Knowledge for Growth – Industrial Research & Innovation (IRI)

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

Michele Cincera[*,+], Julien Ravet[+]

Contributed paper for the 2nd Conference on corporate R&D (CONCORD - 2010)

CORPORATE R&D: AN ENGINE FOR GROWTH, A CHALLENGE FOR EUROPEAN POLICY

Financing corporate R&D

[*] European Commission, Joint Research Centre (JRC), Institute for Prospective Technological Studies (IPTS), Edificio Expo, Calle Inca Garcilaso 3. 41092 Seville. Spain. The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.
The authors would like to thank Constantin Ciupagea for his helpful remarks and suggestions.
+ Solvay Brussels School of Economics and Management, Université Libre de Bruxelles

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 constraints.

Key words: C23, E22, O31

JEL classification: financial constraints, R&D investments, error-correction investment equations, system GMM panel data econometric models

TABLE OF CONTENTS

1 - INTRODUCTION

The existence of capital market imperfections such as asymmetric information between lenders and borrowers affects the firms' capital investment decisions and introduces possible financing constraints, i.e. credit rationing by lenders. Such constraints, actually, may even be more pronounced in the case of intangible investments such as Research and Development (R&D) since these activities are more risky by essence 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 firms' R&D investments. 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 worldwide in the manufacturing and services sectors. The sources of this information are the successive editions of the R&D industrial scoreboards (2004, 2005, 2006, 2007 and 2008) conducted by the JRC-IPTS of the European Commission. This source is matched with the Compustat database gathering financial information, among which the firms' cash flow. The final sample used in the empirical analysis consists of an unbalanced panel of 1962 firms over the 2000-2007 period which is representative of about 80% of all the R&D carried out in the private sector in the world. All variables are in constant exchange rates and prices and R&D stocks are constructed for each firm on the basis of the permanent inventory method (Griliches, 1979).

The model used to identify firms' potential liquidity constraints is an error correction model for R&D investment. This model is derived from the optimal level of R&D investment when considering a CES production function of a profit maximizing firm. Financing constraints are measured by the sensitivity 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 right hand side 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 that allow one to deal with possibly correlated firms' specific unobserved fixed effects and weak exogeneity of the right-hand side variables are reported.

The paper is organised as follows. Section 2 briefly reviews some theoretical aspects of the literature on firms' investment in R&D 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. Section 4 presents the framework implemented for the econometric analysis. Section 5 discusses the main estimation results. Section 6 covers conclusions and suggestions for future work.

2 - REVIEW OF ISSUES AND EMPIRICAL FINDINGS

It is widely agreed 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 Research and Development 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. The agency costs between the shareholders and the R&D management, i.e. risk-adverse R&D managers will under-invest in risky R&D projects and managers tend to spend on activities that benefit them, can be avoided by leveraging the firm. However, the costs of the external funds to finance the R&D projects will be higher (Jensen and Meckling, 1976). Then, investments in intangibles such as R&D are riskier by essence 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 since they can not make accurate appraisals of the values associated with this type of investment[1]. As a result, R&D firms may encounter credit rationing by potential

[1] The output of R&D activities consists of new products and processes, which are typically hard 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*

lenders and be constraint if they do not have enough internal resources to finance their R&D projects[2].

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 partly disclose to the outside world information as regards the contents and the objectives of their technological activities since this knowledge could leak out to rivals. This imperfect appropriability of the returns of innovative activities arises from the non-rival and partially excludable property of the knowledge good. Non rivalry means that the use of an 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 other to benefit from it free of charge.

Another essential characteristics of R&D that makes it different from ordinary investment, is the presence of high adjustment and sunk costs[3]. 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 firm's intangible asset implies substantial costs[4]. Hence the levels of R&D expenditures associated to any innovation projects are unlikely to change substantially from years to years. This feature makes it difficult to assess empirically 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 she knows that she 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.

---

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."

[2] Capital market imperfections can prevent firms to access to 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.*"

[3] 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.

[4] 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).

There have been only a few studies examining financing constraints and R&D[5].

Table 1 provides some features of some selected studies that have investigated the relationship between internal finance and R&D.

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.

Hall (2002) and more recently Hall and Lerner (2009) provide an extended review of the literature about financing constraints. According to Hall and Lerner (2009), most authors in the empirical literature on financing constraints have been relying on two main approaches based on investment equations. The first is to use a neoclassical accelerator model, which can be augmented with dynamics and transformed into an error correction model (ECM). The second approach is based on an Euler equation (an example is Harhoff; 1998). The authors conclude

[5] Schiantarelli (1996) and Hubbard (1998) provide reviews of the literature regarding the role of financial constraints on firms' investment activities 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. traditional between and within firm estimation versus GMM estimators, for estimating firms' investment equations.

their review stating that there are 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.

Comparisons between financing constraints faced by US firms and European firms, and more specifically French firms, have been investigated for mid-80s and early 90s by Hall et al. (1999) and Mulkay, Hall, Mairesse (2001). The paper by Hall, Mairesse, Brandstetter and Crépon (1999) indicate 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 the US firms while the results are somewhat more mixed in France and Japan. Mulkay, Hall and Mairesse (2001) do 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 higher impact on both types of investments in the US than in France. Hence the impact of financial factors on investment and R&D do not differ within a country but rather across them. This finding indicates that it is the financial market environment specific to a country, which 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 of Hall (1992) explores the relationship between investment, R&D and cash flow for US firms by taking into account firms specific unobserved fixed effects and simultaneity. The results point to a positive impact of cash flow on both types of investments, although more significant for physical investment, hence indicating the presence of liquidity constraints in addition to just future demand expectations. On the basis of a sample of 179 US small firms in high-tech industries, Himmelberg and Petersen (1994) estimate 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 external financing of highly risky business activities such as innovation. The absence of collateral value for investment like 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), Aghion et al. (2008) and Savignac (2008).

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

Results from Bond, Harhoff and Van Reenen (1999) lead one to conclude that the differences between British and German firms in the effects of cash flow cannot be simply explained by a greater role of this variable in predicting future sales. On the whole, the empirical findings indicate 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[6]. Furthermore cash flow has an impact on the decision to engage in R&D rather than on the levels of R&D expenditures.

Bougheas, Goerg and Strobl (2001) test the effect of liquidity constraints on the R&D investments of Irish companies. They also come up to the conclusion that R&D investments in these companies are subject to liquidity constraints. This result is in line with previous findings for UK and US companies.

Taking a sample of about 10000 Belgian manufacturing firms active in R&D over the last decade, Cincera (2003) compares financing constraints on both fixed tangible capital and R&D. The empirical analysis is performed on biannual survey data, supplemented with annual accounts data. The analysis is founded on two reduced form equations for investment: an accelerator and an error correction model. Although the results indicate the presence of financial constraints on tangible as well as R&D investment, this effect is unexpectedly not larger for R&D. Furthermore, for fixed capital investment, the author investigates the type of firms for which these constraints are stronger. The estimates show 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

[6] 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.*"

support R&D activities, and firms located in the Walloon region face higher financial constraints.

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

Savignac (2008) provides evidence for 1940 French firms about the role of financing constraints in the decision to undertake innovative activities. A direct measure for financing constraints is obtained from the FIT survey[7]. 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 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

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

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 (2009), this is a standard methodology based on an investment equation. The methodological framework is close to that in Harhoff (1998), Bond, Harhoff and Van Reenen (1999), Mairesse, Hall and Mulkay (1999) and Mulkay, Hall and Mairesse (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 of the 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, Hall and Mairesse (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 proxied by time dummies and firms' specific fixed (over time) effects[8].

Moreover, 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:

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

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

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

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

Where $\delta_0 = \rho_1 - 1$, $\delta_1 = \beta_0$, $\delta_2 = \beta_0 + \beta_1$, $\delta_3 = \rho_1 + \rho_2 - 1$ and $\delta_4 = \beta_0 + \beta_1 + \beta_2 + \rho_1 + \rho_2 - 1$. 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[9] $\Delta c_{it} \approx R_{it} / C_{it-1} - \delta$, with *R* being the R&D expenditures and *δ* the depreciation rate of R&D capital, equation (3) becomes:

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

Following the seminal work of Fazzari, Hubbard and Petersen (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 *K* for normalization) 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:

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

It should be noted that as claimed by Kaplan and Zingales (1997, 2000), the interpretation of the estimated coefficient associated to the cash flow ratio can be misleading since cash flow can be correlated with current profitability. In this case, cash flow will also proxying profit or demand expectations and this variable cannot be interpreted directly as evidence of financing constraints[10]. 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

---

9

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

10 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.

changes in demand than the cash flow variable and thus allow to control, even if imperfectly, for the expectations role played by this variable. Equation (5) can also be augmented with the Tobin's q to control for 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 firm's intertemporal maximisation problem (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 firm specific unobserved effect, 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[11]. These unobservables 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. Hence, we are in the presence of a (positive) correlation between these unobservables and the R&D which invalidates the inference which 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 however 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. 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 in using an instrumental variable approach by choosing an appropriate set of lagged value of the regressors for the instruments. Such an 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 process, then values in levels of these variables lagged two

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

or more periods will be admissible instruments[12]. 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 as compared to the first difference GMM estimator[13]. 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 the error-correction model developed in section 3, we use data about net sales and R&D from the R&D scoreboards while information about cash-flow are given by the financial reports of the companies. The data are taken from the five R&D scoreboards issued every year between 2004 and 2008 by the JRC-IPTS except for the cash flow variable which comes from the Computast database[14]. Each scoreboard provides information on the R&D expenditures, net sales, total employees, capital expenditures, operating profit and market capitalization of the top firms that were active in R&D during the previous year (e.g. the 2008 scoreboard provides information on the year 2007 and not 2008). Growth rates of these variables are also available for the years before and allow us to add more observations in time for each firm. R&D data from the Scoreboards represent all R&D financed by the companies, regardless of the geographical localization of R&D activities. Data are collected from audited financial accounts and reports[15].

When stacking the scoreboards together, we obtain a total of 33600 observations (unbalanced panel). However many observations are redundant as the

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

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

[14] Release of 2009.

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

information for a same firm and year can be provided by more than one scoreboard. For example, the 2007 scoreboard provides information about R&D of firm X for year 2006. But if firm X is present in the 2008 scoreboard, the growth rate of its R&D expenditures between 2006 and 2007 is available in the latter scoreboard, which also allows us to retrieve the amount of R&D of firm X in 2006. As a consequence, both scoreboards give information on the R&D expenditures of firm X in 2006. In order to avoid multiple counting of the same observation, we choose to keep only the most recent scoreboard as a source for each redundant information. This results in an unbalanced panel of 16553 observations, for 2696 firms' names. 706 names concern US firms and 1438 are related to firms in the EU.

Based on this sample, a matching procedure is conducted with the annual financial reports of firms in order to add more information about the cash flow of the companies. The cash flow variable that is used in this study 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 amortization, which are the non-cash charges for obsolescence of and wear and tear on property[16]. .The methodology for the matching between both databases combines automatic procedures and manual procedures. Automatic procedures consist in two steps. First we try to find the financial states of firms whose names are exactly the same as the ones in the R&D scoreboards. Second, we match firms' names after having cleaned these names by deleting 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. This automatic procedure does not take into account other less common prefixes or suffixes or punctuation differences. That is why manual procedure compares the remaining unmatched names (with verifications on the Internet in order to determine whether two matched names refer to the same company or not).

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 is 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.

[16] Compustat (2009).

Each monetary observation was converted into constant euros and prices[17]. It should be noted that informations 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 for every periods that it covers. This is convenient when analyzing data from one scoreboard as they are unaffected by exchange rate variations in time. However, different scoreboards use different exchange rates. As we combine scoreboards from 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[18]. Transforming data into constant prices was performed by using national GDP price deflators[19] with 2007 as the reference year.

The R&D stock was constructed by using the permanent inventory method developed by 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 is 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 litterature[20]. Initial value of C can be computed by using the following expression[21] :

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

---

[17] Year reference is 2007. Sources for exchange rates and deflators are EUROSTAT.
[18] We used the exchange rates in Eurostat for the year 2007.
[19] Eurostat GDP deflators.
[20] 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) find small or no changes in the estimation of the R&D capital effect.
[21] 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).

where g is the growth rate of R and is assumed to be constant. The growth rate that is used in this study is the sample average[22] growth rate of R&D expenditures in the 2-digit ICB industry.

For the sake of comparison of R&D investment liquidity constraints between Europe and the USA, 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 criteria for matching similar firms. It turns out that the sample of the 1962 firms among which 942 are from the EU and 525 from the USA comprises 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 4.35 million Euro and that for the non-EU subsample 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 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[23]). 1% extreme values for the ratio cash-flow to R&D capital stock where also removed as these observations might refer to errors from the matching procedure.

Table 2 presents some descriptive statistics on the variables used in the models with comparisons between the EU27 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 SMEs. However this bias concerns both US and European samples. The comparison of table A1 in the Appendix and table 1 shows the effect of having comparable samples in terms of size. The companies in the matched samples look much more similar in terms of

[22] 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.

[23] 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%.

the distribution of quartiles and standard errors of the main variables used in the regressions[24].

Table 2. Descriptive statistics

		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 basic 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 2 lagged and higher values of regressors while column 3 only consider 3 lagged and higher values. The validity of these additional instrumental variables when we move from column 3 to 2 can be tested through difference Sargan or Hansen over-

[24] Table A2 in the Appendix presents a measure that consists in the difference between US and EU statistics based on the initial sample divided by the difference between the same statistics when using the corrected sample.

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 instruments, i.e. they are uncorrelated with the error terms. Under the null hypothesis, the test statistic is distributed as chi-squared with the number of degrees of freedom being equal to the number of over-identifying restrictions. Rejection of the null hypothesis casts a doubt about the validity of the set of instruments. This appears to be always the case for the Sargan test and only for the model in the second column for the Hansen test[25].

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	(0.02)***	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:
*** (resp. ** and *) statistically significant at the 1% (resp. 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastic-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).

[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:
*** (resp. ** and *) statistically significant at the 1% (resp. 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastic-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).

The second order correlation test statistics does 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 two periods is negative and significant albeit small. This suggests the presence of slightly decreasing returns to scale. Cash flow effects appear to have a positive and significant effect on investment (the long run effect 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 firm's investment opportunities.

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.

Before discussing possible reasons to explain this difference, the next section presents a series of robustness checks of this empirical finding.

5.2 Robustness of results

To start with, Table A3 in the Appendix reports within and random effects estimates of R&D investment error correction model augmented with the cash flow variables. Note first that the statistic of the Hausman test is statistically significant at the 1% level which rejects the null hypothesis of no correlation between the unobserved firms' specific effects and the regressors hence invalidating the random specification. Looking at the fixed effects model estimates, it follows that only the EU firms are subject to liquidity constraints as for the US the coefficients associated with the cash flow variables are not significantly different form zero.

Table A4 in the Appendix reports the results when a consistent one step system GMM estimator is implemented. 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), Windmejer (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, Windmejer (2005) developed a small-sample correction for the standard errors of two-step estimators that allows more accurate inference. Note that except notified elsewhere all the results reported in the paper use this corrected procedure for the two-step estimator.

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 A5 in the Appendix, estimating a simpler accelerator R&D investment specification lead one to the conclusion that only EU firms are sensitive to cash flow variations.

Table A6 to A8 in the Appendix consider alternative specifications where only the current value of the cash flow variable, the one year lagged value or the current, one year and two years lagged values of this variable are considered altogether. Note that the results reported in the two first Tables 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, Table A8 considers 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 are here also clearly indicating that financing constraints are present for EU R&D companies only and not for the US ones.

As an additional test, Table A9 and A10 investigate the role played by the size of companies. Indeed, several studies have shown the central role played by firms' size 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 lore easily finance capital expenditures from internal resources, issuance of equity or debt. In this study, we measure firm's size in two ways. In Table A9, a proxy for size is directly introduced in the specification, i.e. the number of employees at time t and at time t-1. In Table A10, 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 cut of the sample of about one half.

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 to the results when the full sample

[26] See Schiantarelli (1996) for a survey of the empirical literature on this subject.
[27] See for example Stoll (1984) for the US credit market.

is considered. For the US firms, no effect of liquidity constrained is once more detected except to some extent for the specification based on subsample with the largest companies. Yet, in this case the estimated appear to be much lower than the one obtained for the EU companies' subset.

The results as regards the last robustness check are given in Table A11 in the Appendix. This time, the R&D investment error correction is estimated on the EU27 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 look more similar to the US one. It follows that the results and the conclusion do not change quite a lot: Continental European R&D firms are more likely to be hit by financing constraints for their R&D investments.

5.3. Discussion

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

These findings are different than the ones reported in general in the related literature, i.e. US firms appear more financially constrained (Hall et al., 1999; Mulkay et al. 2001; Bond et al. 1999). These authors conclude that the impact of financial factors on investment and R&D do not differ within a country but rather across them, hence suggesting that it is the financial market environment specific to a country as well as institutional differences across country's financial systems which matters in explaining the impact of financial factors on R&D investments[28].

Different factors may explain why the difference between our findings and the ones in the literature. We briefly discuss them in what follows. In sum, in our view the main reason for explaining the divergence in results between this paper and previous studies on the R&D – financing constraints relationship is the period investigated. Our study is actually the only one which uses data after 2000. As a matter of fact, the importance of financing constraints if present at all is likely to differ between the EU and the US economies and/or before and after the passage to the new millennium.

[28] Another difference of our study is the sample of EU countries which 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 consist of very large EU companies, i.e. the largest R&D companies investing in the world.

Since the beginning of the decade, within the framework of the Lisbon process to transform the EU into a knowledge-based and most 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, 2000). As a result, financial institutions face stronger competition and the conditions to lend money for investments in particular intangibles such as R&D are more severe.

Conversely, a lot of exposure with little regulation in lending is one of main cause at the root of the recent burst of the financial bubble in the US and the ensuing financial and economic turmoil. 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 in the US.

Another explanation rests in the relatively high growth rate of output in some, if not most industry sectors in the EU over the period investigated (see Figure A1 in the Appendix)[29]. In this case, the cash flow variables may well capture expectations of demand opportunities, i.e. firms keep more cash flow at their disposal to invest more in the future.

Then, R&D activities are more risky by essence and generally provide less collateral to lenders as compared to investments in capital goods. As a result financing constraints may even be 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 these firms' investment decisions than for other companies. Moreover the provision of public support to R&D may also interfere with the firm's investment decision by alleviating liquidity constraints problems, may they be present at all.

Finally, we should mention another important and well known factor hampering R&D and innovation activities in the EU as compared to the US which rests in the difficulty to get access to external sources of financing, in particular given the scarcity of venture capital.

[29] This is however equally true for the US firms.

6. CONCLUSION

Based on two newly constructed and comparable samples of EU and US private companies among 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 performed by using the recently developed 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 in the firms' R&D investment decisions. However results suggest that only EU companies are facing liquidity constraints, not their US competitors. This result is robust to alternative modelling strategies, econometric methods implemented and data sub samples. In terms of policy implications, these results suggest improving in the EU the conditions for accessing to external capital, in particular venture capital. Policy makers must provide support for these firms and further develop the availability of risk capital.

This result is also in contradiction with the findings of the previous literature on the subject. The main reason for explaining such a divergence rests in the period analysed (current decade in this study versus data before 2000 in the other studies) as well as conjectural and structural changes in the financial systems between the EU and the US and before and after the passage to the new millennium that we need to further investigate in subsequent research.

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 funding R&D, i.e. internal financing, debt and issues of shares on the stock markets. Indeed if firms in the EU are less relying on external sources as compared to their US counterparts, then this could explain why EU firms are indeed 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. "D" component is more financially constraint or the outsourced R&D abroad vs. the research carried out in the home country. Based on a longer history of data it would also 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, maintaining the important division between European and US companies, which has its reasons in very different business environments for R&D firms in the two regions, it may be worth investigating separately groups of firms by sector of activity, as 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 we talk about worldwide-operating firms.

REFERENCES

Abel A.B., O.J. Blanchard (1986), “The Present Value of Profits and the Cyclical Movements in Investment”, Econometrica, 54, pp. 249-273.

Ackerlof G.A. (1970), “The Market for ‘Lemon’: Quality, Uncertainty and the Market Mechanism”, Quarterly Journal of Economics, 84, pp. 488-500.

Aghion P., P. Askenazy, N. Berman, G. Cette, L. Eymard (2008), “Credit Constraints and the Cyclicality of R&D Investment: Evidence from France”, PSE Working Papers 2008-26, PSE (Ecole normale supérieure).

Arellano M., O. Bover (1995), “Another Look at the Instrumental Variable Estimation of Error-Components Models”, Journal of Econometrics, 68(1), pp. 29-51.

Arellano M., S. Bond (1991), “Some Tests of Specification for Panel Data: Monte Carlo Evidence and Application to Employment Equations”, Review of Economic Studies, 58, pp. 277-97.

Arellano M., S. Bond (1998), “Dynamic Panel Data Estimation Using DPD98 for Gauss: A guide for Users”, mimeo.

Arrow K. (1962), “Economic Welfare and the Allocation of Resources for Invention”, in R. Nelson (ed.),“The Rate and Direction of Inventive Activity”, Princeton, pp. 609-626.

Blundell R., S.R. Bond (1998), “Initial Conditions and Moment Restrictions in Dynamic Panel Data”, Journal of Econometrics, 87, pp. 115-143.

Bond S., C. Meghir (1994), “Dynamic Investment Models and the Firm’s Financial Policy”, Review of Economic Studies, 61(2), pp.197-222.

Bond S., D. Harhoff, J. Van Reenen (1999), “Investment, R&D and Financial Constraints in Britain and Germany”, Institute for Fiscal Studies Working Paper #W99/05, 45 pages.

Bond S., J. Elston, J. Mairesse, B. Mulkay (1997), “Financial Factors and Investment in Belgium, France, Germany and the U.K.: A Comparison Using Company Panel Data”, NBER working paper #5900.

Bosworth, D. (1978), “The Rate of Obsolescence of Technical Knowledge - A Note”, Journal of Industrial Economics, 26(3), pp. 273-279.

Bougheas S., H. Goerg, E. Strobl (2001), “Is R&D Financially Constrained? Theory and Evidence from Irish Manufacturing”, University of Nottingham.

Brown, J., S. Fazzari, B. Petersen (2009), “Financing Innovation and Growth: Cash Flow, External Equity, and the 1990s R&D Boom” Journal of Finance, 64(1), pp. 151-185.

Butzen P., C. Fuss, P. Vermeulen (2001), “The Interest Rate and Credit Channels in Belgium: An Investigation with Micro-Level Firm Data”, National Bank of Belgium, Working Papers Research Series, 18.

Cincera M. (2003), “Financing constraints, fixed capital and R&D investment decisions of Belgian firms”, (2003), in P. Butzen, and C. Fuss (eds.), Firms’ Investment and Finance Decisions: Theory and Empirical Methodology, Cheltenham, UK: Edwar Elgar, pp.129-147.

Cincera M. (2005), “The link between firms’ R&D by type of activity and source of funding and the decision to patent”, Working paper DULBEA, Research series, #05-10.RS, April 2005.

Cincera M., R. Veugelers (2000), “Debinnenlandse O&O-uitgaven van de Belgische ondernemingen 1992-98”, VTO-studies #31.

Cincera, M., O. Galgau (2005), “Impact of Market Entry and Exit on EU Productivity and Growth Performance”, European Economy, Economic Papers #222, European Commission, Directorate General for Economic and Financial Affairs.

Czartnisky, D. (2006), “Research and development in small and medium-sized German enterprises: The role of financial constraints and public funding”, Scottish journal of political economy, 53(3), pp. 335-357.

Fazzari S.M., R.G. Hubbard, B.C. Petersen (1988), “Financing Constraints and Corporate Investment ”, Brookings Papers on Economic Activity, 1, pp. 141-195.

Fazzari S.M., R.G. Hubbard, B.C. Petersen (2000), “Investment-Cash Flow Sensitivities Are Useful: A Comment on Kaplan and Zingales”, Quarterly Journal of Economics, 115(2), pp. 695-705.

Griliches Z., J.A. Hausman (1986), “Errors in Variables in Panel Data”, Journal of Econometrics, 31, pp. 93-118.

Griliches, Z, (1979), “Issues in assessing the contribution of research and development to productivity growth”, The Bell Journal of Economics, 10(1), pp.92-116.

Hall B.H. (1992), “Investment and Research and Development at the Firm Level: Does the Source of Financing Matter?”, National Bureau of Economic Research Working Paper #4096, 21 pages.

Hall, B.H., J., Mairesse (1995), “Exploring the Relationship Between R&D and Productivity in French Manufacturing Firms”, Journal of Econometrics, 65, pp. 263-94.

Hall B.H., J. Mairesse, L. Branstetter, B. Crepon (1999), “Does Cash Flow Cause Investment and R&D: An Exploration Using Panel Data for French, Japanese and United States Scientific Firms”, in D. Audretsch and A. R. Thurik (eds.), Innovation, Industry Evolution and Employment, Cambridge University Press.

Hall,B.H., J. Lerner (2010), “Financing R&D and Innovation”, forthcoming in B.H. Hall and N. Rosenberg (eds.), the Economics of Innovation, Elsevier Handbook of the Economics of Innovation.

Harhoff D. (1998), “Are There Financing Constraints for R&D and Investment in German Manufacturing Firms?”, Annales d'Economie et de Statistiques, 49-50, pp. 421-56.

Himmelberg C.P., B.C. Petersen (1994), “R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries”, Review of Economics and Statistics, 76(1), pp. 38-51.

Hubbard R.G. (1998), “Capital Market Imperfections and Investments”, Journal of Economic Literature, 36, pp. 193-225.

Jensen M., W. Meckling (1976), "Theory of the Firm: Managerial Behaviour, Agency Costs and Ownership Structure", Journal of Financial Economics, 3, pp. 305-60.

Jorgenson D.W. (1963), "Capital Theory and Investment Behaviour", American Economic Review, 53(2), pp. 247-259.

Kaplan S.N., L. Zingales (1997), "Do Investment-Cash Flow Sensitivities Provide Useful Measures of Financing Constraints", Quarterly Journal of Economics, 112(1), pp. 169-215.

Kaplan S.N., L. Zingales (2000), "Investment-Cash Flow Sensitivities are Not Valid Measures of Financing Constraints", Quarterly Journal of Economics, 115(2), pp. 707-712.

Mairesse J., B. Mulkay, B.H. Hall (1999), "Firm-Level Investment in France and the United States: An Exploration of What we Have Learned in Twenty Years", National Bureau of Economic Research Working Paper #7437.

Moncada Paterno' Castello P., C. Ciupagea, K. Smith, A. Tübke, M. Tubbs (2009), "Does Europe perform too little corporate R&D?", IPTS Working Paper on Corporate R&D and Innovation, No. 11/2009, European Commission, JRC 51955 – Joint Research Center – Institute for Perspective Technological Studies, Luxembourg: Office for Official Publications of the European Communities.

Mulkay B., B.H. Hall, J. Mairesse (2001), "Investment and R&D in France and the United States", in Herrmann Heinz and Rolf Strauch (eds.), Investing Today for the World of Tomorrow, Springer Verlag, forthcoming.

Myers S.C., N.S. Majluf (1984), "Corporate Financing and Investment Decisions when Firms Have Information that Investors Do not Have", Journal of Financial Economics, 13, pp. 187-221.

OECD and EUROSTAT (1997), Oslo-Manual, Proposed Guidelines for Collecting and Interpreting Technological Innovation Data, Organization for Economic-Co-Operation and Development, Paris.

Patenting Strategies of Belgian Manufacturing Companies", paper presented at the Third CEPR Conference on Applied Industrial Organization, 30 May 2002 - 1 June 2002, Bergen, Norway.

Roodman D. (2006), "How to do Xtabond2: An Introduction to Difference and System GMM in Stata", Center for Global Development, Working Paper 103.

Savignac, F. (2008), "Impact Of Financial Constraints On Innovation: What Can Be Learned From A Direct Measure?", Economics of Innovation and New Technology, 17(6), pp. 553-569.

Schiantarelli F. (1996), "Financial Constraints in Investment: Methodological Issues and International Evidence", Oxford Review of Economic Policy, 12(2), pp. 70-89.

Stiglitz J.E., A. Weiss (1981), "Credit Rationing in Markets with Imperfect Information", American Economic Review, 71(3), pp. 393-410.

Stoll H.R. (1984), "Small Firms' Access to Public Equity Financing", In P.M. Horvitz, R.R. Petit (eds.), Small Business Finance: Problems in the Financing of Small Business, Greenwich, CT: JAI Press, pp. 187-238.

Windmeijer F. (2005), "A finite sample correction for the variance of linear efficient two-step GMM estimators", Journal of Econometrics, 126, pp. 25–51.

Annexes

Table A1. Descriptive statistics on the initial sample

		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

Table A2. Difference between initial and corrected samples[30]

	Mean	*Std.dev.*	*Quantile 25%*	*Quantile 50%*	*Quantile 75%*
R_t/C_t	0.2	5.5	0.8	0.7	0.5
CF_t/C_{t-1}	1.2	1.1	0.7	3.4	2.6
y_t	5.5	2.3	4.8	3.3	1.6
c_t	3.5	2.4	3.0	3.1	3.1
Δy_t	0.8	1.6	1.0	0.8	0.6
Employees	0.4	0.3	1.7	1.8	1.3

[30] With $StatX_{match,EU}$ being a statistic for variable X using the EU corrected sample and $StatX_{nonmatch,EU}$ the same statistic for the non corrected sample, $abs\left(\frac{StatX_{nomatch,US} - StatX_{nomatch,EU}}{StatX_{match,US} - StatX_{match,EU}}\right)$ is the result reported in the table. A value superior to one means that the procedure has decreased the distance between US and EU statistics.

Table A3. 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 A4.1. 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:
*** (resp. ** and *) statistically significant at the 1% (resp. 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastic-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).

Table A4.2. 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:
*** (resp. ** and *) statistically significant at the 1% (resp. 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastic-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).

Table A5. 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:
*** (resp. ** and *) statistically significant at the 1% (resp. 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastic-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).

Table A6. 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:
*** (resp. ** and *) statistically significant at the 1% (resp. 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastic-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).

Table A7. 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:
*** (resp. ** and *) statistically significant at the 1% (resp. 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastic-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).

Table A8. 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:

*** (resp. ** and *) statistically significant at the 1% (resp. 5% and 10%) level.

Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastic-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).

Table A9. 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:
*** (resp. ** and *) statistically significant at the 1% (resp. 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastic-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).

Table A10. 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:
*** (resp. ** and *) statistically significant at the 1% (resp. 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastic-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).

Table A11. 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:
*** (resp. ** and *) statistically significant at the 1% (resp. 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastic-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).

Table A12. 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:

*** (resp. ** and *) statistically significant at the 1% (resp. 5% and 10%) level.

Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastic-consistent standard errors in bracket; P values in square brackets;

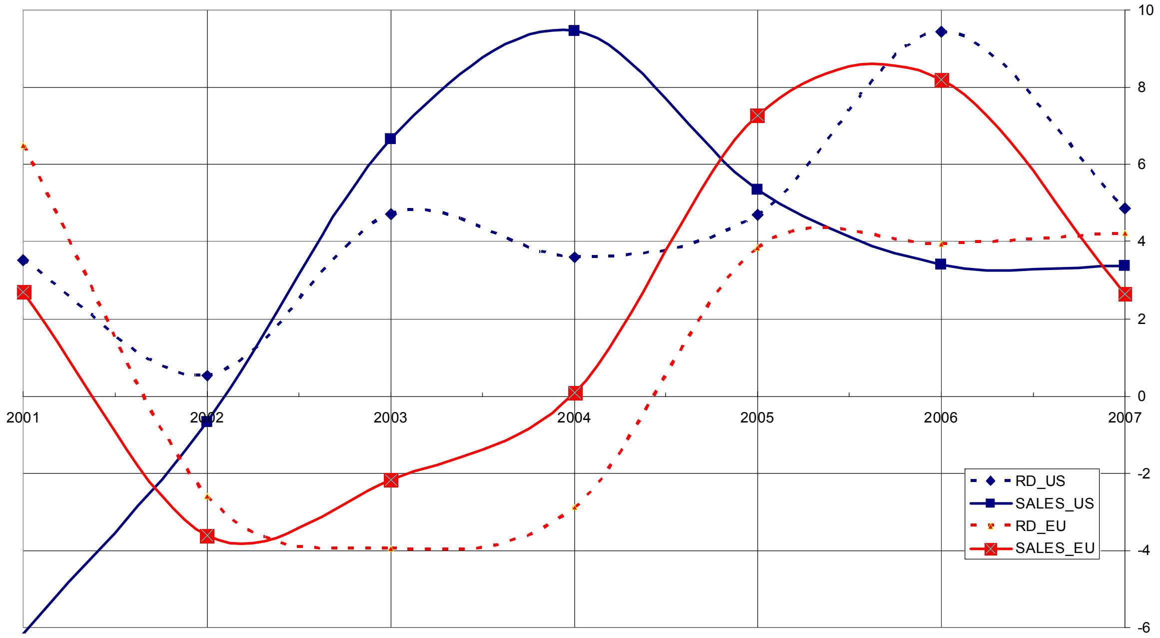
AR(1) and AR(2): tests for first order and second order serial correlation in the first difference residuals; Two-step estimates; instruments used in column s (s=2,3,4): observations dated t-s to t-5 for X_t (transformed equation) and t-s+1 for ΔX_t (equation in level).

Table A13. 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:
*** (resp. ** and *) statistically significant at the 1% (resp. 5% and 10%) level.
Estimation performed using xtabond2 (Roodman, 2006); all equations include time dummies; heteroskedastic-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).

Figure A1. Trends in Rd and Net sales in the EU and the US (2000-2007)



Source

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

File name: Financing constraints and R&D investments of large corporations in Europe and the USA
Author: Michele Cincera
Authors' contact: michele.cincera@ec.europa.eu
Status: Draft
Last updated: 1st December 2009
Organisation: European Commission – JRC – IPTS