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R&D financing constraints of young and old innovation leaders in the EU and the US

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Abstract

Using firm level information on the world leading R&D investors, this paper investigates through a system GMM estimation of the investment error correction model, whether younger innovators face more severe or no financing constraints, as opposed to older innovators, and whether this would hold more for European young firms relative to the US. The analysis indeed confirms that over the last decade young leading innovators appear to be more affected by financing constraints compared to their older counterparts and that particularly EU young innovators exhibit higher sensitivities of R&D investment to cash-flow, particularly in medium and high tech sectors.

Keywords: EU-US R&D gap, young leading innovators, financing constraints

JEL codes: C23, E22, O31, O33

1. INTRODUCTION

The EU innovation environment remains to date weak, especially R&D investment by the business sector. Furthermore, there is relatively little sign of progress. US companies appear to continue to perform better than their EU counterparts. In 2012, R&D by US private companies represented nearly 2% of the US GDP while business R&D in Europe only accounted for 1.22% of EU GDP.[1]

The persistent deficiency of private R&D spending in Europe is a symptom rather than a cause, with the cause rooted in the structure and dynamics of its industry and enterprise. Cincera & Veugelers (2013a) show that the European Union's business research and development deficit relative to the United States can be almost entirely accounted for by the EU having fewer young firms among its leading innovators (or "*yollies*") of the likes of Google, Amazon, Amgen,… and having *yollies* that are less R&D intensive: having fewer *yollies* accounts for 34% of the EU-US business R&D gap, while having less R&D intensive *yollies* accounts for 55% of the EU-US business R&D gap. The lower R&D intensity of old EU leading innovators accounts for a merely 11% of the EU-US business R&D gap.

What explains why Europe has less young firms among its leading innovators and why are its young leading innovators investing less in R&D? Cincera and Veugelers (2013b) further examine the sources of the EU's missing young leading innovators problem. They investigate through econometric analysis whether the lower presence in the EU of young leading innovators and their lower R&D investment rates can be associated with lower rates of return to R&D as compared to their US counterparts.

[1] Eurostat, OECD.

Their econometric analysis indeed finds evidence supporting such lower rates of return to R&D for European *yollies*.

Such lower rates of return to R&D may not only impede young firms to engage in R&D investments for world leading positions. This lower rate of return may also kill the appetite for financiers to fund their projects. Access to external finance is indeed an important barrier for innovation. Cincera and Ravet (2010) analyse the existence and importance of financing constraints for R&D investments in large EU and US manufacturing companies. Their results 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.

Access to finance is especially for young companies a barrier to innovation. Risk and informational asymmetries create capital market imperfections. A company's lack of reputation and collateral become crucial elements in the way they are disadvantaged by these asymmetries. Although *young* highly innovative companies are rich in intangible assets such as technology and specialist knowledge, they lack the sort of collateral assets that help them to access external finance (Brown and Petersen, 2009). Young innovators, combining the disadvantages of small scale, a short history, little or no retained earnings and often more risky innovative projects, can therefore be expected to be more affected by financial barriers. Schneider & Veugelers (2010) demonstrate on German firm level data, that although financial constraints are the main barriers to innovation for all innovative firms, this holds a fortiori for young innovative firms.

In view of the critical role played by access to finance for young innovative firms, the greater willingness on the part of the US financial markets compared to the EU to fund young innovative firms can go a long way towards explaining the US-EU divergence in enterprise and industry dynamics, and the persistent business R&D deficit of the EU relative to the US. The segment of the capital market most adept at addressing the need of external financing for highly innovative growth projects coming from young companies is the venture capital market. To this day, the US has by far the largest and most developed VC market. In 2008, the US accounted for 49% of total venture capital investment in OECD countries (OECD, 2009). In addition to being smaller and more fragmented, the European venture capital industry is structurally different from the US venture capital industry (NESTA 2009). The larger more experienced US venture capital market is more likely to be funding the initial stages of the larger growth projects of their young innovative companies, supporting them in their path to become world leading innovators.

This paper investigates in more detail the access to finance issue as a possible cause for the persistent business R&D gap of the EU relative to the US. Using firm level information on the world leading R&D investors, it investigates through econometric analysis whether younger innovators actually face more severe or no financing constraints, as opposed to older innovators, and whether this would hold more for European young innovators relative to the US. The analysis indeed confirms that over the last decade young leading innovators appear to be more affected by financing constraints compared to their older counterparts and that this holds especially for EU young leading innovators. Before we present the results in section 4, we first present our research methodology to measure financing constraints (section 2) and the data (section 3).

2. Econometric model to assess financing constraints

2.1. A review of empirical methodologies to assess financing constraints

The prevailing methodology in the empirical literature to assess financing constraints for investment decisions is the estimation of a standard investment equation where a variable for the availability of internal finance is added to the model (usually cash flow) (Fazzari et al., 1988). Its significance (and correct sign) should signal the relevance of financing constraint in the firm's investment decisions. The idea behind the investment sensitivity to cash flows, is to measure the importance of retained earnings in the R&D investment decision. Hall and Lerner (2010) present this measure as an experiment that consists in giving additional cash to a company, and observing whether they use it for investment or not. If they pass it to shareholders, either there is no good investment opportunity, or the cost of capital has not fallen. If the additional amount of cash is used for investment, it would mean that the firm has unexploited investment opportunities for which external finance is too costly. This methodological framework is used to assess financing constraints for firm's R&D decisions by a.o. Harhoff (1998), Bond et al. (1999), Mairesse, Mulkay and Hall (1999) and Mulkay et al. (2001). Most of the studies find internal financing an important determinant of R&D expenditures, e.g. Himmelberg & Petersen (1994) for large incumbent US firms, Harhoff (1998) for German firms, Cincera (2003) for Belgian firms, Bond, Harhoff & Van Reenen (2003) for British firms, but not for German firms, which the authors attribute to institutional differences in financial systems in the two countries. No study has addressed differences between US and EU young and old firms.

Kaplan and Zingales (1997) question the monotonicity of the relationship between the investment to cash-flow sensitivity and the level of financing constraints. However, Bond et al. (2003) argue that firms with no financing constraints should still display no excess sensitivity of investment to cash-flow. Moyen (2004) shows that when firms can use debt as a substitute for internal finance, a sensitivity of investment to cash-flow can be generated even when there is no financing friction. This result arises when current debt is correlated with contemporaneous cash-flow. Nevertheless, the conventional interpretation of the investment to cash-flow sensitivity (i.e. a sensitivity that reveals financing constraints) still holds for constrained firms that do not have "*sufficient funds to invest as much as desired. Constrained firms without funds to invest more have investment policies that are more sensitive to cash flow fluctuations than those of other firms."*

Furthermore, as also claimed by Kaplan and Zingales (1997), 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 the effect of this variable cannot be interpreted unambiguously as evidence of financing constraints. Various approaches have been used to better control for the influence of these other factors. Himmelberg and Petersen (1994) include changes in output as better proxies for changes in demand than the cash flow variable and thus allow to control, even if imperfectly, for the demand expectations. Another avenue 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 maximization 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.

Another major problem with the empirical approach to estimate the cash-flow sensitivity is the presence of specific firm characteristics, which may be correlated with other regressors, including the cash-flow variable, but which may not be observable by the researcher. The capability of the firm to find new inventions and turn them into successful innovation is one example of such an unobserved effect specific to the firm.[2] These unobserved variables, linked to the quality of its R&D personnel or its managerial skills, are likely to be 'transmitted' to the R&D decision since firms with higher capabilities or opportunities will invest more in research activities. This in turn will imply a (positive) correlation between these unobservable variables and the R&D investment which invalidates the inference that can be made from an investment equation estimation.

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

While 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 process, then values in levels of these variables lagged two or more periods will be admissible instruments.[3] The validity of the instruments is generally verified by the classical Sargan test and Hansen test of the over-identifying restrictions.

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.[4] 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.

Some contributions avoid the problems associated with the cash-flow sensitivity approach by using a direct indicator of financing constraints. This however requires access to data reflecting financing constraints. Aghion et al. (2012) use a French firm level data set to study the cyclicality of R&D investments and credit constraints. Their direct indicator of credit restrictions is based on non-payments of trade credits (payment incidents). Savignac (2008) looks at the existence and impact of financing constraints as a possibly obstacle to innovation by firms using French survey data on the cost of searching, waiting and getting new finance.

2.2. Our empirical approach to assessing financing constraints

In the absence of direct evidence of financing constraints for all sample of innovating firms, we will test the significance of internal funds (as measured by the cash-flow) in the determination of the R&D investment, in order to investigate whether there is evidence that financing constraints on R&D arise. This section presents the investment error-correction equation as well as the IV econometric methodology implemented for estimating the relationship between cash flow and R&D investments.

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:

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

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[3] As noted by Bond et al. (2003), 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 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.

[4] 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.

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 (*UCC*). This model can be derived by assuming a profit maximizing 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 of a firm.[5]

In order to allow dynamic adjustments of R&D capital, equation 1 is versed 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:

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

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

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

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[6] $\Delta c_{it} \approx R_{it} / C_{it-1} - \delta$, 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 normalization) to test for the presence of financial constraints. Hence, financial constraints can be assessed by analyzing the sensitivity of R&D investments to variations in cash flow available to firms:

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

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

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

$$+ \delta_5 \frac{CF_{it}}{C_{it-1}} + \delta_6 \frac{CF_{it-1}}{C_{it-2}} + \varepsilon_{it} \qquad (5)$$

We employ a system GMM framework to deal with biases from unobserved and correlated factors. Estimates are obtained from a two-step procedure and use as instruments the level of the series lagged two up to five periods and more, combined with the first lag of their first difference.[7] The validity of different sets of instruments can be tested through the difference between Sargan and Hansen over-identification tests. 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.

As we are particularly interested in any differences in financing constraints between US or EU innovators, and particularly for young innovators, we will look for differential sensitivity to cash flows between these sub-samples of firms. We expect a higher sensitivity for young innovators, especially for EU young innovators compared with their US counterparts. Information problems, uncertain returns and lack of collateral value are more likely to arise amongst young companies than mature companies. Hence, young firms are more likely to be financially constrained. This would imply that younger firms rely more heavily on their internal finance when they finance their R&D projects. On the other hand, mature firms often have sufficient cash-flow for their investment and do less depend on equity or debt issue (Brown et al., 2009). Hence, increasing the supply of internal funds should have less impact on the R&D decisions of mature firms. This should hold especially in Europe where the markets for risk financing is more segmented and less developed.

3. DATA

The empirical analysis is based on a representative sample of the largest US and EU R&D active companies in the manufacturing and services sectors in the years 2000. We used the successive editions of the EU industrial R&D investment scoreboards (2004 – 2008) conducted by the JRC-IPTS of the European Commission. According to JRC-IPTS, these scoreboards are representative of more than 85% of all R&D carried out in the private sector in the world. [8] The scoreboard is only representative for the largest R&D investors. It does not cover small firms. The young firms in the scoreboard based analysis are therefore not small start-ups, but those young firms that have quickly grown into world leading innovator status.

The Scoreboard data are matched with the Compustat database in order to gather financial information, including the cash flow of the firms. It has also been merged with the dataset used in Cincera and Veugelers (2013a) which include the data on the age of firms. The final sample used in the empirical analysis consists of a balanced panel of 888 firms over 2000–2007. All variables are presented using constant exchange rates and price indexes, and R&D stocks are constructed for each firm on the basis of the perpetual inventory method (Griliches, 1979).

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[7] Results are robust to different sets and lags of instruments.

[8] Background information and methodology of the 2008 R&D Scoreboard: http://iri.jrc.ec.europa.eu/research/docs/2008/Methodology.pdf.

Table 1 reports some statistics about the age of the firms. While the average EU firm is almost 100 years old, US firms are much younger, with an average age of 55 years. Following Cincera and Veugelers (2013a), we define *yollies* (young leading innovators) as scoreboard firms that were created after 1974 and *ollies* before 1975. In total about 59% of the sample Scoreboard firms are *yollies*, a ratio which is lower among EU Scoreboard firms (56%). Most of these yollies can be found in High and Medium Tech sectors. For both US and EU datasets, companies in high tech sectors are younger in average, but US firms in high tech sectors are on average much younger than their EU counterparts. [9] US firms have a higher share of their yollies present in high-tech sectors (see also Cincera and Veugelers (2013a).

Table 1. Age characteristics of sample scoreboard companies

	# of scoreboard firms	Mean Age of Scoreboard firms	# of Yollies	Mean Age in High Tech	Share of Yollies in High-Tech
EU	421	99	237	73	46
US	467	55	285	45	66

Source: own computation; Yollies are scoreboard firms born after 1974.

Table 2 gives some first descriptive statistics on the cash flow and R&D investment positions of the sample scoreboard firms. It shows that *yollies* have on average a lower relative cash flow position compared to *ollies*, but they have a higher R&D investment ratio. This holds in total, as well as for the US and the EU subsample. EU scoreboard firms have lower R&D investment, while holding higher cash flow positions than their US counterparts. This holds for all EU firms, but a fortiori for *yollies*: European *yollies* have higher cash positions and lower R&D positions relative to their US counterparts. The next section will examine whether these descriptive statistics confirm our expectations of higher sensitivity of R&D investments to cash flow positions for young leading innovators, particularly European ones, which would be evidence supporting that these firms face higher financial constraints.

[9] High-, medium- and low-tech sectors for ICB industries are defined as in Ortega-Argiles et al. (2009) and Cincera and Ravet (2013).

Table 2. Descriptive statistics on Cash Flows and R&D investments of sample scoreboard companies

	Variable	Mean	St. Dev.
All firms	RK	0.2374	0.1013
	CFK	0.8354	1.2775
Yollies	RK	0.2461	0.1094
	CFK	0.7178	1.1836
EU	RK	0.2294	0.1033
	CFK	0.9935	1.5516
US	RK	0.2453	0.0987
	CFK	0.6933	0.9449
EU Yollies	RK	0.2325	0.1072
	CFK	0.8744	1.3176
US Yollies	RK	0.2593	0.1099
	CFK	0.5790	1.0315

Notes: RK is the average R&D investment relative to lagged Capital (Dependent Variable used in the econometric analysis); CFK is the average Cash Flow relative to lagged Capital.

4. ECONOMETRIC RESULTS

4.1. Yollies versus Ollies: All results

Table 3 provides the system GMM estimates of the R&D error correction model related to all firms, yollies, EU and US firms and EU and US yollies.

Insert Table 3

The calculated Hansen test validates the set of instruments used except for column (1). The second order correlation test statistics do not suggest any problems with the time structure of the sets of instruments. With the exception of columns 2 and 6, 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 (except in column 6) and significant albeit only slightly. This suggests the presence of slightly decreasing returns to scale. The positive and significant coefficients (except for cols 2 and 5) 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.

Our major variables of interest are the Cash Flow variables. They have in general a positive and significant effect on R&D investment which indicates the presence of liquidity constraints for world leading innovators. When we compare EU and US firms, the results confirm Cincera & Ravet (2010) that EU firms seem more liquidity constrained than US firms (cols 2 and 3 in Table 3).

When we compare the presence and extent of R&D financing constraints for *yollies* with all scoreboard firms, we observe that these effects are significantly more important for *yollies* (col 1 & 4 in Table 3). In particular, a one unit increase of the contemporaneous cash-flow variable yields an increase of the R&D accumulation rate of .128 for *yollies* against .0789 for all firms. The results therefore confirm that *yollies* are more vulnerable to liquidity constraints. Looking only at EU *yollies* (col 5), seriously reduces the number of observations. Nevertheless, the results show that EU *yollies* are indeed cash constrained, even more so then their US counterparts. The long-term coefficient associated with the cash-flow variables is about .097 for EU yollies against .030 for US yollies.

Rather than splitting the samples by age and region, which reduces sample size, and since we are mostly interested in differences in the cash flow coefficients only, we perform the same system GMM analysis but with interaction effects with age or region dummies on the latter variable.[10] These are reported in Table 4.

Insert table 4 here

The interaction effect results confirm that *yollies* are some sensitive to cash flow fluctuations for their R&D investment decisions as compared to *ollies* (col 1), that EU leading innovators are more sensitive compared to US leading innovators (col 2), and that EU *yollies* are more sensitive as compared to EU *ollies* (col 3). For US firms there does not seem to be any significant difference in cash flow sensitivity between young and old leading innovators (col 4). Column 5 shows that EU *yollies'* R&D investments are more sensitive to cash flows fluctuations than US *yollies*, but the difference is only marginally significant, as there is substantial heterogeneity in this effect.

4.2. Yollies versus Ollies: High and Medium Tech

As a further robustness check, we perform the analysis on the sample of scoreboard firms from the Medium and High Tech (MHT) sectors only.[11] These results are reported in Table 5 and Table 6.

Insert Tables 5 & 6 here

The analysis finds first that scoreboard firms in MHT are more cash constrained than their Low Tech counterparts. This MHT effect follows from comparing cols (1) in Table 3 & Table 5, as well as from the MHT interaction effect in Table 6 (Col 1).

In line with the results found for the total sample, the results also confirm that EU leading innovators in MHT are more cash flow sensitive for their R&D investments than their US counterparts (comparing cols 2 and 3 in Table 5 and col 2 in Table 6.

The results on *yollies* in the MHT subsample (col 4 in Table 5) confirm that, like in the total sample, MHT *yollies* seem cash constrained, as they are sensitive to cash flow fluctuations for their R&D decisions. The size of the coefficient does not seem to be very different from all firms. Nevertheless, the results from the interaction effect analysis (col 3 in Table 6) shows that MHT *yollies* have a significantly higher sensitivity to cash flows in their R&D decisions compared to MHT *ollies*. This higher sensitivity for *yollies* holds in the EU MHT sample, it is not significant in the US MHT sample. So, unlike their US counterparts, the EU MHT *yollies* seem significantly more cash constrained than EU MHT *ollies,* a result that is confirmed in col 6 of Table 6.

To sum up, the R&D sensitivity to cash-flow appears to be higher for young leading innovators, in particular for EU *yollies* which indicates that these companies rely more on their cash-flow in order to

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[10] One advantage of this type of specifications is that the sample of firms is held constant across models. Hence the differences in the estimated rates of returns to R&D are not due to differences in the samples' composition.

[11] Including only the High-Tech sectors would seriously reduce the number of firms in the analysis, particularly European yollies.

finance their R&D investments. US *yollies* seem to have no different cash flow sensitivity from US *ollies*. These results hold for all sectors and for medium and high tech in particular. Hence our results are consistent with the evidence that EU *yollies* do less R&D and are conducting less risky activities since they are exposed to more severe financing constraints for their R&D investments.

5. Conclusion

Based on a representative sample of the largest worldwide private companies active in R&D, this paper investigated the impact of financing constraints on R&D investments over the last decade. As methodology to assess financing constraints, it uses the commonly used approach to measure the sensitivity of R&D investments to cash flow fluctuations. The cash flow augmented error correction equation has been estimated by 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.

Our results help to understand better the EU business R&D landscape and its persistent deficiency relative to the US. First, we confirm that EU leading innovators seem more cash constrained than their US counterparts. Secondly, when looking at the age structure of leading innovators, we find that young leading innovators that were created after 1975 are significantly more sensitive to the availability of internal finance, which suggests they face financing constraints on R&D. This is much less the case for older leading innovators. This higher sensitivity of young firms holds particularly for EU *yollies*. US *yollies* seem to face no significantly different cash sensitivity and seem to be significantly less cash constrained than EU *yollies*. These results hold for all sectors, and for medium and high tech sectors in particular. All these results may explain in turn the lower presence of young leading innovators in the European R&D landscape in particular in the high-tech sectors and their lower R&D intensity.

From a European policy perspective, our results suggest improving conditions in the EU for access to external capital, i.e. debt and equity, in particular for young leading innovators. As stock markets are likely to be an important source of funds for the companies in our sample, this result advocates a better focus on the development and integration of EU equity markets, which are much more fragmented compared to the US. This also includes, particularly for young innovators, supporting the development and integration of EU venture capital markets. Second, tax policies that affect the after-tax cash-flow should also have a significant impact on the R&D activities in Europe. Third, given evidence that younger firms rely more on their cash-flow to finance their R&D projects, EU policies would do well relaxing this constraint by providing them an easier access to external funds, including public funds, and encouraging the development of their R&D activities.

Our findings support the view that Europe needs a functioning internal market, which includes as pivotal having integrated functional financial markets, which are currently still hampered by too much fragmentation. At this stage, our analysis cannot be used to help targeting direct public support. Although it is clear that the often more risky projects of young leading innovators particularly in high tech sectors, should not be disadvantaged in public funding programs over those from incumbent leading innovators, it is not clear whether policy makers should primarily allocate public resources to support large firms which are world leading R&D investors, whether they are young or old, or rather to smaller companies, particularly young small innovators with R&D projects that aspire to become leading innovators. In order to further investigate this question, a larger sample would be needed which would include, besides large R&D corporations, also small young R&D investors.

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Table 3: Yollies split sample results: all sectors

	(1)		(2)		(3)		(4)		(5)		(6)	
	all firms		EU		US		yollies		EU yollies		US yollies	
VARIABLES	Coef	se	coef	se	coef	se	coef	se	coef	se	coef	se
Constant	0.595***	(0.0609)	0.777***	(0.0563)	0.107***	(0.0120)	0.494***	(0.117)	0.868***	(0.0659)	0.0445*	(0.0259)
							-					
L.RK	-0.0335***	(0.0110)	-0.111***	(0.0143)	0.670***	(0.0130)	0.0615***	(0.0121)	-0.216***	(0.0103)	0.575***	(0.0161)
DlogY	0.000110	(0.0411)	-0.163***	(0.0278)	0.121***	(0.0167)	0.452***	(0.0375)	-0.0639***	(0.0208)	0.156***	(0.0176)
L.DlogY	0.0213	(0.0159)	-0.0127	(0.0210)	0.0273***	(0.00587)	0.00614	(0.0262)	0.0897***	(0.0173)	0.0430***	(0.00754)
logK_logY_lag2	-0.0929***	(0.0129)	-0.0171	(0.0121)	-0.00674*	(0.00357)	-0.158***	(0.0176)	-0.174***	(0.0113)	-0.0337***	(0.00503)
CFK	0.0789***	(0.00577)	0.0778***	(0.00519)	-0.00333*	(0.00177)	0.128***	(0.00614)	0.0882***	(0.00322)	0.0230***	(0.00351)
L.CFK	0.00858***	(0.00133)	0.0269***	(0.00155)	0.00179***	(0.000621)	0.00286*	(0.00158)	0.0294***	(0.00110)	-0.0103***	(0.00191)
							-					
L2.logY	-0.0761***	(0.00868)	-0.0882***	(0.00812)	-0.00676***	(0.00158)	0.0822***	(0.0184)	-0.153***	(0.0113)	0.00157	(0.00389)
long term effect of CFK	0.085***	(0.00563)	0.094***	(0.00500)	-0.005	(0.00439)	0.124***	(0.00551)	0.097***	(0.00289)	0.030***	(0.02996)
Observations	3,590		1,675		1,915		1,879		870		1,009	
Number of firms	888		421		467		522		237		285	
Hansen	1787.54	0.000	1629.37	0.000	382.48	0.000	786.12	0.000	1656.15	0.000	333.08	0.000
Sargan	132.17	0.000	95.52	0.075	90.07	0.146	100.95	0.035	98.05	0.053	96.71	0.064
AR1	-1.76	0.078	-2.01	0.045	-2.12	0.034	-3.64	0.000	-1.17	0.241	-1.75	0.080
AR2	-1.32	0.186	-1.61	0.108	-0.91	0.364	0.48	0.632	-0.68	0.497	-0.74	0.459

Notes: Standard errors in parentheses; P-values in square brackets; *(**,***) = stat. significant at the 1% (5%, 10% level); instruments lagged 2, 3, 4 and 5 periods; all regressions include time dummies.

Table 4: Yollies interaction effect results : all sectors

	(1)		(2)		(3)		(4)		(5)	
	all firms		all firms		EU		US		Yollies	
VARIABLES	coef	Se	coef	se	coef	se	coef	se	coef	se
Constant	0.447***	(0.135)	0.647***	(0.0580)	1.028***	(0.0869)	-0.0715*	(0.0382)	0.458***	(0.116)
L.RK	-0.0108	(0.0128)	-0.0171	(0.0114)	-0.132***	(0.0198)	0.642***	(0.0165)	-0.0552***	(0.0111)
DlogY	0.298***	(0.0427)	0.164***	(0.0370)	-0.0541*	(0.0280)	0.0966***	(0.0183)	0.322***	(0.0396)
L.DlogY	0.0490**	(0.0214)	0.0343**	(0.0151)	0.0240	(0.0201)	0.0391***	(0.00697)	0.0406*	(0.0244)
logK_logY_lag2	-0.150***	(0.0159)	-0.118***	(0.0129)	-0.0997***	(0.0148)	-0.0169***	(0.00443)	-0.150***	(0.0166)
CFK	-0.0298**	(0.0122)	0.0200*	(0.0115)	0.00297	(0.00794)	-0.00267	(0.00181)	0.0906***	(0.0204)
L.CFK	-0.000680	(0.00170)	0.00247*	(0.00144)	0.0235***	(0.00190)	0.00236**	(0.000926)	0.00467***	(0.00160)
L2.logY	-0.0614***	(0.0145)	-0.0850***	(0.00827)	-0.118***	(0.0107)	0.00962**	(0.00393)	-0.0621***	(0.0193)
Yollies	-0.0439	(0.0681)			-0.263***	(0.0431)	0.0995***	(0.0159)		
CFKyollies	0.141***	(0.0118)			0.0906***	(0.0107)	0.00301	(0.00497)		
EU			-0.0356	(0.0277)					-0.158***	(0.0436)
CFKEU			0.0847***	(0.0114)					0.0345*	(0.0214)
long term effect of CFK	-0.030**	(0.01208)	0.022**	(0.01127)	0.023***	(0.00704)	-0.001	(0.00571)	0.084	(0.05718)
Observations	3,590		3,590		1,675		1,915		1,879	
Number of firms	888		888		421		467		522	
Hansen	1307.08	0.000	1883.94	0.000	1784.44	0.000	387.33	0.000	314.3	0.000
Sargan	121.41	0.001	136.64	0.000	95.5	0.055	85.99	0.181	73.24	0.536
AR1	-3.15	0.002	-2.31	0.021	-1.38	0.167	-2.15	0.031	-5.38	0.000
AR2	-0.32	0.749	-1.15	0.252	-0.64	0.522	-0.94	0.349	-1.11	0.268

Notes: Standard errors in parentheses; P-values in square brackets; *(**,***) = stat. significant at the 1% (5%, 10% level); instruments lagged 2, 3, 4 and 5 periods; all regressions include time dummies.

Table 5: Yollies split sample MHT results

	(1)		(2)		(3)		(4)		(5)		(6)	
	MHT		MHT EU		MHT US		MHT Yollies		MHT EU Yollies		MHT US Yollies	
VARIABLES	coef	Se	coef	se	coef	se	coef	se	coef	se	coef	Se
Constant	0.488***	(0.0546)	0.576***	(0.0835)	0.127***	(0.0137)	0.728***	(0.0897)	0.884***	(0.0599)	0.0450*	(0.0244)
L.RK	0.0972***	(0.0181)	-0.0625***	(0.0219)	0.645***	(0.0140)	0.0994***	(0.0184)	-0.0335***	(0.0101)	0.551***	(0.0153)
DlogY	-0.0484	(0.0426)	-0.280***	(0.0421)	0.120***	(0.0156)	0.00522	(0.0397)	-0.324***	(0.0267)	0.155***	(0.0162)
L.DlogY	-0.000567	(0.0171)	0.0489**	(0.0220)	0.00177	(0.00649)	-0.0226	(0.0170)	0.0805***	(0.0140)	0.0354***	(0.00761)
logK_logY_lag2	-0.0767***	(0.0178)	-0.0540***	(0.0168)	-0.00361	(0.00453)	-0.0692***	(0.0157)	-0.0985***	(0.0120)	-0.0287***	(0.00580)
CFK	0.208***	(0.00799)	0.164***	(0.00836)	0.0286***	(0.00540)	0.206***	(0.00739)	0.162***	(0.00443)	0.0428***	(0.00615)
L.CFK	-0.0294***	(0.00366)	0.00240	(0.00330)	-0.00275***	(0.000839)	-0.0280***	(0.00380)	-0.00294**	(0.00142)	-0.0102***	(0.00145)
L2.logY	-0.0675***	(0.00798)	-0.0701***	(0.0131)	-0.0101***	(0.00188)	-0.106***	(0.0149)	-0.142***	(0.0111)	0.00195	(0.00372)
long term effect of CFK	0.197***	(0.00887)	0.156***	(0.00719)	0.073***	(0.01467)	0.198***	(0.00810)	0.154***	(0.00402)	0.072***	(0.01234)
Observations	3,243		1,444		1,799		1,736		765		971	
Number of firm	788		347		441		476		200		276	
Hansen	724.03	0.000	665.77	0.000	427.52	0.000	521.48	0.000	439.88	0.000	330.4	0.000
Sargan	125	0.000	89.09	0.163	106.21	0.015	121.84	0.001	88.76	0.169	96.76	0.063
AR1	-4.52	0.000	-4.19	0.000	-2.13	0.033	-3.13	0.002	-4.01	0.000	-1.73	0.083
AR2	-1.14	0.256	0.06	0.949	-0.86	0.390	-0.82	0.415	0.63	0.532	-0.73	0.465

Notes: Standard errors in parentheses; P-values in square brackets; *(**,***) = stat. significant at the 1% (5%, 10% level); instruments lagged 2, 3, 4 and 5 periods; all regressions include time dummies.

Table 6: Yollies MHT interaction effect results

	(1)		(2)		(3)		(4)		(5)		(6)	
	All firms		MHT firms		MHT firms		MHT EU firms		MHT US firms		MHT yollies	
VARIABLES	Coef	se	coef	se	coef	se	coef	se	coef	se	coef	se
Constant	0.589***	(0.0830)	0.478***	(0.0535)	0.721***	(0.125)	0.987***	(0.0928)	0.00838	(0.0394)	0.627***	(0.0778)
L.RK	0.0118	(0.00817)	0.109***	(0.0240)	0.126***	(0.0204)	0.00217	(0.0134)	0.624***	(0.0155)	0.128***	(0.0189)
DlogY	-0.0837**	(0.0413)	0.0360	(0.0393)	-0.0545	(0.0470)	-0.288***	(0.0372)	0.114***	(0.0164)	0.0524	(0.0365)
L.DlogY	0.0152	(0.0150)	0.0366**	(0.0178)	-0.0102	(0.0181)	0.0694***	(0.0202)	0.0168**	(0.00716)	0.0258	(0.0160)
logK_logY_lag2	-0.103***	(0.0148)	-0.104***	(0.0173)	-0.0724***	(0.0174)	-0.0724***	(0.0139)	-0.0148***	(0.00519)	-0.0888***	(0.0125)
CFK	0.0200***	(0.00266)	0.0810***	(0.0199)	0.126***	(0.0290)	0.0545***	(0.0209)	0.0220***	(0.00754)	0.114***	(0.0140)
L.CFK	0.00252**	(0.00118)	-0.0360***	(0.00498)	-0.0327***	(0.00431)	-0.00996***	(0.00233)	-0.00391***	(0.00118)	-0.0366***	(0.00404)
L2.logY	-0.0810***	(0.00832)	-0.0616***	(0.00851)	-0.0838***	(0.0132)	-0.109***	(0.0115)	0.000634	(0.00419)	-0.0848***	(0.0127)
MHT	-0.00377	(0.0504)										
CFKMHT	0.139***	(0.00436)										
EU			-0.0679**	(0.0345)							-0.104***	(0.0278)
CFKEU			0.137***	(0.0169)							0.104***	(0.0131)
US												
CFKUS												
Yollies					-0.169***	(0.0621)	-0.288***	(0.0537)	0.0660***	(0.0174)		
CFKyollies					0.0893***	(0.0280)	0.126***	(0.0212)	0.00545	(0.00938)		
long term effect of CFK	0.023***	(0.00315)	0.050**	(0.02063)	0.107***	(0.00315)	0.045**	(0.02109)	0.048**	(0.02042)	0.089***	(0.01542)
Observations	3,590		3,243		3,243		1,444		1,799		1,736	
Number of firm	888		788		788		347		441		476	
Hansen	1066.01	0.000	791.43	0.000	703.7	0.000	508.48	0.000	430.62	0.000	564.05	0.000
Sargan	121.12	0.001	113.61	0.003	115.48	0.002	102.15	0.020	107.14	0.009	126.91	0.000
AR1	-3.87	0.000	-4.98	0.000	-4.41	0.000	-4.72	0.000	-2.14	0.033	-3.66	0.000
AR2	-1.43	0.154	-0.88	0.378	-1.02	0.309	0.49	0.624	-0.88	0.382	-0.76	0.448

Notes: Standard errors in parentheses; P-values in square brackets; *(**,***) = stat. significant at the 1% (5%, 10% level); instruments lagged 2, 3, 4 and 5 periods; all regressions include time dummies.

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