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Do Financing Constraints Matter for R&D?

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Keywords
Financing innovation, R&D financing constraints, Finance and growth, Stock market development, Value of liquidity

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I. Introduction

R&D is a critical input for innovation and is thus a main driver of economic growth. One key feature of R&D is that knowledge spills across firms and even countries, suggesting that socially optimal rates of R&D are likely much higher than privately optimal levels (see the survey by Hall, Mairesse and Mohnen (2010)).[1] A second important feature of R&D is susceptibility to financing constraints: for several reasons – including lack of collateral value and asymmetric information problems – R&D may face significant adverse selection and moral hazard problems, particularly in younger and smaller firms. For such firms, financing constraints can drive R&D investment below the privately optimal level in a world of no financing frictions. If financing constraints are binding for a sufficient number of firms, country- and world-wide R&D levels will be depressed, leading to lower levels of innovation and growth than would be possible in a world without financing frictions.

Despite R&D's critical role in economic growth and susceptibility to financing difficulties, comparatively few studies evaluate how financing frictions affect R&D, and the results in these studies are decidedly mixed. Furthermore, the evidence supporting economically important financing constraints on R&D is much stronger for U.S. firms compared to European firms, which is a puzzle, as capital markets in the U.S. are at least as developed as those in Europe. For example, early studies by Hall (1992) and Himmelberg and Petersen (1994) report a strong positive relation between R&D and cash flow in U.S. manufacturing firms, and recent studies by Brown, Fazzari and Petersen (2009) and Brown and Petersen (2009) find a strong link between R&D and *both* internal and external equity finance for young publicly traded U.S. firms. On the other hand, Bond, Harhoff, and Van Reenen (2003) find that neither German firms nor U.K. firms display a correlation between the level of R&D and cash flow, and Harhoff (1998) finds a statistically significant but weak relation between R&D and cash flow for small and large German firms. Hall, Mairesse, Branstetter and Crepon (1999) find that R&D is much more sensitive to cash flow in U.S. firms than in French and Japanese firms, and Mulkay, Hall and Mairesse (2001) report a much stronger R&D-cash flow sensitivity for U.S. firms relative to French firms. Finally, Bhagat and Welch (1995) report no evidence of a positive R&D-cash flow link across firms in the U.S., Canada,

[1] R&D is now a central element of the endogenous growth literature (e.g., Romer (1990); Aghion and Howitt (1992)). For evidence on R&D spillovers across countries, see Coe, Helpman and Hoffmaister (2009).

U.K., Continental Europe and Japan. Hall and Lerner (2010) provide a comprehensive summary of the literature and conclude that it remains an open question whether financing constraints matter for R&D.

In this study, we highlight two issues that are crucial for understanding and identifying financing constraints on R&D. The first issue is firm use of external equity issues to finance R&D. Stock issues have several advantages over debt (e.g., no collateral requirements, investors share in upside returns) for financing risky, intangible investments, consistent with the well-known fact that R&D-intensive firms make little use of debt finance (e.g., Hall (2002)). As a consequence, even though external equity finance may be considerably *more expensive* than internal finance, stock issues are the main marginal source of R&D finance for many firms. Given that firms make heavy use of stock issues primarily during the early stage of their life cycle (when cash flow is low and often negative), stock issues and cash flow tend to be negatively correlated. This implies that not controlling for stock issues will lead to a *downward* bias in the estimated link between R&D and cash flow.

The second issue is that high costs of adjusting R&D spending lead firms to aggressively buffer R&D from transitory volatility in internally generated cash flow. The most plausible way for firms to maintain a smooth path of R&D spending is to build and employ buffer stocks of liquidity (e.g., cash reserves).[2] We emphasize that a firm can display relatively little R&D sensitivity to finance shocks in the short-run (because of smoothing), yet over a longer time horizon be just as constrained as firms not engaging in smoothing. The intuition is that smoothing does not change the long-run availability of finance: cash holdings depleted in the current period to buffer R&D must be rebuilt in future periods, displacing future finance for R&D. If firms do actively smooth R&D from transitory shocks to finance, then within-firm regressions that ignore endogenous liquidity management will very likely generate downward biased estimates of the impact that shocks to finance have on R&D. The potential for downward biases are particularly relevant in Europe, where labor laws can make adjustment costs for R&D especially large. To address this potential bias we directly control for firm smoothing efforts by including *changes* in the firm's stock of liquid assets (cash and equivalents) in the regression specification.

[2] Several studies show theoretically that cash reserves can benefit firms facing financing frictions. In particular, Acharya, Almeida and Campello (2007) show that firms with "high hedging needs" will prefer building stocks of cash rather than debt capacity as a hedge against cash flow shortfalls. Also see Kim, Mauer and Sherman (1998) and Almeida, Campello and Weisbach (2004).

To our knowledge, no previous studies explore how use of external finance and active R&D smoothing with cash holdings impact tests for the existence and importance of financing constraints on R&D.[3] One contribution of our study is to show that accounting for these factors provides a more accurate measure of whether financing constraints matter for R&D and can dramatically alter the conclusions concerning whether financing constraints are important. A second contribution is to provide sharper and more conclusive tests for the presence of binding financing constraints for R&D investment. In particular, if financing constraints matter for R&D, then we should observe: i) a negative within-firm link between R&D and changes in cash holdings as firms draw on cash reserves for R&D smoothing, and ii) a substantial increase in the estimated impact that *other* financial factors have on R&D when changes in cash holdings are controlled for (revealing more of the long-run impact that access to finance has on investment). As we discuss in detail in the next section, collectively these findings are not subject to standard critiques of financing constraint studies, such as difficulties controlling for R&D investment opportunities.

We study a large panel of R&D reporting firms across sixteen European economies for the time period 1995-2007. The summary statistics show that R&D investment is large (e.g., comparable to physical investment), and stock issues are substantial, particularly for younger firms. In addition, young firms maintain large stocks of cash and equivalents. R&D intensity and cash holdings are particularly high for young firms in the U.K. and Sweden, two countries with highly developed stock markets where firms rely heavily on volatile stock issues.

To explore the impact financial factors have on R&D, we modify a dynamic structural model that Bond and Meghir (1994) develop to study fixed investment. We estimate the R&D model using a "systems" GMM estimator that accounts for unobserved firm-specific effects and allows us to address the potential endogeneity of all financial variables. We find little or no evidence that the availability of

[3] This is not to say that prior studies have entirely ignored the importance of external finance for R&D or completely overlooked the potential for firms to smooth R&D. For example, Brown, Fazzari, and Petersen (2009) document a strong connection between public stock issues and R&D investment during the 1990s U.S. R&D boom, and several studies note the potential for adjustment costs to limit the R&D response to transitory finance shocks (e.g., Hall and Lerner (2010)). Brown and Petersen (2011) is the only other study we know of that directly examines the connection between cash reserves and R&D investment in U.S. firms. Their study, however, has nothing to say about the implications of R&D smoothing for identifying the impact that internal and external finance has on R&D. Nor do they (or any other study) discuss how active cash management can generate additional tests for the existence and importance of financing constraints on R&D.

internal finance matters for R&D in standard specifications that include only cash flow (i.e., the estimated R&D-cash flow sensitivity is near zero), which indicates that a positive link between R&D and cash flow is not occurring simply because of poor demand controls. However, when we include stock issues, and particularly when we control for R&D smoothing by including changes in cash holdings, we find a positive, statistically significant and quantitatively important link between R&D and both cash flow and stock issues. More importantly for identifying binding financing constraints, the coefficient on the change in cash holdings is negative and large (in absolute value), and the coefficient estimates on cash flow and stock issues increase sharply when the change in cash holdings is included in the regression. Furthermore, cash holdings and access to equity finance have by far the strongest impact on R&D in the groups of firms most likely to face binding financing constraints (e.g., younger, smaller, and low dividend firms). In contrast, we find no evidence that access to debt has an important impact on R&D spending. We are aware of no single alternative to the financing constraint explanation that can rationalize this full set of results.

Our findings have a number of economic implications. First, our evidence indicates that financing constraints do matter for the R&D investment of publicly traded firms in Europe, contrary to much of the existing evidence. Second, controlling for investment smoothing can be crucial for testing for the presence and importance of financing constraints on investments with high adjustment costs. Third, our findings suggest that the need to buffer R&D from finance shocks influences corporate liquidity management across a wide range of countries, extending the literature on the causes and consequences of financial flexibility (e.g., Denis (2011)). Fourth, our study highlights an important role of stock markets for innovation in Europe, suggesting that additional stock market development can substantially increase R&D investment, which is an important public policy objective in the EU and many other countries. Finally, our findings highlight a causal channel through which stock market development and liberalization can foster innovative activity, thereby leading to economic growth.

The next section discusses the role of external equity and stocks of liquidity for financing R&D and the omitted variable bias from ignoring these sources of funds. Section III discusses our sample and summary statistics and Section IV describes our empirical approach and the main findings. The final sections discuss the implications of our findings and review related literature on finance and innovation.

II. Financial Factors and R&D Investment

A. Stock Issues and the R&D-Cash Flow Sensitivity

Figure 1 presents a supply of finance schedule that depicts the standard financing hierarchy described in many places in the literature (e.g., see the review in Hubbard (1998)).[4] The quantity of finance is measured on the horizontal axis, and the marginal cost of funds is measured on the vertical axis. The supply of finance schedule is given by S (or S') and consists of two pieces. The first piece consists of internal finance, or cash flow, with a maximum amount of CF and a constant marginal opportunity cost of MC_{CF}. There is a vertical jump in the supply schedule at CF which is the point at which the firm exhausts internal finance and switches to more costly external equity finance. There are multiple reasons why external equity is not a perfect substitute for internal finance, including substantial flotation costs (Lee, Lochhead, Ritter, and Zhao (1996)) and the "lemons premium" due to asymmetric information (Myers and Majluf (1984)). These frictions can create a sizable wedge between the cost of internal and external equity finance, and there is evidence that the size of the wedge increases with the size of the issue, implying a rising supply curve for external finance (e.g., Asquith and Mullins (1986) and Cornett and Tehranian (1994)).

The demand curve for R&D is depicted by D_{RD} and thus the equilibrium level of R&D is the intersection of D_{RD} and S, which occurs at RD. Since the marginal cost of external finance is increasing, it is obvious that this equilibrium depends critically on the quantity of cash flow. If, for example, the level of cash flow increases from CF to CF', then the supply of finance schedule shifts from S to S', and the new equilibrium shifts from RD to RD'. Thus, even though the firm in Figure 1 is issuing a substantial amount of external equity (difference between RD and CF), the firm is clearly facing a binding financing constraint in the sense that more internal finance (or cheaper external finance) would lead to more R&D. We argue below, however, that this simple illustration becomes more complicated once we include adjustment costs.

[Insert Figure 1 here]

[4] We assume the firm has no access to external debt for financing R&D. Our diagram is thus modified in the sense that the upward sloping portion is external equity finance only. Debt finance is likely the marginal source of finance for investments with collateral value, such as fixed investment.

There are at least two key reasons to directly consider stock issues when testing for financing constraints on R&D. First, as discussed in the introduction, firms rely heavily on stock issues in the years immediately following their IPO (e.g., Rajan and Zingales (1998)), which is often a period of low (or negative) cash flows and high R&D intensity. This negative correlation between stock issues and cash flow should lead to a downward bias in the estimated R&D-cash flow sensitivity in regressions that omit stock issues.[5] Second, including stock issues in the R&D regression (appropriately instrumented) permits tests of whether variation in access to external finance matters for R&D (shifts or rotations in the upward sloping portion of S in Figure 1), as it should in a world of imperfect access to external finance.[6] There is strong evidence that firms use the proceeds from stock issues to fund R&D (e.g., Kim and Weisbach (2008); Brown, Fazzari and Petersen (2009); Martinsson (2010)), but virtually all studies of R&D and financing constraints ignore stock issues.

B. R&D Smoothing

It has long been appreciated that R&D has high adjustment costs (e.g., see the discussions in Hall (1992) and Himmelberg and Petersen (1994)). Most R&D investment consists of wage payments to highly trained scientists, engineers, and other skilled technology workers who often require a great deal of firm-specific training. Thus, cutting R&D typically entails firing workers. If the cut in R&D is temporary – as in response to a transitory shock to finance – then new workers need to be hired in future periods, creating additional hiring and training costs. In addition, fired R&D workers know critical proprietary information that firms do not wish to share with competitors, and the dissemination of such information could undermine the value of innovation being undertaken by the firm. Also of relevance is the fact that labor regulations present in many European economies can limit the adjustment of workers to temporary shocks.[7] Finally, studies estimating costs of adjustment for both R&D and physical investment

5 In our sample, the Pearson correlation coefficient between stock issues and cash flow for new firms is -0.1663 and significant at the 1% level.

6 In our sample period there is substantial variation in young firm use of external equity, particularly during the late 1990s and early 2000s, a period when stock prices exploded, and then collapsed, particularly for R&D-intensive firms. In Sweden, for example, the young-firm average stock-to-assets ratio increased by over 200% between 1999 and 2000, and then declined by 85% between 2000 and 2001. Similarly, between 1999 and 2000, young-firm stock issues increased by 42% in the U.K. and 93% in France, and then fell by 59% and 46%, respectively, the following year.

7 Messina and Vallanti (2007) show that firing workers in Europe is comparatively unresponsive to economic fluctuations since firms try to smooth labor reallocation over the business cycle due to regulations making such reallocation costly and time consuming.

typically report substantially larger costs for R&D (Bernstein and Nadiri (1989)), an issue we return to in Section V when we discuss auxiliary regressions for physical investment (and find little or no use of cash holdings to smooth fixed investment).

High adjustment costs suggest that firms will actively seek to maintain a relatively smooth flow of R&D spending. For firms not facing financing frictions, smoothing R&D should be straightforward, as there are multiple forms of finance that can be used to offset shocks to internal finance. However, for R&D-intensive firms facing substantial financing frictions, external finance may be extremely costly or unavailable during periods of negative shocks to internal finance. For these firms, the obvious R&D smoothing strategy is to not rely on external markets but to build and manage stocks of *internal* liquidity, which appear on the balance sheet of the firm as "cash and equivalents." The stock of liquidity has expanded dramatically in the last few decades and is a quantitatively large component of the balance sheets of publicly traded firms in Europe (see Table 1), giving them substantial capacity to buffer R&D from negative finance shocks.[8]

Active R&D smoothing complicates testing for the impact that financing constraints have on R&D. This can readily be seen by referring back to Figure 1. Suppose a firm receives a positive cash flow shock that increases cash flow from CF to CF'. If the firm believes this is a temporary shock, it presumably will not increase R&D all the way to RD'. Rather, the firm will increase R&D by some fraction of the cash flow shock, banking the remainder in anticipation of leaner times. A similar story holds when there are positive shocks to the cost of external finance (driving down S in Figure 1): the firm is likely to bank much of the extra stock issue, dampening the increase in R&D. Likewise, if a firm receives a negative shock to finance, it is likely to draw down cash holdings to dampen much of the shock to finance. The firm, of course, still faces binding financing constraints, and in the *long-run*, R&D remains *just as constrained* by the level of cash flow (and access to external finance) as if the firm did not engage in smoothing. But within-firm regressions that ignore endogenous liquidity management will almost surely result in a downward biased estimate of financing constraints as much of the year-to-year

[8] We note, however, that there are substantial costs to building and maintaining large cash holdings, including agency costs and the fact that interest earned on cash holdings is often taxed at a higher rate than interest earned by individuals (e.g., Opler, Pinkowitz, Stulz, and Williamson (1999) and Faulkender and Wang (2006)). Thus, while we expect financially constrained firms to maintain larger stocks of liquidity, there are limits to the extent that constrained firms can buffer R&D from shocks to finance.

variation in R&D is being buffered by active smoothing with cash holdings. This smoothing behavior can potentially explain why some studies find much stronger evidence of binding financing constraints on fixed capital spending than on R&D.

In our tests for the presence of financing constraints, we control for this liquidity management by including the *change* in cash holdings (or ΔCashHoldings) in our regressions. Brown and Petersen (2011) use a similar approach to show that young U.S. firms use cash reserves to smooth R&D during the volatile 1998-2002 period. We note, however, that their paper is narrowly focused on how firms manage to smooth R&D, not on what this smoothing activity means for identifying financing constraints. That is, they do not discuss or explore how R&D smoothing can cause misleading inference about the importance of financing constraints for R&D. Nor do they show how active cash management can be used to provide additional tests and evidence of financing constraints. We are aware of no other studies of R&D financing constraints that directly account for firm smoothing efforts.

C. Testing for Financing Constraints on R&D

The standard approach for testing for financing constraints has been to examine the cash flow sensitivity of investment (e.g., Fazzari, Hubbard and Petersen (1988)). A potential weakness of this approach is that the controls for investment demand are likely imperfect; as a consequence, because changes in financial variables correlate positively with changes in profits, cash flow may simply be capturing new information about the profitability of investment. Some recent studies (e.g., Kaplan and Zingales (1997) and Moyen (2004)) raise other questions about the use of conventional investment-cash flow regressions to draw inference about the importance of financing constraints, particularly in studies that do not address the endogeneity of cash flow or fail to control for the potential use of external finance.[9]

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[9] Kaplan and Zingales (1997) argue that it is theoretically possible for more constrained firms (i.e., firms facing a steeper external finance schedule) to display a lower investment-cash flow sensitivity than relatively less constrained firms. Bond, Elston, Mairesse and Mulkay (2003, p. 154) note that it "remains the case in [the Kaplan-Zingales] model that a firm facing no financial constraint … would display no excess sensitivity to cash flow," in which case the Kaplan-Zingales criticism does not apply. Moyen (2004) calibrates a model where firms use debt as a substitute for internal finance and uses an OLS regression on simulated data to show that positive cash flow sensitivities can be generated even if firms do not face financing frictions. The unconstrained firms in Moyen's (2004) study display cash flow sensitivities because current period debt finance is correlated with contemporaneous cash flow and debt finance is not included in the regression. We directly control for the use of external finance in the R&D regressions, and we instrument cash flow to eliminate the contemporaneous correlation between external finance and the cash flow regression variable.

We emphasize that our approach for evaluating the importance of financing constraints on R&D is not based on standard estimates of the investment-cash flow sensitivity (indeed, we find no evidence of an important R&D-finance link if we estimate only conventional R&D-cash flow regressions). Rather, by examining several different predictions that follow from active R&D smoothing with cash holdings, our approach avoids these critiques and provides new tests for the presence of financing constraints on R&D. First, ΔCashHoldings should have a *negative* association with R&D in within-firm regressions with controls for other sources of finance, as reductions in cash holdings free liquidity for R&D smoothing. We emphasize that ΔCashHoldings is *positively* correlated with firm investment spending, the other financial variables, and standard measures of investment opportunities. Therefore, problems measuring investment demand should bias *upwards* the estimated coefficients on ΔCashHoldings in the R&D regressions (i.e., lead to positive coefficients), so a negative coefficient on ΔCashHoldings is not an artifact of inadequate demand control.[10] Second, if firms actively manage their cash reserves to buffer R&D from transitory finance shocks, then *controlling* for the smoothing role of cash holdings should *increase* the estimated impact that other financial factors have on R&D, revealing the longer-run impact that access to finance has on R&D. Finally, the above connections between R&D and cash holdings should arise primarily for firms which are *a priori* most likely to face binding financing constraints. It is difficult to provide a single alternative explanation (other than financing constraints) that can readily rationalize this *set* of predictions.

III. Sample and Summary Statistics

A. Sample

We build the regression sample from all European firms with coverage in the Compustat Global database over the period 1995-2007. All major economies in Europe are in the sample and a list of the 16 countries (and number of firms) appears in Table 1A in the Appendix. We necessarily focus only on firms that report positive R&D spending, and we exclude any firm that does not have at least one string of three consecutive R&D-to-assets observations during the sample period (firms without three

[10] Fazzari and Petersen (1993) make a related argument, but not in the context of R&D smoothing or the use of cash holdings. Across all firm-years of data for the young firms in our sample, the Pearson correlation coefficient with ΔCashHoldings is 0.342 for R&D, 0.117 for capital spending, 0.745 for stock issues, 0.058 for cash flow, 0.229 for sales growth, and 0.210 for the market-to-book ratio.

consecutive R&D observations would contribute no observations to the regressions). To be consistent with the related literature, we focus only on firms with a primary SIC code in a manufacturing industry (SIC 2000-3999), the sector of the economy that accounts for the majority of R&D. Before estimating the regressions we trim the 1% tails of all regression variables (the results are similar if we Winsorize instead of trim).

B. Summary Statistics

Table 1 reports summary statistics for the sample used in the regressions. We first report statistics for "all of Europe" and we then provide separate statistics for the U.K., Sweden, Germany, France and "all other Europe", which includes the remaining 12 countries. There are two main reasons for reporting separate results for the U.K., Sweden, Germany, and France. First, these countries have the largest number of firms in the sample, with the U.K. accounting for 25.7% of the sample, followed by Germany (15.5%), France (9.6%) and Sweden (9.4%). Second, the U.K. and Sweden are leading examples of "market based" economies with strong public equity markets, while Germany and France are "bank based" economies. Focusing on these countries thus allows us to compare how financial factors impact R&D across countries with different financial systems. For each group we sort firms into "young" and "mature" based on the year the firm first appears in Compustat Global with non-missing sales. Firms who first appear after 1995 are typically recently listed firms and we classify them as "young."[11] In the regression section we use firm age (along with firm size and dividend payment) to sort firms into constrained and unconstrained groups, following the approach in a number of recent studies (e.g., Fee, Hadlock and Pierce (2009) and Brown, Fazzari and Petersen (2009)). With the exception of number of employees, all variables are scaled by beginning of year total assets.

The first column of Table 1 reports information for the full sample of 16 countries. Four numbers are particularly important. First, the R&D ratio is substantial: the mean is 0.085, which is larger than the mean physical investment ratio (0.058). Second, the mean (net) stock issue-to-assets ratio (0.108) is only slightly smaller than the mean cash flow ratio (0.125), showing the importance of stock issues as a source of funds. (The median value of stock issues is zero, as expected, as Table 1 reports values for pooled

[11] In order to evaluate appropriateness of this sample split we have checked the actual year of the IPO for the Swedish sample. The average year of the IPO in the "young" sample is 1999 while in the "old" sample the average year of IPO is 1966.

firm-year observations and stock issues tend to be large in some years and zero in others.) Third, the mean of new long-term debt issues (0.015) is quite small, which is the main reason we ignore debt in the primary regression specification. (We include debt in the regressions in Table 5 and find no effect). Fourth, the average cash holdings ratio (0.223) is well above the mean of either cash flow or stock issues, showing that firms do in fact have substantial stocks of liquidity that can potentially be used to buffer R&D from transitory shocks to finance.

Columns two and three report information for the full sample split into "young" and "mature" firms. As expected, older firms are much larger than young firms. There are three other noteworthy differences between young and mature firms. First, younger firms are more R&D-intensive than older firms, which is expected for a number of reasons, including relatively greater growth opportunities for young firms. Second, stock issues are far more important for young firms: the mean of the stock issue ratio is 0.181 for young firms but only 0.025 for mature firms. The lack of stock issues for mature firms is consistent with previous findings in the literature that stock issues are used primarily in the early stage of the firm's life cycle. Third, young firms have average cash holdings ratios that are over twice as large as the cash holdings for mature firms (0.296 compared to 0.139), showing that buffer stocks of liquidity are more important for firms likely to face financing constraints.

The remaining columns in Table 1 report separate statistics for the U.K, Sweden, Germany, France and all other Europe. There are some noteworthy similarities and differences across countries. First, young German and French firms (particularly the latter), are much larger than young U.K. and Swedish firms, a point we will return to when we interpret the somewhat weaker link between financial factors and R&D for German and French firms. Second, young U.K. firms are considerably more R&D intensive, rely more on stock issues, and have higher cash holdings ratios than their counterparts in Germany, France and the rest of Europe. Swedish firms fall somewhere between firms from the U.K and those from Germany, France, and the rest of Europe. The greater reliance on stock issues for U.K. and Swedish firms is consistent with both countries having a more "market based" financial system. It is important to point out, however, that stock issues are also quantitatively important for some young firms in Germany, France and the rest of Europe, as indicated by the substantial average stock ratios.

[Insert Table 1 here]

IV. R&D Regressions

A. Specification and Empirical Approach

We follow Brown, Fazzari and Petersen (2009) and explore the importance of financial factors for R&D by modifying an investment model that Bond and Meghir (1994) develop to study fixed investment. The Bond and Meghir (1994) approach (also used in Bond et al. (2003)) is based on the dynamic optimization "Euler condition" for imperfectly competitive firms that accumulate productive assets with a quadratic adjustment cost technology. As Bond, Elston, Mairesse and Mulkay (2003, p. 153) discuss, a significant advantage of this approach is that "under the maintained structure, the model captures the influence of current expectations of future profitability on current investment decisions; and it can therefore be argued that current or lagged financial variables should not enter this specification merely as proxies for expected future profitability." Bond, Harhoff and Van Reenen (2003) note that another advantage is that the resulting empirical specification corresponds to an intuitive, dynamic R&D regression, and thus the parameter estimates have a readily understandable interpretation even if some of the assumptions required of the underlying structural model do not strictly hold in the data.

Similar to Bond and Meghir (1994), we augment the baseline Euler specification derived under the assumption of no financing frictions with variables that measure the firm's access to both internal and external equity finance. We also add the *change* in cash holdings to the specification to control for the use of cash for R&D smoothing. In addition, we add Tobin's Q as an additional control for investment demand. The resulting empirical specification is:

$$\begin{aligned} RD_{j,t} &= \beta_1 RD_{j,t-1} + \beta_2 RD^2_{j,t-1} + \beta_3 Q_{j,t} + \beta_4 Sales_{j,t-1} + \beta_5 CashFlow_{j,t} \\ &+ \beta_6 CashFlow_{j,t-1} + \beta_7 StkIssues_{j,t} + \beta_8 StkIssues_{j,t-1} + \beta_9 \Delta CashHoldings_{j,t} \\ &+ \beta_{10} \Delta CashHoldings_{j,t-1} + d_t + \alpha_j + \nu_{j,t}. \end{aligned} \qquad (1)$$

$RD_{j,t}$ is R&D spending for firm j in period t. The expected coefficient (in the Euler condition) on lagged R&D is positive and the expected coefficient on the quadratic term is negative; in the model with no financing frictions both coefficients will slightly exceed one in absolute value. In Bond and Meghir (1994), lagged sales enters the Euler condition if there is imperfect competition. The financial variables include contemporaneous and lagged cash flow (*CashFlow*), funds from stock issues net of repurchases (*StkIssues*), and changes in cash holdings (*ΔCashHoldings*). All regression variables are scaled by the beginning-of-period stock of firm assets. The model includes a firm-specific effect (α_j) to control for all unobserved time-invariant determinants of R&D at the firm level, such as the technology of the firm, industry characteristics, and country-specific regulatory or institutional characteristics that are constant over the sample period. The model also includes a time-specific effect (d_t) to control for aggregate changes that could affect the demand for R&D, such as the state of the macro economy. We discuss alternative specifications, including specifications that include new debt issues, in Section V.

We estimate equation (1) with the "system" GMM estimator developed for dynamic panel models by Arellano and Bover (1995) and Blundell and Bond (1998). This approach allows us to address the potential endogeneity of all financial variables, including stock issues and ΔCashHoldings, by jointly estimating a regression of equation (1) in differences and in levels, using lagged levels as instruments for the regression in differences and lagged differences as instruments for the regression in levels.[12] In addition, Almeida, Campello, and Galvao (2010) have recently shown that an OLS-IV approach similar in spirit to the GMM estimator we use is a tractable and relatively robust way to deal with measurement error in standard empirical investment equations.

Our primary results use one-step GMM and rely on lagged levels dated *t*-3 and *t*-4 as instruments for the regression in differences and lagged differences dated *t*-2 for the regression in levels. The standard errors are robust to heteroskedasticity and within-firm serial correlation. As we discuss in Section V, the estimates are similar if we use two-step GMM or employ alternative instrument sets. To assess instrument validity we report a Hansen *J*-test of the null that the over-identifying restrictions are valid, a difference-in-Hansen test that evaluates the validity of the additional instruments required for systems estimation (i.e., the validity of the instruments used in the levels equation), and an *m2* test for second-order autocorrelation in the first-differenced residuals. These tests generally indicate no major problems with our primary instrument set, particularly in the most important specifications.

[12] Estimating the regression in both differences and levels addresses the weak instrument problem that arises from using lagged levels of persistent explanatory variables as instruments for the regression in differences (Blundell and Bond (1998)). Including the levels equation does, however, require that an additional moment restriction hold in the data: *differences* in the right-hand side variables in equation (1) cannot be correlated with the firm-specific effect. Furthermore, identification in this setting rests on the assumption that past changes in the endogenous financial variables (e.g., ΔCashHoldings) are correlated with current period R&D only through their correlation with current period financial variables.

B. Impact of Adding Stock Issues and Controlling for Smoothing

Table 2 reports GMM estimates of equation (1) for six samples: i) all Europe, ii) U.K., iii) Sweden, iv) Germany, v) France and vi) all other Europe. For each sample, we report three regressions. We begin with a dynamic R&D regression model containing only cash flow, the standard financial variable examined in the literature. We then add stock issues to the specification and, finally, we include ΔCashHoldings. Before discussing the main findings, we note that in all regressions, the coefficient for lagged R&D is close to one (reflecting the persistence in R&D) and the coefficient on lagged R&D-squared is negative and statistically significant, but somewhat smaller in absolute value than predicted by the Euler condition (under the assumption of quadratic adjustment costs). In addition, the estimated coefficient for Tobin's *Q* is positive in all regressions and often statistically significant.

For the "all Europe" sample, the sum of the cash flow coefficients in the initial specification (column (1)) is near zero (0.010). Adding stock issues in the second regression results in a rise in the sum of the estimated cash flow coefficients (to 0.046), but a chi-squared test continues to reject the null that the sum is statistically different from zero (p-value of 0.519). The estimated coefficients for stock issues have opposite signs and are nearly offsetting. Of particular importance, adding ΔCashHoldings in the third regression results in a very sharp rise in the coefficients on both cash flow and stock issues: the sum of the cash flow coefficients increases to 0.176 and the sum of the stock coefficients increases to 0.131. Furthermore, both sums are now highly statistically significant (p-values of 0.003 or smaller). In addition, the sum of the current and lagged coefficients on ΔCashHoldings is negative, large in absolute value (-0.142) and statistically significant. The point estimates on ΔCashHoldings and the impact that including this variable has on the other financial coefficients indicate that firms rely heavily on cash holdings to smooth R&D. Overall, the results are consistent with important omitted variable biases from excluding stock issues and not controlling for R&D smoothing.

Columns (4)-(6) report the results for the U.K. The sum of the cash flow coefficients is positive but insignificant (0.081) in the initial specification (column (4)) and the sum of the stock coefficients is negative and insignificant in column (5). In column six, controlling for changes in cash holdings causes the estimated coefficients on both cash flow and stock issues to rise sharply (the sum of the cash flow coefficients is now 0.201 (p-value = 0.002) and the sum of the stock coefficients is now 0.114 (p-value =

0.011)), and the sum of the coefficients on ΔCashHoldings is negative, large in absolute value (-0.155) and highly significant. For Sweden (columns (7)-(9)), the pattern of results is broadly similar to the pattern for the U.K. That is, the financial coefficients are all small in regressions that exclude ΔCashHoldings (columns (7) and (8)), but increase sharply and are statistically and economically significant once ΔCashHoldings is included in the regression. Likewise, the sum of the coefficients on ΔCashHoldings is negative, quantitatively important (-0.213) and highly significant.

The pattern for Germany and France is generally similar to that of the U.K. and Sweden, except the statistical significance in the French sample is substantially weaker. For both Germany and France there is little or no evidence of financing constraints in the regressions that exclude ΔCashHoldings (columns (10) and (11) and columns (13) and (14)). When ΔCashHoldings is included in the regression (columns (12) and (15)) there is a large jump in the estimated sum of stock issue coefficients in both countries, and there is also a substantial jump in the sum of the cash flow coefficients for France (from -0.032 to 0.042). In addition, in both France and Germany the sum of the coefficients on ΔCashHoldings is negative and substantial (in absolute value), although not significant at conventional levels for France. For both Germany and France the sum of the cash flow coefficients are positive, but the values are modest and the sum of the coefficients is statistically insignificant in the French sample.

In the rest of Europe (remaining 12 countries) there is evidence of a cash flow effect even without controlling for smoothing. When ΔCashHoldings in included in the final regression, there is a modest jump in the sum of cash flow coefficients and a doubling of the sum of coefficients for stock issues. In this final regression, the sum of the cash flow coefficients is 0.166, the sum of the stock coefficients is 0.151, and sum of the ΔCashHoldings coefficients is -0.112 and all sums are statistically significant with exception of ΔCashHoldings (which just misses statistical significance at the ten percent level).

The six sets of regressions show a consistent pattern. For all Europe and the individual countries, we find evidence of a strong link between financial factors and R&D, but only when we directly control for endogenous R&D smoothing by including ΔCashHoldings in the regression. In general, the estimated impact that cash flow and stock issues have on R&D increases sharply after we control for changes in cash holdings. In all sets of regressions the coefficients on ΔCashHoldings are negative and substantial (in absolute value), further indicating that firms use buffer stocks of liquidity to smooth R&D.

[Insert Table 2 here]

C. Sample Splits: All Europe

We expect a stronger link between the financial variables and R&D in the groups of firms most likely to be financially constrained. We also expect the predicted signs and magnitude of the lagged R&D terms from the structural model derived under the assumption of no financing constraints to hold best in the groups of firms least likely to face binding constraints. We follow the literature and use age, firm size, and dividend payouts to sort firms into constrained and unconstrained groups.[13] Firm age is likely strongly correlated with asymmetric information problems and has the advantage of being potentially less endogenous than other splitting criteria. Young firms also rely heavily on external equity finance (see Table 1), suggesting that they are operating along a rising portion of the supply of finance schedule (if capital markets are imperfect). Size of firms is another commonly used split and small firms in our sample often rely heavily on external equity finance (but large firms typically do not). We consider firms to be "large" if their average level of employment over the sample period is above the 70th percentile, and "small" otherwise. Finally, following the logic in Fazzari, Hubbard and Petersen (1988) that low dividend firms are more likely to face binding financing constraints, we split firms into low and high dividend groups. We put firms into the high dividend group if their average dividend-to-assets ratio over the sample period is above the 70th percentile; otherwise they are put in the low payout group. For ease of discussion, we refer to the new, small, and low dividend groups of firms as "plausibly constrained," and the old, large, and high dividend groups as "plausibly unconstrained".

To economize on space (and to make comparisons less tedious), we report the sums of the financial coefficients in Table 3. For the *plausibly constrained* groups, the coefficients on lagged R&D and lagged R&D-squared are smaller (in absolute value) than predicted by the Euler condition, as expected given the condition is derived under the null of no financing constraints. More importantly, the sums of the coefficients on the financial factors are always large (in absolute value) and statistically significant. For example for the *plausibly constrained* group, the sum of cash flow coefficients ranges from 0.170 for low dividend firms to 0.202 for young firms.

[13] Hadlock and Pierce (2010) use qualitative information disclosed by firms to create an index of financing constraints for a large random sample of firms and conclude that firm age and size are the two variables most related to the qualitative information reported by firms concerning the presence of financing constraints.

For the *plausibly unconstrained* groups, the coefficients on lagged R&D and lagged R&D-squared are consistent with the predictions from the structural model derived under the assumption of no financing constraints (see the discussion of equation (1)) for all splits except high dividend firms. In addition, sums of the coefficients for the financial factors are quantitatively small and generally statistically insignificant, and are always far smaller than the sums of the coefficients for the *plausibly constrained* groups. In particular, for both large firms and high dividend firms, none of the financial factors are statistically significant; for the mature firms the only significant financial factor is ΔCashHoldings. These small and insignificant coefficients are important, as Bond, Elston, Mairesse and Mulkay (2003) argue that heterogeneity tests are most convincing when the plausibly unconstrained group displays no evidence of financing constraints.[14]

[Insert Table 3 here]

D. Sample Splits for Individual Countries

Table 4 reports regression results for our three different sample splits for individual countries. Once again, we sum the financial coefficients and we report the corresponding chi-squared tests below the sum. We also leave out the lagged R&D terms, Q and lagged sales to conserve space. Test statistics are reported at the bottom of each panel.[15]

Panel A reports the results when our sample is split into young and mature firms. For young firms, financial coefficients are generally quantitatively large (in absolute value) and statistically significant in the U.K., Sweden, Germany and all other Europe. The sum of the cash flow coefficients is particularly large in the U.K. (0.244). France is the one country with no evidence of a link between financial factors and R&D. For mature firms, the coefficients on all of the financial variables are quantitatively small and insignificant for the U.K, Sweden and France. In Germany, mature firms have

[14] We also repeat (but do not report) the exercise in Table 3, where the regressions progress from one financial factor (cash flow) to all three financial factors. For the *plausibly constrained* group, we get exactly the same pattern of results as reported in Table 2: adding stock issues impacts the cash flow coefficients, but the largest impact arises from adding ΔCashHoldings to the regressions. For the *plausibly unconstrained* groups, adding stock issues makes little difference and the impact of adding ΔCashHoldings is quantitatively small.

[15] In several of the country level splits we have a small number of firms relative to the number of instruments generated by our estimation approach. The instrument validity tests are less reliable in this setting, as evidenced by the implausibly high *p*-values generated by the *J*-test. See Bowsher (2002).

significant sums for cash flow and ΔCashHoldings; in all other Europe, the sum of the cash flow coefficients is significant, but much smaller than the cash flow sum for young firms.

Panel B reports regressions split by firm size. Once again, for the small firms (*plausibly constrained* group), all of the financial coefficients are quantitatively large (in absolute value) and statistically significant in the U.K., Sweden, Germany and "all other Europe". As in Panel A, financial effects are not evident in France. For large firms, with the exception of cash flow for Germany and 'all other Europe', there are no positive and statistically significant sums for either cash flow or stock issues.

Finally, Panel C reports findings when the sample is split by dividends. For the low dividend firms (*plausibly constrained* group), the pattern of financial coefficients (size and significance) is similar to the results in Panels A and B. There is somewhat stronger evidence of financial effects in France (compared to Panels A and B), but the sums are statistically insignificant for all three financial variables. For high dividend firms, cash flow is significantly positive only in the 'all other Europe' sample, but this sum is substantially smaller than the sum for low dividends firms. Stock issues are significant for mature firms in Germany and France, but we note that the sample of high dividend firms in both of these countries is very small.

Thus, for the U.K., Sweden and "all other Europe", the findings in Table 4 line up very closely with the full sample findings in Table 3. That is, there are quantitatively large and typically significant sums of coefficients on all financial variables in the *plausibly constrained* groupings, and small and generally insignificant coefficients for the *plausibly unconstrained* groupings. This is reassuring, as the U.K., Sweden and "all other Europe" constitute approximately 75% of the total sample. For Germany, for *plausibly constrained* firms, there are quantitatively substantial and statistically significant coefficients on all financial variables; for *plausibly unconstrained* firms, there are some instances of significant financial effects. For France, there is evidence of financial effects only for low dividend firms.

[Insert Table 4 here]

V. Robustness

A. Additional Results for R&D

The findings we present above are robust to a number of alternative specifications and estimation approaches. We present three of the most important checks in Table 5. While we report results using the age split only, we obtain a similar pattern of results when we use either dividends or size to classify firms as plausibly constrained or unconstrained. First, in columns (1) and (2), we adjust the instrument set to include lagged levels dated *t*-2 to *t*-4 and lagged differences dated *t*-1. For young firms, we recover financial effects that are very similar to the findings in the corresponding regression in Table 3. For mature firms, the estimates on the lagged R&D terms are consistent with the predictions of the structural model and the financial effects are small and insignificant, consistent with the findings in Table 3. Second, in columns (3) and (4), we include sales growth as an alternative to Q for controlling for firm's investment opportunities. For young firms, the estimates for the key financial variables are similar to their counterparts in Table 3. In contrast, the estimated financial effects for mature firms are much smaller and only ΔCashHoldings is statistically significant.

Third, in columns (5) and (6), we include current and lagged values of new long-term debt issues in equation (1) and recover similar coefficient estimates on the key financial variables. In addition, unlike cash flow and stock issues, the estimated coefficient on new debt issues is negative but insignificant for constrained firms and approximately zero for unconstrained firms. These results are consistent with arguments that debt is poorly suited for funding R&D and further highlight the particular importance of stock market development and the availability of equity finance for funding innovative activity.[16]

[Insert Table here]

B. Fixed Investment

Cooper and Haltiwanger (2006) provide a careful study of the nature of adjustment costs for physical investment and find that costs of adjustment for physical investment are "relatively modest." As a result, firms should rely much less on cash reserves for buffering fixed investment than they do for R&D. Indeed, when we substitute fixed capital investment for R&D in the main regressions the sum of the coefficients for ΔCashHoldings are always near zero and typically insignificant at conventional levels. For example, for the regression that corresponds to the third specification in Table 2 (all countries, all firms), the sum of the coefficients for ΔCashHoldings is 0.002 and statistically insignificant. We find exactly the same pattern when we split the sample by age, size and dividend payout. In these regressions,

[16] We explore a number of other robustness checks that are available on request. We note that our findings are also similar if we use alternative data transformations (forward orthogonal deviations instead of first differences) or rely on two-step GMM with Windmeijer (2005) corrected standard errors.

for constrained firms, the largest absolute value for the sum of ΔCashHoldings is -0.010 (for low dividend firms) and the estimate is statistically insignificant. In addition, running the fixed investment regressions without ΔCashHoldings has little or no impact on the estimated coefficients for the other financial variables (e.g., cash flow). Thus, when testing for financing constraints, controlling for smoothing appears to be much less important for fixed investment compared to R&D. These findings provide additional confidence in the results for R&D, since cash reserves should be much less important for investments that have modest adjustment costs, which is an extension of the basic predictions discussed in Section II.

VI. Discussion and Implications

A. Testing for Financing Constraints on R&D

Our paper provides new insights into testing for whether financing constraints matter for R&D. First, ignoring stock issues and R&D smoothing with cash holdings can result in sharp downward biases in the estimated link between R&D and cash flow, potentially leading to an incorrect assessment of the importance of financing constraints in studies that look only at the standard R&D-cash flow sensitivity. (We show, in fact, that firms *a priori* most likely to face substantial financing frictions can exhibit essentially no R&D-cash flow relation if stock issues and R&D smoothing are ignored.) Second, as discussed in the introduction, our full set of findings – particularly the negative link between changes in cash holdings and R&D and the sharp increase in the estimated link between R&D and the equity finance variables when we control for R&D smoothing with cash holdings – offer new tests for the presence of quantitatively important financing constraints on R&D that are difficult to rationalize with alternative explanations.

B. Financing Constraints across Countries

Several studies rely on a comparison of investment-finance sensitivities across countries to draw inference about the relative importance of binding financing frictions (e.g., Bond, Elston, Mairesse and Mulkay (2003)). One possible interpretation of our findings is that R&D financing constraints are more severe in the market-based economies of the U.K. and Sweden than the bank-based systems in Germany and France. We think this need not be the case. Rather, we believe these findings reflect the fact that market-based financial systems tend to have better-developed stock markets, and better stock markets generate more young publicly traded firms at a stage in their life cycle when internal finance is low and costly external finance is used extensively to fund R&D investment. The summary statistics in Table 1 show that "young" U.K. and Swedish firms are much smaller and have lower cash flow ratios than "young" German or French firms, almost surely because "young" firms in the U.K and Sweden went public at an earlier stage of development.[17] The link between finance and investment may be strongest in countries with well-developed stock markets precisely because strong stock markets support a larger number of firms that are highly dependent on costly external finance and thus have investment that is especially sensitive to internal and external finance shocks. Thus, our approach is useful for identifying the presence of financing constraints within a country (or group of countries), but it may not identify the *relative* importance of financing constraints across countries.

Hall and Lerner (2010, p. 23) note that an alternative explanation for stronger financial effects in market-based financial systems is that "firms are more sensitive to demand signals in thick financial equity markets." For several reasons, we believe that a "financing constraint" explanation is more consistent with our set of findings than a "demand-side" explanation. First, when we follow the standard practice of regressing R&D on cash flow (with no other financial variables) we obtain quantitatively small and insignificant cash flow coefficients in the U.K. and Sweden, countries with thick financial equity markets, which is inconsistent with a "demand-side" explanation. Second, when we include ΔCashHoldings to control for R&D smoothing, financial effects are present in the U.K. and Sweden only for the plausibly constrained firms (see Table 4). If demand signals drive R&D-finance sensitivities, then R&D and finance correlations should be present for *all firm types*, regardless of the likelihood they face binding financing constraints. Third, as we discuss above, ΔCashHoldings is positively correlated with the other financial variables, and hence with demand shocks, so if demand shocks cause positive coefficients on other financial variables, they should lead to a positive coefficient on ΔCashHoldings, the opposite of our findings.

C. Finance and Innovation

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[17] Vandemaele (2003) reports a median age of 28 years for French firms going public, while Ljungqvist (1997) reports a median age of 52 for German IPOs in the period 1970-1990, compared to 7 years for the U.S.

While the focus of our study is to explore whether financing constraints matter for R&D, our findings also provide new evidence that access to external equity finance matters for R&D. In particular, in our GMM-IV regressions, the estimated coefficients for stock issues are statistically significant and of a magnitude similar to the coefficient for internal finance for firms who plausibly face binding constraints. Given the magnitude of the coefficient on stock issues, our findings suggest that access to stock issues plays an important role in funding R&D for firms whose investment demand outstrips the flow of internal finance.

It is interesting to compare our study with a complementary paper by Hsu, Tian and Xu (2012), which examines the connection between financial development and innovation in a sample of 34 countries (including the countries used in our study). They show that the development of *equity* markets (as measured by market capitalization) encourages innovation productivity (as measured by patenting), which is consistent with our evidence on the linkage between stock issues and R&D. They also report evidence that the development of *credit* markets actually impedes innovation productivity, suggesting that credit market development is a bad substitute for equity market development when it comes to encouraging innovation. While we do not focus on credit market development in our study, when we include current and lagged values of new long-term debt issues in equation (1) we recover negative (but insignificant) coefficients on debt issues (for plausibly constrained firms). This finding is generally supportive of the negative linkage between credit and innovation emphasized in Hsu, Tian and Xu (2012).

More generally, our study is related to a rapidly growing literature on finance and innovation. Much of this literature focuses on patenting, which is an output of R&D.[18] One portion of the broad literature focuses on the connection between legal institutions and finance and innovation. Given the importance of equity markets for R&D, countries with better investor protection for shareholders should arguably have better developed stock markets and greater R&D intensity, a proposition supported by evidence in Brown, Martinsson and Petersen (2012). Their findings suggest that strengthening shareholder protection can lead to higher levels of innovation. Laws permitting antitakeover provisions

[18] To our knowledge, firm level data on patenting is not readily available for a broad international sample like we study. It would be interesting to check our results using R&D with information on firms' patenting and therefore be able to extend the analysis to innovation output. Attempting to merge information on patents to the Compustat Global database is a complex process demanding considerable resources (see Thoma et al. (2010) for a description of the process of merging firm-level data and patent statistics).

may also promote innovation in an environment where outside shareholders undervalue R&D and other innovative investments because of the information asymmetries that are naturally associated with innovation. In this environment, antitakeover mechanisms can insulate managers from short-term pressures from outside investors, creating greater incentives for long-term investments in innovation, a view strongly supported by findings in Chemmanur and Tian (2012). Given the riskiness of innovation, the nature of the bankruptcy codes is likely to impact the incentives to innovate, given that the bankruptcy code impacts the transfer of control rights if a firm enters a period of financial distress. Acharya and Subramanian (2009) provide evidence that a debtor-friendly bankruptcy code increases the overall rate of innovation in the economy, suggesting that strengthening creditor protection is not the right policy for promoting innovation.

Besides legal institutions, there are several other recent studies on connections between finance and innovation, including papers that deal with the importance of "failure tolerance." Manso (2011) argues that incentive schemes designed to encourage managers to innovate should be forgiving (or even rewarding) of early stage failure. Aghion, Van Reenen and Zingales (2009) argue that the long-term focus of institutional ownership (of public companies) stimulates innovation because institutions are less likely to fire managers for not meeting short-term earnings targets. Tian and Wang (2011) show that IPO firms financed by more failure-tolerant venture capital investors produce a larger number of patents, particularly in industries where the failure risk is very high. Finally a number of other studies provide evidence of economic factors that appear to impede innovation, including conglomeration (Seru (2011)), enhanced stock market liquidity (Fang, Tian and Tice (2011)) and greater analyst coverage (He and Tian (2012)).

D. Public Policy and R&D Intensity

R&D intensity has long been lower in the EU than in the U.S., and the main reason is lower business R&D intensity in the EU.[19] The lower levels of R&D in Europe were a key subject of the Lisbon European Council (2000) and the Barcelona European Council (2002), which recommended an R&D goal for the EU of 3% of GDP by 2010 (compared to 1.85% for the EU-27 in 2007). Our findings suggest that

[19] For example, over the period 2000-2005, R&D spending by businesses averaged 1.2% of GDP in the EU-15 compared to 1.9% in the U.S. (Uppenberg (2009)). Furthermore, Uppenberg shows that the lower level of business R&D investment in Europe is due to lower R&D intensity at the sectoral level, and is *not* due to different sectoral specialization.

policies increasing access to external equity finance can increase R&D investment in firms with insufficient internal resources to fully fund investment demand. Straightforward policy initiatives include efforts to improve accounting standards and craft regulations that permit firms to list on equity markets at an earlier age (perhaps even before they are profitable). For example, beginning in the 1980s, Sweden removed many restrictions in their financial markets, which led to a 20-fold increase in the transaction volume on their stock exchange between 1980-1990 (Englund (1990)).[20] Other policy initiatives involve strengthening investor protection, which appears to be strongly associated with improved access to equity finance (e.g., La Porta et al. (1997, Tables IV and VI)). Finally, improvements in the microstructure of European equity markets can increase access to public equity finance (see Pagano (1998) for an overview of the dramatic changes in the structure of European equity markets).

There are currently large differences in stock market development *within* Europe, suggesting considerable scope for improving access to public equity in Europe. To illustrate, consider some facts highlighting the differences between the market-based economies of the U.K and Sweden and the bank-based economies of France and Germany. First, based on the number of IPOs reported in Loughran, Ritter and Rydqvist (1994, updated in 2009), the U.K. and Sweden had three to four times as many IPOs as Germany and France in recent decades, after adjusting for the size of the economy. Second, the total number of publicly listed firms is three to four times larger in the U.K. and Sweden compared to Germany and France (after adjusting for size of the economy). Third, the ratio of stock market value traded to GDP is much greater in the U.K. and Sweden than in Germany and France.[21] Fourth, Kim and Weisbach (2008) report that for 1990-2003, the level of public equity raised (adjusted for size of the economy) is more than twice as high in the U.K. and Sweden than in Germany and France. Our summary statistics are consistent with the differences noted above for these four countries: young U.K. and Swedish firms have

[20] One change was allowing foreigners to purchase stock on Swedish exchanges. As in the U.S., Swedish banks are restricted from owning equity in non-financial firms, which has increased the transparency of publicly traded firms in Sweden and reduced the possibility of a given firm becoming dependent on a single bank for the provision of funds. Sweden was also a pioneer in Europe in electronic stock market trading.

[21] Statistics on the number of listed firms (per 10 thousand population) and stock market value traded to GDP comes from Beck and Demigruc-Kunt (2009).

considerably higher average stock issues than young German and French firms. Furthermore, as expected, young firms in the U.K. and Sweden also have substantially higher R&D intensities.[22]

VIII. Conclusions

Determining whether financing constraints matter for R&D is important for identifying the causal connections between finance and economic growth and for understanding how financing frictions influence real activity. While there are strong theoretical reasons to suspect that financing constraints should matter for R&D, prior studies focusing on European firms tend to find weak evidence (at most) that financing constraints have a quantitatively important impact on R&D. Utilizing a broad sample of European firms, we also find little or no evidence that finance matters for R&D if we look only at the R&D-cash flow sensitivity, consistent with the approach in nearly all studies of finance and R&D. However, when we expand the analysis to include stock issues as a source of funds and changes in cash holdings to control for endogenous R&D smoothing, our findings show that access to internal and external equity finance matters a great deal for R&D, particularly in firms most likely to face binding financing constraints. The main reason for this reversal of results appears to be resolving an important left-out variable problem: firms facing financing frictions have strong incentives to build and utilize costly stocks of liquidity to keep the flow of R&D spending relatively smooth compared to transitory finance shocks, avoiding the very large adjustment costs associated with R&D. Focusing on R&D smoothing with stocks of liquidity also allows us to introduce stronger tests for the presence of financing constraints.

Our results indicate that better access to equity finance can substantially increase R&D investment, which has long been a key public policy goal in the EU and many other countries. In particular, we show that stock markets are much more than a “sideshow” when it comes to financing R&D, which helps explain the very high R&D-intensities of young publicly traded firms in countries such

[22] Sweden has the highest R&D intensity in the EU, with business R&D spending over 3.0%, 2.5 times the EU-15 average. Germany and France are well below Sweden, and the UK is below all three countries. The lower *aggregate* number in the UK is due composition: manufacturing is the sector responsible for most of R&D spending but UK manufacturing is below the EU average and well below countries like Germany. For example, in 2005, manufacturing accounted for only 13.6 percent of GDP in the UK compared with 23.2 percent in Germany. Within individual sectors, however, the UK’s R&D intensity compares favorably with France and Germany (see Uppenberg (2009)).

as the U.K. and Sweden. More generally, our study provides new micro-level evidence that is useful for understanding the positive link between economic growth and broad measures of stock market development and liberalization documented in studies like Levine and Zervos (1998), Beck and Levine (2002) and Bekaert, Harvey and Lundblad (2005): public stock markets can foster economic growth by directly funding the innovative activity of young, entrepreneurial firms.

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Figure 1: Financing Hierarchy for R&D

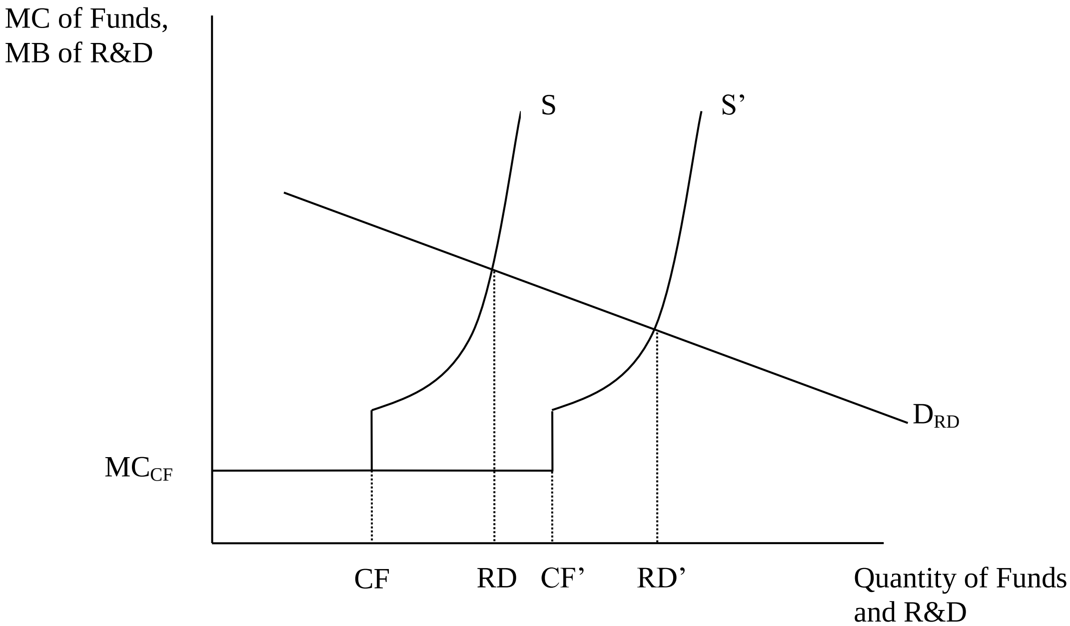

Table 1: Sample Statistics

The sample is constructed from European manufacturing firms (SIC codes 20-39) with coverage in the Compustat Global database during 1995-2007. The sample consists only of R&D reporting firms that have at least one string of three consecutive R&D observations. All variables except employees are scaled by beginning-of-period total assets. Cash flow is measured gross of both R&D and fixed investment by summing income before extraordinary items, depreciation, and R&D expenses. Stock issues are measured net of repurchases (gross proceeds minus stock repurchases) and debt issues are measured as the net change in the stock of long-term debt outstanding. Firms are classified as young if the first year Compustat reports non-missing sales is after 1995. All other Europe includes firms from all countries except the UK, Sweden, France and Germany. Outliers in all variables are trimmed at the 1% level.

		All Europe			**U.K.**			**Sweden**		
		Full	Young	Mature	Full	Young	Mature	Full	Young	Mature
Employees	Mean	10607.575	3161.684	17875.277	1755.940	761.116	2669.109	10653.737	859.855	26108.303
	Median	1570.000	479.000	4845.000	582.500	202.000	1477.000	610.000	215.000	14335.000
Capex	Mean	0.058	0.056	0.060	0.051	0.050	0.053	0.046	0.043	0.052
	Median	0.045	0.037	0.051	0.038	0.032	0.043	0.035	0.027	0.048
R&D	Mean	0.085	0.120	0.044	0.115	0.170	0.049	0.097	0.129	0.036
	Median	0.041	0.062	0.029	0.051	0.095	0.028	0.038	0.078	0.025
Sales	Mean	1.068	0.987	1.161	1.000	0.841	1.190	1.046	1.040	1.058
	Median	1.060	0.972	1.113	1.047	0.781	1.152	1.020	1.033	1.002
CashFlow	Mean	0.125	0.109	0.143	0.098	0.066	0.134	0.094	0.062	0.154
	Median	0.129	0.122	0.134	0.114	0.086	0.130	0.128	0.099	0.148
StkIssues	Mean	0.108	0.181	0.025	0.209	0.338	0.054	0.114	0.163	0.011
	Median	0.000	0.000	0.000	0.002	0.006	0.001	0.000	0.000	0.000
DbtIssues	Mean	0.015	0.014	0.016	0.011	0.010	0.011	0.019	0.014	0.029
	Median	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006
CashHoldings	Mean	0.223	0.296	0.139	0.294	0.393	0.177	0.234	0.297	0.108
	Median	0.114	0.151	0.091	0.152	0.232	0.106	0.124	0.159	0.068
Firms		746	467	279	192	122	70	70	52	18

Table 1: Sample Statistics (Continued)

		Germany			France			All Other Europe		
		Full	Young	Mature	Full	Young	Mature	Full	Young	Mature
Employees	Mean	14869.127	2574.144	28894.706	28399.528	10281.184	39073.902	9489.839	4024.526	14752.579
	Median	2130.000	570.000	8430.000	6250.000	515.000	12730.000	2180.000	800.000	5330.000
Capex	Mean	0.067	0.062	0.073	0.059	0.052	0.064	0.062	0.063	0.060
	Median	0.049	0.039	0.059	0.052	0.036	0.061	0.047	0.045	0.049
R&D	Mean	0.074	0.098	0.042	0.069	0.103	0.042	0.072	0.097	0.044
	Median	0.051	0.069	0.034	0.031	0.043	0.027	0.035	0.046	0.028
Sales	Mean	1.154	1.038	1.296	1.045	0.966	1.101	1.089	1.052	1.130
	Median	1.139	1.031	1.260	1.048	0.958	1.093	1.045	1.002	1.067
CashFlow	Mean	0.137	0.130	0.147	0.120	0.112	0.127	0.145	0.142	0.149
	Median	0.139	0.144	0.136	0.115	0.100	0.123	0.135	0.135	0.135
StkIssues	Mean	0.076	0.129	0.011	0.059	0.126	0.011	0.067	0.112	0.019
	Median	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DbtIssues	Mean	0.013	0.008	0.019	0.009	0.003	0.014	0.018	0.020	0.016
	Median	0.000	-0.001	0.000	-0.001	-0.002	-0.001	0.000	0.000	-0.001
CashHoldings	Mean	0.192	0.265	0.104	0.177	0.265	0.115	0.200	0.253	0.143
	Median	0.100	0.153	0.067	0.098	0.120	0.092	0.108	0.125	0.095
Firms		116	74	42	72	37	35	296	182	114

Table 2: Dynamic R&D Regressions

Estimation is by systems GMM with lagged levels dated *t*-3 to *t*-4 used as instruments for the equation in differences and lagged differences dated *t*-2 used as instruments for the equation in levels. Fixed firm and time effects are included in all regressions. The sample is described in Table 1. Outliers in all regression variables are trimmed at the 1% level. Standard errors robust to heteroskedasticity and within-firm serial correlation are reported in parenthesis.

Dependent Variable: $(R\&D)_t$

	All Europe			U.K.			Sweden		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$(R\&D)_{t-1}$	0.966	0.979	0.872	0.844	1.122	1.007	0.878	1.114	1.021
	(0.191)	*(0.147)*	*(0.113)*	*(0.165)*	*(0.161)*	*(0.107)*	*(0.107)*	*(0.108)*	*(0.081)*
$(R\&D)_{t-1}^2$	-0.641	-0.503	-0.493	-0.595	-0.656	-0.600	-0.288	-0.474	-0.457
	(0.277)	*(0.178)*	*(0.147)*	*(0.239)*	*(0.193)*	*(0.154)*	*(0.146)*	*(0.157)*	*(0.120)*
$(Q)_t$	0.009	0.007	0.007	0.028	0.021	0.012	0.010	0.003	0.001
	(0.004)	*(0.004)*	*(0.002)*	*(0.009)*	*(0.007)*	*(0.004)*	*(0.003)*	*(0.003)*	*(0.002)*
$(Sales)_{t-1}$	-0.062	-0.048	-0.046	-0.056	-0.027	-0.029	-0.026	-0.020	-0.013
	(0.015)	*(0.014)*	*(0.012)*	*(0.018)*	*(0.013)*	*(0.013)*	*(0.010)*	*(0.008)*	*(0.008)*
$(CashFlow)_t$	-0.009	0.054	0.137	0.031	0.089	0.163	0.015	0.031	0.096
	(0.060)	*(0.041)*	*(0.035)*	*(0.061)*	*(0.048)*	*(0.034)*	*(0.041)*	*(0.032)*	*(0.044)*
$(CashFlow)_{t-1}$	0.019	-0.008	0.039	0.050	-0.029	0.038	0.005	-0.028	-0.003
	(0.052)	*(0.053)*	*(0.042)*	*(0.050)*	*(0.055)*	*(0.044)*	*(0.038)*	*(0.025)*	*(0.027)*
$(StkIssues)_t$		0.073	0.198		0.047	0.175		0.043	0.137
		(0.015)	*(0.041)*		*(0.016)*	*(0.044)*		*(0.017)*	*(0.030)*
$(StkIssues)_{t-1}$		-0.074	-0.067		-0.083	-0.061		-0.075	-0.013
		(0.020)	*(0.027)*		*(0.020)*	*(0.023)*		*(0.013)*	*(0.028)*
$(\Delta CashHoldings)_t$			-0.134			-0.131			-0.131
			(0.042)			*(0.047)*			*(0.033)*
$(\Delta CashHoldings)_{t-1}$			-0.008			-0.024			-0.082
			(0.031)			*(0.032)*			*(0.030)*
Sum CashFlow (p-value)	0.877	0.519	0.002	0.212	0.294	0.002	0.577	0.926	0.046
Sum StkIssues (p-value)		0.989	0.003		0.234	0.011		0.083	0.012
Sum* ΔCashHoldings *(p-value)			0.003			0.003			0.000
m2	0.29	-1.02	-0.04	0.16	-1.43	-0.58	0.93	0.36	0.08
J-test (p-value)	0.369	0.597	0.703	0.257	0.323	0.805	1.000	1.000	1.000
Diff-Hansen (p-value)	0.295	0.775	0.763	0.277	0.659	0.945	1.000	1.000	1.000
Observations	3,977	3,746	3,694	931	873	844	453	437	427
Firms	725	716	705	185	184	176	69	69	69

Table 2: Dynamic R&D Regressions (Continued)

	Germany			France			All Other Europe		
	(10)	**(11)**	**(12)**	**(13)**	**(14)**	**(15)**	**(16)**	**(17)**	**(18)**
$(R\&D)_{t-1}$	1.302	0.897	0.853	1.249	1.150	1.016	1.112	0.946	0.941
	(0.230)	*(0.123)*	*(0.111)*	*(0.142)*	*(0.092)*	*(0.109)*	*(0.144)*	*(0.173)*	*(0.153)*
$(R\&D)_{t-1}^2$	-1.322	-0.060	-0.206	-0.942	-0.782	-0.788	-0.732	-0.561	-0.597
	(0.402)	*(0.256)*	*(0.201)*	*(0.328)*	*(0.292)*	*(0.308)*	*(0.169)*	*(0.169)*	*(0.141)*
$(Q)_t$	0.004	0.003	0.002	0.006	0.005	0.008	0.001	0.004	0.004
	(0.003)	*(0.002)*	*(0.002)*	*(0.009)*	*(0.005)*	*(0.004)*	*(0.004)*	*(0.003)*	*(0.003)*
$(Sales)_{t-1}$	-0.022	-0.023	-0.011	-0.046	-0.027	-0.019	-0.049	-0.045	-0.036
	(0.011)	*(0.009)*	*(0.007)*	*(0.013)*	*(0.010)*	*(0.007)*	*(0.020)*	*(0.016)*	*(0.013)*
$(CashFlow)_t$	0.109	0.089	0.099	0.209	0.071	0.094	0.097	0.130	0.171
	(0.042)	*(0.029)*	*(0.028)*	*(0.171)*	*(0.044)*	*(0.050)*	*(0.060)*	*(0.038)*	*(0.043)*
$(CashFlow)_{t-1}$	-0.072	-0.055	-0.048	-0.126	-0.103	-0.052	0.035	-0.013	-0.005
	(0.052)	*(0.037)*	*(0.031)*	*(0.117)*	*(0.091)*	*(0.060)*	*(0.087)*	*(0.056)*	*(0.047)*
$(StkIssues)_t$		0.109	0.184		0.091	0.107		0.148	0.173
		(0.029)	*(0.024)*		*(0.027)*	*(0.050)*		*(0.030)*	*(0.052)*
$(StkIssues)_{t-1}$		-0.097	-0.032		-0.028	0.039		-0.070	-0.022
		(0.030)	*(0.026)*		*(0.032)*	*(0.052)*		*(0.046)*	*(0.042)*
$(\Delta CashHoldings)_t$			-0.100			-0.061			-0.055
			(0.024)			*(0.055)*			*(0.055)*
$(\Delta CashHoldings)_{t-1}$			-0.059			-0.072			-0.057
			(0.027)			*(0.046)*			*(0.030)*
Sum CashFlow (p-value)	0.543	0.389	0.042	0.342	0.699	0.383	0.078	0.074	0.005
Sum StkIssues (p-value)		0.825	0.000		0.167	0.099		0.102	0.015
Sum* ΔCashHoldings *(p-value)			0.000			0.134			0.102
m2	1.98	0.29	0.77	1.93	-1.28	-1.47	-1.24	0.91	-0.26
J-test (p-value)	0.956	1.000	1.000	1.000	1.000	1.000	0.097	0.105	0.289
Diff-Hansen (p-value)	1.000	1.000	1.000	1.000	1.000	1.000	0.115	0.180	0.307
Observations	625	599	596	369	356	353	1,599	1,481	1,474
Firms	114	113	113	71	71	70	286	279	277

Table 3: Sample Splits All Europe

Estimation is by systems GMM with lagged levels dated *t*-3 to *t*-4 used as instruments for the equation in differences and lagged differences dated *t*-2 used as instruments for the equation in levels. Fixed firm and time effects are included in all regressions. The sample is described in Table 1. Outliers in all regression variables are trimmed at the 1% level. Standard errors robust to heteroskedasticity and within-firm serial correlation are reported in parenthesis below the coefficient estimates on the lagged R&D terms, Q, and sales. P-values from tests that the sum of the coefficients is equal to zero are reported in parenthesis below the financial variables.

Dependent Variable: $(R\&D)_t$

	Young	Mature	Small	Large	Low Dividend	High Dividend
	(1)	(2)	(3)	(4)	(5)	(6)
$(R\&D)_{t-1}$	0.884	1.017	0.904	1.043	0.864	1.009
	(0.124)	*(0.068)*	*(0.123)*	*(0.135)*	*(0.122)*	*(0.100)*
$(R\&D)_{t-1}^2$	-0.466	-1.196	-0.498	-1.228	-0.503	-0.159
	(0.158)	*(0.135)*	*(0.154)*	*(0.176)*	*(0.141)*	*(0.263)*
$(Q)_t$	0.007	0.004	0.006	0.001	0.009	0.002
	(0.003)	*(0.002)*	*(0.002)*	*(0.001)*	*(0.003)*	*(0.001)*
$(Sales)_{t-1}$	-0.045	-0.012	-0.041	-0.007	-0.043	-0.020
	(0.014)	*(0.004)*	*(0.013)*	*(0.002)*	*(0.013)*	*(0.007)*
Sum CashFlow	0.202	0.029	0.188	0.070	0.170	-0.013
(p-value)	*(0.001)*	*(0.427)*	*(0.001)*	*(0.258)*	*(0.003)*	*(0.725)*
Sum StkIssues	0.167	0.029	0.141	0.001	0.125	-0.018
(p-value)	*(0.000)*	*(0.332)*	*(0.001)*	*(0.991)*	*(0.005)*	*(0.645)*
Sum ΔCashHoldings	-0.221	-0.057	-0.172	-0.029	-0.128	-0.045
(p-value)	*(0.000)*	*(0.031)*	*(0.000)*	*(0.686)*	*(0.013)*	*(0.258)*
m2	-0.01	-0.41	-0.02	-0.04	0.17	-0.08
J-test (p-value)	0.647	0.297	0.764	0.665	0.347	0.836
Diff-Hansen (p-value)	0.696	0.237	0.784	0.485	0.388	0.956
Observations	1,888	1,806	2,487	1,207	2,722	972
Firms	434	271	523	182	529	176

Table 4: Sample Splits by Country

Estimation is by systems GMM with lagged levels dated *t*-3 to *t*-4 used as instruments for the equation in differences and lagged differences dated *t*-2 used as instruments for the equation in levels. Fixed firm and time effects are included in all regressions. The sample is described in Table 1. Outliers in all regression variables are trimmed at the 1% level. Standard errors are robust to heteroskedasticity and within-firm serial correlation; p-values from tests that the sum of the coefficients is equal to zero are reported in parenthesis.

	U.K.		**Sweden**		**Germany**		**France**		**All Other Europe**	
Panel A: Sample Split Based on Age										
	Young	**Mature**	**Young**	**Mature**	**Young**	**Mature**	**Young**	**Mature**	**Young**	**Mature**
Sum CashFlow	0.244	-0.024	0.126	-0.001	0.067	0.051	0.011	-0.002	0.178	0.085
(p-value)	*(0.000)*	*(0.297)*	*(0.012)*	*(0.960)*	*(0.004)*	*(0.009)*	*(0.770)*	*(0.915)*	*(0.005)*	*(0.045)*
Sum StkIssues	0.125	-0.011	0.130	-0.069	0.130	0.054	-0.009	-0.049	0.157	-0.005
(p-value)	*(0.017)*	*(0.665)*	*(0.013)*	*(0.106)*	*(0.001)*	*(0.080)*	*(0.861)*	*(0.205)*	*(0.009)*	*(0.915)*
Sum ΔCashHoldings	-0.173	-0.055	-0.214	-0.012	-0.133	-0.124	-0.023	0.027	-0.131	-0.021
(p-value)	*(0.006)*	*(0.145)*	*(0.000)*	*(0.592)*	*(0.007)*	*(0.000)*	*(0.552)*	*(0.303)*	*(0.045)*	*(0.550)*
m2	-0.95	-0.67	0.02	0.89	0.54	2.17	-1.39	-1.28	-0.64	0.32
J-test (p-value)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.891	1.000
Diff-Hansen (p-value)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.996	1.000
Observations	415	429	260	167	337	259	149	204	727	747
Firms	107	69	51	18	73	40	36	34	167	110

Panel B: Sample Split Based on Size										
	Small	**Large**	**Small**	**Large**	**Small**	**Large**	**Small**	**Large**	**Small**	**Large**
Sum CashFlow	0.199	-0.022	0.095	0.037	0.071	0.040	0.016	0.022	0.150	0.133
(p-value)	*(0.000)*	*(0.103)*	*(0.036)*	*(0.306)*	*(0.009)*	*(0.064)*	*(0.606)*	*(0.190)*	*(0.017)*	*(0.000)*
Sum StkIssues	0.112	-0.199	0.110	-0.012	0.131	-0.012	-0.038	-0.084	0.153	0.036
(p-value)	*(0.011)*	*(0.000)*	*(0.042)*	*(0.744)*	*(0.002)*	*(0.683)*	*(0.379)*	*(0.002)*	*(0.010)*	*(0.669)*
Sum ΔCashHoldings	-0.154	-0.032	-0.198	-0.049	-0.127	-0.123	0.001	0.006	-0.119	0.054
(p-value)	*(0.004)*	*(0.082)*	*(0.000)*	*(0.001)*	*(0.018)*	*(0.000)*	*(0.960)*	*(0.734)*	*(0.053)*	*(0.302)*
m2	-0.68	-1.13	0.07	0.76	0.43	1.52	-1.23	-0.66	-0.36	-0.08
J-test (p-value)	0.983	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.808	1.000
Diff-Hansen (p-value)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	1.000
Observations	750	94	300	127	354	242	160	193	923	551
Firms	159	17	55	14	75	38	40	30	194	83

Panel C: Sample Split Based on Dividend Payout										
	Low Div	**High Div**	**Low Div**	**High Div**	**Low Div**	**High Div**	**Low Div**	**High Div**	**Low Div**	**High Div**
Sum CashFlow	0.148	-0.017	0.113	-0.004	0.079	-0.068	0.054	-0.162	0.170	0.100
(p-value)	*(0.001)*	*(0.369)*	*(0.010)*	*(0.849)*	*(0.005)*	*(0.096)*	*(0.271)*	*(0.001)*	*(0.015)*	*(0.018)*
Sum StkIssues	0.063	-0.064	0.134	-0.053	0.115	0.142	0.161	0.297	0.153	-0.017
(p-value)	*(0.107)*	*(0.000)*	*(0.010)*	*(0.065)*	*(0.002)*	*(0.005)*	*(0.071)*	*(0.016)*	*(0.017)*	*(0.548)*
Sum ΔCashHoldings	-0.112	0.025	-0.228	-0.059	-0.061	-0.197	-0.146	-0.007	-0.135	-0.033
(p-value)	*(0.021)*	*(0.457)*	*(0.000)*	*(0.027)*	*(0.029)*	*(0.000)*	*(0.107)*	*(0.889)*	*(0.047)*	*(0.203)*
m2	-0.53	-1.53	0.03	-0.90	0.59	-0.12	-1.53	0.42	0.08	-0.51
J-test (p-value)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.563	1.000
Diff-Hansen (p-value)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.691	1.000
Observations	575	269	325	102	515	81	306	47	1,001	473
Firms	125	51	53	16	96	17	59	11	196	81

Table 5: Alternative Estimates: Pooled Sample

Estimation is by systems GMM on the full Europe sample described in Table 1. Fixed firm and time effects are included in all regressions. The sample is described in Table 1. Outliers in all regression variables are trimmed at the 1% level. Standard errors robust to heteroskedasticity and within-firm serial correlation are reported in parenthesis below the coefficient estimates on the lagged R&D terms, Q, and sales. P-values from tests that the sum of the coefficients is equal to zero are reported in parenthesis below the financial variables.

Dependent Variable: $(R\&D)_t$

	***t*-2 to *t*-4 instruments**		**Replace Q with sales growth**		**Add New Debt Issues**	
	Young	**Mature**	**Young**	**Mature**	**Young**	**Mature**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
$(R\&D)_{t-1}$	0.818	1.083	0.786	1.036	0.849	1.235
	(0.102)	*(0.045)*	*(0.138)*	*(0.088)*	*(0.129)*	*(0.132)*
$(R\&D)_{t-1}^2$	-0.514	-1.299	-0.321	-1.292	-0.421	-2.213
	(0.121)	*(0.064)*	*(0.201)*	*(0.150)*	*(0.171)*	*(0.561)*
$(Q)_t$	0.008	0.003			0.007	0.005
	(0.002)	*(0.002)*			*(0.003)*	*(0.002)*
$(Sales)_{t-1}$	-0.054	-0.007	-0.049	-0.016	-0.042	-0.010
	(0.011)	*(0.003)*	*(0.013)*	*(0.004)*	*(0.014)*	*(0.004)*
$(SalesGrowth)_t$			0.028	0.018		
			(0.019)	*(0.011)*		
Sum CashFlow	0.199	0.020	0.261	0.054	0.175	-0.004
(p-value)	*(0.000)*	*(0.360)*	*(0.001)*	*(0.091)*	*(0.002)*	*(0.879)*
Sum StkIssues	0.166	0.031	0.175	0.069	0.186	0.026
(p-value)	*(0.000)*	*(0.162)*	*(0.000)*	*(0.069)*	*(0.000)*	*(0.284)*
Sum ΔCashHoldings	-0.178	-0.041	-0.216	-0.089	-0.218	-0.061
(p-value)	*(0.000)*	*(0.141)*	*(0.000)*	*(0.028)*	*(0.000)*	*(0.036)*
Sum NewDebt					-0.081	0.004
(p-value)					*(0.363)*	*(0.873)*
m2	-0.86	-0.21	0.24	-0.61	-0.84	-0.28
J-test (p-value)	0.472	0.448	0.723	0.557	0.723	0.531
Diff-Hansen (p-value)	0.189	0.475	0.334	0.673	0.829	0.577
Observations	1,888	1,806	1,965	1,906	1,807	1,774
Firms	434	271	437	277	423	271

Table A1: Firm and Observation Count by Country

Table A1 reports the number of firms and observations from each country in the sample. The count is based on the number of firms and observations each country contributes to the baseline regression that includes only cash flow. The number of observations declines slightly as additional financial variables are included in the specification.

	Firms	Observations
UK	185	931
Germany	114	625
France	71	369
Sweden	69	453
Switzerland	64	414
Finland	51	333
Denmark	27	160
Netherlands	25	167
Turkey	25	102
Belgium	22	115
Norway	19	73
Greece	16	71
Italy	13	43
Ireland	11	82
Austria	10	33
Spain	3	6
	725	3977