

Do Liquidity Constraints Matter for R&D and Investment in the Pharmaceutical Industry?

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This paper expands previous country focused studies of liquidity constraints for R&D, investment and growth of firms by considering several hundred firms in fifteen OECD countries, using dynamic panel specification, and controlling for country specific institutional and financial environments. Cash flow has a positive effect on firms R&D: the estimated elasticity of R&D to cash flow is 0.36 at median values and this effect is more significant for young firms and firms with less than 500 employees. Firms with low investment prospects have lower sensitivity of their R&D to cash flow, but cash flow appears unimportant in physical investment decisions.

Key words: liquidity constraints, R&D, investment, pharmaceutical industry

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1. Introduction.

The Pharmaceutical industry is an important component of the health sector and the modern innovation economy. Agrawal (1999, pp.6, 49) noticed that the competitiveness of the pharmaceutical industry depends largely on the innovation abilities of firms. Her survey of the chief executive officers of 45 pharmaceutical corporations in 1992 showed that innovation was recognised as the single most important factor of global competitiveness.

However, the costs of discovery and development of new drugs is rapidly increasing, which requires larger demand in order to compensate for the growing costs. According to the US industrial association data (PhRMA, 2008, p.2), R&D costs per drug averaged \$138 million in 1975, \$318 million in 1987, \$802 million in 2001, and US\$1,318 million in 2005. This trend exacerbates the problem of orphan and neglected diseases drugs that do not have a patient base with sufficiently strong purchasing power to finance commercial pharmaceutical R&D. According to an estimation of Bartfai and Lees (2006, pp.14,71), only 12.5% of 400 disease entities generate enough return on the investments of pharmaceutical firms and less than 6% of the diseases have a potential for blockbuster sales over one billion dollars.

Many researchers alarm about decreasing productivity in the industry, leading to the coining of the so-called 'innovation productivity paradox' in which rapidly growing R&D spending in the industry has little effect on the number of innovative drugs developed (Gassmann et al, 2008). If one assumes twelve-year drug development lag, ratio of new drug applications to R&D spending has been roughly

decreasing in the US since 1975 (Pattikawa, 2007, p.42). It is debateable if this is a temporal trend or a crisis of the blockbuster business model of pharmaceutical firms, which must focus their efforts on high demand therapeutic areas to finance increasingly high costs of drug R&D. Before the financial crisis of 2007, the profitability trend in the industry was discouraging. According to PriceWaterHouseCoopers (2007), thirteen of world's largest pharmaceutical companies had negatively weighted average shareholder returns between 2001 and 2007.

Shallow drug markets for most diseases call for new public policy incentives for corporate R&D in relation to neglected diseases and stimulation of pharmaceutical innovations. These incentives must adapt to financial constraints, especially in conditions of information asymmetry in financial markets that hinder investment opportunities into new R&D projects for new and young firms. For such firms, the choice of supporting national innovation systems with a variety of risk and reward combinations can be crucial such that the availability of advance rewards or purchasing commitments, cash guarantees, cash prizes, or push incentives for R&D are not neutral.

R&D can be conventionally viewed as a long-term investment guided in respect to the risk adjusted rate of return. Pharmaceutical companies in OECD countries have more evenly distributed access to frontier technologies and human resources provided they can afford them. The ability to purchase resources for R&D is determined by the cost of capital as extracted from imperfect capital markets. Grabowski and Vernon (2000, p.209) point out that expectations depend not only on a firm's own performance, but also on the success of the industry as a whole as investors charge interest in accordance to the expected risk for the industry. This

interest rate might essentially reflect a higher perception of industrial risk than that what a less known company itself considers to be accurate and this can lead to self selection of good firms to internal finance.

R&D financing is especially important for small firms as in the pharmaceutical industry, according to Comanor (1986), the most important drug innovations were done by small firms. Attention must be paid to the participation of small firms in innovation schemes, and given the fragility of small firm existence, the size of monetary rewards could be essential for innovate R&D in biotechnology as a whole. As firms plan to allocate their cash flow over different activities, including dividends and physical investment, cash flows provided under different public innovation schemes could be very important for small start-up companies.

Theoretical models show that creditors might ration loans in the presence of high asymmetry of information instead of charging high risk premiums, which can depend on the capital structure of a firm (Stiglitz and Weiss 1981; Myers and Majluf 1984). Fazzari, Hubbard et al. (1988). Reviewing the relevant literature on asymmetric information and capital market imperfections points out that a firm's cost of internal funds generated by revenue can be substantially lower than its cost of external finance that takes place in the form of issuing equity, bonds, or obtaining loans. Hall (2002) concluded that small and new innovative firms experience high costs of capital and even large firms prefer internal funds for the financing of R&D.

The next sections review the literature on liquidity constraints for investment in general and as applied to the pharmaceutical industry. Section 4 explains the econometric approach of dynamic panels, section 5 describes the data, and section 6 reports estimated impacts of liquidity constraints on R&D and investment, followed by a conclusion.

2. Literature on liquidity constraints.

For a profit maximizing firm in the perfect market, marginal returns on all types of assets must be the same at the optimum, i.e. returns on physical capital and R&D. According to the Modigliani-Miller theorem (1958), due to this non-arbitrage condition, the capital structure of a firm does not matter. However, in the real world of information asymmetry between borrowers and lenders interest rates can differ by type of investment. Government policies such as price controls, approval procedures, patent protection, and public purchases can also affect risks associated with specifics of how the industry is financed.

R&D has many features of investment as this is a result of long term accumulation of knowledge capital, although R&D has a much smaller variance than physical investment in plant and equipment (Hall and Hayashi, 1989). However, Hall (2002) summarizes several important features of R&D that can make the cost of external capital for an R&D project higher than cost of cash generated through a firm's revenue:

- Asymmetric information between inventor and investor, as the inventor has more expertise in their own project or else hesitates to reveal all information. The situation is exacerbated by the high uncertainty of R&D projects that unevenly declines as a project progresses.
- Moral hazard on the part of the inventor or inventor's firm management by diverting funds into unnecessary expenditures.
- Tax deduction legislation that affects the servicing external debts.

- Incomplete markets as debt-holders prefer physical assets as collateral to secure loans in case of bankruptcy. Sunk costs of R&D are usually higher than physical investment.

Carpenter and Petersen (2002) cite endemic information asymmetry for high-tech firms as the “returns to high-tech investment are skewed and highly uncertain, in part because R&D projects have a low probability of financial success”. Asymmetry of information is quite high in pharmaceuticals as the quality of a drug candidate can remain uncertain for several years from preclinical research until clinical trials (at least phase II trials, which establish drug efficiency) are mostly completed and this usually takes 3-5 years. Moral hazard problems also naturally arise in the pharmaceutical industry due to secrecy of information and incomplete disclosure of the relative efficacy of one drug versus another. Secrecy in pre-clinical drug discovery is important as first entry into a market can result in much larger profits than that what is generally on offer to a latecomer.

Under Hayashi's (1982) assumptions about perfect competition and firms' investment decisions, average Tobin's Q sufficiently characterizes firm's investment opportunities. However, pharmaceutical markets usually contradict Hayashi's assumptions such as perfect competition at product markets, linear homogeneity of technologies for production and zero adjustment costs. R&D costs are often sunk, patented drugs markets are segmented and often have oligopolistic characteristics, and tacit knowledge and skills of some scientists make it difficult to fire them. These factors might create a dependence of investment and R&D decisions on cash flow.

The seminal paper of Fazzari, Hubbard et al. (1988) points out the key role of cash flow in investment decisions of firms. They split their sample of American firms into three groups of financially constrained firms as proxied by dividends to income

ratio and run instrumented regression of the investment-capital ratio. The regressors were Tobin's Q defined as the sum of the value of equity and debt less the value of inventories divided by the replacement cost of the capital stock adjusted for corporate and personal taxes, the cash flow-capital ratio, the ratio of sales to capital and working capital less the book value of inventories. It is found statistically significant coefficients for the cash flow indicator, which were larger for low dividend paying firms.

Branch (1974) used a distributed lag regression technique for profit and patents in a sample of 111 firms from various industries for the period 1950-65 and concluded that R&D was positively affected by past profitability, but that R&D itself also positively influenced future sales and profitability. To account for firm heterogeneity, he normalized all variables in the regression to assets.

Himmelberg and Petersen (1994) found a significant relationship between R&D and internal finance in a panel of 179 American small technological firms and that elasticity by cash flow for capital investment is twice as high as the elasticity for R&D in within-firm estimates. This difference is explained by higher adjustment costs for R&D associated with payments to specialists who possess critical and often tacit firm-specific knowledge. Himmelberg and Petersen used fixed effect regression to estimate the effects of cash flow, change in sales and Tobin's q on R&D expenditures and estimated cash flow elasticities for R&D at 0.67 and physical investment at 0.82. Himmelberg and Petersen (1994, p.41) forward a hypothesis that "to minimize both the current and future adjustment costs, firms set the level of R&D investment in accordance with the permanent level of internal finance".

Determination of cash constrained firms is tricky. Beck, Demirguc-Kunt et al. (2006) using surveys of over 10,000 firms from 80 countries find that older, larger,

and foreign-owned firms report less financing obstacles. It could be that cash constrained firms respond with higher levels of investment. Boyle and Guthrie (2003) develop a model, which explains overinvestment bias for small firms as future risks related to own cash flows can lead to funding shortages.

Kaplan and Zingales (1997) using annual reports of firms from the study of Fazzari, Hubbard et al. (1988) find that the group which was assumed to be a financially constrained one, in fact, shows the lowest sensitivity of investment to cash flow. Hubbard (1998) suggests that this could be explained by Kaplan and Zingales assigning firms into constrained based on managerial statements and, in this case, financially distressed firms can be presented as cash constrained ones. However, Cleary (1999) using accounting ratios with multiple discriminant analysis for a sample of American firms that companies with high creditworthiness are more sensitive to internal funds than less creditworthy firms. This result supports Kaplan and Zingales (1997) findings that investments of the least constrained firms are more sensitive to the cash flow.

Allayannis and Mozumdar (2004) find that Cleary's results can be explained by negative cash flow observations in Cleary's sample and the Kaplan–Zingales results are affected by a few influential observations. They explain that the negative cash flow is a proxy for financially distressed situations and as firms in this condition must afford only essential investment, cash flow sensitivity must be very low. Allayannis and Mozumdar find that investment–cash flow sensitivity estimates are similar for all firms in the financially constraint group of firms by excluding the negative cash flow observations.

However, the interpretation of a positive cash flow relationship with investment is not clear as was evident in Gomes (2001), who argues that this

relationship can be explained by investment expectations for a firm rather than by cash flow per se. Review of Hubbard (1998, p.200) suggests that “If cash flow is correlated with future profitability, a link between cash flow and investment for a given firm over time could reflect the link between expected profitability and investment.” Hubbard also suggests that if managers use internal funds for other purposes other than firm value-maximizing projects, then cash flow-investment links can also emerge. Aggarwal and Samwick (2006) argue that managers’ incentives to expand investment and operations are countered by increasing burden of oversight responsibilities and this balance is not obvious ex ante.

Cooper and Ejarque (2003) through a model with numerical simulations argue that market power rather than capital market imperfections explain the positive relationship between investment and internal funds of firms. Erickson and Whited (2000) and Gomes (2001) argue that the significance of internal funds in investment regressions may reflect measurement error in Tobin’s Q, which is imperfectly approximated by an average Q. Erickson and Whited (2000) use a higher order moment conditions to account for measurement error in Tobin’s Q and find that the coefficient of the cash-flow variable becomes insignificant. Alti (2003) proposes a model to explain sensitivity of investment to cash flow for small and young firms through learning about their cash flow realizations.

Bond, Klemm et al. (2004) find that cash flow does not explain the investment decisions of firms if expected profitability predicted by securities analysts is used instead of imperfectly measured average Tobin’s Q for a panel sample of the UK firms. They argue that significant coefficients for cash flow can be a result of measurement error in Tobin’s Q or reflect misspecification of the basic model. It is

pointed out that stock exchange ‘bubbles’ or other factors that influence the expected future profitability of current investment.

Cummins, Hassett et al. (2006) confirm these findings for the set of the US firms too. They argue that the positive and statistically significant cash-flow coefficient could emerge as the result of mismanagement in the average Tobin’s Q and its significance disappears after controlling for analyst-based average Q. The only problem of the approach of using securities analysts’ forecasts is that we do not know how the forecasts are obtained and if the forecasts actually include cash flow variables.

Another important parameter affecting investment and R&D decisions is leverage, a ratio of liabilities to total assets. The impact of this ratio is not clear both in theoretical and empirical literature. Modigliani and Miller (1963) show corporate taxes bring a positive relationship between leverage and the value of the firm. However, high leverage can increase risk of bankruptcy. Jensen and Meckling (1976) propose a moral hazard model in which firms with high debt would be prone for risky investment projects due to limited liability: downside risks can be largely born by external creditors, whereas upside returns benefit more the firm. Myers (1977) develops a model showing that high debt can reduce investments as cash must be used to service previous debts, as higher debt increases likelihood of bankruptcy. Jensen (1986) proposes high leverage as a tool to reduce moral hazards on the side of managers to mispend firm’s cash so that managers would invest cash only if they see a high probability of getting appropriate return on their projects. Hall (2002) criticizes this tool as it increases cost of capital for R&D and debt repayment will likely divert cash from R&D and other investment.

Szewczyk, Tsetsekos et al. (1996) find that average approximation for Tobin's Q is statistically significant in explaining abnormal returns connected to R&D projects, and that these returns are higher for leveraged firms. Because marginal Tobin's Q is unobservable, the average Q is proxied by price to book ratio. McConnell and Servaes (1995) detect the leverage has a negative impact on corporate value of the US firms with high Tobin's Q, but a positive impact on the value of firms with low Tobin's Q. This could indicate the moral hazard problem for firms with low investment opportunities as indicated by Q. Aivazian, Geb et al. (2005) using instrumental variable of the ratio of tangible assets to total find that leverage is negatively related to investment of Canadian firms.

Lang, Ofek et al. (1996) find a negative impact of leverage on investment for low Q firms. McConnell and Servaes (1995) divide their sample of firms into three groups based on the stock price to operating earnings per share and find a positive relation between Tobin's Q and leverage among bottom price to earnings ratio and a negative relation between Tobin's Q and leverage for firms with the top group of firms. Ahn, Denis et al. (2006) empirically find a negative impact of leverage on investment for diversified firms with high q.

3. Related literature on the pharmaceutical industry.

Most studies of R&D at firm level are devoted to a specific country, the majority to the US. Cross-country difference in capital markets and institutional organizations complicate uniform consideration of liquidity constraints. For example, Agrawal (1999, p.105) found that a large market for pharmaceuticals is associated with larger R&D expenditures in developed countries, but this relationship is not statistically

significant for developing country firms. In this regard, this study focused on OECD countries, which are more homogeneous.

Scherer (2007, p.39-40) noticed that in times of high abnormal profits, firms increase R&D to obtain larger share of these virtuous rents, but competition over these rents eventually reduce the rents with a subsequent decrease in R&D. Higher profits from innovations increase the incentives for rivals to create substitutes in the form of 'me-too' drugs, which are similar in drug mechanism, but sufficiently different to not infringe the original drug patent. A patent does not fully protect the profit of the innovator from imitative destruction, and it does force the firm to disclose a lot of information about drug structure and therapy.

Competition in pharmaceutical markets is often dynamic due to the introduction of new technology and substitutive new or generic products. Philipson and Dai (2003, p.46) estimated that competition with newly patented drugs in the US reduces net present value of the original drug sales similarly or even greater than entry of drugs after patent expiration. According to Gassmann et al, (2008, p.16), the first entrant in respect to a class of drug usually takes a market share of 40-60%, the second entrant captures around 15%, whilst a third might not even recover its costs. Average time for a drug to be under patent protection was about 11 years in 2005 (PhRMA, 2008, p.2) and firms naturally try to maximize their return during this period. According to Bartfai and Lees (2006, pp.41-42,197) if a good drug target is found, other companies enter the market with their drugs addressing the same target often within a year. Often drugs that enter the market second or third in a new therapeutic class are chemically superior to the first and will acquire a larger slice of the market than that of the original innovator's drug. It would appear that the first five drugs in a commercially attractive class generate enough returns to at least justify

the costs of their creation, whilst the first three drugs in a therapeutic class are generally quite profitable.

Pisano (2006, pp.142-143) points out that biotechnology companies usually have no actual final products ready - only some research and expectations of future possible sales from the current research succeeds. Information about such research is highly asymmetric and there are no financial standards to disclose and evaluate risks that relate to ongoing research. Pisano concludes new firms in biotechnology are financially constrained and cannot straddle an optimal learning curve, as just a few unsuccessful drug candidates can finish a small firm off.

Although many small firms in innovation-driven sectors may call venture capitalists to raise capital, but firms in the industry might not prefer venture capital due to its high costs. Grabowski and Vernon (2000, p.207) gave the example of a presentation made by the CEO of a biotech to the US House of Representatives for a hearing in 1995. It was stated that a drug project needed to generate a 25-35% annual return in order to attract investments from venture capitalists.

Several empirical studies have been devoted to R&D in the pharmaceutical industry. Hsieh, Mishra et al. (2003) used an IV regression technique and found positive associations between R&D intensity (R&D to firm's revenue) and performance indicators such as net margin, operating margin, sales growth, and Tobin's Q in respect to pharmaceutical and chemical industries. They concluded that (i) the average rate of return from R&D investment operated at a margin of 19%; this is much higher than the average industry specific cost of capital (9% to 11%); (ii) the return on R&D is much higher than the average rate of return from fixed asset investment, which was 4%; (iii) the R&D expenditures effects on a firm's market value is about twice as much the effect of an investment in fixed assets.

Grabowski and Vernon (2000) using data on 11 firms specify an OLS regression of R&D divided by sales as linear function of a contemporaneous index of expected returns to R&D, one year lagged cash flow divided by sales, and a dummy variable for each firm. The index of expected returns was calculated in two ways. Firstly, it is estimated as the total new product sales in the first three years for the whole industry after introduction of new molecular drugs divided by real R&D expenditures. And secondly as the industry profit margin – a weighted average of pre-tax profits divided by sales. Their estimations generate a coefficient before cash flow that is between 0.12 and 0.31. Vernon (2005) later criticized this approach by pointing to the fact that firms have sustainably different profitability levels and heterogeneous expectations. He proposed to replace the industry profit margin with the current period pre-tax profit margin (pre-tax profit to sales) as proxy for expected profitability. Vernon obtained statistically significant result for 14 US firms on a panel dataset over four years using OLS, fixed and random effects panel regressions.

The specification of Grabowski and Vernon might not provide a consistent estimate. Corrections are needed in case of persistence of R&D as OLS estimators are likely to be biased in this case. Hall and Hayashi (1989) empirically found persistency in R&D investment across a number of industries. As pharmaceutical R&D projects usually continue between 8 and 15 years, some persistency of R&D in the industry should be expected. This suggests that dynamic panel models are more appropriate for estimations of impacts of cash flow on R&D.

Hall (2002) suggests using the approach of Griliches and Hausman (1984) in estimating the coefficient for cash flow impact on R&D by removing firm effects with first differencing, and thereafter estimating it with instrumental variables such as t-2 and earlier lags of cash flow. All of which takes place under the assumption that the

R&D transitory component is independently distributed. If the component follows an MA(1) process, one must use $t - 3$ and earlier lags of cash flow as instruments.

Mahlich and Roediger-Schluga (2006) consider a dynamic model that is estimated with systems GMM in regression of R&D spending divided by sales on sales of old and new drugs, the weighted average profit rate of the entire industry, and dummies for expected price regulations, and cash flows in Japan. Their estimations for a panel dataset of Japanese pharmaceutical firms indicate little impact on sales in relation to R&D intensity and heralded a positive coefficient for cash flow in the range of 0.027-0.062.

4. Empirical methods and expected results

Given the endogeneity of many financial indicators and assuming the persistence of R&D for a firm, GMM estimators for dynamic panel regressions are used in the following functional form:

$$Y_{it} = \alpha_i + Y_{it-1}\beta_0 + (CF/K)_{it-1}\beta_1 + (Cash/K)_{it-1}\beta_2 + Q_{it-1}\beta_3 + (Sales/K)_{it-1}\beta_4 + (Debt/Assets)_{it-1}\beta_5 + Risk\beta_6 + \log(Size)_{it}\beta_7 + Mit\mu_1 + Yt\mu_2 + Cc\mu_2 + \epsilon_{it}$$

where Y_{it} is either ratio of R&D or physical investment to total assets of firm i at time t ; K – total assets of a firm; CF – cash flow; Q – Tobin's Q as proxied by market-to-book ratio; $Sales$ are total sales; $Debt$ - total liabilities and debt; $Size$ – a variable to control for a firm's size as proxied either by logarithm of the number of employees or logarithm of total assets, which could control for economies of scale and greater market information available on larger firms; Cc – country dummies; Yt – year dummies; ϵ_{it} - white noise. $Risk$ is logarithm of ratio of a firm's highest stock price

to its lowest stock price in a year, which is an indicator used in finance literature as a proxy for market volatility of a firm's assets. High volatility of a firm stock's price could be a signal for creditors of higher risks and, hence, they could demand higher risk premiums, which enforce dependence of the firm finance on internal cash flows. Bulan (2005) emphasises market uncertainty as a factor that depresses firm investment. **Cash** – cash and cash equivalent holdings, which can be a useful regressor as used by Almeida, Campello et al. (2004), who find that financially constrained firms save more cash from their own cash flows.

The **Mit** term includes country specific time varying macroeconomic factors based on the World Bank World Development Indicators 2009 (available online):

- *regquality* – regulatory quality in a country, percentile rank of the country from the World Bank Governance Indicators for 1996-2007, available at www.govindicators.org;
- *crtoprivate* - domestic credit to private sector (percent of GDP), which reflects availability of external capital;
- *population* – total population to account for the market size.

Controlling for a financial development indicator is important and credit to the private sector is the relevant indicator but suffers a few missing data. Love (2003) using an Euler-equation based model and cross-sectional data for 40 countries shows that the sensitivity of investment to cash flow decreases with financial market development as the latter relaxes the financing constraints on investment.

Based on the literature review, I expect the coefficients for cash flow to be positive. This relationship should be statistically significant for young and small pharmaceutical firms. The coefficients for debt and risk must be negative. Carpenter and Petersen (2002, f59) argue that “for high-tech firms, the limited collateral value of

assets, together with adverse selection, moral hazard, and financial distress should cause the marginal cost of debt to increase rapidly with leverage”. Higher volatility in stock prices creates additional risks for a firm to invest and to spend on R&D with a negative effect.

Right hand side variables are largely simultaneous with sales and a consistent estimation of the coefficients in this dynamic panel specification can be performed with an Arellano and Bond (1991) differenced GMM method and the system GMM method of Blundell and Bond (1998), under the assumption that ε_{it} are independent across firms. I use a lagged dependent variable as the GMM instrument to tackle this problem and the full set of year dummies as IV instruments. Implementation of the estimations is performed with Stata software using the `xtabond2` program command as developed by Roodman (2006).

Bond (2002) explains that a within group estimator is often biased downwards in panel data with small time periods, whereas the OLS levels estimator is biased upwards in large samples and this can be used to estimate the possible range for a parameter. A consistent estimation can be performed with a GMM method, which uses moment conditions $E[Z_i' \Delta \varepsilon_i] = 0$, where Z_i is an instrument matrix with lagged values of $Y_{i,T-k}$, k - a time lag that provides no correlation with the error term, k is equal to or greater than two. For example, if ε_{it} is a moving average process of order one, MA(1), then Y_{it-2} cannot be a valid instrument, but Y_{it-3} and longer lags are still valid. If explanatory variables X_{it} are correlated with ε_{it} , lags of X_{it-k} are also valid instruments and must be included into the matrix Z of instruments.

Two-step GMM estimates consistently the first difference residuals $\Delta \varepsilon_i$ and then minimizes a weighted distance of the first difference residuals from regression. If residuals ε_i are homoskedastic, a consistent estimation can be obtained in the one step

computing of a weight matrix. Blundell, Bond et al. (2000) have shown with simulations that a two-step estimator often has little efficiency gains in comparison to a one-step method, the former also tends to exaggerate t-ratios. Xtbond2 uses Windmeijer (2005) finite sample corrections for covariance matrix that address this problem for the two-step estimator. I use the dependent variable lagged at t-2, t-3 and further lags as the GMM instrument, and year dummies are used as IV instruments.

The system GMM combines the moment conditions for the first difference model with level moments and has less bias if the series is close to a random walk as ΔY_{iT-k} is often a good instrument for Y_{iT-k} (Blundell and Bond, 1998). I use both difference and system GMM.

5. The data.

Firm level indicators have been extracted from an OrbisTM dataset of financial indicators for pharmaceutical companies in fifteen OECD countries (table 1).

Table 1. Percent of observations in the dataset by countries

Country	Frequency	Share, percent	Cumulative
Austria	2	0.28	0.28
Belgium	7	0.97	1.25
Denmark	20	2.78	4.03
Finland	4	0.56	4.59
France	14	1.95	6.54
Germany	73	10.15	16.69
Ireland	7	0.97	17.66
Italy	1	0.14	17.80
Japan	164	22.81	40.61
Netherlands	9	1.25	41.86
Norway	2	0.28	42.14
Sweden	14	1.95	44.09
Switzerland	16	2.23	46.31
United Kingdom	69	9.60	55.91
USA	317	44.09	100.00

I use an unbalanced panel data of quoted pharmaceutical firms from fifteen countries for the period 1997-2007. The value variables are in euro adjusted by annual exchange rates. Majority of data come from Japanese and American companies.

Almost all variables are scaled by total assets for every firm. Definitions of the variables (table 2):

totas – total assets in national currencies; **ltotase** – logarithm of total assets converted in euro by average exchange rate; **inta** – ratio of investment to total assets; **cashta** – ratio of cash and cash equivalent holdings to total assets; **cashflta** – ratio of cash flow to total assets; **saleta** – ratio of sales to total assets; **nsalet** – ratio of net sales to total assets; **debta** – ratio of total liabilities and debt to total assets; **ltanfase** – logarithm of tangible fixed assets in euro; **tanfixase** – tangible fixed assets in euro; **rdasn** – ratio of R&D expenditures to total assets, which characterizes R&D intensity; **age** – age of firm estimated as difference between a current year and the year of incorporation; **risk** – logarithm of ratio of a firm's highest stock price to its lowest stock price in a year; **employs** – number of employees in a firm; **lemp** – logarithm of the number of employees in a firm; **pbookr** – price-to-book ratio of a firm's assets, a proxy for the average Tobin's Q.

One percent of tails in the distributions of R&D to assets, growth of sales, cash flow to assets, and price-to-book ratio were cut off to exclude dominant influence of outliers. The median share of R&D and investment in cash flows of firms is 0.464, but standard deviation is 2.33. This suggests that roughly half of a firm's cash flows were spent on R&D and investment, mostly on R&D.

The data have some persistency and most of the variance comes between groups. Many firms are multiproduct companies with different technological cycles

and it must be understood that the company level aggregate financial indicators being used here cannot capture individual products.

Table 2. Descriptive statistics of firms' indicators.

Variable	Panel	Mean	Std. dev.	Minimum	Maximum	Observations
inta	overall	.0639	.1091	2.63e-07	.9883	4055
	between		.0989	3.62e-06	.9691	714
	within		.0551	-.5958	.5832	5.6793
cashta	overall	.1839	.2438	4.16e-07	.9714	16313
	between		.2269	1.45e-06	.9689	2465
	within		.1044	-.4399	.9299	6.6178
cashflta	overall	.0049	.2242	-1.2383	.4513	14532
	between		.2106	-1.1164	.4068	2215
	within		.1199	-1.0131	.8388	6.5607
saleta	overall	1.1692	1.0817	5.86e-07	6.2672	13678
	between		1.0538	.00007	5.9051	2135
	within		.3414	-2.3329	4.8879	6.4066
lemp	overall	5.8961	1.9485	0	12.7367	12722
	between		1.9038	0	12.6411	2224
	within		.4636	-1.0971	9.9586	5.7203
debta	overall	.4514	.3385	.00008	3.5381	8032
	between		.2845	.00073	2.9651	1166
	within		.2220	-1.1724	2.8529	6.8885
ltanfase	overall	10.1891	3.2741	-.1210	19.5284	10954
	between		3.1848	.2043	19.3151	1505
	within		.8892	2.7058	19.2125	7.27841
ltotase	overall	12.4585	2.8830	-.1210	24.3176	11796
	between		2.7530	.3830	24.3176	1606
	within		.8895	1.7462	21.7461	7.3450
rdasn	overall	.1826	.2539	-1.8645	-.000018	4924
	between		.2160	-1.7536	-.0000461	751
	within		.1558	-1.5352	.6548776	6.5565
risk	overall	.6437	1.3142	-9.7910	11.2396	5699
	between		1.1808	-7.7619	5.4404	1053
	within		.5076	-2.9865	8.7977	5.4122
employs	overall	2888.207	13642.27	1	340000	12722
	between		10629.73	1	309400	2224
	within		2013.901	-39104.1	63479.92	5.72032
pbookr	overall	3.7067	4.2071	.14	33.08	5007
	between		3.5043	.17	28.01	965
	within		2.6501	-11.8399	25.3510	5.1886
regquality	overall	77.7270	23.2909	14.15	100	29190
	between		22.8768	20.9227	99.3336	2656
	within		4.3654	39.5507	112.2616	10.9902
crtoprivate	overall	111.9615	53.9842	2.457	326.983	25648
	between		51.1962	12.9717	199.6446	2607
	within		16.3080	24.8478	301.0619	9.8381
population	overall	2.62e+08	4.07e+08	43000	1.31e+09	26220
	between		4.06e+08	44500	1.27e+09	2631
	within		1.36e+07	1.88e+08	3.32e+08	9.9658

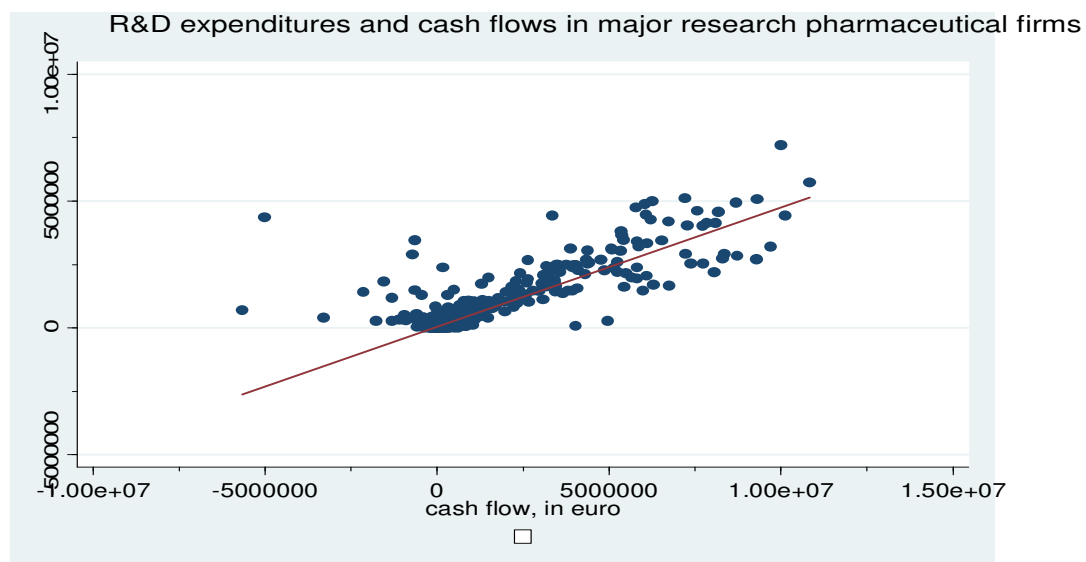
Accounting policy may vary across firms and countries, for example, to optimize local taxes and depreciation allowances, but most accounting standards are similar across those fifteen countries. I assume that accounting practice in the countries have not dramatically changed over the considered period.

Correlation between cash flow and R&D expenditures scaled by total assets is 0.78 across all firms in the sample (table 3). This correlation can be seen on graph 1, which shows likely linear dependence between R&D expenditures in absolute terms and cash flow in euro for major pharmaceutical firms in Europe, Japan, and USA.

Table 3. Correlation between major regressors

	rdasn	inta	cashflta	cashta	saleta	pbookr	debta	lemp	risk	ltotase
rdasn	1.00									
inta	-0.08	1.00								
cashflta	0.78	-0.10	1.00							
cashta	-0.60	0.04	-0.57	1.00						
saleta	0.40	-0.28	0.55	-0.62	1.00					
pbookr	-0.28	-0.02	-0.09	0.17	-0.02	1.00				
debta	0.10	-0.30	0.09	-0.37	0.37	0.29	1.00			
lemp	0.46	-0.19	0.59	-0.60	0.49	0.00	0.40	1.00		
risk	-0.26	0.01	-0.35	0.30	-0.29	0.11	-0.06	-0.33	1.00	
ltotase	0.41	-0.06	0.51	-0.43	0.26	-0.03	0.24	0.78	-0.24	1.00

Graph 1. R&D expenditures and cash flow of pharmaceutical firms, in euro



6. Empirical results

6.1. Impact of liquidity constraints on R&D. The same specification was used to estimate the coefficients with robust standard deviations by four methods: pooled cluster OLS, panel within estimator, difference and system GMM (table 4).

Table 4. Regression results for R&D intensity in the global industry

	Pooled cluster OLS	Panel within estimator	Difference GMM	System GMM
R&D to assets, <i>rdasn</i> at t-1	.1453*** (.0310)	.0482 (.0328)	-.0202 (.0458)	-.0050 (.0439)
Cash flow to assets, <i>cashflta</i>	.3741*** (.0300)	.3391*** (.0280)	.5572*** (.1488)	.5592*** (.1426)
Cash to assets, <i>cashta</i>	-.0656*** (.0200)	.0061 (.0239)	.6894* (.3794)	.7103* (.3783)
Sales to assets, <i>saleta</i>	-.0706*** (.0192)	-.1363 (.0211)	-.2028 (.1976)	-.1508 (.1840)
Price-to-book ratio, <i>pbookr</i>	-.0032*** (.0012)	-.0025** (.0012)	.0079 (.0079)	.0130 (.0092)
Debt to assets, <i>debtat</i>	-.0047 (.0218)	-.0309 (.0248)	-.1305 (.2010)	-.1011 (.2460)
Logarithm of number of employs, <i>lemp</i>	-.0015 (.0026)	-.0135* (.0081)	.1319 (.1189)	.1363** (.0670)
<i>Risk</i>	-.0075* (.0038)	-.0084 (.0043)	.0494 (.0483)	.0385 (.0458)
Regulatory quality, <i>regquality</i>	-.0005 (.0005)	-.0008* (.0004)	-.0339* (.0188)	-.0223* (.0123)
Credit to private sector, <i>crtoprivate</i> at t-1	-.00006 (.0003)	.00006 (.0003)	.0002 (.0047)	.0002 (.0025)
<i>Population</i> , at t-1	-1.03e-09 (7.49e-10)	-1.17e-09 (7.43e-10)	-4.23e-09 (1.55e-08)	-1.14e-09 (1.00e-09)
Intercept	.1762*** (.0604)	.4085*** (.1515)		1.0311 (.7789)
Year and country dummies are included				
Arellano-Bond test AR(1)			0.018	0.008
Arellano-Bond test AR(2)			0.868	0.513
Sargan test of overid. restrictions, p-value			0.591	0.056
Hansen test of overid. restrictions, p-value			0.966	0.995
Difference-in-Hansen tests of exogeneity of instrument subsets, p-value			0.870	0.955
Difference test of exogenous instruments			0.953	0.995
Wald chi2 or F-test	29697.66	15.68	95.89	137.7
R2 (within)	0.32	0.38		
Number of firms	482	482	415	482
Number of observations	2125	2125	1555	2125

Note: t-statistics are shown in parentheses. Significance levels in a two-tailed test:
*** at the 1%, 0.01 level, ** - 5%, * - 10%.

I fail to reject the null of Sargan test of overidentifying restrictions that the error term in the first-differenced equations is orthogonal to the instrument. Both

Sargan and Hansen tests for overidentified restrictions indicate the orthogonality conditions of the difference GMM estimator failed to be rejected, which implies that the instruments are likely to be valid and not correlated with the errors. However, the Sargan test p-value for the system GMM estimations reject the null, but coefficients for the regressors are quite close to the difference GMM estimations. Wald and F statistics reject the null hypothesis of joint insignificance of the coefficients.

The Arellano-Bond test for AR(1) in first differences, I reject the null of no serial correlations in errors, but failed to reject it for the second order AR(2) correlations, which confirms validity of the instruments. Because first-differencing introduces an MA(1) error, failure to reject the presence of second-order serial correlation AR(2) in the first-differenced residuals suggest in favour of a proper specification.

Cash flow to assets shows positive and significant coefficients in all four estimations, which herald the cash sensitivity of R&D. The coefficient suggests that an additional Euro of cash flow increases R&D to about 56 Euro cents. The elasticity point estimation at the median value of the R&D expenditures, cash flows, and assets in the sample shows that 10% growth of cash flow leads to 3.6% growth in R&D expenditures.

Pharmaceutical companies with higher cash holdings are likely to spend more on R&D too, but causality might be reversed: companies planning significant R&D projects tend to accumulate larger cash holding. Coefficients for regulatory quality suggest negative relationship with R&D to assets, which can be explained by stringency of regulations that can discourage R&D or, perhaps, a large part of R&D expenditures on ‘me-too’ drug projects that do not provide much therapeutically advancement.

Because it is empirically hard to identify firms with liquidity constraints (Moyen 2004), I use several criteria for such identification and estimate the cash flow coefficients for every definition of cash constraint firms. I check cash flow sensitivity of R&D for the following likely financially constraint firms using difference GMM estimations (table 5):

- 1) for small firms with 100 or less employees as small firms are usually less known to outside investors;
- 2) for large firms with 500 and more employees, which tend to be established businesses;
- 3) excluding firm-years with negative cash flows as negative cash flows could be a sign of accelerating expenditures or financial distress;
- 4) firms with Tobin's q less than one as proxied by price-to-book ratio, which imply firm-years with low investment opportunities;
- 5) for young firms with age of fifteen or less years old;
- 6) for firms with bottom half of the dividends to after tax income payout ratio, which is less than 0.144.

The sensitivity of R&D to cash flow is higher for smaller firms (0.75) than for all firms (0.56), whereas the cash flow sensitivity for large firms is becoming statistically insignificant. For larger firms debt burden appear to play more negative role in their R&D decisions. If we exclude firms with negative cash flows, the sensitivity of R&D to cash flow is still statistically significant, but much smaller (0.27).

Firms with low investment prospects as proxied by less than one price-to-book ratio also have reduced sensitivity of their R&D to cash flow. Young firms have higher sensitivity of R&D to cash flow. Young firms have significant sensitivity of their R&D to price-to-book ratio and they seem to finance their R&D with debt while

having a negative relationship of R&D with the number of employees, sales, and cash holdings.

Table 5. Difference GMM estimations for different subsets of firm-years

	1	2	3	4	5	6
R&D to assets, <i>rdasn</i> at t-1	.0294 (.0787)	-.1002 (.0785)	-.0081 (.0600)	-.0533 (.1052)	.4353*** (.0619)	-.0389 (.1818)
Cash flow to assets, <i>cashflta</i>	.7482*** (.1944)	.1407 (.1169)	.2749*** (.0554)	.3732* (.1967)	.7052*** (.1098)	.0936* (.0548)
Cash to assets, <i>cashta</i>	.7860 (.4906)	-.0625 (.0927)	.0953 (.0734)	.0132 (.1436)	-.2055*** (.0535)	-.1075 (.1163)
Sales to assets, <i>saleta</i>	-.5636 (.3570)	-.1454 (.1083)	.0100 (.0780)	-.1890 (.1915)	-.5457*** (.1034)	-.0485 (.0442)
Price-to-book ratio, <i>pbookr</i>	.0180 (.0173)	-.0045 (.0034)	-.0034 (.0029)	.0210 (.0180)	.0226*** (.0051)	-.0013 (.0022)
Debt to assets, <i>debtat</i>	-.2430 (.3788)	-.1517** (.0653)	.0306 (.0536)	-.3473 (.3948)	.2424*** (.0851)	-.0189 (.0446)
Logarithm of number of employees, <i>lemp</i>	.1476 (.1637)	.0020 (.0371)	-.0012 (.0531)	.1184 (.1779)	-.3521*** (.1192)	.0339* (.0189)
<i>Risk</i>	.0278 (.0639)	-.0081 (.0198)	.0163 (.0193)	.0105 (.0295)	-.0137 (.0086)	-.0207 (.0150)
Regulatory quality, <i>regquality</i>	.0234 (.0806)	-.0017 (.0049)	.0005 (.0023)	.0172 (.0136)	.0039 (.0035)	-.0014 (.0022)
Credit to private sector, <i>crtoprivate</i> at t-1	.0066 (.0172)	-.0001 (.0011)	-.0005 (.0012)	.0043 (.0046)	.0024 (.0018)	.0003 (.0012)
<i>Population</i> , at t-1	-4.1e-8 (5.4e-8)	-2.3e-9 (4.3e-9)	9.0e-10 (6.2e-9)	-1.0e-8 (2.7e-8)	4.0e-9*** (1.4e-9)	-1.6e-9 (4.0e-9)
Arellano-Bond test AR(1)	0.088	0.051	0.073	0.246	0.243	0.246
Arellano-Bond test AR(2)	0.302	0.822	0.332	0.248	0.500	0.958
Sargan test of overid. restrictions, p-value	0.982	0.000	0.408	0.575	0.937	0.167
Hansen test of overid. restrictions, p-value	0.927	0.775	0.736	0.577	1.000	0.329
Difference-in-Hansen tests of exogeneity of instrument subsets, p-value	0.934	0.599	0.590	0.454	1.000	0.278
Difference test of exogenous instruments	0.573	0.836	0.713	0.616	0.999	0.445
Wald chi2 or F-test	89.84	34.61	63.14	86.78	7537	337.7
Number of firms	125	171	258	131	19	34
Number of observations	308	678	871	243	37	95

Note: R&D to assets is the dependent variable. Numbers at the top heading of the table corresponds to the liquidity constraint identifications used.

t-statistics are shown in parentheses. Significance levels in a two-tailed test:

*** at the 1%, 0.01 level, ** - 5%, * - 10%.

This is a typical situation for biotech start ups. Cash constraint firms with lower dividend payout ratio tend to spend much less out of cash flow on R&D, which suggests that such firms have a poorer business performance.

6.2. Impact of liquidity constraints on physical investment.

Mean physical investment to assets ratio is just 6.4% and cash flow indicators may not be as important to R&D for such small investment. The median share of property, plant and equipment in a pharmaceutical company's assets is just 19.8% and seems to play only a minor role. Cash flow seems do not play an important role in physical investment decisions; although price-to-book ratio and number of employers tend to positively affect investment (table 6).

Table 6. Investment regression results.

	Pooled cluster OLS	Panel within estimator	Difference GMM	System GMM
Investment to assets, <i>inta</i> at t-1	.4707*** (.0958)	.0189 (.0799)	-.1945* (.1070)	.0936 (.2742)
Cash flow to assets, <i>cashflta</i>	-.0072 (.0232)	.0501* (.0267)	-.1013 (.1386)	-.0856 (.2803)
Cash to assets, <i>cashta</i>	-.1225*** (.0313)	-.2499*** (.0469)	-.2701 (.2023)	-.6830 (.8335)
Sales to assets, <i>saleta</i>	-.0255*** (.0097)	-.0354*** (.0132)	-.0971 (.1144)	-.2374 (.6183)
Price-to-book ratio, <i>pbookr</i>	.0022** (.0011)	.0003** (.0011)	.0142** (.0056)	.0129 (.0254)
Debt to assets, <i>debta</i>	-.0929*** (.0252)	-.0847** (.0375)	-.2133 (.1636)	-.6675 (1.5439)
Logarithm of number of employs, <i>lemp</i>	-.0026 (.0021)	-.0221** (.0099)	.1134* (.0678)	.1362 (.1758)
<i>Risk</i>	-.0009 (.0030)	-.0032 (.0040)	.0339 (.0280)	-.0450 (.0824)
Regulatory quality, <i>regquality</i>	-.0002 (.0006)	.0001 (.0007)	.0022 (.0073)	.0097 (.0250)
Credit to private sector, <i>crtoprivate</i> at t-1	-.0002 (.0002)	-.0001 (.0002)	.0028 (.0025)	.0063 (.0089)
<i>Population</i> , at t-1	-2.01e-09 (1.03e-09)	-4.1e-9*** (1.2e-9)	-1.51e-08** (7.36e-09)	7.13e-10 (3.19e-08)
Intercept	.8036** (.3333)	1.1101*** (.2807)		-4.6227 (16.1188)
Year and country dummies are included			0.051	0.503
Arellano-Bond test AR(1)			0.377	0.925
Arellano-Bond test AR(2)			0.542	0.431
Sargan test of overid. restrictions, p-value			0.908	0.818
Hansen test of overid. restrictions, p-value			0.930	0.110
Difference-in-Hansen tests of exogeneity of instrument subsets, p-value			0.512	1.000
Difference test of exogenous instruments	3.05e+07	4.36	98.29	17.21
Wald chi2 or F-test	0.08	0.23		
R2 (within)	222	222	173	222
Number of firms	914	914	667	914

Note: t-statistics are shown in parentheses. Significance levels in a two-tailed test: *** at the 1%, ** - 5%, * - 10%.

This suggests a principal difference between more risky and uncertain R&D projects versus physical investment in the industry: R&D is likely to be dependent on the availability of internal finance in form of cash flow.

Conclusion.

This paper expands previous country focused studies of liquidity constraints for R&D, investment and growth of firms by (i) considering several hundred firms from OECD countries, (ii) using dynamic panel specification with a number of liquidity constraint indicators, (iii) controlling for country specific institutional and financial environments. Cash flow has a positive effect of firms R&D in the sample and across several subsamples of definitions for the likely financially constrained firms. The estimated point elasticity of R&D to cash flow is 0.36 at median values and this effect is more significant for young firms and firms with less than 500 employees. Firms with low investment prospects as proxied by less than one price-to-book ratio or by lower dividend payout ratio have lower sensitivity of their R&D to cash flow.

Pharmaceutical companies with higher cash holdings are likely to spend more on R&D too, but causality might be reversed: companies planning significant R&D projects tend to accumulate larger cash holding. The uncovered negative relationship of regulatory quality with R&D to assets is likely to be explained by higher risks of R&D due to stringency of regulations as most European countries and Japan employ cost-containment controls to limit pharmaceutical expenditures. Cash flow seems do not play important role in physical investment decisions; although price-to-book ratio and number of employers tend to positively affect investment.

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