis will depend on the financial health of the banks. As long as banks can fulfill their commitment for credit line contracts, firms can continue to rely on credit lines (or can possibly increase their use of credit lines) for financing their R&D investments during a time of crisis. We find that the sum of the coefficients for *Used credit lines*Crisis* is negative and statistically insignificant, while it is positive and statistically significant for *Used credit lines* only. Thus, we do not observe any significant difference between the crisis and non-crisis periods in terms of how used credit lines influence R&D investments. Overall, credit lines have a positive impact on R&D investments, and firms seem to continue to rely on credit lines during the crisis period as a way of financing their R&D investments. Our findings are consistent with Campello et al. (2012)'s survey showing that European firms extensively used their credit lines during the financial crisis.

Moreover, our analysis supports previous studies, which have argued that the European banking system is more of a relationship-based system when compared to the system in the US.[25] Recently, Bolton et al. (2016) have used credit registry data for a sample of Italian firms to differentiate between relationship and transactional lending. They document that relationship banking plays an important role in dampening the impact of a negative exogenous shock, i.e., financial crisis. Their results show that firms relying on relationship lending can weather crises better, as they continue to borrow from their banks on favorable terms.[26] In column (2), we observe the coefficients for the current and lagged values of Δ*Cash*Crisis,* and their sum is positive, but statistically insignificant. Thus, our results suggest that the impact of cash holdings on R&D investments does not change during the crisis period, compared to the non-crisis period.

In columns (3) and (4), we investigate the effect of the European sovereign debt crisis on the financing of R&D investments. We test whether the use of credit lines and cash reserves for R&D investments differ between the European sovereign debt crisis period and before this period. In column (3), we interact *Crisis* with *Used credit lines* to investigate whether firms continued to rely on credit lines during the sovereign debt crisis period when access to external financing sources is limited. We find that the sum of the coefficients for *Used credit lines*Crisis* is negative and statistically insignificant, but it is positive and statistically significant for *Used credit lines*. Hence, in terms of how credit lines influence R&D investments, we do not observe any significant

[25] We also run regressions using US data and find that credit lines (or term loans) do not exert any statistically significant influence on R&D investments. This finding is in line with arguments that the US banking system is relatively less relation-based than the European banking system. See, for instance, Ongena and Smith (2000) and Detragiache et al. (2000). Additionally, Berg et al. (2017) show that large and rated European firms obtain 45% of their debt financing from bond markets, while the percentage for large and rated US firms is over 75%. For brevity, we do not tabulate our R&D regression results for US firms.

[26] For our sample of firms, we do not have access to detailed credit registry data, which would allow us to examine how bank-firm relationships changed throughout the crisis and non-crisis periods. We checked the Dealscan database, which provides characteristics of syndicated loan contracts. This dataset is available only for 248 firms of our sample of 939 firms. Table A4 in the Appendix shows that the cost of debt increased more for term loans than for credit lines during the crisis period, which could partly explain why firms rely on credit lines rather than term loans for financing their R&D investments.

difference between the European sovereign debt crisis and the pre-crisis periods. Overall, our findings suggest that firms continued to rely on credit lines during the European sovereign debt crisis period as a way of financing their R&D investments.[27]

In column (4), we add both Δ*Cash*Crisis* and *Used credit lines*Crisis* interaction terms to our regression model. We find that the coefficient estimate for $\Delta Cash_{i,t-1}$ is -0.026, while it is -0.091 for $\Delta Cash_{i,t-1}*Crisis$. These coefficients are statistically significant at the 5% and 1% levels, respectively. These findings suggest that the impact of cash holdings on R&D investments increased during the sovereign debt crisis, showing that firms' reliance on cash was higher during the sovereign debt crisis. Further, our results are consistent with the literature, documenting that during the sovereign debt crisis in Europe, firms' access to external finance became more limited, i.e., the cost of debt (spread) increased during this period (e.g., Gilchrist and Mojon, 2017). Therefore, as expected, firms relied more on cash reserves for financing their R&D investments during the European sovereign debt crisis. Further, we observe that the sum of the current and lagged coefficients for Δ*Cash*Crisis* is negative, but statistically insignificant (*p*-value =0.29). Hence, we could not find statistically significant long-term effect of cash holdings on R&D investments during the sovereign debt crisis. More importantly, our results show that the sum of the lagged and current coefficients for *Used credit lines* is positive and significant (*p*-value =0.02), while this coefficient for *Used credit lines*Crisis* is negative and statistically insignificant (*p*-value =0.69), suggesting that used credit lines provided financing for R&D investments in both the European sovereign debt crisis and before this debt crisis period.

5.6. Financially constrained firms and financial crises

[27] France, the UK and Germany were relatively less affected countries by the sovereign debt crisis (Acharya et al., 2016). Hence, we conducted the same analysis by excluding the UK, Germany, and France. Unreported results from this analysis are still consistent, showing that the findings are not driven by firms from these countries.

In this subsection, we investigate whether financially constrained firms use more credit lines during crisis times when it would normally be more difficult to raise financing externally. Given that R&D investments mainly involve the salaries of scientists and employees with high firm-specific human capital, firms would have the priority to protect their R&D investments during a crisis period (Brown and Petersen, 2015). If they fire their employees during a crisis, it would be considerably difficult to hire new employees with a similar level of firm-specific human capital, which could lead to major productivity losses. Costly hiring and firing of these highly skilled employees create high adjustment costs for R&D investments. Hence, firms strategically try to maintain a smooth path of R&D investment in order to reduce their R&D adjustment costs (Brown and Petersen, 2011).

As long as creditors can honor their commitment for firms' existing credit lines, firms with more limited access to alternative sources of financing can draw funds from their existing credit lines and can finance their R&D investments. Table 6 presents our estimation results with the crisis interaction dummies, i.e., the financial crisis 2007-2009 dummy and the European sovereign debt crisis dummy. For brevity, we do not report the coefficient estimates for firm-level control variables, as shown in Equation (1). Our findings in columns (1), (3), (5) and (7) show that financially constrained firms continued to use credit lines as a source of financing during both crises. However, they did not seem to increase their use of credit lines for financing their R&D investments during the crises (i.e., none of the *p*-values for *Used credit lines**Crisis* are significant). This might be due to supply- or demand-driven effects. As we do not have detailed firm-bank level credit registry data, we cannot examine how the bank-firm relationship evolved throughout the crisis and non-crisis periods. However, our results are consistent with the view that relationship banking in Europe can help firms relieve their financial constraints during a time of crisis.

For financially unconstrained firms in columns (2), (4), (6) and (8), we observe that the sum of the coefficient estimates for *Used credit lines***Crisis* is not statistically significant. Thus, we do not observe any significant difference in these firms' use of credit lines for financing their R&D investments between crisis and non-crisis periods. Further, we observe that the sum of the coefficient estimates for Δ*Cash* is negative and statistically significant, while the sum of the coefficient estimates for Δ*Cash*Crisis* is statistically insignificant. This finding shows that financially unconstrained firms continued to rely on their cash holdings during the crisis periods.

[Insert Table 6]

5.7. Additional Tests

5.7.1. R&D investments and credit lines in bank-based countries

In this subsection, we test whether the link between R&D investments and used credit lines vary, depending on the level of credit market development relative to the level of stock market development, i.e., bank-based versus market-based financial structures.[28] As Brown et al. (2012) argue, European countries vary considerably in their stock market development and credit market development, which could have implications for firms' financing patterns. Following Demirguc-Kunt and Levine (2001) and Didier et al. (2014), we use the ratio of credit market development to stock market development and classify our sample of European countries into groups of bank-based and market-based financial systems. Countries with an average ratio of credit market development to stock market development above the median are classified into the group of bank-based countries, while those below the median are classified into the group of market-based countries. To classify the countries, we use the data for credit market development and stock

[28] Prior studies have emphasized the importance of financial development, i.e., stock market development and credit market development, in determining innovation and R&D investments. Using a cross-country sample, Hsu et al. (2014) report that stock market development has a positive impact on innovation, while credit market development discourages innovation. Additionally, Brown et al. (2013) find that access to equity financing through well-developed stock markets increases R&D investments for a sample of firms from 32 countries. In contrast, their results show that credit market development has no significant impact on R&D investments.

market development for 2006, which is the year before the 2007-2009 financial crisis, given that crises may affect the values of these variables. Alternatively, using the average values of credit market development and stock market development over the period 2004-2006 rather than 2006 yields the same classification. Based on this classification, we have Austria, Denmark, Germany, Ireland, Italy, the Netherlands, Norway, and Spain in the group of countries with the bank-based financial system, while Belgium, Finland, France, Greece, Poland, Sweden, Switzerland, Turkey, and the UK are classified into the group of countries with the market-based financial system.

Relationship banking is likely to be more prevalent in countries with the bank-based financial system, as banks in these countries have more opportunities to obtain proprietary borrower information through repeated interaction with borrowers (Beck et al., 2017). Bolton et al. (2016) provide evidence that relationship banking may have played an important role in dampening the effects of negative shocks of the 2007-2009 crisis on Italian firms.[29] They find that Italian firms relying on relationship banks were less likely to default on their loans and could withstand the 2007-2009 crisis better, since their relationship banks continued to lend to them on favorable terms. Our sample of firms from bank-based countries can benefit from relationship lending, which can help them protect their R&D investments during a period of exogenous shock. Hence, these firms can increase their use of credit lines during a financial crisis relatively more than firms in market-based countries. However, the increase in their use of credit lines will be limited to the extent that banks are able to fulfill their commitments.

In our dynamic regression model, we interact used credit lines with a crisis dummy and a dummy for bank-based countries to investigate whether firms in bank-based countries rely more on credit lines during a period when access to alternative sources of financing becomes more

[29] Relationship banks accumulate valuable information during the lending relationship and can more easily adjust their lending terms to changing economic circumstances (e.g., Beck et al., 2017; Puri et al., 2011; Jiménez et al., 2016).

limited. Table 7a reports the estimation results for our regression model, which incorporates the dummy for bank-based countries. In column (1), we observe that the coefficient estimate in the case of the dummy for bank-based countries is negative and statistically significant. This finding is consistent with results from Hsu et al. (2014), showing that credit market development does not encourage innovation. Further, we observe that the sum of the coefficient estimates for *Used credit lines* is statistically insignificant, while the sum of the coefficients for *Used credit lines***Bank-based* is positive and significant. Thus, our results show that firms in bank-based countries rely on credit lines to finance their R&D investments, contrary to those firms in market-based countries. In column (2), we observe that the sum of the coefficient estimates for *Used credit lines*Crisis*Bank-based* is positive and statistically significant (*p*-value =0.09). This result indicates that firms in bank-based countries increased their use of credit lines as a source of financing for R&D investments during the 2007-2009 crisis. However, in column (3) we observe that the sum of the coefficient estimates for *Used credit lines*Crisis*Bank-based* is negative and statistically significant (*p*-value =0.05). Thus, firms in bank-based countries reduced their use of credit lines for funding their R&D investments in the case of the sovereign debt crisis. This result is consistent with findings from prior studies, which show that bank lending declined considerably during the European sovereign debt crisis (e.g., Becker and Ivashina, 2016). Further, in columns (2) and (3), the sum of the coefficient estimates for *Used credit lines*Crisis* is statistically insignificant, indicating that firms in market-based countries did not change their use of credit lines during the crisis periods.

Overall, we find that the association between used credit lines and R&D investments varies among firms, depending on whether they are in a bank-based or market-based country. More importantly, the effects of the 2007-2009 crisis and the European sovereign debt crisis on the link between R&D investments and used credit lines seem to be different in bank-based countries, compared to those in market-based countries.

[Insert Table 7a here]

In Table 7b, we first split our sample into groups of young, mature, small, and large firms, as in section 5.2. We then interact *Crisis* and *Bank-based* dummy variables with *Used credit lines* to investigate whether young and small firms in bank-based countries rely more on credit lines to protect their R&D investments during a crisis. Columns (1) to (4) show that the sum of the coefficient estimates for *Used credit lines*Crisis* Bank-based* is positive and significant only for young and small firms. The sum of the coefficient estimates for *Used credit lines*Crisis*, however, is negative and insignificant for all subgroups of firms, regardless of their firm age and firm size. These findings suggest that only young and small firms in bank-based countries increased their use of credit lines to finance their R&D investments during the 2007-2009 financial crisis. We could not find similar results for the young and small firms in market-based countries. These findings are consistent with the view that relationship banking, which can help firms weather crises relatively more easily, is likely to be more prevalent in bank-based countries

Next, in Panel B of Table 7b, we investigate the effect of the European sovereign debt crisis on the relationship between used credit lines and R&D investments for financially constrained (small and young) firms and unconstrained firms (large and mature). Columns (5) to (8) show that the sum of the coefficient estimates for *Used credit lines*Crisis*Bank-based* is negative and significant only for young and small firms. However, the sum of the coefficient estimates for *Used credit lines*Crisis* is statistically insignificant in all columns. These results suggest that young and small firms in bank-based countries reduced their use of credit lines for R&D investments during the European sovereign debt crisis period. In columns (6) and (8) the sum of the coefficient estimates for *Used credit lines*Crisis*Bank-based* is statistically insignificant. This finding shows that mature firms and larger firms, different from young and small firms, do not change their use of credit lines for financing their R&D investment in bank-based countries.

Overall, our findings in Table 7b reveal that only young and small firms in bank-based countries, but not those in market-based countries, increased their reliance on credit lines for financing their R&D investments during the 2007-2009 financial. Conversely, the same group of firms decreased their use of credit lines during the European sovereign debt crisis. This finding is consistent with prior studies, which document that relative to the 2007-2009 financial crisis, the European sovereign debt crisis has had a substantially more adverse impact on the corporate lending of European banks (e.g., Becker and Ivashina, 2016).

[Insert Table 7b here]

5.7.2. Sample split between the UK and continental Europe

In this section, we investigate whether our results are robust and not driven by the sub-sample of UK firms, which constitutes a large part of our sample. In Table 8, we estimate our model, excluding the UK firms. We observe that the sum of the *Used credit lines* coefficients is positive and statistically significant (*p*-value = 0.08), as in our full sample. The sum of cash holding coefficients (Δ*Cash*) is also significant. Moreover, the sum of the coefficients for *Cash flow* and *Stock issues* is not significant, as it was the case for our whole sample. This table documents that excluding the UK does not change our main result, which suggests that used credit lines have a positive impact on R&D investments. Overall, Table 8 shows that our results are not driven by the dominance of the UK subsample, and the findings remain qualitatively very similar if we exclude the UK firms from our sample.

[Insert Table 8 here]

6. Conclusion

This paper examines the impact of bank debt and its components, i.e., term loans and credit lines, on R&D investments for a sample of European firms over the period 2004 to 2013. We find that bank debt and term loans do not have a significant impact on R&D investments, while there is a significant and positive relationship between used credit lines and R&D investments. Additionally, we observe that the effect of used credit lines on R&D investments is relatively stronger for financially constrained firms, i.e., small and young firms, than for financially unconstrained firms, i.e., large and mature firms, suggesting that firms with limited access to external capital markets use credit lines as a source of financing their R&D investments.

Further, our results show that firms continued to rely on credit lines to fund their R&D investments during the crisis periods, i.e., the 2007-2009 financial crisis and the Euro area sovereign debt crisis, when access to alternative sources of financing became more limited. However, when we classify our sample of European countries into groups of bank-based and market based countries, we find that European firms in bank-based countries increased their use of credit lines for financing their R&D investments during the financial crisis of 2007-2009, while the link between R&D investments and used credit lines becomes weaker during the European sovereign debt crisis of 2010-2013.

Overall, our findings provide supporting evidence for the role of banks in shaping R&D investment decisions by showing that firms rely on credit lines as a source of financing for their R&D investments. Our results also complement the findings from previous studies showing that credit lines could be important as a liquidity management tool, particularly for those firms that have relatively more limited access to external capital markets. Further, our results offer new insights on why R&D investments have been considerably stable during financial crises. Our sample of European firms has been able to rely on credit lines, as well as cash holdings, to smooth their R&D investments during periods when access to external capital markets becomes relatively more limited. Finally, our results suggest that banks can influence R&D investments in Europe and can play a role in determining firms' responses to financial crises.

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Appendix

Table A1
Variable definitions.

Variable	Definition
R&D	Research and development expenses (WC01201)/total assets$_{i,t-1}$ (WC02999). *Source:* Worldscope
Cash flow	[Net income (WC01551) + depreciation (WC01148) + R&D (WC01201)]/total assets$_{i,t-1}$ (WC02999). *Source:* Worldscope
Stock issues	[The received amount from the sale of common and/or preferred stocks (WC04251) less repurchases (WC04751)]/total assets$_{i,t-1}$ (WC02999). *Source:* Worldscope
Tobin's Q	[Total assets (WC02999) + market value of equity (WC08001) less book value of equity (WC03501)]/total assets$_{i,t-1}$ (WC02999). Market and book value of equities are adjusted for their fiscal year-end. *Source:* Worldscope
Sales growth	[Net sales$_{i,t}$ – net sales$_{i,t-1}$]/net sales$_{i,t-1}$. Net sales are gross sales and other operating revenue less discounts, returns and allowances (WC01001). *Source:* Worldscope
Cash	Cash & short term investments (WC02005)/total assets$_{i,t-1}$ (WC02999). *Source:* Worldscope
Employee	Number of employees (WC07011). *Source*: Worldscope
Total assets	Sum of total current assets, long-term receivables, investment in unconsolidated subsidiaries, other investments, net property plant and equipment and other assets (WC02999). *Source:* Worldscope
Leverage	Total debt (WC03255)/total assets$_{i,t-1}$ (WC02999). *Source:* Worldscope
Bank debt	[Credit lines+ term loans]/total assets$_{i,t-1}$ (WC02999). *Source:* Capital IQ
Used credit lines	Drawn credit lines/total assets$_{i,t-1}$ (WC02999). *Source:* Capital IQ
Unused credit lines	Undrawn credit lines/total assets$_{i,t-1}$ (WC02999). *Source:* Capital IQ
Term loans	Term loans/total assets$_{i,t-1}$ (WC02999). *Source:* Capital IQ
Credit market development	Lending from domestic banks to the private non-financial sectors as a proportion of GDP (%). *Source*: Lending data are from the Bank for International Settlements (BIS). GDP data (at current and non-adjusted prices) are from International Financial Statistics or World Economic Outlook, IMF.
Stock market development	Stock market capitalization to GDP (%). *Source:* World Bank.
Bank-based	A country-level binary variable that is 1 if the ratio of *Credit Market Development* to *Stock Market Development* is higher than the sample median, and 0 otherwise. To classify the countries, we use the data from 2006, a year before the recent financial crisis, since crises may affect the values. Using the data from 2004-2006 rather than 2006 provides the same classification. A similar approach is used in Didier et al. (2014). This construct shows that our sample of bank-based countries are Austria, Denmark, Germany, Ireland, Italy, the Netherlands, Norway, Spain, while market-based countries are Belgium, Finland, France, Greece, Poland, Sweden, Switzerland, Turkey and the UK.

Table A2
Sample distribution across countries and descriptive statistics for country-specific characteristics.

	Number (%) of firms	Number of firm-years	Stock market development	Credit market development	Credit market development/Stock market development
			Mean [Median]	Mean [Median]	Mean [Median]
Austria	24 (2.56)	97	0.346 [0.301]	0.948 [0.944]	2.740 [3.136]
Belgium	24 (2.56)	92	0.603 [0.570]	0.594 [0.577]	0.985 [1.012]
Denmark	31 (3.3)	113	0.647 [0.624]	1.641 [1.648]	2.536 [2.641]
Finland	62 (6.6)	297	0.787 [0.572]	0.869 [0.875]	1.104 [1.530]
France	74 (7.88)	366	0.737 [0.720]	0.982 [1.024]	1.332 [1.422]
Germany	159 (16.93)	706	0.428 [0.418]	0.816 [0.859]	1.907 [2.055]
Greece	11 (1.17)	37	0.354 [0.295]	0.900 [0.915]	2.542 [3.102]
Ireland	12 (1.28)	46	0.437 [0.468]	1.381 [1.351]	3.160 [2.887]
Italy	25 (2.66)	114	0.345 [0.354]	0.831 [0.821]	2.409 [2.319]
Netherlands	40 (4.26)	174	0.796 [0.767]	1.161 [1.162]	1.459 [1.515]
Norway	23 (2.45)	81	0.576 [0.550]	0.802 [0.837]	1.392 [1.522]
Poland	5 (0.53)	10	0.324 [0.320]	0.455 [0.474]	1.404 [1.481]
Spain	9 (0.96)	32	0.869 [0.882]	1.536 [1.596]	1.768 [1.810]
Sweden	84 (8.95)	327	1.005 [0.995]	1.166 [1.243]	1.160 [1.249]
Switzerland	61 (6.5)	345	2.010 [2.039]	1.488 [1.497]	0.740 [0.734]
Turkey	36 (3.83)	155	0.313 [0.304]	0.424 [0.413]	1.355 [1.359]
UK	259 (27.58)	1,254	1.155 [1.187]	1.026 [1.020]	0.888 [0.859]
All countries	939 (100)	4,246	0.894 [0.888]	1.009 [0.988]	1.129 [1.113]

Table A3

Descriptive statistics for debt components (Debt types/Total debt).

All debt variables are scaled by total debt. Our sample consists of 939 firms from 17 European countries over the period 2004-2013. Panel A reports average values of debt variables over the period 2004-2013, while Panel B reports average values of debt variables for each year from 2004 to 2013.

Panel A. Full sample

	Bank debt	*Used credit lines*	*Term loans*
Mean	0.288	0.042	0.245
Median	0.270	0.038	0.229
No. of observations	4,231	4,243	4,222
No. of firms	939	939	939

Panel B. Descriptive statistics by year

Year	N	*Bank debt*	*Used credit lines*	*Term loans*
2004	80	0.160	0.028	0.132
2005	337	0.256	0.026	0.229
2006	476	0.270	0.045	0.224
2007	495	0.342	0.047	0.296
2008	507	0.395	0.079	0.315
2009	527	0.286	0.035	0.250
2010	504	0.271	0.024	0.247
2011	483	0.264	0.048	0.216
2012	455	0.257	0.038	0.219
2013	377	0.238	0.031	0.206

Table A4

Descriptive statistics for characteristics of new credit lines and term loans.

This table reports descriptive statistics for the characteristics of new credit lines and term loans from 2004 to 2012. The Dealscan data for the year 2013 are not available. We merge our sample of 939 firms from 17 European countries, which are covered by Worldscope and Capital IQ, with loan contract data from the Dealscan database. In column (1), we report the number of new credit lines and term loan facilities from the deals between firms and banks. Each package can have more than one debt type. In columns (2) and (3), the cost of debt is in basis points (bps) and includes the fees borrowers pay over LIBOR for each dollar drawn down.

We have loan contract data available for 248 of our sample firms. We observe that the number of credit lines (term loans) is 43(19) in 2006, while it is 51(46) in 2009. Thus, there is no decline in the number of new credit lines (term loans) during the financial crisis period 2007-2009. However, the table shows that there is a considerable increase in fees for new credit lines (term loans) from 2006 to 2009. We observe that the average fee for new credit lines (term loans) moves from 61.2 (69.3) bps in 2006 to 238.3 (335.0) bps in 2009. The average (median) fees for new credit lines and terms loans decline from 2009 to 2012. As previous studies have shown, loan contracts have option-like characteristics (Berg et al., 2016; Thakor et al., 1981). For instance, a borrowing firm can exercise the option of drawing down on a line of credit when the committed interest rate is relatively lower than the spot market rate. Thus, fees for credit lines can be viewed as a proxy for measuring the price for options embedded in credit line contracts. Further, fees provide a way of screening, based on whether they have private information about exercising the options in loan contracts. We observe that the average size of new credit lines (term loans) provided by banks declines from $1.717 billion ($1.718 billion) in 2006 to $600 ($258) million in 2009. We further observe that there is an increase (decrease) in the average maturity of new credit lines (term loans) from 2009 onward.

Year	Number of new credit lines (new term loans) (1)	Cost of debt for credit lines: mean (median) (2)	Cost of debt for term loans: mean (median) (3)	Amount of new credit lines, in million $: mean (median) (4)	Amount of new term loans, in million $: mean (median) (5)	Maturities for credit lines, in months: mean (median) (6)	Maturities for term loans, in months: mean (median) (7)
2004	32 (7)	59.7 (33)	118.3 (40)	2,036 (936)	330 (150)	56.7 (60)	47.0 (36)
2005	73 (23)	36.5 (25)	124.5 (70)	1,737 (837)	1,036 (189)	66.3 (60)	63.7 (60)
2006	43 (19)	61.2 (37)	69.3 (45)	1,717 (856)	1,718 (447)	61.1 (60)	83.3 (60)
2007	50 (25)	70.5 (26)	100.6 (71)	1,437 (641)	2,587 (433)	65.0 (60)	71.3 (60)
2008	44 (36)	83.0 (70)	105.8 (80)	873 (603)	1,172 (547)	44.3 (36)	75.0 (57.5)
2009	51 (46)	238.3 (250)	335.0 (308)	600 (352)	258 (114)	38.9 (36)	69.6 (36)
2010	59 (26)	186.6 (146)	206.3 (220)	968 (485)	865 (250)	50.4 (50)	57.2 (45)
2011	87 (25)	120.1 (93)	249.3 (275)	1,208 (553)	599 (371)	55.5 (60)	51.9 (42)
2012	25 (8)	145.2 (85)	232.0 (300)	1,035 (603)	832 (286)	57.4 (60)	28.1 (27)

Table 1a

Descriptive statistics for debt-related variables (Debt/Lagged total assets).

This table reports descriptive statistics for debt-related variables, which are scaled by beginning of the year total assets. Our sample of firms comes from 17 major European countries covered by Worldscope and Capital IQ over the period 2004-2013. Panel A reports average values of debt-related variables for the whole period, while Panel B reports average values of debt-related variables for each year. Unused credit lines data are available only for 477 firms out of our sample of 939 firms. Thus, we do not include it as a variable in our main regression analyses, but we provide descriptive statistics here for comparison purposes.

Panel A. Full sample

	Leverage	*Bank debt*	*Used credit lines*	*Unused credit lines*	*Term loans*
Mean	0.235	0.154	0.036	0.139	0.117
Median	0.210	0.115	0.000	0.117	0.065
Standard deviation	0.167	0.149	0.068	0.103	0.143
No. of observations	4246	4246	4246	1,818	4246
No. of firms	939	939	939	477	939

Panel B. Descriptive statistics by year

Year	N	*Leverage*	*Bank debt*	*Used credit lines*	*Unused credit lines*	*Term loans*
2004	80	0.242	0.093	0.018	0.122	0.075
2005	336	0.253	0.169	0.028	0.125	0.138
2006	478	0.236	0.154	0.031	0.126	0.123
2007	497	0.245	0.165	0.035	0.140	0.130
2008	508	0.254	0.181	0.042	0.130	0.139
2009	528	0.216	0.147	0.038	0.150	0.109
2010	504	0.234	0.151	0.038	0.144	0.111
2011	483	0.236	0.150	0.037	0.135	0.112
2012	455	0.229	0.142	0.039	0.139	0.103
2013	377	0.211	0.132	0.036	0.148	0.090

Table 1b

Descriptive statistics for firm characteristics.

This table reports descriptive statistics for firm characteristics over the period 2004-2013. All variables are scaled by the beginning of the year total assets except Tobin's Q, Sales growth and Employee. The sample includes firms from 17 European countries covered by Worldscope and Capital IQ over the period 2004-2013. Panel A reports average values of the firm characteristics for the whole period, while Panel B reports their average values for each year.

Panel A: Full sample

	R&D	*Cash flow*	*Stock issues*	*Tobin's Q*	*Sales growth*	*Cash*	*ΔCash*	*Employee*
Mean	0.040	0.113	0.014	1.574	0.053	0.126	-0.002	15,860
Median	0.021	0.110	0.000	1.357	0.052	0.091	0.00	2,841
Standard deviation	0.054	0.106	0.084	0.837	0.190	0.117	0.095	40,902
No. of observations	4,246	4,246	4,246	4,246	4,246	4,246	4,246	4,246
No. of firms	939	939	939	939	939	939	939	939

Panel B: Descriptive statistics by year

Year	N	*R&D*	*Cash flow*	*Stock issues*	*Tobin's Q*	*Sales growth*	*Cash*	*ΔCash*	*Employee*
2004	80	0.045	0.132	0.006	1.688	0.053	0.132	0.008	47,249
2005	336	0.049	0.142	0.020	1.719	0.072	0.137	0.009	20,574
2006	478	0.046	0.131	0.021	1.877	0.099	0.140	-0.001	15,255
2007	497	0.041	0.132	0.013	1.751	0.089	0.128	-0.011	13,690
2008	508	0.037	0.100	0.010	1.263	0.034	0.112	-0.019	14,021
2009	528	0.036	0.077	0.015	1.403	-0.103	0.119	0.003	13,993
2010	504	0.036	0.115	0.011	1.512	0.135	0.130	0.017	14,586
2011	483	0.037	0.109	0.014	1.417	0.082	0.119	-0.017	15,759
2012	455	0.041	0.117	0.011	1.564	0.091	0.129	0.002	15,411
2013	377	0.038	0.106	0.011	1.761	-0.016	0.127	-0.001	16,080

Table 1c

Descriptive statistics for firm characteristics for subsamples.

This table reports descriptive statistics for firm-specific characteristics and debt-related variables for our subsample of firms, which are classified as young (small) and mature (large). It also shows t-test (Wilcoxon) for the differences in means (medians) of the variables. All variables are scaled by the beginning of year total assets except *Tobin's Q*, *Sales growth* and *Employee*. The sample consists of non-utilities (excluding SIC codes 4900-4949) and non-financial (excluding SIC codes 6000-6999) firms from 17 major European countries covered by Worldscope and Capital IQ over the period 2004-2013. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Full Sample	Young	Mature		Small	Large	
Variables	Mean [Median]	Mean [Median]	Mean [Median]	*(t-test) [Wilcoxon]*	Mean [Median]	Mean [Median]	*(t-test) [Wilcoxon]*
R&D	0.040	0.050	0.029	*(12.20)****	0.045	0.027	*(9.70)****
	[0.021]	[0.024]	[0.019]	*[9.40]****	[0.023]	[0.018]	*[9.30]****
Cash flow	0.113	0.110	0.120	*(-1.60)*	0.111	0.120	*(-1.43)*
	[0.110]	[0.11]	[0.11]	*[-0.12]*	[0.11]	[0.11]	*[0.29]*
Stock issues	0.014	0.023	0.003	*(7.80)****	0.020	-0.001	*(7.65)****
	[0.000]	[0.000]	[0.000]	*[5.76]****	[0.000]	[0.000]	*[9.63]****
Tobin's Q	1.574	1.639	1.508	*(4.80)****	1.590	1.540	*(1.58)*
	[1.357]	[1.390]	[1.324]	*[3.30]****	[1.33]	[1.39]	*[-3.00]****
Sales growth	0.053	0.060	0.045	*(2.69)****	0.054	0.050	*(0.46)*
	[0.052]	[0.056]	[0.047]	*[2.67]****	[0.053]	[0.051]	*[0.47]*
Cash	0.126	0.142	0.110	*(8.90)****	0.131	0.116	*(3.86)****
	[0.091]	[0.099]	[0.085]	*[6.50]****	[0.091]	[0.09]	*[0.24]*
Employee	15,860	7,696	24,569	*(-13.68)****	2,150	47,878	*(-38.72)****
	[2,841]	[1,616]	[5,712]	*[-20.20]****	[1317]	[23,819]	*[-51.50]****
Leverage	0.235	0.235	0.234	*(0.45)*	0.230	0.250	*(-4.10)****
	[0.21]	[0.20]	[0.214]	*[-1.58]*	[0.20]	[0.23]	*[-6.20]****
Bank debt	0.154	0.169	0.141	*(5.64)****	0.176	0.104	*(14.78)****
	[0.115]	[0.125]	[0.107]	*[3.9]****	[0.143]	[0.067]	*[15.94]****
Used credit lines	0.036	0.035	0.037	*(-0.87)*	0.042	0.023	*(8.10)****
	[0.00]	[0.00]	[0.00]	*[-2.91]****	[0.00]	[0.00]	*[3.20]****
Term loans	0.117	0.129	0.103	*[6.05]****	0.133	0.081	*(11.06)****
	[0.065]	0.072	0.056	*[4.2]****	[0.082]	[0.038]	*[9.65]****
No. of observations	4,246	2,188	2,058		2,952	1,294	

Table 2

R&D investment regressions.

This table reports coefficient estimates using the system-GMM estimation method with lagged levels dated t-3 and t-4 used as instruments for the equations in differences and lagged differences dated t-2 employed as instruments for the equations in levels. We control for year and firm fixed effects in all regressions. Robust standard errors are in parentheses and clustered at the firm level. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
$R\&D_{i,t-1}$	1.140***	1.129***	1.105***	1.111***	1.092***	1.086***
	(0.099)	(0.099)	(0.093)	(0.096)	(0.091)	(0.090)
$R\&D_{i,t-1}^2$	-0.613**	-0.602**	-0.570**	-0.527**	-0.561**	-0.557**
	(0.278)	(0.287)	(0.262)	(0.258)	(0.253)	(0.248)
Cash flow$_{i,t}$	0.100***	0.107***	0.092***	0.093***	0.096***	0.098***
	(0.036)	(0.034)	(0.033)	(0.031)	(0.033)	(0.030)
Cash flow$_{i,t-1}$	-0.082**	-0.089***	-0.074**	-0.073**	-0.072**	-0.073**
	(0.034)	(0.032)	(0.032)	(0.031)	(0.033)	(0.030)
Stock issues$_{i,t}$	0.077***	0.094***	0.078***	0.065***	0.079***	0.080***
	(0.029)	(0.029)	(0.024)	(0.022)	(0.025)	(0.024)
Stock issues$_{i,t-1}$	-0.027	-0.025	-0.023	-0.036	-0.020	-0.019
	(0.031)	(0.028)	(0.030)	(0.032)	(0.029)	(0.028)
Tobin's Q$_{i,t}$	0.005	0.002	0.002	0.004	0.002	0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Tobin's Q$_{i,t-1}$	-0.005*	-0.003	-0.003	-0.004*	-0.003	-0.003
	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)
Sales growth$_{i,t}$	0.000	0.001	-0.004	-0.002	-0.004	-0.006
	(0.018)	(0.016)	(0.016)	(0.015)	(0.015)	(0.014)
Sales growth$_{i,t-1}$	-0.005	-0.005	-0.010	-0.006	-0.011	-0.011
	(0.012)	(0.011)	(0.011)	(0.011)	(0.011)	(0.010)
Δ*Cash*$_{i,t}$	-0.030	-0.039	-0.017	-0.013	-0.014	-0.018
	(0.028)	(0.025)	(0.024)	(0.026)	(0.025)	(0.024)
Δ*Cash*$_{i,t-1}$	-0.040***	-0.038***	-0.038***	-0.039***	-0.037***	-0.036***
	(0.014)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Leverage$_{i,t}$		-0.016				
		(0.021)				
Leverage$_{i,t-1}$		0.020				
		(0.020)				
Bank debt$_{i,t}$			0.011			
			(0.019)			
Bank debt$_{i\ t-1}$			0.000			
			(0.017)			
Used credit lines$_{i,t}$				0.096**		0.067*
				(0.046)		(0.040)
Used credit lines$_{i,t-1}$				-0.047		-0.014
				(0.036)		(0.031)
Term loans$_{i,t}$					-0.017	-0.010
					(0.017)	(0.017)
Term loans$_{i,t-1}$					0.011	0.010
					(0.018)	(0.017)
Sum *Debt type* (p-value)	-	0.75	0.41	0.04	0.64	0.02
Sum *term loans* (p-value)	-	-	-	-	-	0.96
Sum Δ*Cash* (p-value)	0.02	0.004	0.04	0.05	0.06	0.04
Sum *Cash flow* (p-value)	0.59	0.55	0.56	0.51	0.44	0.04
Sum *Stock issues* (p-value)	0.20	0.08	0.11	0.36	0.08	0.38
m1	0.000	0.000	0.000	0.000	0.000	0.000
m2	0.536	0.376	0.84	0.735	0.689	0.886
Hansen-J	0.358	0.76	0.408	0.413	0.161	0.597
Difference-in-Hansen	0.659	0.878	0.623	0.766	0.645	0.8
No. of observations	4,246	4,246	4,246	4,246	4,246	4,246

Table 3

R&D investment regressions for young (small) and mature (large) firms.

This table reports coefficient estimates for young (small) and mature (large) firms using the system-GMM estimation method. In all columns, except in column (2), we use lagged levels dated t-3 and t-4 used as instruments for the equations in differences and lagged differences dated t-2 used as instruments for the equations in levels. In column (2) we use lagged levels dated t-4 and lagged differences dated t-3 for this group. We control for year and firm fixed effects in all regressions. Robust standard errors are in parentheses and clustered at the firm level. ***, **, and indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Young	Mature	Small	Large
	(1)	(2)	(3)	(4)
R&D $_{i,t-1}$	1.112***	1.143***	1.130***	1.021***
	(0.109)	(0.077)	(0.099)	(0.067)
$R\&D_{i,t-1}^2$	-0.488*	-0.917***	-0.509**	-0.778**
	(0.256)	(0.282)	(0.251)	(0.348)
Cash flow $_{i,t}$	0.078***	0.113***	0.069**	0.152***
	(0.028)	(0.034)	(0.028)	(0.038)
Cash flow $_{i,t-1}$	-0.058**	-0.129***	-0.054*	-0.039**
	(0.029)	(0.044)	(0.030)	(0.018)
Stock issues $_{i,t}$	0.052**	0.024	0.055**	0.050*
	(0.020)	(0.050)	(0.022)	(0.028)
Stock issues $_{i,t-1}$	-0.038	0.059*	-0.045	0.002
	(0.030)	(0.031)	(0.030)	(0.024)
Tobin's Q $_{i,t}$	0.006*	-0.002	0.004	-0.004
	(0.003)	(0.002)	(0.003)	(0.004)
Tobin's Q $_{i,t-1}$	-0.004	0.003	-0.003	-0.003
	(0.003)	(0.003)	(0.003)	(0.004)
Sales growth $_{i,t}$	-0.002	0.001	-0.005	0.004
	(0.016)	(0.009)	(0.015)	(0.006)
Sales growth $_{i,t-1}$	-0.011	0.003	-0.009	-0.019***
	(0.011)	(0.008)	(0.011)	(0.005)
Δ*Cash* $_{i,t}$	0.014	-0.065***	0.011	-0.037
	(0.023)	(0.009)	(0.025)	(0.024)
Δ*Cash* $_{i,t-1}$	-0.042***	-0.043***	-0.037***	-0.044***
	(0.016)	(0.014)	(0.013)	(0.015)
Used credit lines $_{i,t}$	0.110**	0.070	0.106**	0.038*
	(0.048)	(0.057)	(0.053)	(0.022)
Used credit lines $_{i,t-1}$	-0.029	-0.038	-0.045	-0.028*
	(0.039)	(0.047)	(0.038)	(0.017)
Sum *Used credit lines* (p-value)	0.02	0.15	0.05	0.63
Sum Δ*Cash* (p-value)	0.32	0.00	0.36	0.01
Sum *Cash flow* (p-value)	0.51	0.6	0.59	0.01
Sum *Stock issues* (p-value)	0.61	0.12	0.74	0.16
m1	0.000	0.000	0.000	0.000
m2	0.654	0.459	0.950	0.780
Hansen-J	0.204	0.885	0.240	0.500
Difference-in-Hansen	0.300	0.420	0.650	0.810
No. of observations	2,188	2,058	2,952	1,294

Table 4

R&D investment regressions for firms with low and high R&D.

This table reports coefficient estimates for low and high R&D firms, and high R&D firms with low and high cash holdings, low and high stock issues, and low and high cash flows. We use the system-GMM estimation method. In all columns, except in columns (5) and (6), we use lagged levels dated t-3 and t-4 used as instruments for the equations in differences and lagged differences dated t-2 used as instruments for the equations in levels. In column (5), we use lagged levels dated t-4 and lagged differences dated t-3, while in column (6), we use lagged levels dated t-2 and lagged differences dated t-1. We control for year and firm fixed effects in all regressions. Robust standard errors are in parentheses and clustered at the firm level. ***, **, and indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Low *R&D* (1)	High *R&D* (2)	High R&D, low cash (3)	High R&D, high cash (4)	High R&D, low stock (5)	High R&D, high stock (6)	High R&D, low CF (7)	High R&D, high CF (8)
$R\&D_{i,t-1}$	0.565***	1.109***	1.046***	1.043***	1.297***	1.165***	1.092***	1.126***
	(0.158)	(0.105)	(0.153)	(0.109)	(0.114)	(0.109)	(0.117)	(0.104)
$R\&D^2_{i,t-1}$	0.139	-0.596**	-0.949*	-0.475**	-1.602***	-0.637***	-0.830***	-0.657***
	(1.329)	(0.251)	(0.561)	(0.222)	(0.383)	(0.205)	(0.272)	(0.243)
$Cash\ flow_{i,t}$	0.018	0.095***	0.050*	0.115***	0.080***	0.147***	0.086***	0.087***
	(0.014)	(0.031)	(0.026)	(0.037)	(0.030)	(0.036)	(0.027)	(0.028)
$Cash\ flow_{i,t-1}$	-0.021*	-0.090***	-0.070***	-0.096***	-0.078**	-0.105***	-0.064**	-0.080***
	(0.011)	(0.032)	(0.025)	(0.033)	(0.031)	(0.029)	(0.032)	(0.026)
$Stock\ issues_{i,t}$	0.003	0.057**	0.089	0.048**	-0.031	0.054**	0.074***	-0.006
	(0.012)	(0.023)	(0.055)	(0.021)	(0.036)	(0.026)	(0.026)	(0.022)
$Stock\ issues_{i,t-1}$	-0.012*	-0.031	-0.002	-0.043	-0.018	-0.054**	-0.060**	-0.071*
	(0.007)	(0.031)	(0.023)	(0.028)	(0.035)	(0.022)	(0.025)	(0.039)
$Tobin's\ Q_{i,t}$	0.001	0.005	0.008**	0.002	0.005	0.004	0.001	0.001
	(0.002)	(0.003)	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)	(0.003)
$Tobin's\ Q_{i,t-1}$	0.000	-0.004	-0.004	0.000	0.003	0.003	0.001	-0.001
	(0.001)	(0.003)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)
$Sales\ growth_{i,t}$	0.010*	-0.011	-0.006	-0.016	-0.029	-0.018	-0.003	0.009
	(0.006)	(0.020)	(0.016)	(0.019)	(0.022)	(0.023)	(0.019)	(0.018)
$Sales\ growth_{i,t-1}$	0.002	-0.013	-0.008	-0.003	-0.020	-0.021*	-0.027**	-0.005
	(0.003)	(0.013)	(0.010)	(0.014)	(0.017)	(0.011)	(0.011)	(0.016)
$\Delta Cash_{i,t}$	-0.028*	-0.022	0.022	-0.018	0.016	-0.036	-0.040	-0.007
	(0.015)	(0.027)	(0.037)	(0.022)	(0.037)	(0.022)	(0.034)	(0.019)
$\Delta Cash_{i,t-1}$	-0.005	-0.051***	0.036	-0.065***	-0.038	-0.043***	-0.054**	-0.043***
	(0.005)	(0.019)	(0.025)	(0.017)	(0.028)	(0.014)	(0.025)	(0.014)
$Used\ credit\ lines_{i,t}$	0.014	0.150***	0.075**	0.085	0.125*	0.172**	0.094*	0.121**
	(0.023)	(0.048)	(0.031)	(0.066)	(0.066)	(0.079)	(0.053)	(0.049)
$Used\ credit\ lines_{i,t-1}$	-0.009	-0.054	0.006	-0.076	-0.012	-0.103	-0.040	-0.041
	(0.022)	(0.040)	(0.027)	(0.050)	(0.055)	(0.067)	(0.046)	(0.040)
Sum *Used credit lines* (p-value)	0.48	0.02	0.023	0.87	0.04	0.31	0.24	0.03
Sum Δ*Cash* (p-value)	0.07	0.03	0.25	0.01	0.701	0.01	0.07	0.03
Sum *Cash flow* (p-value)	0.83	0.87	0.44	0.54	0.94	0.26	0.42	0.81
Sum *Stock issues* (p-value)	0.61	0.45	0.21	0.87	0.42	0.99	0.67	0.07
m1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
m2	0.632	0.189	0.945	0.489	0.705	0.100	0.459	0.387
Hansen-J	0.567	0.398	0.397	0.232	0.483	0.237	0.204	0.430
Difference-in-Hansen	0.639	0.646	0.672	0.174	0.668	0.806	0.772	0.688
No. of observations	2,125	2,121	877	1,244	1,254	867	738	1,383

Table 5

Difference-in-differences estimations for the effect of crises on R&D investment.

This table reports coefficient estimates for the impact of the 2007-2009 financial crisis and the European sovereign debt crisis on financing of R&D investments. *Crisis* is a dummy variable that is 1 for the period 2007-2009, and 0 otherwise in columns (1) and (2); it is equal to 1 for the period 2010-2013, and 0 otherwise in columns (3) and (4). We use the system-GMM estimation method with lagged levels dated t-3 and t-4 used as instruments for the equations in differences and lagged differences dated t-2 used as instruments for the equations in levels. We control for year and firm fixed effects in all regressions. Robust standard errors are in parentheses and clustered at the firm level. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	2007-2009 Financial Crisis		European Sovereign Debt Crisis	
	(1)	(2)	(3)	(4)
$\Delta Cash_{i,t}$	-0.013	-0.036	-0.013	-0.026
	(0.026)	(0.036)	(0.026)	(0.028)
$\Delta Cash_{i,t-1}$	-0.039***	-0.056*	-0.039***	-0.026**
	(0.013)	(0.033)	(0.013)	(0.012)
$\Delta Cash_{i,t}$ * *Crisis*		0.043		0.009
		(0.056)		(0.059)
$\Delta Cash_{i,t-1}$* *Crisis*		0.025		-0.091***
		(0.036)		(0.034)
Used credit lines$_{i,t}$	0.100**	0.096**	0.095**	0.114**
	(0.047)	(0.047)	(0.049)	(0.047)
Used credit lines$_{i,t-1}$	-0.044	-0.039	-0.040	-0.049
	(0.036)	(0.036)	(0.040)	(0.039)
Used credit lines$_{i,t}$* *Crisis*	0.001	0.000	-0.006	-0.005
	(0.021)	(0.021)	(0.027)	(0.027)
Used credit lines$_{i,t-1}$* *Crisis*	-0.011	-0.014	-0.009	-0.005
	(0.014)	(0.015)	(0.020)	(0.022)
Other firm-level controls used	Yes	Yes	Yes	Yes
Sum *Used credit lines* (p-value)	0.03	0.029	0.05	0.02
Sum *Used credit lines* Crisis* (p-value)	0.61	0.51	0.56	0.69
Sum Δ*Cash* (p-value)	0.05	0.08	0.06	0.05
Sum Δ*Cash* *Crisis* (p-value)	-	0.34	-	0.29
m1	0.000	0.000	0.000	0.000
m2	0.727	0.737	0.739	0.942
Hansen-J	0.395	0.4	0.348	0.35
Difference-in-Hansen	0.74	0.74	0.72	0.81
No. of observations	4,246	4,246	4,246	4,246

Table 6

Difference-in-differences estimations for the effect of crises on R&D investment for young (small) and mature (large) firms. This table reports coefficient estimates for the impact of the 2007-2009 financial crisis and the European sovereign debt crisis on financing of R&D investments for young (small) and mature (large) firms. *Crisis* is a dummy variable that is 1 for the period 2007-2009, and 0 otherwise in columns (1) to (4); it is equal to 1 for the period 2010-2013, and 0 otherwise in columns (5) to (8). We use the system-GMM estimation method with lagged levels dated t-3 and t-4 used as instruments for the equations in differences and lagged differences dated t-2 used as instruments for the equations in levels. We control for year and firm fixed effects in all regressions. Robust standard errors are in parentheses and clustered at the firm level. For brevity, we do not report the coefficient estimates of the firm-level control variables, as shown in Equation (1). ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	2007-2009 Financial Crisis				European Sovereign Debt Crisis			
	Young (1)	Mature (2)	Small (3)	Large (4)	Young (5)	Mature (6)	Small (7)	Large (8)
$\Delta Cash_{i,t}$	0.003	-0.065***	0.000	-0.036	0.008	-0.074***	-0.004	-0.049**
	(0.036)	(0.023)	(0.037)	(0.030)	(0.025)	(0.013)	(0.027)	(0.025)
$\Delta Cash_{i,t-1}$	-0.042	-0.038	-0.052	-0.032*	-0.027*	-0.034**	-0.024**	-0.047***
	(0.034)	(0.028)	(0.033)	(0.017)	(0.015)	(0.016)	(0.011)	(0.015)
$\Delta Cash_{i,t}$*Crisis*	0.025	-0.018	0.015	0.003	-0.011	0.092***	0.018	0.06
	(0.051)	(0.057)	(0.054)	(0.044)	(0.052)	(0.035)	(0.059)	(0.039)
$\Delta Cash_{i,t-1}$*Crisis*	0.003	0.023	0.022	-0.022	-0.083**	-0.048	-0.084**	0.018
	(0.038)	(0.042)	(0.036)	(0.022)	(0.035)	(0.059)	(0.034)	(0.036)
Used credit lines$_{i,t}$	0.116**	0.128*	0.097*	0.04	0.145***	0.028	0.127**	0.040*
	(0.048)	(0.069)	(0.053)	(0.025)	(0.055)	(0.033)	(0.055)	(0.022)
Used credit lines$_{i,t-1}$	-0.021	-0.085*	-0.039	-0.020	-0.029	-0.030	-0.037	-0.029*
	(0.038)	(0.050)	(0.039)	(0.019)	(0.046)	(0.021)	(0.042)	(0.016)
Used credit lines$_{i,t}$* *Crisis*	0.014	-0.038	0.029	0.001	-0.038	0.085**	-0.031	0.003
	(0.036)	(0.030)	(0.028)	(0.015)	(0.039)	(0.037)	(0.032)	(0.026)
Used credit lines$_{i,t-1}$* *Crisis*	-0.045*	0.018	-0.014	-0.016	0.013	-0.033	-0.023	0.031
	(0.025)	(0.019)	(0.019)	(0.017)	(0.030)	(0.026)	(0.027)	(0.026)
Other firm-level controls used	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sum *Used credit lines* (p-value)	0.008	0.16	0.07	0.50	0.01	0.92	0.013	0.52
Sum *Used credit line*Crisis* (p-value)	0.43	0.43	0.61	0.45	0.54	0.81	0.41	0.12
Sum Δ*Cash* (p-value)	0.52	0.02	0.36	0.05	0.49	0.00	0.30	0.003
Sum Δ*Cash *Crisis* (p-value)	0.73	0.95	0.61	0.72	0.18	0.59	0.41	0.12
m1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
m2	0.732	0.358	0.935	0.672	0.748	0.556	0.898	0.771
Hansen-J	0.321	0.466	0.23	0.515	0.174	0.12	0.35	0.478
Difference-in-Hansen	0.385	0.525	0.633	0.658	0.431	0.43	0.65	0.82
No. of observations	2,188	2,058	2,952	1,294	2,188	2,058	2,952	1,294

Table 7a

Difference-in-differences estimations for the effect of crises on R&D investments in bank-based countries.

This table reports coefficient estimates for the impact of the 2007-2009 and the European sovereign debt crisis on financing of R&D investments in bank-based countries. *Bank-based* is a dummy variable that is 1 if a country has a bank-based economy, and 0 for a market-based economy. *Crisis* is a dummy variable that is 1 for the period 2007-2009, and 0 otherwise in column (2), while it is equal to 1 for the period 2010-2013, and 0 otherwise in column (3). We use the system-GMM estimation method with lagged levels dated t-3 and t-4 used as instruments for the equations in differences and lagged differences dated t-2 used as instruments for the equations in levels. We control for year and firm fixed effects. Robust standard errors are in parentheses and clustered at the firm level. For brevity, we do not report the coefficient estimates of firm-level control variables, as shown in Equation (1). ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

		2007-2009 Crisis	Sovereign Debt Crisis
	(1)	(2)	(3)
$\Delta Cash_{i,t}$	-0.033	-0.057	-0.015
	(0.032)	(0.035)	(0.029)
$\Delta Cash_{i,t-1}$	-0.062**	-0.077***	-0.036***
	(0.024)	(0.029)	(0.012)
$\Delta Cash_{i,t}$*Crisis*		0.113*	0.062
		(0.063)	(0.051)
$\Delta Cash_{i,t-1}$*Crisis*		0.038	-0.039
		(0.041)	(0.028)
$\Delta Cash_{i,t}$* *Bank-based*	-0.02		
	(0.039)		
$\Delta Cash_{i,t-1}$* *Bank-based*	0.080*		
	(0.044)		
$\Delta Cash_{i,t}$*Crisis* *Bank-based*		-0.115*	-0.165**
		(0.068)	(0.075)
$\Delta Cash_{i,t-1}$*Crisis* *Bank-based*		0.018	0.104*
		(0.040)	(0.059)
Used credit lines$_{i,t}$	-0.007	0.078	0.119**
	(0.055)	(0.048)	(0.050)
Used credit lines$_{i,t-1}$	-0.011	-0.024	-0.044
	(0.055)	(0.044)	(0.040)
Used credit lines$_{i,t}$*Crisis*		-0.022	0.042
		(0.042)	(0.031)
Used credit lines$_{i,t-1}$*Crisis*		-0.032	-0.015
		(0.026)	(0.025)
Bank-based	-0.013**	-0.008**	0.001
	(0.006)	(0.003)	(0.004)
Used credit lines$_{i,t}$ * *Bank-based*	0.127		
	(0.084)		
Used credit lines$_{i,t-1}$* *Bank-based*	-0.012		
	(0.078)		
Used credit lines$_{i,t}$*Crisis*Bank-based*		0.176	-0.156
		(0.122)	(0.111)
Used credit lines$_{i,t-1}$*Crisis*Bank-based*		0.04	0.068
		(0.042)	(0.100)
Other firm-level controls used	Yes	Yes	Yes
Sum *Used credit lines* (p-value)	0.48	0.06	0.01
Sum *Used credit lines*Crisis*(p-value)	-	0.25	0.41
Sum *Used credit lines*Crisis*Bank-based* (p-value)	-	0.09	0.05
Sum *Used credit lines* Bank-based* (p-value)	0.06	-	-
Sum Δ*Cash* (p-value)	0.04	0.00	0.12
Sum Δ*Cash *Crisis* (p-value)	-	0.08	0.70
Sum Δ*Cash *Crisis*Bank-based* (p-value)	-	0.32	0.60
Sum Δ*Cash *Bank-based* (p-value)	0.41	-	-
m1	0.000	0.000	0.000
m2	0.485	0.92	0.944
Hansen-J	0.704	0.473	0.317
Difference-in-Hansen	0.962	0.853	0.669
No. of observations	4,246	4,246	4,246

Table 7b

Difference-in-differences estimations for the effect of crises on R&D investment for young (small) and mature (large) firms in bank-based countries.

This table reports coefficient estimates for the impact of the 2007-2009 financial crisis and the European sovereign debt crisis on financing of R&D investments for young (small) and mature (large) firms in bank-based countries. *Bank-based* is a dummy variable that is 1 if a country has a bank-based economy, and 0 for a market-based economy. *Crisis* is a dummy variable that is 1 for the period 2007-2009, and 0 otherwise in columns (1) to (4), while it is equal to 1 for the period 2010-2013, and 0 otherwise in columns (5) to (8). We use the system-GMM estimation method. In all columns, except in column (2), lagged levels dated t-3 and t-4 are used as instruments for the equations in differences, and lagged differences dated t-2 are used as instruments for the equations in levels. In column (2), we use lagged levels dated t-4 and lagged differences dated t-3 for the mature firms. We control for year and firm fixed effects. Robust standard errors are in parentheses and clustered at the firm level. For brevity, we do not report the coefficient estimates of firm-level control variables, as shown in Equation (1). ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Panel A: 2007-2009 Financial Crisis				Panel B: European Sovereign Debt Crisis			
	Young	Mature	Small	Large	Young	Mature	Small	Large
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta Cash_{i,t}$	0.014	-0.055**	0.014	-0.041	0.020	-0.055***	-0.038	-0.051**
	(0.032)	(0.026)	(0.043)	(0.028)	(0.030)	(0.007)	(0.025)	(0.025)
$\Delta Cash_{i,t-1}$	-0.041	-0.046	-0.047	-0.042**	-0.041***	-0.028***	-0.044***	-0.046**
	(0.025)	(0.028)	(0.030)	(0.020)	(0.016)	(0.008)	(0.013)	(0.021)
$\Delta Cash_{i,t}$*Crisis*	0.048	0.005	0.065	-0.002	0.036	0.126***	0.099**	0.034
	(0.050)	(0.050)	(0.067)	(0.065)	(0.046)	(0.031)	(0.046)	(0.032)
$\Delta Cash_{i,t-1}$*Crisis*	0.004	0.027	0.027	0.018	-0.039	-0.002	-0.039	0.047**
	(0.036)	(0.038)	(0.039)	(0.035)	(0.027)	(0.039)	(0.039)	(0.022)
$\Delta Cash_{i,t}$*Crisis* Bank-based*	-0.087	-0.008	-0.160**	0.012	-0.196***	-0.092*	-0.181**	0.052*
	(0.072)	(0.057)	(0.073)	(0.059)	(0.071)	(0.050)	(0.081)	(0.030)
$\Delta Cash_{i,t-1}$*Crisis* Bank-based*	0.026	-0.015	0.017	-0.073	0.08	-0.078	0.054	-0.025
	(0.039)	(0.037)	(0.055)	(0.061)	(0.052)	(0.057)	(0.050)	(0.028)
Used credit lines$_{i,t}$	0.090**	0.061	0.158**	0.035*	0.158***	0.039	0.107**	0.032
	(0.043)	(0.039)	(0.062)	(0.021)	(0.054)	(0.029)	(0.047)	(0.024)
Used credit lines$_{i,t-1}$	-0.018	-0.029	-0.073	-0.024	-0.033	-0.030	-0.01	-0.034
	(0.036)	(0.031)	(0.062)	(0.017)	(0.042)	(0.020)	(0.040)	(0.023)
Used credit lines$_{i,t}$*Crisis*	-0.013	-0.060	-0.012	0.009	0.010	0.040	0.019	-0.002
	(0.034)	(0.039)	(0.072)	(0.032)	(0.043)	(0.042)	(0.035)	(0.027)
Used credit lines$_{i,t-1}$*Crisis*	-0.048*	0.010	-0.066	0.013	0.016	-0.001	-0.031	0.012
	(0.025)	(0.022)	(0.060)	(0.021)	(0.031)	(0.023)	(0.026)	(0.023)
Bank-based	-0.008**	-0.001	-0.006	0.000	0.001	0.001	0.002	0.000
	(0.003)	(0.003)	(0.004)	(0.002)	(0.005)	(0.002)	(0.005)	(0.002)
Used credit lines$_{i,t}$*Crisis*Bank-based*	0.133	0.067	0.174	-0.009	-0.079	-0.116	-0.059	-0.027
	(0.104)	(0.063)	(0.192)	(0.044)	(0.117)	(0.080)	(0.129)	(0.063)
Used credit lines$_{i,t-1}$*Crisis*Bank-based*	0.032	-0.006	0.133	-0.050	-0.053	0.088	-0.018	0.034
	(0.054)	(0.028)	(0.137)	(0.048)	(0.102)	(0.055)	(0.117)	(0.052)
Other firm-level controls used	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sum *Used credit lines* (p-value)	0.03	0.17	0.03	0.57	0.01	0.61	0.01	0.94
Sum *Used credit lines*Crisis* (p-value)	0.12	0.16	0.21	0.52	0.55	0.24	0.71	0.73
Sum *Used credit lines*Crisis*Bank-based* (p-value)	0.08	0.31	0.09	0.35	0.06	0.57	0.09	0.86

(Continued)

Table 7b (Continued)

Sum Δ*Cash* (p-value)	0.51	0.01	0.57	0.03	0.58	0	0.01	0.009
Sum Δ*Cash*Crisis* (p-value)	0.45	0.62	0.30	0.85	0.96	0.004	0.39	0.04
Sum Δ*Cash*Crisis*Bank-based* (p-value)	0.52	0.75	0.214	0.55	0.29	0.04	0.27	0.47
m1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
m2	0.775	0.419	0.608	0.782	0.821	0.922	0.752	0.681
Hansen-J	0.216	0.879	0.566	0.466	0.386	0.360	0.546	0.451
Difference-in-Hansen	0.630	0.746	0.960	0.906	0.570	0.844	0.830	0.903
No. of observations	2,188	2,058	2,952	1,294	2,188	2,058	2,952	1,294

Table 8
R&D investment regressions for non-UK subsample.
This table reports coefficient estimates for the sample, excluding UK firms. We use the system-GMM method with lagged levels dated t-3 and t-4 used as instruments for the equations in differences and lagged differences dated t-2 used as instruments for the equations in levels. We control for year and firm fixed effects. Robust standard errors are in parentheses and clustered at the firm level. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Non-UK Sample
$R\&D_{i,t-1}$	1.010***
	(0.123)
$R\&D^2_{i,t-1}$	-0.340
	(0.557)
Cash flow$_{i,t}$	0.096***
	(0.028)
Cash flow$_{i,t-1}$	-0.081***
	(0.031)
Stock issues$_{i,t}$	0.033
	(0.039)
Stock issues$_{i,t-1}$	0.011
	(0.048)
Tobin's Q$_{i,t}$	0.003
	(0.004)
Tobin's Q$_{i,t-1}$	-0.001
	(0.003)
Sales growth$_{i,t}$	-0.007
	(0.016)
Sales growth$_{i,t-1}$	-0.001
	(0.009)
$\Delta Cash_{i,t}$	-0.023
	(0.025)
$\Delta Cash_{i,t-1}$	-0.027**
	(0.014)
Used credit lines$_{i,t}$	0.083**
	(0.044)
Used credit lines$_{i,t-1}$	-0.033
	(0.031)
Sum *Used credit lines* (p-value)	0.08
Sum Δ*Cash* (p-value)	0.08
Sum *Cash flow* (p-value)	0.60
Sum *Stock issues* (p-value)	0.44
m1	0.00
m2	0.95
Hansen-J	0.64
Difference-in-Hansen	0.82
No. of observations	2,992
No. of firms	680