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Financing constraints and R&D investments of large corporations in Europe and the USA

Michele Cincera and Julien Ravet

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The main authors of this paper are Michele Cincera (European Commission – JRC, IPTS and Solvay Brussels School of Economics and Management, Université Libre de Bruxelles) and Julien Ravet (Solvay Brussels School of Economics and Management, Université Libre de Bruxelles). The authors are grateful to Andries Brandsma, Constantin Ciupagea and Pietro Moncada Paternò Castello for their useful comments.

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Contact information: P. Moncada-Paternò-Castello
European Commission, Joint Research Centre - Institute for Prospective Technological Studies
Edificio Expo
C/ Inca Garcilaso, 3
E-41092 Seville (Spain)
Fax: +34 95 448 83 26; E-mail: jrc-ipts-kfg-secretariat@ec.europa.eu
IPTS website: http://ipts.jrc.ec.europa.eu/; JRC website: http://www.jrc.ec.europa.eu
DG RTD-C website: http://ec.europa.eu/invest-in-research/index_en.htm

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Abstract

This paper explores the existence and importance of financing constraints for R&D investments in large EU and US manufacturing companies over the 2000 – 2007 period. The main results obtained by estimating error-correction equations suggest that the sensitivity of R&D investments to cash flow variations are important for European firms while US ones do not appear to be financially constrained. In terms of policy implications, these results suggest improving the conditions for access to external capital to finance R&D activities in the EU.

JEL Classification: C 23, E 22, O 31

Keywords: Financial constraints, R&D investments, error-correction investment equations, system GMM panel data econometric models.

1 INTRODUCTION[1]

The existence of capital market imperfections such as asymmetric information between lenders and borrowers affects the capital investment decisions of a firm and introduces possible financing constraints, i.e. credit rationing by lenders. Such constraints may actually be even more pronounced in the case of intangible investments such as Research and Development (R&D) since these activities are more risky by nature and typically provide less collateral to lenders than capital goods do. Based on a representative sample of worldwide firms active in R&D activities over the recent period, this study aims at assessing the existence and importance of financing constraints on the R&D investments of firms. In particular, the paper examines the differences in the extent to which these constraints differ across firms between the EU and the US.

The empirical analysis is based on a consolidated sample of large R&D active companies in the manufacturing and services sectors. The sources of this information are the successive editions of the EU industrial R&D investment scoreboards (2004 – 2008) conducted by the JRC-IPTS of the European Commission. This source is matched with the Compustat database gathering financial information, including the cash flow of the firms. The final sample used in the empirical analysis consists of an unbalanced panel of 1962 firms over 2000 – 2007 which is representative of about 80 % of all R&D carried out in the private sector in the world. All variables are presented using constant exchange rates and prices and R&D stocks are constructed for each firm on the basis of the perpetual inventory method (Griliches, 1979).

The model used to identify the potential liquidity of the constraints of the firms is an error correction model for R&D investment. This model is derived from the optimal level of R&D investment when considering a Constant Elasticity of Substitution (CES) production function of a profit-maximising firm. Financing constraints are measured by the sensitivity

[1] The authors are grateful to Andries Brandsma, Constantin Ciupagea, Tiffany Hardy and Pietro Moncada Paternò Castello as well as an anonymous referee for their useful comments. The findings, interpretations and conclusions expressed in this paper are entirely those of the authors and do not necessarily represent those of the European Commission. They should not be attributed to the European Commission.

of R&D investment decisions to cash flow, assuming that investments of firms that face liquidity constraints are more likely to be sensitive to the availability of internal finance.

This model is estimated using econometric methods for panel data. Traditional fixed-effect estimators are not suited for this model when the explanatory variables are weakly exogenous and contain random measurement errors. In order to address these issues and the dynamic structure of the model, GMM system estimators are implemented. These estimators allow one to deal with the possibly correlated specific unobserved fixed effects of the firms and the weak exogeneity of the explanatory variables.

The paper is organised as follows: Section 2 briefly reviews some theoretical aspects of the literature on the investment in R&D of firms as well as the main empirical findings of some selected previous studies; the construction of the data set, the different samples estimated and their main features are documented in Section 3. In Section 4 the main estimation results are presented. Section 5 covers conclusions, policy implications and suggestions for future work.

2 REVIEW OF ISSUES AND EMPIRICAL FINDINGS

It is widely agreed in the literature that given the existence of asymmetric information between firms and lenders and other agency costs or moral hazard problems, investments in physical capital and more particularly in R&D must be primarily funded by internal resources of firms. On the theoretical side, Stiglitz and Weiss (1981) and Myers and Majluf (1984) developed formal models of moral hazard problems in debt and equity markets. On the empirical side, since the pioneering work of Fazzari, Hubbard and Petersen (1988), many studies have examined the extent of liquidity constraints in the financing of physical investment. Risk-averse R&D managers will under-invest in risky R&D projects and managers tend to spend on activities that benefit them. These agency costs between the shareholders and the R&D management can be avoided by leveraging the firm. However, the costs of the external funds to finance the R&D projects will be higher as compared to the internal funds of the firms (Jensen and Meckling, 1976). In addition, investments in intangibles such as R&D are riskier by nature than ordinary investments and R&D managers often have better information regarding the likelihood of the success of their R&D projects than outside investors or lenders. Furthermore, R&D investments provide less collateral to outsiders who can not make accurate appraisals of the values associated with this type of investment[2]. As a result, R&D firms may encounter credit rationing by potential lenders and may be constrained if they do not have enough internal resources to finance their R&D projects[3].

Besides the risks and uncertainties inherent to R&D activities, strategic considerations are another source of asymmetric information between the borrower and the lender. Inventors may indeed be reluctant to fully or partially disclose to the outside world information as regards the contents and the objectives of their technological activities since this knowledge could leak out to competitors. This imperfect appropriability of the returns of innovative activities arises from the non-rival and the partially-excludable property of the knowledge good. Non rivalry means that the use of innovation by an economic agent does not preclude others from using it, while partial excludability implies that the owner of an innovation can not impede others from benefitting from it free of charge.

Another essential characteristic of R&D that makes it different from ordinary investment is the presence of high adjustment and sunk costs[4]. The wages of the R&D personnel, for instance, represent more than 50 % of R&D expenditures and training. Firing or re-hiring this highly specialised personnel embedded in the intangible asset of the firm implies

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[2] The output of R&D activities consists of new products and processes, which are typically difficult to use as collateral. According to Himmelberg and Petersen (1994) who refer to Ackerlof's (1970) classic example of a car market with asymmetric information and adverse selection problems, 'A potential buyer of a used car can, at relatively low cost, hire a mechanic to assess the car's true quality. In contrast, a potential investor might have to hire a team of scientists to make an accurate appraisal of the potential value of a firm's R&D projects.'

[3] Capital market imperfections can prevent firms from accessing these external funds at least at the same costs than the internal resources. As stressed by Harhoff (1998), 'If providers of finance face greater uncertainty with respect to R&D than to investment projects, they will require a higher lemon's premium for the former type of investment. Hence, even without rationing behaviour on behalf of banks and other financial institutions, there will be a premium to be paid for obtaining external funding'.

[4] As emphasised by Arrow (1962), given the time it takes to succeed, a typical R&D project involves important fixed set-up costs. This 'indivisible' aspect of R&D as an input views R&D activities mainly as a fixed factor of production.

substantial costs[5]. Hence the levels of R&D expenditures associated with any innovation projects are unlikely to substantially change from year to year. This feature makes it difficult to empirically assess the relationship between possible liquidity constraints and expenses in R&D investments since the changes in the costs of this type of capital can be weak in the short term. More fundamentally, given these high adjustment costs, a firm may decide to start new R&D programmes only if they know that they will have sufficient resources to pursue the R&D from the very beginning of the project to its end. In that case, liquidity constraints should not be a concern for the decision of the firm to engage in R&D activities.

There have only been a few studies examining financing constraints and R&D[6]. Table 1 provides some features of selected studies that have investigated the relationship between internal finance and R&D investments of firms.

Hall (2002) and more recently Hall and Lerner (2010) provide an extended review of the literature about financing constraints. According to Hall and Lerner (2010), most authors in the empirical literature on financing constraints have relied on two main approaches based on investment equations. The first has been to use a neoclassical accelerator model that can be augmented with dynamics and transformed into an error correction model (ECM). The second approach has been based on an Euler equation (an example is Harhoff, 1998). The authors conclude their review by stating that there is evidence that 'debt is a disfavored source of finance for R&D investment […], Anglo-Saxon economies seem to exhibit more sensitivity and responsiveness of R&D to cash-flow than continental economies […] and this greater responsiveness may arise because they are financially constrained, in the sense that they view external sources of finance as much more costly than internal'. However, this responsiveness may also be related to demand signals in thick financial equity markets.

[5] In Belgium in 1995, the distribution of intramural R&D expenditures by type of costs was as follows: 58 % for the R&D personnel, 9 % for investment and 33 % for the organisation of these activities (Cincera, 2005).
[6] Schiantarelli (1996) and Hubbard (1998) provide reviews of the literature regarding the role of financial constraints on the investment activities of a firm on fixed capital. Mairesse, Mulkay and Hall (1999) discuss and compare alternative modelling specifications, i.e. simple accelerator and error correction specifications, as well as panel data econometric methodologies, i.e. traditionally between and within firm estimation versus GMM estimators, for estimating investment equations of a firm.

Table 1. Features of some selected studies on R&D and financing constraints

	Firms	Countries	Period	Model- Econometrics
Hall (1992)	Large manufacturing	US	1973-1987	Tobin's Q
Himmelberg and Petersen (1994)	Small high-tech	US	1983-1987	Acc., Tobin's Q – Within/FD GMM
Harhoff (1998)	Large manufacturing	DE	1990-1994	Acc., ECM, Euler- FD GMM
Bond et al. (1999)	Manufacturing and high-tech	UK, DE	1985-1994	ECM – GMM SYS
Hall et al. (1999)	High-Tech	FR, JP, US	1978-1989	VAR – GMM SYS
Mulkay et al. (2001)	Large manufacturing	FR, US	1982-1993	ECM – Within/GMM FD & SYS
Bougheas et al. (2001)	Manufacturing	IE	1991-1997	Acc. – OLS
Cincera (2003)	Large manufacturing	BE	1991-2000	Acc. and ECM – Within/GMM FD & SYS
Czarnitsky (2006)	SMEs manufacturing	DE	1994-1998	Tobit
Savignac (2008)	Large manufacturing	FR	1997-1999	Bivariate probit
Aghion et al. (2008)	SMEs and Large manufacturing and services	FR	1993-2004	Acc./GLS/Tobit/ GMM FD
Brown et al. (2009)	High-Tech	US	1990-2004	Euler – GMM FD & SYS

Notes: Acc; = accelerator investment model; ECM = Error correction model; GMM FD and SYS = First difference and system generalized method of moment estimator; VAR = Vector Autoregressive Regression.

Comparisons between financing constraints faced by US firms and European firms, and more specifically French firms were investigated for the mid-1980s and early 1990s by Hall, Brandstetter and Crépon (1999) and Mulkay, Hall and Mairesse (2001). The paper by Hall et al. (1999) indicates that investment and R&D are sensitive to cash flow in the US only and show evidence of a positive impact of both investment and R&D in predicting sales and cash flow for US firms while the results are somewhat more mixed in France and Japan. Mulkay et al. (2001) did not find any significant differences (for both countries) in the effects of output on physical and R&D investments. Yet cash flow or profit appears to have a much greater impact on both types of investments in the US than in France. Hence the impact of financial factors on investment and R&D does not differ within a country but rather across them. This finding indicates that the financial market environment specific to a country matters in explaining the impact of financial factors on investment.

Examples of studies focused on US firms are Hall (1992) and Himmelberg and Petersen (1994). The study by Hall (1992) explores the relationship between investment, R&D and cash flow for US firms by taking into account the specific unobserved fixed effects and simultaneity of firms. The results point to a positive impact of cash flow for both types of investments, although this effect is more significant for physical investment, hence indicating the presence of liquidity constraints in addition to future demand expectations. On the basis of a sample of 179 small US firms in high-tech industries, Himmelberg and Petersen (1994) estimated the relationship between R&D investment, physical capital and internal finance. The results support the Schumpeterian hypothesis, which states that internal finance is an important determinant of R&D expenditures. As stressed by Arrow (1962), moral hazard problems hinder the external financing of highly risky business activities such as innovation. The absence of collateral value for investment as with R&D creates adverse incentives and selection problems in debt and equity markets.

Examples of studies carried out for European countries are Harhoff (1998), Bond, Harhoff and Van Reenen (1999), Czarnitzki (2006), Bougheas, Goerg and Strobl (2001), Cincera (2003) and Savignac (2008).

Harhoff (1998) found an important sensitivity of R&D and investment to cash flow for accelerator and error-correction equations for German firms. Significant results are found for small firms only for the latter specification. No conclusion for R&D could be drawn from the Euler equation model, probably because the sample was too small for a precise estimation.

Results from Bond et al. (1999) lead one to conclude that financial constraints are significant in the UK economy while no effect is found for German firms, which can be explained by the institutional differences across the financial systems in the two countries[7].

[7] Quoting the authors, 'Shareownership in Germany tends to be more concentrated than in Britain, which may mitigate asymmetric information and conflicts of interest between shareholders and managers. Bank representation on supervisory boards and long-term repeated relationships between banks and firms in Germany may mitigate asymmetric information between lenders and borrowers. Large German firms are more likely to remain unquoted, hostile takeovers are extremely rare, and dividend payout ratios tend to be both lower and less rigid in German firms than in British firms'.

Furthermore cash flow has an impact on the decision to engage in R&D rather than on the levels of R&D expenditures.

Bougheas et al. (2001) tested the effect of liquidity constraints on the R&D investments of Irish companies. They also concluded that R&D investments in these companies are subject to liquidity constraints. This result is in line with the findings of previous studies examining UK and US companies.

Based on a sample of about 10000 Belgian manufacturing firms over the last decade, Cincera (2003) compared financing constraints on both fixed tangible capital and R&D. The analysis was founded on two reduced form equations for investment: an accelerator and an error correction model. Although the results indicated the presence of financial constraints on tangible as well as R&D investment, this effect was unexpectedly found to be smaller for R&D. The estimates also indicated that young firms, small firms, firms that are not part of a multinational company, firms that do not perform R&D on a permanent basis, firms that benefit from public funds to support R&D activities, and firms located in the Walloon region face higher financial constraints.

Czarnitzki (2006) used a modified price-cost margin as a proxy for internal funds of German SMEs, while external financing constraints were measured by a lagged credit rating index. R&D expenditures of West German firms were found to be sensitive to internal and external resources while there was no evidence of financial constraints for East German firms. The role of public funding was shown to be relevant for R&D expenditures in both regions, with a greater relevance for East Germany.

Savignac (2008) used data on 1940 French firms and provide evidence about the role of financing constraints in the decision to undertake innovative activities. A direct measure for financing constraints was obtained from the FIT survey[8]. The author considers the decision to innovate and the likelihood to be financially constrained as two simultaneous issues. In order to address this endogeneity of financing constraints to innovation decisions, a recursive bivariate probit model is estimated. Results show that the likelihood for a firm to undertake innovative activities is decreased by more than 20 % when the firm faces financial constraints.

In a more recent study, Aghion et al. (2008) found that the share of R&D investment over total investment is countercyclical without credit constraints, but less so if firms face tighter credit constraints. This result is magnified for firms in sectors that depend more heavily upon external finance, or that are characterized by a low degree of asset tangibility.

Brown, Fazzari and Petersen (2009) test the age of the company for a representative sample of 1347 publicly traded high-tech US companies from 1990 to 2004. Their results show that young firms, i.e. firms created less than 15 years ago, that almost entirely finance their R&D investment with cash-flow or public share issue are financially constrained which is not the case for mature companies. The authors then propose an explanation for the R&D boom in the US during the 1990s (and its subsequent decline) which is mainly attributed (75%) to young high-tech companies. Controlling for demand side effects and departing from the idea that these firms "typically exhaust internal finance and then issue stock as their marginal source of funds", they claim that the shift in the last decade in the supply of both internal and external equity to finance R&D relaxed the financing constraints these young R&D companies faced and that restricted their R&D investments.

3 ECONOMETRIC FRAMEWORK

This section presents the investment error-correction equation as well as the econometric methodology to be implemented for estimating the relationship between cash flow and R&D investments. As stressed by Hall and Lerner (2010), this is a standard methodology based on an investment equation. The methodological framework is close to that used by Harhoff (1998), Bond et al. (1999), Mairesse, Mulkay and Hall (1999) and Mulkay et al.

[8] The 'Financement de l'Innovation Technologique' (FIT) survey is based upon the technological innovation concept exposed in the Oslo manual (OECD and EUROSTAT, 1997).

(2001). Following the neo-classical long run model (Jorgenson, 1963), the logarithm of the desired (or long run) stock of capital is proportional to the logarithm of output and user cost of capital:

$$c_{it} = \alpha_t + \beta y_{it} - \sigma ucc_{it} \tag{1}$$

where c is the logarithm of the stock of R&D, y is the logarithm of the sales and ucc is the logarithm of the user cost of capital. This model can be derived by assuming a profit maximising firm with a CES production function with elasticity σ.

The user cost of capital, $UCC_{it} = \left(P_t^I / P_t\right)\left(r_t P_{t-1}^I / P_t^I + \delta_i - \Delta P_t^I / P_t^I\right)$, as noted by Mulkay et al. (2001), is difficult to measure at the firm level given the absence (in general) of the output price P_t and investment price P_t^I at such a disaggregated level. This problem is in general addressed by assuming that the variations in the user costs can be represented by time dummies and the specific fixed (long-term) effects[9] of a firm.

In order to allow dynamic adjustments of R&D capital, we transform Equation (1) in an autoregressive distributed lag model ADL(2,2). This is a standard specification in the literature that is convenient for short period samples as it captures temporal dynamics without abusively dropping data in the estimations because of the lag variables. We obtain the following equation:

$$c_{it} = \alpha_i + \alpha_t + \rho_1 c_{it-1} + \rho_2 c_{it-2} + \beta_0 y_{it} + \beta_1 y_{it-1} + \beta_2 y_{it-2} + \varepsilon_{it} \tag{2}$$

Following Bond and Meghir (1994), Harhoff (1998) and Mulkay et al. (2001), this equation can be rewritten in an error correction framework:

$$\Delta c_{it} = \alpha_i + \alpha_t + \delta_0 \Delta c_{it-1} + \delta_1 \Delta y_{it} + \delta_2 \Delta y_{it-1} + \delta_3 (c_{it-2} - y_{it-2}) + \delta_4 y_{it-2} + \varepsilon_{it} \tag{3}$$

where $\delta_0 = \rho_1 - 1$, $\delta_1 = \beta_0$, $\delta_2 = \beta_0 + \beta_1$, $\delta_3 = \rho_1 + \rho_2 - 1$ and $\delta_4 = \beta_0 + \beta_1 + \beta_2 + \rho_1 + \rho_2 - 1$.

[9] See, however, Butzen, Fuss and Vermeulen (2001) for an application that estimates the user cost of capital.

δ_3 is the coefficient of the error correction term and is expected to be negative. δ_4, if non-significant, indicates that returns to scales are constant.

By applying the usual approximation[10] $\Delta c_{it} \approx R_{it} / C_{it-1} - \delta$, with R being the R&D expenditures and δ the depreciation rate of R&D capital, Equation (3) becomes:

$$\frac{R_{it}}{C_{it-1}} = \alpha_i + \alpha_t + \delta_0 \frac{R_{it-1}}{C_{it-2}} + \delta_1 \Delta y_{it} + \delta_2 \Delta y_{it-1} + \delta_3 (c_{it-2} - y_{it-2}) + \delta_4 y_{it-2} + \varepsilon_{it} \quad (4)$$

Following the seminal work of Fazzari et al. (1988), if we assume that investments of credit-constrained firms are more sensitive to the availability of internal finance, equation (4) can be augmented with cash flow effects (divided by one period lagged C for normalisation) to test for the presence of financial constraints. Hence, financial constraints can be assessed by analysing the sensitivity of R&D investments to variations in cash flow available to firms:

$$\frac{R_{it}}{C_{it-1}} = \alpha_i + \alpha_t + \delta_0 \frac{R_{it-1}}{C_{it-2}} + \delta_1 \Delta y_{it} + \delta_2 \Delta y_{it-1} + \delta_3 (c_{it-2} - y_{it-2}) + \delta_4 y_{it-2}$$
$$+ \delta_5 \frac{CF_{it}}{C_{it-1}} + \delta_6 \frac{CF_{it-1}}{C_{it-2}} + \varepsilon_{it} \quad (5)$$

It should be noted that as claimed by Kaplan and Zingales (1997, 2000), the interpretation of the estimated coefficient associated with the cash flow ratio can be misleading since cash flow can be correlated with current profitability. In this case, cash flow will also be a proxy of profit or demand expectations and this variable cannot be interpreted directly as evidence of financing constraints[11]. In this paper, we follow the view point of Himmelberg and Petersen (1994), which states that changes in output, i.e. Δy_{it} and Δy_{it-1} in Equation (5), are better proxies for changes in demand than the cash flow variable and thus allow to control, even if imperfectly, for the expectations role played by this variable in terms of expected demand. Equation (5) can also be augmented with the Tobin's q to control for

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$$\Delta c_{it} = \log(C_{it}) - \log(C_{it-1}) = \log\left(\frac{C_{it}}{C_{it-1}}\right) = \log\left(\frac{C_{it} - C_{it-1} + C_{it-1}}{C_{it-1}}\right) = \log\left(1 + \frac{\Delta C_{it}}{C_{it-1}}\right) \cong \frac{\Delta C_{it}}{C_{it-1}} \cong \frac{R_{it}}{C_{it-1}} - \delta$$

11 For Fazzari, Hubbard and Petersen (2000), however, the theoretical model of Kaplan and Zingales fails to capture the approach used in this literature and therefore does not provide a relevant critique.

investment opportunities. Another possibility is to consider the projections of future profits on past variables and use them as implicit proxies for the expectations of future profits (Abel and Blanchard, 1986) or implement a structural Euler equation model derived from the intertemporal maximisation problem of the firms (Bond and Meghir, 1994). However, as pointed out by Butzen, Fuss and Vermeulen (2001) among others, this last approach, while more appropriate from a theoretical point of view, has often failed to produce significant and correctly signed adjustment costs parameters.

Equation (5) can be estimated using a within estimator by taking deviations from individual means or by taking all variables in first differences in order to remove the specific unobserved effect of the firm, α_i, which is assumed to be constant over the period under investigation, and which may be correlated with other regressors. The ability of the R&D personnel to find new inventions is one example of such an unobserved effect specific to the firm[12]. These unobserved variables are likely to be 'transmitted' to the R&D decision since firms with higher technological opportunities or abilities of their scientists and engineers will generally invest more in research activities. This in turn will imply a (positive) correlation between these unobservable variables and the R&D which invalidates the inference that can be made from Equation (5).

While the within and first differences estimators take care of the biases arising from possible correlated effects, it should be noted that these estimators could still be biased for three other possibly important reasons. The first source of bias rests in possible random measurement errors in the right hand side variables of the equation. These errors typically tend to be magnified when applying the first difference or within transformations (Griliches and Hausman, 1986). The two other sources of bias refer to the simultaneity between the contemporaneous regressors and the disturbances and the endogeneity of the contemporaneous regressors and the past disturbances. A solution to these three potential sources of biases consists of using an instrumental variable approach by choosing an appropriate set of lagged values of the regressors for the instruments. This approach can be implemented by means of a GMM framework such as the one developed by Arellano and Bond (1991) among others. If the original error term follows a white noise

[12] R&D opportunity or managerial skills may also be mentioned.

process, then values in levels of these variables lagged two or more periods will be admissible instruments[13]. The validity of the instruments is generally verified by the classical Sargan test and Hansen test of the over-identifying restrictions.

More recently, Arellano and Bover (1995) and Blundell and Bond (1998) developed a system GMM estimator, which combines the instruments of the first difference equation with additional instruments of the untransformed equation in level. Given the higher number of instruments, the system GMM estimator can lead to dramatic improvements in terms of efficiency compared with the first difference GMM estimator[14]. The validity of these additional instruments, which consist of past first difference values of the regressors, can again be tested through Difference Sargan over-identification tests.

4 DATA

In order to estimate an error-correction model for R&D investments, we use data on net sales and R&D from the five EU R&D investment scoreboards editions issued every year between 2004 and 2008 by the JRC-IPTS (scoreboards). R&D data from the scoreboards represent all R&D financed by the companies, regardless of the geographical localisation of R&D activities. Scoreboard data were collected from audited financial accounts and reports[15].

Combining the scoreboards resulted first in a raw unbalanced panel of 33600 observations. However many observations were redundant as the information for a same firm and year can be provided by more than one scoreboard. In order to avoid multiple counting of the same observation, we choose to keep only the most recent scoreboard as

[13] As noted by Bond et al. (1997), if the error term in levels is serially uncorrelated, then the error term in the first difference has a moving average structure of order 1 (MA(1)) and only instruments lagged by two periods or more will be valid. If the error term in levels already has a moving average structure, then longer lags will have to be considered.

[14] More fundamentally, as shown by Blundell and Bond (1998), when the autoregressive parameter is high and the number of time periods is low, the first difference GMM estimator can be subject to serious finite sample bias as a result of the weak explanatory power of the instruments.

[15] See Moncada Paternò Castello et al. (2009) for more details.

a source for each redundant observation. After applying this procedure, we obtained an unbalanced panel of 16553 observations for 2696 firms (706 US firms and 1438 EU firms).

Based on this sample, a matching procedure was conducted with the Compustat database in order to gather information about the cash flow of the companies[16]. The cash flow variable is equal to the income before extraordinary items, which represents the income of a company after all expenses except provisions for common and or preferred dividends, plus depreciation and amortisation, i.e. the non-cash charges for obsolescence and wear and tear on property[17].

The methodology for the matching between both databases combined automatic procedures and manual procedures. Automatic procedures consisted in two steps. First we matched firms with identical names in both databases. Second, we matched the names after clearing the following terms: AG, SA, CO, PLC, INC, LTD, SPA, BHD and CORP. These terms are the suffixes that appear the most often in our database. A manual procedure was conducted in order to compare the remaining unmatched names.

Out of the 2696 names of the R&D scoreboards, 1962 (73%) were matched, with matching procedures consisting in about 36% of automatic procedures, 33% of manual procedures and 31% of combination of both procedures. Ex post validation of the matching was carried up by checking the localization and industry of the firms as well as comparing the currency of the monetary data and the values of financial data in both sources.

Each monetary observation was converted into constant currency (in EUR) and prices[18]. It should be noted that data in the R&D scoreboards are already expressed in Euros and that a single scoreboard uses a fixed exchange rate for each currency to convert data into Euros for every periods that it covers. This is convenient when analysing data from one single scoreboard as they are unaffected by exchange rate variations in time. However, different scoreboards use different exchange rates. As we combine scoreboards from

[16] Release of 2009.
[17] Compustat (2009).
[18] Reference year is 2007. Sources for exchange rates and deflators are EUROSTAT.

different years, as well as several years within each scoreboard, we had to convert the data into constant Euros with the following procedure. First, we converted the data into original currencies by using the exchange rates specific to each scoreboard. Second, data in original currencies were converted into Euros using a fixed exchange rate[19]. Transforming data into constant prices was performed by using national GDP price deflators[20] with 2007 as the reference year.

The R&D stock was constructed by using a perpetual inventory method (Griliches, 1979). For each firm, the R&D stock at time t is defined by:

$$C_t = (1-\delta)C_{t-1} + R_t \qquad (6)$$

where δ represents the depreciation rate of R&D capital and R is the deflated amount of R&D expenditures. The depreciation rate was set to 0.15, which is usually assumed in the literature[21]. The initial value of C can be computed by using the following formula[22]:

$$C_0 = \frac{R_0}{g+\delta} \qquad (7)$$

where g is the growth rate of R and is assumed to be constant. The growth rates that are used in this study are the sample average[23] growth rates of R&D expenditures in each two-digit ICB industry.

In order to compare R&D investment liquidity constraints between Europe and the US, two samples of similar companies have been constructed for the EU and the US. Following Moncada Paternò Castello et al. (2009), size as measured by the amount of R&D investment in the firm is used as the criterion for matching similar firms. It turns out that the

19 We used the exchange rates in Eurostat for year 2007.
20 Eurostat GDP deflators.
21 An estimation of the depreciation rate of R&D has been performed by Bosworth (1978). The estimated range is 0.1 to 0.15. When testing different values for δ, Hall and Mairesse (1995) found little or no changes in the estimation of the R&D capital effect.
22 This expression can be derived from the definition of the R&D stock in equation (6), which can be rearranged into $C_t = \sum_{s=0}^{\infty}(1-\delta)^s R_{t-s}$. The latter equation leads to $C_0 = \sum_{s=0}^{\infty}\frac{(1-\delta)^s}{(1-g)}R_0$ and thus (7).
23 The average growth rate for an industry is computed as the average of the distribution of individual growth rates inside the range [Q1 – 1.5(Q3-Q1) , Q3 + 1.5(Q3-Q1)] where Q1 and Q3 are the first and third quartiles of the distribution.

sample of the 1962 firms among which 942 are from the EU and 525 from the US includes firms with different volumes of R&D investment. For the 2008 edition of the scoreboard, the R&D investment threshold for the EU subsample is EUR 4.35 million and that for the non-EU sub-sample EUR 24.21 million. In order to construct sub-samples of comparable EU and non-EU companies, it is preferable to consider only companies with R&D investments above the US threshold.

Furthermore, in order to trim the dataset from outliers, the following procedure has been implemented. All observations for which the R&D intensity (defined as the R&D investments divided by the firm's net sales) was below 0.1% or above 100% were deleted. This removed 29 firms for the first threshold (mainly firms from the retail and travel and leisure industry sectors) and 93 firms for the second criteria (firms mainly in the pharmaceuticals sector[24]). 1% extreme values for the ratio cash-flow to R&D capital stock were also removed as these observations might refer to errors from the matching procedure.

Table 2 presents some descriptive statistics for the variables used in the regression analyses with comparisons between the EU-27 and the US. The Global sample refers to the sample including both EU and US firms.

The average number of employees is large due to the nature of the R&D scoreboards. The median number of employees is about 6000 employees. We assume that this is a limitation in our analysis of financing constraints as large firms are expected to be less constrained compared to small and medium enterprises (SMEs). However this bias concerns both the European and US samples. Tables 2 and A1 in the Appendix show the effect of having comparable samples in terms of size. The companies in the matched samples look much more similar in terms of the distribution of quartiles and standard errors of the main variables used in the regression calculations.

[24] These firms are research specialized laboratories whose unique activity is R&D. There sales are therefore very limited which explains their very high R&D intensity, i.e. above 100%.

Table 2. Descriptive statistics

Variables	Region	Mean	Std.dev.	Quantile 25 %	Quantile 50 %	Quantile 75 %
R_t / C_{t-1}	Global	0.237	0.101	0.175	0.213	0.270
	EU27	0.229	0.103	0.169	0.206	0.257
	US	0.245	0.099	0.182	0.221	0.283
CF_t / C_{t-1}	Global	0.835	1.277	0.236	0.454	0.932
	EU27	0.994	1.552	0.262	0.494	1.038
	US	0.693	0.945	0.210	0.430	0.823
y_t	Global	7.248	1.693	5.971	7.183	8.435
	EU27	7.310	1.780	6.082	7.276	8.597
	US	7.186	1.599	5.909	7.089	8.310
c_t	Global	5.879	1.391	4.845	5.572	6.630
	EU27	5.697	1.456	4.602	5.329	6.434
	US	6.059	1.300	5.123	5.727	6.777
Δy_t	Global	0.074	0.221	-0.019	0.052	0.138
	EU27	0.056	0.214	-0.029	0.035	0.110
	US	0.092	0.225	-0.006	0.069	0.161
Employees	Global	22916	48707	1860	6108	22000
	EU27	25957	55300	2143	6892	24264
	US	19899	40924	1634	5600	18803

5 EMPIRICAL FINDINGS

5.1 Basic results

Table 3 presents the system GMM results as regards the R&D investment error correction model when all firms of the sample are considered. These estimates are obtained from a two-step procedure and different sets of instruments. Column 2 for instance uses as instruments two lagged and higher values of regressors while column 3 only consider three lagged and higher values. The validity of these additional instrumental variables when we move from column 3 to 2 can be tested through the difference between Sargan or Hansen over-identification tests. Another strategy is to compare the results for these tests across models, i.e. columns. The null hypothesis is that the instruments are valid, i.e. they are uncorrelated with the error terms. Under the null hypothesis, the test statistic follows a chi-squared distribution with a number of degrees of freedom being equal to the number of over-identifying restrictions. Rejection of the null hypothesis casts a doubt on the validity of the set of instruments. This appears to always be the case for the Sargan test and only for the model in the second column for the Hansen test[25].

The second order correlation test statistics do not suggest any problems with the time structure of the sets of instruments except again in Column 2. With the exception of Column 4, the error correction term has the expected negative sign and is statistically significant at the 1 % level. The coefficient of output lagged by two periods is negative and significant albeit only slightly. This suggests the presence of slightly decreasing returns to scale. Cash flow effects have a positive and significant effect on investment (the long-term coefficient is about .489) and this indicates the presence of liquidity constraints. Finally, the positive and significant coefficients associated with the changes in output suggest positive expectations of future profitability to the extent that these variables are a proxy of the investment opportunities of a firm.

Table 3. System GMM two step estimates - all firms

Instruments set	Lag(2,.)		lag(3,.)		lag(4,.)	
R_{t-1}/C_{t-2}	-0.059	(0.108)	0.175	(0.071)**	0.400	(0.153)***
Δy_t	0.009	(0.112)	0.228	(0.115)**	0.111	(0.119)
Δy_{t-1}	0.019	(0.031)	0.037	(0.062)	0.018	(0.084)
$c_{t-2}-y_{t-2}$	-0.093	(0.034)***	-0.053	(0.020)***	0.002	(0.032)
CF_t/C_{t-1}	0.074	(0.033)**	0.061	(0.028)**	0.030	(0.020)
CF_{t-1}/C_{t-2}	0.013	(0.011)	-0.009	(0.010)	0.011	(0.019)
y_{t-2}	-0.078	(0.014)***	-0.048	(0.012)***	-0.025	(0.020)
Obs	3 590					
N	888					
AR(1)	-0.46	[0.647]	-1.58	[0.115]	-1.90	[0.058]
AR(2)	-1.31	[0.190]	-1.19	[0.235]	-1.18	[0.238]
Sargan test	2904.02	[0.000]	607.12	[0.000]	370.69	[0.000]
Hansen test	145.95	[0.000]	77.83	[0.072]	49.68	[0.117]

Notes:
*** (respectively ** and *) statistically significant at the 1 % (respectively 5 % and 10 %) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastically-consistent standard errors in brackets; P values in square brackets;
AR(1) and AR(2): tests for first order and second order serial correlation in the first difference residuals; Two-step estimates; instruments used in column s (s=2,3,4): observations dated t-s to t-5 for X_t (transformed equation) and t-s+1 for ΔX_t (equation in level).

[25] As pointed out by Roodman (2006), Sargan's statistic is a special case of Hansen's J test under the assumption of homoscedasticity. Therefore, for robust GMM estimation, the Sargan test statistic is inconsistent.

Table 4. System GMM two-step estimates - EU27 and US samples

	EU27						USA					
Instruments set	lag(2,.)		lag(3,.)		lag(4,.)		lag(2,.)		lag(3,.)		lag(4,.)	
R_{t-1}/C_{t-2}	-0.145	(0.065)**	-0.074	(0.159)	-0.000	(0.142)	0.673	(0.055)***	0.691	(0.038)***	0.728	(0.039)***
Δy_t	-0.181	(0.133)	-0.077	(0.071)	0.02	(0.122)	0.129	(0.039)***	0.193	(0.05)***	0.111	(0.046)**
Δy_{t-1}	0.007	(0.052)	0.156	(0.071)**	0.096	(0.150)	0.029	(0.011)***	0.012	(0.025)	-0.005	(0.038)
$c_{t-2} - y_{t-2}$	-0.031	(0.044)	-0.083	(0.035)**	-0.050	(0.057)	-0.007	(0.009)	-0.014	(0.007)*	-0.006	(0.014)
CF_t/C_{t-1}	0.073	(0.019)***	0.042	(0.020)**	0.038	(0.023)*	-0.005	(0.008)	-0.000	(0.012)	0.000	(0.015)
CF_{t-1}/C_{t-2}	0.031	(0.01)***	0.018	(0.015)	0.010	(0.016)	0.002	(0.004)	-0.002	(0.003)	0.007	(0.018)
y_{t-2}	-0.094	(0.017)***	-0.082	(0.027)***	-0.084	(0.034)**	-0.006	(0.003)**	-0.004	(0.003)	-0.003	(0.005)
Obs	1 675						1 915					
N	421						467					
AR(1)	-0.94	[0.348]	-1.87	[0.061]	-1.15	[0.250]	-2.09	[0.037]	-2.24	[0.025]	-2.03	[0.042]
AR(2)	-1.32	[0.188]	-0.28	[0.783]	-1.27	[0.202]	-0.90	[0.366]	-0.79	[0.428]	-0.91	[0.361]
Sargan test	2304.69	[0.000]	971.10	[0.000]	287.71	[0.000]	494.51	[0.000]	215.47	[0.000]	84.33	[0.000]
Hansen test	103.52	[0.084]	62.24	[0.432]	20.18	[0.995]	99.50	[0.135]	74.72	[0.111]	52.44	[0.074]

Notes:
*** (respectively ** and *) statistically significant at the 1% (respectively 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastically-consistent standard errors in bracket; P values in square brackets;
AR(1) and AR(2): tests for first order and second order serial correlation in the first difference residuals; Two-step estimates; instruments used in column s (s=2,3,4): observations dated t-s to t-5 for X_t (transformed equation) and t-s+1 for ΔX_t (equation in level).

In Table 4 we compare the presence and extent of R&D financing constraints of EU and US firms. Note that the different test statistics vindicate the use of the specification of Column 3 for EU firms and Columns 2, 3 and 4 for US firms. The coefficients associated with the cash flow variables are positive and significant for the EU while for the US no evidence of liquidity constraints is found. Interestingly these results are not in line with the ones found in previous studies that examined the R&D internal financing relationship.

5.2 Robustness of results

This section discusses some alternative regression analyses performed to assess the robustness of the main results. To start with, Table B1 reports within and random effects estimates of R&D investment error correction model augmented with the cash flow variables. When a fixed effects model (within transformation) is estimated, only EU firms are subject to liquidity constraints; as for the US ones, the coefficients associated with the cash flow variables are not significantly different from zero. The Hausman test is statistically significant at the 1 % level which rejects the null hypothesis of no correlation between the unobserved specific effects of the firms and the regressors, hence invalidating the random specification.

The results reported in this paper are obtained from two-step GMM estimators. One-step GMM estimators are calculated by weighting the moment conditions with an arbitrary chosen matrix which does not depend on estimated parameters while two-step estimators use a weight matrix based on the consistent one-step estimation. Arellano and Bond (1991), Arellano and Bond (1998), Windmeijer (2005) and Roodman (2006) have shown that the one-step GMM estimator may be more reliable than the two-step one for statistical inference as the latter provide downward biased asymptotic standard errors. However, Windmeijer (2005) developed a small-sample correction for the standard errors of two-step estimators that allows for more accurate inference. We used this correction for the reported two-step estimators. Tables B2a and B2b reports the results when a consistent one step system GMM estimator is implemented. For the EU sample, both the Sargan and Hansen tests reject the validity of the different sets of instruments used. Yet a positive coefficient is still observed for the cash flow variables. This is not the case for the US firms which once again do not appear to be financially constrained.

As can be seen in Table B3, estimating a simpler accelerator R&D investment specification leads one to the conclusion that only EU firms are sensitive to cash flow variations. In tables B4 to B6, we considered alternative specifications where only the current value of the cash flow variable, the one-year lagged value or the current, one-year and two-year lagged values of this variable are considered altogether. These specifications allow one to control for the presence of multicollinearity which could alter the estimated coefficients of cash flow variables when different periods of this variable are introduced simultaneously in the specification. On the other hand, we also considered an additional lag of the cash flow-R&D capital ratio, i.e. CF_{t-2}/C_{t-3}. While the results as regards this specification are not conclusive for the US sample, on the whole, the findings clearly indicate that financing constraints are present for EU R&D companies.

As an additional test, we investigated the role played by the size of companies. Indeed, several studies have shown the central role played by the size of a firm in explaining the sensitivity of capital and R&D investment to cash flow variations[26]. Small firms are more dependent upon internal resources since the loan rates charged by commercial banks tend to be higher[27]. Conversely, larger firms can more easily finance capital expenditures from internal resources, issuance of equity or debt. In this study, we measure the size of a firm in two ways. First, in Table B7, the regression is performed on a subset of the largest companies, i.e. the ones with more than 1000 employees. Note that this results in a cut of the sample by about one half. Second, in Table B8, a proxy for size is directly introduced in the specification, i.e. the number of employees at time t and at time t-1.

For the EU companies, the results appear to be in line with these theoretical predictions as the magnitude of the estimated coefficient associated with the cash flow variables are somewhat smaller as compared with the results when the full sample is considered. For the US firms, again, no effect of liquidity constraints is detected except to some extent for the specification based on the sub-sample with the largest companies. Yet, in this case, the estimated effects appear to be much smaller than the ones obtained for the EU subset.

As an alternative to the cash flow variable, the operating profit of the firm is also considered to proxy the internal available financial resources of a firm in Tables B9a and B9b. This variable is defined as profit (or loss) before taxation, plus net interest cost (or minus interest

[26] See Schiantarelli (1996) for a survey of the empirical literature on this subject.

cost) and government grants, less gains (or plus losses) arising from the sale/disposal of businesses or fixed assets. Here too the main conclusions are not altered when the operating profit is used as an alternative proxy for cash flow.

The last robustness check consists of estimating the R&D investment error correction model for the EU-27 sample but without the UK companies. The rationale for this test is that the UK financial system may be different than the European continental one and more similar to the US one. The results in Table 10 do not change our main conclusion: continental European R&D firms are more likely to be hit by financing constraints for their R&D investments than US ones.

5.3 Discussion

The main finding of this paper is that large European firms are subject to liquidity constraints in the financing of their R&D investments, whereas US ones do not appear to be financially constrained. This result is robust to different specifications of the R&D investment model, sub-samples of data, outliers, and econometric methods that address the heterogeneity and possible endogeneity of the variables of interest of the firms, i.e. cash flow and R&D.

These findings are different from the ones usually reported in the literature, that US firms appear more financially constrained (Hall et al., 1999; Mulkay et al. 2001; Bond et al. 1999). Many authors conclude that the impact of financial factors on investment and R&D differs across countries and not so much within a given country, hence suggesting that it is the financial market environment specific to a country as well as institutional differences in financial systems that matter in explaining the impact of financial factors on R&D investments[28].

Different factors may explain the difference between our findings and the ones in the literature. We briefly discuss them here. In sum, in our view, the main explanation for the divergence in results between this paper and previous studies is the period investigated. Our

[27] See, for example, Stoll (1984) for the US credit market.
[28] Another difference of our study is that the sample of EU countries includes almost all EU countries, not only Germany vs. UK or France vs. the US like in the other studies comparing micro-data from different countries. Finally, as pointed out by (Harhoff, 1998), large quoted EU firms are more subject to financing constraints. As a matter of fact, our sample also consists of very large EU companies, i.e. the largest R&D companies investing in the world.

study is actually the only one which uses data after 2000; a period in which the world's financial systems have undergone fundamental changes that may have affected the EU and the US differently.

Since the beginning of this decade, within the framework of the Lisbon process to transform the EU into a knowledge-based and more dynamic and competitive economy in the world, several product market reforms have been put in place in the EU to catch up with the US, especially in the capital market (Cincera and Galgau, 2005). As a result, financial institutions face stronger competition and the conditions for borrowing money for investments, in particular for intangibles such as R&D, are more difficult.

The null-years of the 21st century have been a period with a lack of regulation in lending; one of the root causes of the recent burst of the financial bubble in the US and the ensuing financial and economic turmoil in the world. This lack of regulation and the risks taken by banks may have alleviated the constraints to get loans for investment projects and therefore firms investing in R&D may well have been less concerned by financing constraints to fund their R&D investments, especially in the US.

R&D activities are riskier by nature and generally provide less collateral to lenders as compared to investments in capital goods. As a result, financing constraints may be even more pronounced in the case of such intangible investments. However, given the existence of high adjustment and sunk costs associated with this kind of investment, firms will engage in R&D activities if they do not expect to be seriously affected by financial constraints. As such, cash flow effects tend to matter less for large investors than for smaller companies. Moreover, the provision of public support to R&D may interfere with the investment decision of a firm by alleviating liquidity constraints problems, if present at all.

The outcome has been factors hampering R&D and innovation activities, exemplified by a scarcity of venture capital. And there are indications, corroborated by the empirical findings of our study that one of these factors - the difficulty to get access to external sources of financing - has affected the EU more than the US.

6 CONCLUSION

Based on two newly constructed and comparable samples of EU and US private companies which represent the largest in the world, this paper investigates the impact of financing constraints on R&D investments over the current decade. The results based on an error correction equation have been obtained by using a system GMM estimator, which compared to the usual first difference GMM estimator produces in general more precise estimates and reduces the possible bias arising from the weak explanatory power of the instruments and high values of the autoregressive parameter.

The main empirical findings of the paper indicate a positive impact of cash flow effects on the firms R&D investment decisions. However, they also suggest that only large EU R&D companies are facing liquidity constraints, not their large US competitors. This finding is robust to alternative modelling strategies, econometric methods implemented and data sub-samples. In terms of policy implications, these results suggest improving conditions in the EU for access to external capital, i.e. debt and equity. Policy makers would do well to provide direct R&D support for these firms, i.e. tax incentives and R&D subsidies and further develop the availability of risk capital. Indirectly, clearer framework conditions in the EU, in particular for private equity should be achieved. However, in terms of direct support, it is not clear whether policy makers should primarily allocate public resources to support large firms which are top R&D investors and fewer to smaller companies as the former may be less concerned with financing constraints of funding their R&D investments than the latter. In order to further investigate this question, it would be useful to consider a larger sample which would include, besides large R&D corporations, small and medium R&D investors.

To some extent, the main results obtained in this paper contradict the findings of the existing literature on the subject. In our view, the main reason lies in the period considered for the regression analyses (the first decade of the 21st century in this study versus data before 2000 in the other studies) as well as, possibly, conjectural and structural changes in the financial systems of the EU and the US before and after the passage to the new millennium, which need further investigation. A second explanation rests in the sample retained in the present analysis which consists of the largest R&D companies in the EU and in the US. It is not certain that the main conclusions of the paper will remain applicable when smaller firms are considered as well. This question also deserves further investigation.

In order to better understand the relationship between R&D investing behaviours and financing constraints it would also be helpful to know more precisely the share of the different sources for the funding of R&D, i.e. internal financing, debt and issues of shares on the stock markets. Indeed if firms in the EU are relying less on external sources compared with their US counterparts, then this could explain why EU firms are more sensitive to liquidity constraints.

Another interesting extension of this work would be to investigate which component of R&D investment, i.e. the 'R' vs. the 'D', is more financially constrained; the outsourced R&D abroad or the research carried out in the home country. Based on a longer history of data, it would be interesting to compare both periods in the EU and the US, i.e. 1990 – 1999 vs. 2000 – 2009 and investigate whether indeed the importance and existence of liquidity constraints has changed over time and across the two regions.

Finally, while maintaining the important division between European and US companies, which is because of the very different business environments for R&D firms in the two regions, it may be worth investigating separately groups of firms by sector of economic activity. Quite often, the differences in financial constraints and management of R&D resources differ significantly from one sector to another. Generally, differences are larger between sectors than between regions in the same sector of activity, particularly when considering worldwide-operating firms.

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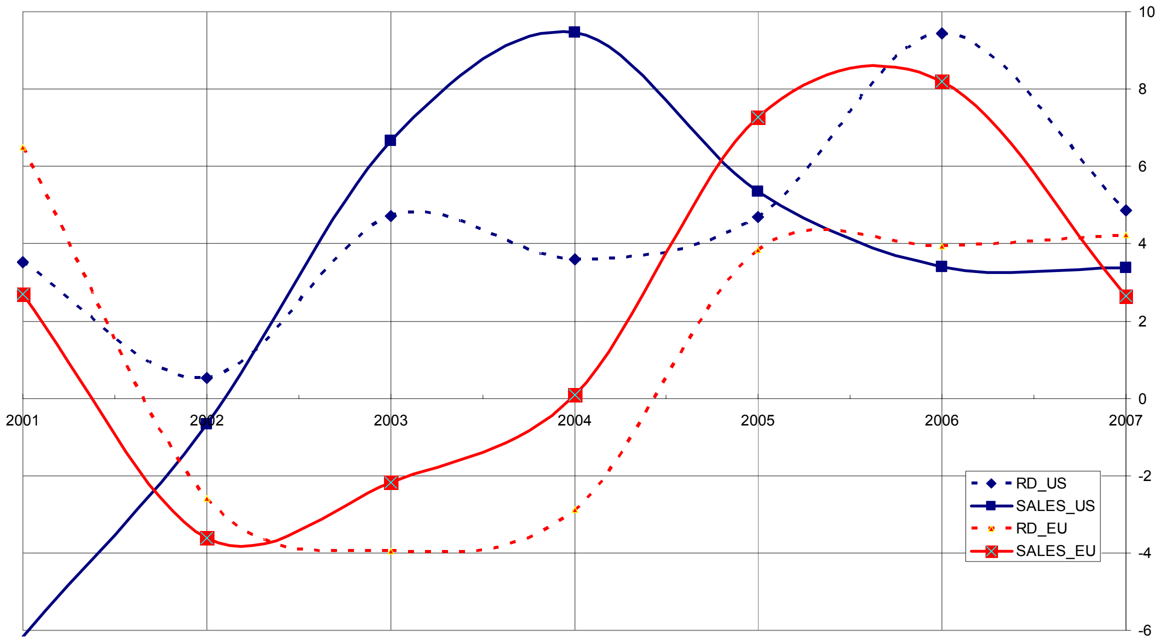
APPENDIX A. Descriptive Statistics

Table A1. Descriptive statistics on the initial sample

Variables	Region	Mean	Std.dev.	Quantile 25 %	Quantile 50 %	Quantile 75 %
R_{t-1}/C_{t-2}	Global	0.245	0.112	0.178	0.215	0.277
	EU27	0.244	0.123	0.172	0.212	0.273
	US	0.247	0.101	0.182	0.222	0.286
CF_t/C_{t-1}	Global	0.907	1.335	0.256	0.478	1.007
	EU27	1.061	1.639	0.172	0.212	0.273
	US	0.692	0.945	0.209	0.430	0.821
y_t	Global	6.963	1.906	5.707	7.017	8.267
	EU27	6.430	2.089	5.014	6.452	7.816
	US	7.118	1.677	5.852	7.065	8.284
c_t	Global	5.462	1.602	4.425	5.362	6.391
	EU27	4.777	1.674	3.570	4.470	5.704
	US	6.043	1.296	5.115	5.708	6.762
Δy_t	Global	0.081	0.238	-0.012	0.058	0.145
	EU27	0.066	0.253	-0.028	0.043	0.133
	US	0.094	0.236	-0.006	0.070	0.164
Employees	Global	20184	46122	1324	5087	17725
	EU27	16966	45410	691	3101	11246
	US	19576	40663	1556	5400	18100

Figure A1. Trends in R&D and net sales in the EU and the US (2000 – 2007)



Source: Own calculations based on samples of EU and US Scoreboard companies.

APPENDIX B. Robustness of results

Table B1. Within/Random effects - EU27 and US samples

	Fixed effects				Random effects			
	EU27		US		EU27		US	
R_{t-1}/C_{t-2}	0.069	(0.013)***	0.038	(0.019)**	0.116	(0.009)***	0.427	(0.015)***
Δy_t	0.098	(0.011)***	0.142	(0.009)***	0.069	(0.010)***	0.105	(0.008)***
Δy_{t-1}	0.118	(0.009)***	0.131	(0.009)***	0.081	(0.008)***	0.038	(0.007)***
$c_{t-2} - y_{t-2}$	-0.127	(0.013)***	-0.187	(0.012)***	-0.026	(0.004)***	-0.010	(0.003)***
CF_t/C_{t-1}	0.005	(0.003)*	-0.002	(0.005)	0.017	(0.002)***	0.017	(0.002)***
CF_{t-1}/C_{t-2}	-0.002	(0.001)	0.002	(0.001)	-0.000	(0.001)	0.001	(0.001)
y_{t-2}	-0.028	(0.013)**	-0.026	(0.010)**	-0.015	(0.002)***	-0.010	(0.002)***
Obs	1 675		1 915		1 675		1 915	
N	421		467		421		467	
Hausman test	214	[0.000]	1 215	[0.000]				
Adj.R-squared	0.330		0.303		0.269		0.106	

Table B2a. System GMM one step estimates - All firms

Instruments set	lag(2,.)		lag(3,.)		lag(4,.)	
R_{t-1}/C_{t-2}	-0.086	(0.088)	0.127	(0.148)	0.150	(0.170)
Δy_t	0.172	(0.145)	0.387	(0.158)**	0.238	(0.176)
Δy_{t-1}	-0.035	(0.047)	0.020	(0.078)	0.154	(0.096)
$c_{t-2} - y_{t-2}$	-0.059	(0.036)*	-0.029	(0.030)	0.034	(0.039)
CF_t/C_{t-1}	0.098	(0.027)***	0.093	(0.038)**	0.057	(0.023)**
CF_{t-1}/C_{t-2}	0.020	(0.010)*	-0.003	(0.016)	0.020	(0.019)
y_{t-2}	-0.097	(0.017)***	-0.054	(0.019)***	-0.045	(0.018)**
Obs			3 590			
N			888			
AR(1)	-0.07	[0.941]	-1.37	[0.169]	-0.16	[0.873]
AR(2)	-0.95	[0.343]	-1.08	[0.281]	-2.13	[0.033]
Sargan test	2904.02	[0.000]	607.12	[0.000]	370.69	[0.000]
Hansen test	145.95	[0.000]	77.83	[0.072]	49.68	[0.117]

Notes:
*** (respectively ** and *) statistically significant at the 1% (respectively 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastically-consistent standard errors in bracket; P values in square brackets;
AR(1) and AR(2): tests for first order and second order serial correlation in the first difference residuals; Two-step estimates; instruments used in column s (s=2,3,4): observations dated t-s to t-5 for Xt (transformed equation) and t-s+1 for ΔXt (equation in level).

Table B2b. System GMM one-step estimates - EU27 and US samples

	EU27						USA					
Instruments set	lag(2,.)		lag(3,.)		lag(4,.)		lag(2,.)		lag(3,.)		lag(4,.)	
R_{t-1} / C_{t-2}	-0.188	(0.072)***	-0.195	(0.147)	-0.180	(0.140)	0.61	(0.071)***	0.657	(0.043)***	0.746	(0.074)***
Δy_t	-0.191	(0.155)	-0.054	(0.097)	-0.042	(0.154)	0.132	(0.063)**	0.167	(0.058)***	0.064	(0.107)
Δy_{t-1}	-0.043	(0.063)	0.120	(0.103)	0.335	(0.173)*	0.032	(0.012)***	-0.010	(0.041)	-0.025	(0.060)
$c_{t-2} - y_{t-2}$	-0.023	(0.054)	-0.098	(0.040)**	-0.013	(0.053)	-0.008	(0.010)	0.003	(0.013)	-0.008	(0.011)
CF_t / C_{t-1}	0.085	(0.022)***	0.061	(0.02)***	0.059	(0.019)***	-0.004	(0.006)	0.014	(0.016)	-0.008	(0.014)
CF_{t-1} / C_{t-2}	0.036	(0.011)***	0.029	(0.015)**	0.038	(0.016)**	0.001	(0.003)	0.000	(0.003)	0.009	(0.012)
y_{t-2}	-0.116	(0.022)***	-0.114	(0.032)***	-0.118	(0.029)***	-0.012	(0.005)***	-0.005	(0.006)	-0.002	(0.006)
Obs	1 675						1 915					
N	421						467					
AR(1)	-0.42	[0.675]	-0.70	[0.485]	-2.64	[0.008]	-2.60	[0.009]	-2.29	[0.022]	-2.31	[0.021]
AR(2)	-1.50	[0.134]	-0.61	[0.542]	-0.05	[0.961]	-0.89	[0.376]	-0.78	[0.434]	-0.97	[0.334]
Sargan test	2304.69	[0.000]	971.10	[0.000]	287.71	[0.000]	494.51	[0.000]	215.47	[0.000]	84.33	[0.000]
Hansen test	103.52	[0.084]	62.24	[0.432]	20.18	[0.995]	99.50	[0.135]	74.72	[0.111]	52.44	[0.074]

Notes:
*** (respectively ** and *) statistically significant at the 1% (respectively 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastically-consistent standard errors in bracket; P values in square brackets;
AR(1) and AR(2): tests for first order and second order serial correlation in the first difference residuals; Two-step estimates; instruments used in column s (s=2,3,4): observations dated t-s to t-5 for Xt (transformed equation) and t-s+1 for ΔXt (equation in level).

Table B3. Simple accelerator model - System GMM two step estimates - EU27 and US samples

	EU27						USA					
Instruments set	lag(2,.)		lag(3,.)		lag(4,.)		lag(2,.)		lag(3,.)		lag(4,.)	
R_{t-1} / C_{t-2}	-0.059	(0.131)	0.043	(0.042)	0.169	(0.128)	0.711	(0.049)***	0.708	(0.033)***	0.738	(0.037)***
Δy_t	0.059	(0.155)	0.174	(0.106)*	-0.009	(0.257)	0.141	(0.049)***	0.202	(0.048)***	0.123	(0.075)*
Δy_{t-1}	0.075	(0.035)**	0.200	(0.071)***	0.308	(0.207)	0.033	(0.012)***	-0.005	(0.021)	0.001	(0.042)
CF_t / C_{t-1}	0.091	(0.026)***	0.054	(0.019)***	0.030	(0.021)	-0.005	(0.007)	0.007	(0.010)	0.005	(0.013)
CF_{t-1} / C_{t-2}	0.024	(0.015)*	0.014	(0.005)***	0.007	(0.013)	0.002	(0.002)	-0.001	(0.004)	0.012	(0.013)
Obs	1 675						1 915					
N	421						467					
AR(1)	-0.47	[0.639]	-0.96	[0.336]	-3.01	[0.003]	-2.09	[0.037]	-2.31	[0.021]	-2.04	[0.041]
AR(2)	-2.06	[0.039]	-2.38	[0.017]	-0.39	[0.693]	-0.91	[0.364]	-0.75	[0.453]	-0.91	[0.364]
Sargan test	2651.81	[0.000]	860.30	[0.000]	297.84	[0.000]	491.14	[0.000]	214.42	[0.000]	85.92	[0.000]
Hansen test	132.21	[0.001]	68.12	[0.307]	46.30	[0.263]	99.30	[0.173]	86.91	[0.025]	52.36	[0.110]

Notes:
*** (respectively ** and *) statistically significant at the 1% (respectively 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastically-consistent standard errors in bracket; P values in square brackets;
AR(1) and AR(2): tests for first order and second order serial correlation in the first difference residuals; Two-step estimates; instruments used in column s (s=2,3,4): observations dated t-s to t-5 for Xt (transformed equation) and t-s+1 for ΔXt (equation in level).

Table B4. System GMM two step estimates – current value of cash-flow-R&D capital ratio - EU27 and US samples

	EU27						USA					
Instruments set	lag(2,.)		lag(3,.)		lag(4,.)		lag(2,.)		lag(3,.)		lag(4,.)	
R_{t-1}/C_{t-2}	0.025	(0.047)	0.072	(0.058)	0.106	(0.096)	0.679	(0.053)***	0.694	(0.037)***	0.723	(0.039)***
Δy_t	-0.060	(0.223)	0.025	(0.093)	0.069	(0.148)	0.129	(0.036)***	0.187	(0.051)***	0.118	(0.041)***
Δy_{t-1}	-0.040	(0.069)	0.097	(0.066)	0.184	(0.121)	0.029	(0.010)***	0.007	(0.024)	0.005	(0.035)
$c_{t-2} - y_{t-2}$	-0.018	(0.055)	-0.069	(0.035)**	-0.080	(0.038)**	-0.008	(0.007)	-0.012	(0.008)	-0.011	(0.007)
CF_t / C_{t-1}	0.117	(0.039)***	0.047	(0.019)**	0.022	(0.027)	-0.004	(0.006)	-0.002	(0.010)	-0.004	(0.007)
y_{t-2}	-0.078	(0.024)***	-0.067	(0.021)***	-0.073	(0.028)***	-0.006	(0.003)**	-0.004	(0.003)	-0.002	(0.005)
Obs	1 690						1 922					
N	421						468					
AR(1)	-1.41	[0.159]	-3.80	[0.000]	-3.31	[0.001]	-2.11	[0.035]	-2.23	[0.026]	-2.06	[0.039]
AR(2)	-1.38	[0.168]	-1.62	[0.106]	-1.33	[0.184]	-0.92	[0.358]	-0.82	[0.413]	-0.92	[0.357]
Sargan test	1474.13	[0.000]	691.46	[0.000]	298.23	[0.000]	480.49	[0.000]	213.76	[0.000]	89.36	[0.000]
Hansen test	118.16	[0.012]	55.93	[0.693]	24.31	[0.976]	95.48	[0.227]	76.94	[0.096]	52.78	[0.085]

Notes:
*** (respectively ** and *) statistically significant at the 1% (respectively 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastically-consistent standard errors in bracket; P values in square brackets;
AR(1) and AR(2): tests for first order and second order serial correlation in the first difference residuals; Two-step estimates; instruments used in column s (s=2,3,4): observations dated t-s to t-5 for Xt (transformed equation) and t-s+1 for ΔXt (equation in level).

Table B5. System GMM two step estimates – one year lagged value of current cash-flow-R&D capital ratio - EU27 and US samples

	EU27						USA					
Instruments set	lag(2,.)		lag(3,.)		lag(4,.)		lag(2,.)		lag(3,.)		lag(4,.)	
R_{t-1}/C_{t-2}	-0.378	(0.180)**	-0.209	(0.181)	0.106	(0.103)	0.670	(0.054)***	0.693	(0.036)***	0.734	(0.040)***
Δy_t	-0.130	(0.128)	-0.095	(0.149)	0.024	(0.124)	0.131	(0.050)***	0.190	(0.047)***	0.112	(0.053)**
Δy_{t-1}	0.127	(0.041)***	0.111	(0.068)	0.067	(0.110)	0.023	(0.011)**	0.005	(0.025)	-0.004	(0.037)
$c_{t-2} - y_{t-2}$	-0.178	(0.045)***	-0.190	(0.068)***	-0.109	(0.048)**	-0.003	(0.010)	-0.010	(0.006)*	-0.006	(0.011)
CF_{t-1}/C_{t-2}	0.061	(0.028)**	0.029	(0.016)*	-0.001	(0.015)	0.002	(0.004)	-0.001	(0.002)	0.007	(0.016)
y_{t-2}	-0.113	(0.026)***	-0.108	(0.030)***	-0.082	(0.026)***	-0.006	(0.003)**	-0.005	(0.002)*	-0.003	(0.005)
Obs	1 686						1 917					
AR(1)	-1.91	[0.056]	-0.98	[0.326]	-2.84	[0.004]	-2.10	[0.036]	-2.23	[0.026]	-2.02	[0.043]
AR(2)	0.96	[0.338]	0.06	[0.952]	-1.07	[0.286]	-0.89	[0.372]	-0.79	[0.431]	-0.91	[0.361]
Sargan test	1877.19	[0.000]	894.83	[0.000]	233.30	[0.000]	497.04	[0.000]	220.10	[0.000]	87.90	[0.000]
Hansen test	105.67	[0.074]	60.19	[0.542]	17.53	[0.999]	100.23	[0.140]	81.07	[0.052]	52.45	[0.090]

Notes:
*** (respectively ** and *) statistically significant at the 1% (respectively 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastically-consistent standard errors in bracket; P values in square brackets;
AR(1) and AR(2): tests for first order and second order serial correlation in the first difference residuals; Two-step estimates; instruments used in column s (s=2,3,4): observations dated t-s to t-5 for Xt (transformed equation) and t-s+1 for ΔXt (equation in level).

Table B6. System GMM two step estimates – current, one year and two years lagged values of current cash-flow-R&D capital ratio - EU27 and US samples

	EU27						USA					
Instruments set	lag(2,.)		lag(3,.)		lag(4,.)		lag(2,.)		lag(3,.)		lag(4,.)	
R_{t-1}/C_{t-2}	0.078	(0.06)	0.238	(0.059)***	0.225	(0.094)**	0.638	(0.058)***	0.665	(0.048)***	0.738	(0.055)***
Δy_t	0.092	(0.062)	0.056	(0.062)	0.067	(0.088)	0.220	(0.096)**	0.245	(0.061)***	0.181	(0.154)
Δy_{t-1}	0.033	(0.037)	0.134	(0.040)***	0.117	(0.084)	0.008	(0.019)	0.025	(0.069)	-0.007	(0.057)
$c_{t-2}-y_{t-2}$	-0.115	(0.030)***	-0.054	(0.024)**	-0.072	(0.03)**	0.008	(0.012)	-0.003	(0.010)	0.002	(0.012)
CF_t/C_{t-1}	0.022	(0.015)	0.014	(0.007)**	0.003	(0.012)	0.002	(0.009)	-0.003	(0.010)	0.010	(0.014)
CF_{t-1}/C_{t-2}	-0.004	(0.005)	-0.01	(0.006)*	-0.008	(0.008)	0.005	(0.005)	0.005	(0.006)	0.011	(0.012)
CF_{t-2}/C_{t-3}	-0.001	(0.001)	0.000	(0.000)*	0.002	(0.001)	0.005	(0.005)	0.006	(0.006)	-0.001	(0.018)
y_{t-2}	-0.078	(0.012)***	-0.051	(0.014)***	-0.056	(0.017)***	-0.003	(0.003)	-0.003	(0.002)	-0.003	(0.003)
Obs	1 298						1 532					
N	374						451					
AR(1)	-2.94	[0.003]	-3.84	[0.000]	-3.31	[0.001]	-2.02	[0.044]	-1.92	[0.055]	-1.81	[0.071]
AR(2)	-1.14	[0.253]	-0.97	[0.333]	-1.03	[0.302]	0.80	[0.426]	0.80	[0.426]	0.47	[0.637]
Sargan test	1070.85	[0.000]	377.88	[0.000]	295.83	[0.000]	401.47	[0.000	190.69	[0.000]	114.34	[0.000]
Hansen test	94.26	[0.076]	53.56	[0.641]	35.00	[0.609]	97.76	[0.047]	85.58	[0.011]	53.37	[0.05]

Notes:
*** (respectively ** and *) statistically significant at the 1% (respectively 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastically-consistent standard errors in bracket; P values in square brackets;
AR(1) and AR(2): tests for first order and second order serial correlation in the first difference residuals; Two-step estimates; instruments used in column s (s=2,3,4): observations dated t-s to t-5 for Xt (transformed equation) and t-s+1 for ΔXt (equation in level).

Table B7. System GMM two step estimates – large firms - EU27 and US samples

	EU27						USA					
Instruments set	lag(2,.)		lag(3,.)		lag(4,.)		lag(2,.)		lag(3,.)		lag(4,.)	
R_{t-1}/C_{t-2}	0.481	(0.081)***	0.454	(0.114)***	0.579	(0.124)***	0.739	(0.064)***	0.766	(0.052)***	0.824	(0.05)***
Δy_t	0.117	(0.075)	0.194	(0.129)	0.052	(0.159)	0.091	(0.051)*	0.140	(0.042)***	0.098	(0.091)
Δy_{t-1}	0.018	(0.027)	0.015	(0.082)	0.037	(0.099)	0.019	(0.015)	-0.002	(0.02)	-0.029	(0.061)
$c_{t-2} - y_{t-2}$	0.011	(0.015)	-0.03	(0.023)	0.006	(0.015)	0.018	(0.014)	0.005	(0.008)	0.013	(0.011)
CF_t/C_{t-1}	0.015	(0.007)**	0.002	(0.009)	0.007	(0.005)	0.005	(0.003)*	0.004	(0.005)	0.007	(0.013)
CF_{t-1}/C_{t-2}	0.006	(0.005)	0.006	(0.006)	0.004	(0.004)	0.006	(0.004)	0.003	(0.002)	0.015	(0.013)
y_{t-2}	-0.019	(0.011)*	-0.009	(0.014)	-0.024	(0.018)	-0.008	(0.006)	-0.001	(0.004)	-0.001	(0.007)
Obs	714						815					
AR(1)	-2.78	[0.005]	-2.80	[0.005]	-2.87	[0.004]	-3.61	[0.000]	-3.98	[0.000]	-3.56	[0.000]
AR(2)	0.55	[0.581]	1.02	[0.307]	1.37	[0.169]	0.21	[0.837]	0.53	[0.599]	0.47	[0.640]
Sargan test	435.72	[0.000]	306.51	[0.000]	160.14	[0.000]	364.72	[0.000]	184.61	[0.000]	54.21	[0.053]
Hansen test	90.69	[0.316]	69.89	[0.204]	39.52	[0.447]	98.40	[0.152]	67.76	[0.258]	50.54	[0.102]

Notes:
*** (respectively ** and *) statistically significant at the 1% (respectively 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastically-consistent standard errors in bracket; P values in square brackets;
AR(1) and AR(2): tests for first order and second order serial correlation in the first difference residuals; Two-step estimates; instruments used in column s (s=2,3,4): observations dated t-s to t-5 for Xt (transformed equation) and t-s+1 for ΔXt (equation in level).

Table B8. System GMM two step estimates – with number of employees - EU27 and US samples

	EU27						USA					
Instruments set	lag(2,.)		lag(3,.)		lag(4,.)		lag(2,.)		lag(3,.)		lag(4,.)	
R_{t-1}/C_{t-2}	-0.124	(0.051)**	-0.017	(0.195)	-0.004	(0.190)	0.592	(0.076)***	0.612	(0.059)***	0.67	(0.065)***
Δy_t	-0.159	(0.135)	-0.145	(0.134)	-0.101	(0.125)	0.171	(0.105)	0.251	(0.056)***	0.172	(0.043)***
Δy_{t-1}	-0.001	(0.112)	0.081	(0.103)	-0.031	(0.140)	0.097	(0.035)***	0.079	(0.04)**	0.048	(0.037)
$c_{t-2}-y_{t-2}$	-0.004	(0.044)	-0.072	(0.046)	-0.082	(0.059)	-0.014	(0.013)	-0.023	(0.010)**	-0.014	(0.015)
CF_t/C_{t-1}	0.076	(0.017)***	0.036	(0.025)	0.034	(0.023)	-0.005	(0.007)	-0.008	(0.013)	-0.004	(0.020)
CF_{t-1}/C_{t-2}	0.030	(0.008)***	0.014	(0.016)	0.008	(0.018)	0.002	(0.004)	-0.002	(0.003)	0.010	(0.019)
y_{t-2}	-0.087	(0.108)	-0.173	(0.077)**	-0.234	(0.072)***	0.069	(0.033)**	0.028	(0.029)	0.047	(0.027)*
l_t	0.077	(0.103)	0.121	(0.069)*	0.083	(0.062)	-0.061	(0.050)	0.004	(0.033)	-0.027	(0.031)
l_{t-1}	-0.018	(0.011)*	-0.004	(0.012)	0.014	(0.019)	-0.005	(0.008)	-0.009	(0.005)*	-0.007	(0.006)
Obs	1 670						1 914					
AR(1)	-1.00	[0.316]	-2.15	[0.032]	-1.13	[0.261]	-2.20	[0.028]	-2.28	[0.022]	-2.16	[0.031]
AR(2)	-1.50	[0.135]	-0.07	[0.948]	-0.53	[0.599]	-0.99	[0.322]	-0.81	[0.421]	-0.92	[0.358]
Sargan test	2223.53	[0.000]	844.30	[0.000]	254.32	[0.000]	464.07	[0.000]	221.39	[0.000]	79.99	[0.000]
Hansen test	104.21	[0.058]	55.78	[0.595]	20.33	[0.988]	104.07	[0.059]	63.04	[0.335]	44.64	[0.181]

Notes:
*** (respectively ** and *) statistically significant at the 1% (respectively 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastically-consistent standard errors in bracket; P values in square brackets;
AR(1) and AR(2): tests for first order and second order serial correlation in the first difference residuals; Two-step estimates; instruments used in column s (s=2,3,4): observations dated t-s to t-5 for Xt (transformed equation) and t-s+1 for ΔXt (equation in level).

Table B9a. System GMM one step estimates - operating profit - All firms

Instruments set	lag(2,.)		lag(3,.)		lag(4,.)	
R_{t-1}/C_{t-2}	-0.094	(0.082)	0.049	(0.079)	0.439	(0.083)***
Δy_t	0.301	(0.151)**	-0.045	(0.134)	0.109	(0.145)
Δy_{t-1}	0.088	(0.033)***	0.218	(0.069)***	0.215	(0.069)***
$c_{t-2} - y_{t-2}$	-0.243	(0.046)***	-0.116	(0.025)***	0.004	(0.017)
OP_t / C_{t-1}	0.009	(0.008)	0.012	(0.007)*	0.01	(0.015)
OP_{t-1} / C_{t-2}	0.004	(0.004)	-0.002	(0.003)	0.003	(0.003)
y_{t-2}	-0.12	(0.023)***	-0.085	(0.019)***	-0.006	(0.016)
Obs	3 590					
N	888					
AR(1)	-1.26	[0.208]	-2.30	[0.021]	0.68	[0.498]
AR(2)	-0.99	[0.321]	-0.43	[0.666]	-1.66	[0.097]
Sargan test	3111.26	[0.000]	984.87	[0.000]	25.38	[0.955]
Hansen test	208.25	[0.000]	146.02	[0.000]	59.89	[0.017]

Notes:
*** (respectively ** and *) statistically significant at the 1% (respectively 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastically-consistent standard errors in bracket; P values in square brackets;
AR(1) and AR(2): tests for first order and second order serial correlation in the first difference residuals; Two-step estimates; instruments used in column s (s=2,3,4): observations dated t-s to t-5 for Xt (transformed equation) and t-s+1 for ΔXt (equation in level).

Table B9b. System GMM two step estimates – operating profit - EU27 and US samples

	EU27						USA					
Instruments set	lag(2,.)		lag(3,.)		lag(4,.)		lag(2,.)		lag(3,.)		lag(4,.)	
R_{t-1}/C_{t-2}	-0.091	(0.119)	-0.020	(0.082)	-0.093	(0.127)	0.535	(0.077)***	0.623	(0.06)***	0.692	(0.036)***
Δy_t	0.016	(0.116)	-0.213	(0.151)	0.000	(0.205)	0.152	(0.042)***	0.178	(0.025)***	0.151	(0.074)**
Δy_{t-1}	0.119	(0.041)***	0.111	(0.079)	0.180	(0.158)	0.075	(0.02)***	0.059	(0.029)**	0.074	(0.061)
$c_{t-2} - y_{t-2}$	-0.220	(0.074)***	-0.150	(0.034)***	-0.193	(0.05)***	-0.067	(0.022)***	-0.033	(0.008)***	-0.01	(0.007)
OP_t/C_{t-1}	0.007	(0.006)	0.008	(0.005)	0.000	(0.01)	-0.004	(0.008)	0.011	(0.008)	-0.005	(0.008)
OP_{t-1}/C_{t-2}	0.006	(0.005)	0.004	(0.002)**	0.002	(0.001)	-0.024	(0.003)***	-0.027	(0.003)***	0.002	(0.005)
y_{t-2}	-0.115	(0.037)***	-0.126	(0.027)***	-0.157	(0.04)***	-0.015	(0.006)***	-0.008	(0.004)**	0.000	(0.003)
Obs	2 338						2 439					
AR(1)	-0.25	[0.805]	-1.05	[0.294]	-0.89	[0.376]	-3.04	[0.002]	-3.00	[0.003]	0.82	[0.415]
AR(2)	-1.78	[0.075]	-0.47	[0.637]	-0.64	[0.520]	-0.83	[0.405]	-0.80	[0.425]	-0.95	[0.342]
Sargan test	2121.26	[0.000]	705.22	[0.000]	190.79	[0.000]	885.27	[0.000]	287.91	[0.000]	0.06	[1.000]
Hansen test	105.72	[0.064]	68.73	[0.232]	36.02	[0.606]	136.94	[0.000]	83.69	[0.029]	53.43	[0.062]

Notes:
*** (respectively ** and *) statistically significant at the 1% (respectively 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastically-consistent standard errors in bracket; P values in square brackets;
AR(1) and AR(2): tests for first order and second order serial correlation in the first difference residuals; Two-step estimates; instruments used in column s (s=2,3,4): observations dated t-s to t-5 for Xt (transformed equation) and t-s+1 for ΔXt (equation in level).

Table B10. System GMM two step estimates - EU27 less UK

	EU27 without UK					
Instruments set	lag(2,.)		lag(3,.)		lag(4,.)	
R_{t-1}/C_{t-2}	0.133	(0.059)**	0.228	(0.061)***	0.266	(0.075)***
Δy_t	0.040	(0.052)	0.077	(0.082)	0.180	(0.115)
Δy_{t-1}	0.043	(0.023)*	0.091	(0.067)	0.055	(0.069)
$c_{t-2} - y_{t-2}$	-0.066	(0.020)***	-0.038	(0.020)*	-0.073	(0.032)**
CF_t / C_{t-1}	0.023	(0.006)***	0.021	(0.012)*	0.019	(0.008)**
CF_{t-1} / C_{t-2}	-0.003	(0.006)	-0.008	(0.008)	-0.017	(0.008)**
y_{t-2}	-0.064	(0.012)***	-0.049	(0.017)***	-0.057	(0.022)***
Obs	1 329					
N	332					
AR(1)	-3.10	[0.002]	-3.33	[0.001]	-2.89	[0.004]
AR(2)	-1.30	[0.193]	-1.34	[0.181]	-1.38	[0.168]
Sargan test	959.66	[0.000]	381.86	[0.000]	108.54	[0.000]
Hansen test	111.32	[0.029]	59.77	[0.520]	29.07	[0.877]

Notes:
*** (respectively ** and *) statistically significant at the 1% (respectively 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastically-consistent standard errors in bracket; P values in square brackets;
AR(1) and AR(2): tests for first order and second order serial correlation in the first difference residuals; Two-step estimates; instruments used in column s (s=2,3,4): observations dated t-s to t-5 for Xt (transformed equation) and t-s+1 for ΔXt (equation in level).

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Abstract

This paper explores the existence and importance of financing constraints for R&D investments in large manufacturing companies representative over the 2000-2007 period of about 80% of the R&D carried out in the business sector worldwide. The main system GMM results obtained by estimating error-correction equations suggest that the sensitivity of R&D investments to cash flow variations are more important for European firms while US ones do not appear to be financially constrained. In terms of policy implications, these results suggest improving the conditions for access to external capital to finance R&D activities in the EU.

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