The Effects of Future Capital Investment and R&D Expenditures on Firms' Liquidity

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Abstract

The paper explores factors that lead to accumulation or decumulation of firms' cash reserves. In particular, we empirically examine whether additional future fixed capital and R&D investment expenditures induce firms to change their liquidity ratio while considering the role of market imperfections. Implementing a dynamic framework on a panel of US, UK and German firms, we find that firms in all three countries make larger adjustments to cash holdings when they plan additional future R&D rather than fixed capital investment expenditures. This behavior is particularly prevalent among financially constrained firms. (JEL Classification Numbers: G31, G32)

Key words: cash holdings, fixed investment, R&D investment, dynamic panel regression

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1. Introduction

It is important to understand why firms hold substantial amounts of cash, which earns little or no interest, rather than channeling those funds towards capital investment projects or as dividends to shareholders. In an environment with no market imperfections, firms can tap into financial markets costlessly and need not hold cash (Keynes, John Maynard (1936)) as cash has a zero net present investment value (Modigliani, Franco & Miller, Merton (1958)). However, in the presence of financial frictions, firms do not undertake all positive net present value projects, but rather choose to save funds for transactions or precautionary motives. In that sense, firms facing market imperfections must choose their level of liquidity at each point in time while taking into account current and future business opportunities.

In this paper we empirically examine the changes in firms' cash holdings, focusing on the effects of future investment expenditures on the accumulation or decumulation of firms' cash reserves. Although we are not the first to investigate how firms' investment expenditures affect their cash holding behavior, our study differs from the rest of the literature on several grounds. An inspection of the literature shows that researchers have recognized the significance of current and future investment plans for liquidity management, yet there seems to be little consensus on how to capture those effects. For instance, some researchers use current investment expenditures or reported investment plans, while others use Tobin's Q to proxy future investment opportunities of the firm. However, all of these strategies have their drawbacks, as we later discuss. In this paper, we examine the effect of one-period-ahead additional investment expenditures on firms' liquidity management behavior. We reason that a rational manager who plans to expand her firm's investment in the next period would take measures to improve the liquid assets of the company so that the project could be realized despite the potential effects of external or internal financial constraints. In such circumstances we should observe that firm's cash holdings will increase.

Our second objective is to examine which type of future investment, fixed capital *versus* R&D expenditures, would lead to a higher accumulation of cash buffer stocks. We conjecture that an increase in future R&D expenditures will require firms to increase their cash holdings by more than that of fixed capital expenditures. Our reasoning, similar to that of the earlier

literature including Brown, James R. & Petersen, Bruce C. (2011), Hall, Bronwyn H. & Lerner, Josh (2009), Bates, Thomas W. et al. (2009), and Opler, Tim C. & Titman, Sheridan (1994), can be explained as follows. In contrast to fixed capital investment, R&D investment contributes to the stock of intangible capital and cannot be used as collateral. Thus, firms undergoing large R&D expenditures do not have the financial flexibility of firms that mainly invest in physical capital, as the latter firms may pledge their fixed investment as collateral. As most of a firm's R&D capital stock is represented by human capital, it would be much more difficult to temporarily reduce R&D expenditures without losing much of the specialized human capital to other companies.[1] Therefore, companies that have carried out sizable R&D activities are more likely to face greater obstacles in accessing external financing in comparison to those firms that have largely invested in pledgeable physical or financial assets. In the presence of financial frictions, this will require firms to hoard more cash should they plan to increase their R&D expenditures. Another reason linking expansion in R&D activities to those firms' increase in cash holdings is the fact that R&D expenditures have a lengthy and highly uncertain payback.

Some studies in the literature have considered the impact of R&D and fixed investment expenditures along with several potential firm-specific variables which may also affect firms' cash holding behavior. In particular, Bates, Thomas W. et al. (2009) examine why cash holdings of US firms increased. They suggest that the precautionary demand for cash can plausibly explain the secular increase in cash holdings, and show that firms whose R&D expenditures increase hold more cash, while cash is generally negatively correlated with fixed capital investment. An earlier, influential study by Opler, Tim et al. (1999) also implies that firms' cash holdings increase significantly as their capital expenditures-to-assets ratio as well as their R&D-to-sales ratio increases. In contrast to these studies' findings, Brown, James R. & Petersen, Bruce C. (2011) investigate the factors that affect firms' R&D expenditures and show that in order to smooth their R&D activities, firms build up their cash reserves when cash flow is available while drawing them down when cash flow is reduced.[2] In this context, our study is closer to those of Bates, Thomas W. et al. (2009) and Opler, Tim et al. (1999). However, we investigate firms' cash holding behavior in a dynamic setting as we evaluate the impact of firms' future investment activities on this process, and we deal with issues

of endogeneity that are not addressed in those studies. Hence, our work complements the prior literature, as we show that accumulation of cash holdings is related to firms' future investment activities, but is most sensitive to planned R&D activities. These implications are forthcoming from the analytical findings of Almeida, Heitor et al. (2011), who present several propositions for firms' choice of liquid vs. illiquid investments, and safe vs. risky assets in the context of future financing constraints.

To test the hypothesis that future fixed capital and R&D investment expenditures have an impact on firms' cash holdings, we use large panels of quoted manufacturing firms obtained from Global COMPUSTAT for the US, UK and Germany over the 1989–2007 period. We employ the Dynamic Panel Data System-GMM estimator of Blundell, Richard & Bond, Stephen R. (1998) to allow for the possible endogeneity of the explanatory variables. Our approach considers how changes in future investment expenditures may lead to changes in firms' current cash holdings.[3] In estimating our models, we take into account firm-level fixed effects and time effects as well as other firm-specific factors. As the impact of additional investment expenditures may differ across categories of firms due to the presence of financial frictions, we report results for two sample categorizations based on firms' size and their dividend status.

Our analysis provides evidence that firms increase their cash holdings by a larger amount when they incur additional future R&D expenditures than in the case of future fixed capital investment. Scrutinizing the data in more detail, we find that this behavior is particularly prevalent among the so-called 'financially constrained' firms (firms that are small in size or pay no dividends) that are heavily involved in R&D activities. Also, similar to the earlier literature, we show that the cash flow sensitivity of cash is higher for constrained firms with respect to their unconstrained counterparts. Robustness checks support our findings.

Section 2 reviews the literature. Section 3 presents the model and describes our data. Section 4 provides the empirical results and Section 5 concludes.

2. Literature Review

2.1. Determinants of Cash Holdings

Keynes, John Maynard (1936) suggests the transaction costs motive and the precaution-

ary motive are the two major reasons why firms hold cash buffers.[4] To attain a certain level of liquidity, although a firm manager could raise capital by selling assets or issuing new debt or equity, there are significant costs associated with any of these strategies. Bates, Thomas W. et al. (2009) show that over the years, the transactions-based demand for funds declined as both firms and financial intermediaries developed more efficient transactions technologies. However, the precautionary motive, which emphasizes the costs associated with foregone capital investment opportunities due to financial constraints—as well as managers' desire to avoid financial embarrassment in the case of an unexpected shortfall in cash flow—still plays an important role. For instance, many firms have imperfect access to external funds and they cannot borrow sizable sums on short notice, particularly if they experience shortfalls in their cash flow. Furthermore, as firms with weak track records enter the market and experience various firm-specific risks over the business cycle, it would be difficult for firms' managers to successfully raise capital to satisfy their need for liquidity.[5] In such circumstances, even if a lender is willing to extend external credit, it is likely that the premium will be high. Hence, we would observe that firms follow a financial hierarchy, or 'pecking order', as they first tap cheaper internal sources of funds followed by more expensive alternatives in financing their activities (see Myers, Stewart C. (1984) and Myers, Stewart C. & Majluf, Nicholas S. (1984)). Consequently, those firms which are adversely affected by financial frictions would make use of their cash buffer in order to minimize the explicit and implicit costs of liquidity management.

The subsequent empirical literature that builds upon the seminal work of Fazzari, Steven et al. (1988) helps us to appreciate why internal funds for the so-called 'financially constrained' firms is an important determinant of capital or R&D investment behavior. The basic premise in this line of empirical work is to capture the differential impact of cash flow on investment expenditures of firms that are constrained *versus* those that are not. In other words, the focus of attention is placed on the dependence of constrained firms on internally generated funds. Although there are some challenges with respect to the modeling of the problem, the methodology that one uses to categorize firms, or the control variables used in the model, it is widely accepted that financial market frictions adversely affect capital investment expenditures of the constrained firms in comparison to unconstrained firms.[6]

Given the developments in the literature on fixed investment behavior of firms and financial frictions, several researchers implement those methodologies to model firms' liquidity behavior. Kim, Chang-Soo et al. (1998), using a sample of US firms, show that firms facing higher costs of external financing, having more volatile earnings and exhibiting lower returns on assets carry larger stocks of liquid assets. In a similar vein Opler, Tim et al. (1999) provide evidence that small firms and firms with strong growth opportunities and riskier cash flows hold larger amounts of cash.[7] Almeida, Heitor et al. (2004) show that constrained firms have a positive cash flow sensitivity of cash, while unconstrained firms' cash balance adjustments are not systematically related to cash flows. Khurana, Inder K. et al. (2006), using data from several countries, find that the sensitivity of cash holdings to cash flows decreases with financial development. In a related study, Faulkender, Michael & Wang, Rong (2006) present evidence that the value of cash is higher for constrained firms than for unconstrained firms.[8]

2.2. Effects of Expected Investment Opportunities on Liquidity

Although researchers seek to show that firms' cash holdings will be related to their investment opportunities, there is no consensus on how to capture those effects. Researchers (e.g., Opler, Tim et al. (1999)) often incorporate firms' current investment expenditures in empirical models to capture the impact of investment opportunities on cash holding behavior. However, empirical models that use current investment expenditures do not necessarily capture the effect of future investment. To our knowledge, only Lamont, Owen A. (2000)) has used firms' investment plans, which more closely address the notion that capital expenditures are largely determined for a multiperiod horizon. However, data on investment plans are very limited.

Perhaps the most common approach in the literature is the use of Tobin's Q as a measure of future investment opportunities of firms, although there are several problems about this strategy. For instance, Riddick, Leigh A. & Whited, Toni M. (2009), after correcting for measurement error associated with Tobin's Q, estimate negative propensities to save out of cash flow. Almeida, Heitor et al. (2004) replace the standard Q measure in their basic regressions model with the average growth of investment over two periods to capture the impact of current and future investment opportunities on cash holdings.[9] In a similar vein,

Baum, Christopher F et al. (2009) study firms' leverage decisions by employing not current, but realized future values of the level of capital investment. We follow a similar approach in this study.

While acknowledging the importance of expected investment opportunities, few researchers distinguish how different types of investment affect corporate liquidity. As we have discussed above, fixed capital investment leads to the accumulation of pledgeable assets, whereas investment in R&D may not. We expect that a firm that increases its non-pledgeable investment activities would hold more liquid assets than a similar firm whose assets may readily be pledged as collateral. Notably, Almeida, Heitor & Campello, Murillo (2007) claim that accumulation of pledgeable assets supports more borrowing and hence more capital expenditures.[10] Bates, Thomas W. et al. (2009), implementing a model where they consider firm-specific factors including fixed capital and R&D expenditures, provide evidence that firms that are R&D-intensive hold greater cash buffers against future shocks to cash flows. Opler, Tim et al. (1999) show that cash holdings increase significantly as firms increase their capital expenditures-to-assets ratio as well as when the R&D-to-sales ratio increases. More recently, Brown, James R. & Petersen, Bruce C. (2011) implement dynamic R&D investment models that provide evidence on the importance of cash reserves, particularly for young firms. However, in none of these studies do researchers consider firms' demand for liquidity that arises from *future* investment activities.

In our study, we investigate the impact of two types of firms' future investment activity on the accumulation of cash holdings: R&D investment *versus* investment in physical capital. As discussed in the introduction, the former may be considered as intangible capital investment, which has a substantially higher marginal cost of external financing because of its limited pledgeability. Another reason linking expansion in R&D activities to those firms' increase in cash holdings is the fact that R&D expenditures have a lengthy and highly uncertain payback. A firm which is engaged in R&D activity may not realize any benefit in the near future, and may indeed never receive a meaningful return on that investment. This increases the uncertainty surrounding the firm's cash flows and working capital. As Hall, Bronwyn H. (2002) points out, uncertain returns from R&D investment might lead to greater asymmetric information and more serious problems of moral hazard, rendering

borrowing a costly option.[11] Therefore, one would expect that firms planning to expand their R&D activities would increase their liquid assets in comparison to other firms which only plan to increase their fixed capital.

3. Empirical Implementation

3.1. The Baseline Model

To quantify the motivation for firms' liquid asset holdings, we use a variant of an empirical specification which is often employed in the literature. The main difference in our approach is the introduction of two types of investment, fixed capital and R&D, rather than merely focusing on the role of fixed capital investment. Second, we investigate the effect of changes in investment expenditures rather than the level. In doing so we would like to capture the impact of actual changes in investment patterns on the accumulation or decumulation of cash holdings. If the firm changes either sort of future investment by a sizable amount, we expect to find a concomitant change in the firm's cash holdings.

Our baseline model takes the following form:

$$
\begin{aligned}
\Delta Cash_{it} =\ & \alpha_0 + \alpha_1 \Delta Cash_{i,t-1} + \alpha_2 CashFlow_{it} + \alpha_3 \Delta RD_{i,t+1} \\
& + \alpha_4 \Delta FixInv_{i,t+1} + \alpha_5 \Delta ShortDebt_{it} + \alpha_6 \Delta NWC_{it} \\
& + \mu_i + \tau_t + \epsilon_{it}
\end{aligned}
\tag{1}
$$

where i indexes the firm, t the year, $\Delta Cash$ is a ratio of the change in cash and short term investment to beginning-of-period total assets $((Cash_t - Cash_{t-1})/TA_{t-1})$, and $CashFlow$ is defined as income before extraordinary items plus depreciation, also normalized by total assets. The key coefficients of interest are α_3 and α_4, which determine the response of liquid assets' holdings to changes in *actual future* R&D, ΔRD, and fixed capital investment, $\Delta FixInv$, respectively.[12] Additionally, the decision to hold cash crucially depends on changes in net working capital (ΔNWC) and changes in short term debt ($\Delta ShortDebt$), which could be considered as cash substitutes. These two firm-specific characteristics are also normalized by beginning-of-period total assets (TA_{t-1}). The firm and year-specific effects are denoted by μ and τ, respectively. Finally, ϵ is an idiosyncratic error term.

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We allow for dynamics in the adjustment of cash holdings, as the firm's managers (un-beknownst to the econometrician) may have a multi-year investment plan in place that may imply several years' adjustments to their liquidity ratio. Taking this into account, we believe it is wise to allow the data to indicate whether dynamics in the changes of the liquidity ratio should play a role in the model.

3.2. The Augmented Model

While allowing for differences between R&D and fixed investment's effects on corporate liquidity, Equation (1) does not allow us to explore variations of the cash–future investment sensitivity between financially constrained and unconstrained firms. To investigate this issue as well as the differential impact of cash flow between constrained and unconstrained firms, we specify an extended model in which cash flow and future fixed capital and R&D investment expenditures are interacted with a vector of firm categories.

The first categorization is based on firm size, given the widespread use of size as a proxy for financial constraints in the literature. For each firm, we compute the annual average of their book value of total assets over the full period for which they are observed. We assign the top and bottom quartiles to large and small firms, respectively, while the two intermediate quartiles constitute medium size firms. The second category is dichotomous, considering whether the dividend payout ratio is positive or zero.

Our augmented model takes the form

$$
\begin{aligned}
\Delta Cash_{it} \;=\; & \alpha_0 + \alpha_1 \Delta Cash_{i,t-1} + [CashFlow_{it} \times TYPE_{it}]\,\eta + [\Delta RD_{i,t+1} \times TYPE_{it}]\,\gamma_1 \\
& + \; [\Delta FixInv_{i,t+1} \times TYPE_{it}]\,\gamma_2 + \alpha_5 \Delta ShortDebt_{it} + \alpha_6 \Delta NWC_{it} \qquad (2) \\
& + \; \mu_i + \tau_t + \epsilon_{it}
\end{aligned}
$$

where $TYPE_{it}$ is a vector of dummies capturing one of the categorizations of firms as more or less likely to face financial constraints.

To aid in comparing results across categories, we estimate a single model where we interact the category indicators with cash flow and changes of future investment.[13] This approach allows us to properly conduct a test of coefficients' stability over these categories of firms. This strategy also allows firms to transition among categories, year by year, rather

than categorizing them once and for all.

To estimate equations (1) and (2) we must take into account the endogeneity of financial and investment decisions. In particular, including the lagged dependent variable as an explanatory variable renders a fixed effects estimator biased and inconsistent. To overcome this difficulty previous researchers relied heavily on using various GMM-family estimators (e.g. IV or 2SLS). However, quite often the choice of instruments in those settings requires very careful justification. To address this critique, we employ the Dynamic Panel Data (DPD) estimator that proposes an appropriate set of instruments by construction. All our models are estimated with the two-step GMM-System estimator, which combines equations in differences of the variables with equations in levels of the variables. Individual firm fixed effects are removed by using a first difference transformation.

The reliability of our econometric methodology depends crucially on the validity of the instruments, which can be evaluated with the Sargan–Hansen J test of overidentifying restrictions, asymptotically distributed as χ^2 in the number of restrictions. A rejection of the null hypothesis that instruments are orthogonal to the error process would indicate that the estimates are not consistent. We also present test statistics for second-order serial correlation in the error process. The instrument lag structure for each model has been chosen to ensure that the p-value of the Hansen J statistic is below unity wherever possible. In each of the models presented below, the Hansen J statistic for overidentifying restrictions and the Arellano–Bond AR(2) tests show that our instruments are appropriate and no second order serial correlation is detected, respectively.

3.3. Data

In our empirical investigation we use manufacturing firm-level data extracted from S&P's Global COMPUSTAT database which reports accounting information on large corporations. Although this dataset covers a number of countries, we constrain our investigation to three advanced economies: the US, UK and Germany. In each of these economies manufacturing sector has a significant role—particularly Germany, the world's leading exporter—but in terms of both capital investment and R&D expenditures different sectors are emphasized.

In total, our sample consists of an unbalanced panel of about 32,000 manufacturing

firm-year observations over the period from 1989–2007.[14] Prior to estimating our models we apply a number of sample selection criteria which roughly follow Almeida, Heitor et al. (2004). First, we retain companies which have not undergone substantial changes in their composition during the sample period (e.g., participation in a merger, acquisition or substantial divestment). As these phenomena are not observable in the data, we calculate the growth rate of each firm's total assets and sales, and trim the annual distribution of these growth rates exceeding 100%.Second, we remove all firms that have fewer than three observations over the time span. Third, the top and bottom 1% observations of all firm-specific variables are winsorized. Missing values of R&D expenditures are replaced with zeros. Finally, we drop all those companies that have cash flow-to-assets ratio lower than −0.5 (−50%) for at least three years to remove those companies in financial distress.[15] The screened US sample is the largest and consists of 17,813 observations pertaining to 2,006 companies. The German and UK screened samples consist of 2,306 (352 firms) and 3,202 (505 firms) firm-years' data, respectively. All data items are transferred into US dollars and CPI adjusted.

Descriptive statistics for the firm-year observations entering the analysis are presented in Table 1. As anticipated, there are considerable variations in liquidity ratios across countries. The highest average liquidity ratio (14.4%) is maintained by US companies, while the lowest (8.6%) is found for companies headquartered in Germany. Importantly, Table 1 shows that those US companies that are involved in R&D invest almost as much in R&D as in fixed capital, while UK firms have a smaller R&D to asset ratio and German firms have the smallest. We should also note that German firms maintain the highest fixed investment rates and the highest short-term debt among the three countries.

4. Empirical Results

4.1. The Baseline Model

We start our investigation by implementing a dynamic model (Equation 1) for each country to explore the effects of cash flow, lagged change in cash holding, change in future R&D and fixed capital investment expenditures, and changes in non-cash net working capital and short-term debt ratios on firms' cash holding behavior. Our premise is that cash flow and future R&D and fixed investment expenditures should have positive and significant

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coefficients, with the impact of increases in R&D expenditures greater than that of increases in fixed capital investment expenditures, as explained earlier. The coefficients of changes in the non-cash net working capital and short-term debt ratios are expected to be negative. The impact of R&D expenditures are likely to be most significant for the US firms, as the data show that US firms are more heavily engaged in R&D activities.

It is useful to note that there are many firms in each country's sample that do not report positive R&D spending in any year. If we were attempting to model the firm's decision to carry out R&D, and if so how much to spend, we would have to take that stylized fact into account. In our context, as R&D expenditures only appear on the right side of our estimated equations, the distribution of that variable is not a concern. In fact, we do not consider the level of expenditures, but only its change, $\Delta \text{RD}_{i,t+1}$. In that context, a firm that never carries out R&D and a firm that always spends the same amount on R&D are observationally equivalent. To the extent that zero R&D expenditures are commonly observed—e.g., the median values of R&D spending in Germany and the UK are both zero—our findings of the importance of *future changes* in spending as an important determinant of firms' liquidity adjustments are all the more meaningful.

Table 2 presents the results for the dynamic model given in Equation (1). The change in future fixed investment expenditures is positive for all countries but it is only significant for the US at the five percent level. That is, an increase in fixed investment behavior does not necessarily lead to a significant change in cash holdings. This evidence could be explained by the pledgeability of investments in physical capital. Bester, Helmut (1985) argues that collateral can be used as a signaling mechanism to distinguish between high-risk and low-risk borrowers. In contrast, R&D capital has limited collateral value and it is a riskier type of investment. We expect that those firms that are planning to increase their R&D investment expenditures are likely to accumulate liquid assets to finance this type of investment. We find support for this conjecture. Table 2 provides evidence that the effect of the change in future R&D expenditures leads to a positive and significant increase in liquidity (at the one percent level for the US and Germany and at the five percent level for the UK). This observation implies that firms increase their current cash holdings in anticipation of next period's R&D expenditures. Furthermore, given the results we can say that firms accumulate

more cash for future R&D expenditures than for future fixed investment expenditures, as captured by the relative magnitudes of their coefficients. The tests of equality of $\gamma_{\Delta RD}$ and $\gamma_{\Delta FixInv}$ coefficients yields p-values of less than 0.10, unambiguously rejecting the null of equal coefficients.

In Table 2 the coefficient on the lagged dependent variable for all countries is significant and negative, implying that dynamics of the cash adjustment process are important. Interestingly, our coefficient estimates are very similar to those reported on a firm level by Opler, Tim et al. (1999) from their Eqn. 1, a pure autoregressive model of the change in the cash/assets ratio. They find a median coefficient of -0.242 at the firm level. The table also shows that an increase in cash flow leads to an accumulation of cash for all countries, as its coefficient is positive and significant for all three countries at the 1% level. As earlier research has shown, changes in the non-cash net working capital ratio possess negative and significant coefficients for all countries. Finally, we find that the change in the short-term debt ratio has a negative and significant effect on cash accumulation for UK firms, but an insignificant effect in the US and Germany.

4.2. The Augmented Model

The results given in Tables 3 and 4 present our findings for Equation (2) where we model firms' adjustment of their cash balances for different size and payout categories, respectively. Each table depicts six models (two per country) where columns 1, 3 and 5 only allow the cash flow coefficients to differ across categories. In columns 2, 4 and 6, interactions with R&D and fixed investment are also included, per Equation (2).

4.2.1. Firms' Liquidity and the Role of Firm Size

Table 3 presents our results for Equation (2) for different firm size categories. Comparing results from this table with that of Table 2, we see that the lagged dependent variable and the changes in non-cash net working capital ratios have similar significance and effects on firms' adjustments of their liquidity. Our results show that small firms contribute to their liquidity more than their larger counterparts do as their cash flow increases. In line with earlier research, cash flow has a small and insignificant effect on large firms' liquidity behavior across all three countries. Although the differences between these effects' magnitudes across

size categories are generally not statistically significant, the point estimates clearly suggest the greater importance of cash flow for smaller firms.

Having examined the impact of cash flow across different size categories, we next consider the effects of R&D and fixed capital expenditure on the liquidity behavior of firms as firm size is allowed to change for the same set of models. Columns 1, 3, and 5 of the table show that future capital investment expenditures affect US firms' liquidity at the one percent level while the effect is insignificant for the other countries. In contrast, future change in R&D affects liquidity in all three countries positively and significantly: at the five percent level for US firms and the ten percent level for UK and German firms.

We next allow the impact of the change in R&D and fixed investment to differ across different categories along with the effect of cash flow. Inspecting the results given in columns 2, 4 and 6, we see that only US small firms' liquidity responds to an increase in future capital investment expenditures. When we consider the effects of future R&D expenditures, we find that small firms' future R&D expenditures have a significant and large impact on firms' liquidity, yet we find no such effect for medium or large firms. This means that medium and large firms do not significantly increase their liquidity in response to an increase in future R&D expenditures. Financially constrained firms tend to save more in comparison to unconstrained firms, with future R&D expenditures emerging as an important factor that induces firms to adjust their cash holdings.

4.2.2. Firms' Liquidity and Dividend Status

Table 4 presents our regression results when we investigate firms' liquidity behavior comparing dividend-paying with non-dividend-paying firms. In all models, the coefficient of the lagged dependent variable is negative and significant, indicating that dynamics play an important role in this relationship. The significance and sign of changes in the non-cash net working capital and short-term debt ratios are unchanged: non-cash net working capital is negative and significant for US and UK firms but insignificant for German firms, while the short-term debt ratio is negative for all cases but significant only for UK firms (see column 5). When we inspect the effect of cash flow for dividend-paying *versus* non-dividend-paying firms, we see that non-dividend-paying US firms increase their liquidity significantly in com-

parison to their dividend-paying counterparts. For the case of German and UK firms we find no difference across dividend paying and non-dividend paying firms, as an increase in their cash flow leads to an increase in their liquidity.

Next we concentrate on the effects of fixed capital investment and R&D expenditures. In contrast to the results presented in Table 3, when we categorize the firms between dividend-paying and non-dividend paying firms, we see no differential effect of future fixed investment expenditures on either type of firms' liquidity behavior. However, when we inspect the impact of an increase in future R&D expenditures, we see that non-dividend-paying firms augment their liquidity, while dividend-paying firms do not significantly change their liquidity behavior. This pattern holds for firms in all three economies, supporting the claim that an increase in future R&D expenditures leads to an increase in financially constrained firms' liquidity.

4.2.3. Robustness checks and a general discussion

The augmented model presented in Tables 3 and 4 constrains some of the coefficients (e.g., that of the lagged dependent variable, $\Delta Cash_{t-1}$) to a single value for different size classes and dividend categories. This makes it possible to perform formal tests of coefficient variation across categories in the context of a single equation. Nevertheless, one may suspect that equations fit separately to each category might exhibit different dynamic behavior. To evaluate the robustness of our findings, we estimate separate equations for the whole sample and four subsamples (small and large firms, and each dividend category) of US firms. We also include the lagged ratio of new equity issuance to total assets in the model to investigate whether funds raised from equity issuance will impact firms' cash accumulation behavior along the lines suggested by Kim, Woojin & Weisbach, Michael. S. (2008).[16] In general, the results obtained from the full sample and the subsamples, which are available from the authors, provide support for our earlier findings.

5. Conclusions

In this paper we empirically examine the factors that affect the accumulation or decumulation of cash reserves of firms using data from three advanced economies: the US, UK and Germany. Our investigation specifically considers the impact of future fixed capital and

R&D expenditures on firms' liquidity behavior. Although one can expect that an increase in either type of investment will lead to an improvement in firms' cash holdings, we conjecture that the effect of R&D expenditures on firms' cash holdings should be stronger based on the observation that R&D investment leads to accumulation of intangible assets and yields highly uncertain returns. As a result, asymmetric information problems weigh more heavily in the case of R&D investment in comparison to investment in fixed capital, rendering R&D activity more dependent on internal financial resources.

To carry out our investigation, we use panels of quoted manufacturing firms obtained from Global COMPUSTAT for the US, UK and Germany over 1989–2007. The empirical models implement a dynamic framework to allow the adjustment of cash balances to reflect the many unobserved factors that may be associated with firms' multi-year investment plans for both fixed capital and R&D expenditures. We also consider the impact of market imperfections resulting in financial constraints by categorizing firms based on size, dividend payout ratio and dividend status. Our analysis reveals that firms in each country augment their cash holdings more vigorously in response to additional future R&D expenditures than they do for increases in future fixed capital investment. Scrutinizing the data in more detail, we find that this behavior is particularly prominent among firms more likely to be financially constrained: small or those who do not pay dividends. In line with the earlier literature, we also show that point estimates of the cash flow sensitivity of cash is higher for constrained firms with respect to their larger counterparts in all three countries. The results for US firms are robust to the inclusion of new equity issuance as a source of cash.

From the policy perspective, one cannot underestimate the importance of technology-producing mechanisms for knowledge-based economies. Our study reveals that companies that plan to increase their R&D activities would increase their cash buffers, implying their need for internally generated funds. This observation holds for all countries in our dataset. In that sense, our findings are unique in light of previous studies, which have not shown such diverse and significant effects. In particular we show that future R&D investment has an economically significant effect on firms' liquidity behavior, and that this effect is much larger than that related to future fixed investment. Robustness checks support these findings and our hypotheses relating to the severity of financial frictions.

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Notes

[1]As Hall, Bronwyn H. & Lerner, Josh (2009) stress (p. 5), a multi-year purchase of machinery could be rescheduled in the face of financial exigencies, but it would be much more difficult to temporarily reduce R&D expenditures. They indicate that this is perhaps the most important distinguishing characteristic of R&D investment, and leads to firms smoothing R&D spending over time to retain their skilled human capital.

[2]Brown, James R. & Petersen, Bruce C. (2011) do not investigate firms' cash accumulation, but rather consider the role of changes in cash holdings required to smooth their R&D expenditures.

[3]Bates, Thomas W. et al. (2009) consider models of the level and change in the cash ratio. However, their reliance on OLS in a context with several plausibly endogenous regressors, including capital spending and R&D expenditures, may cast doubt on their results.

[4]Keynes, John Maynard (1936) also considers that firms may accumulate cash for speculative purposes. Bates, Thomas W. et al. (2009) discuss two other possible motives based on taxes and agency costs. Jensen, Michael C. (1986) argues that entrenched managers prefer to hoard cash, rather than pay dividends, if the firm has poor investment opportunities.

[5]See Campbell et al. (2001), Fama, Eugene F. & French, Kenneth R. (2004) and Irvine, Paul J. & Pontiff, Jeffrey (2009).

[6]See Kaplan, Steven N. & Zingales, Luigi (1997), and Fazzari, Steven M. et al. (2000) for more along these lines.

[7]Pinkowitz, Lee & Williamson, Rohan (2001) report similar findings for firms in Germany and Japan.

[8]There is also active research that relates the value of cash to corporate governance. For instance Dittmar, Amy & Mahrt–Smith, Jan (2007) and Harford, Jarrad et al. (2008) present evidence that cash has lower value for firms with weak shareholder rights, pointing out the presence of agency problems. Ozkan, Aydin & Ozkan, Neslihan (2004), using a panel of UK firms, show that there is a non-monotonic relationship between managerial ownership and cash holdings.

[9]Time zero investment opportunities are measured as $(I_2 + I_1)/(2I_0)$.

[10]Almeida, Heitor & Campello, Murillo (2007) define tangibility as a function of receivables, inventories and capital stock. They also use a proxy to measure how easily lenders can liquidate the firm and another proxy based on product type (durable/nondurable) of each firm.

[11]Also see Brown, James R. & Petersen, Bruce C. (2011), Bates, Thomas W. et al. (2009) and Opler, Tim C. & Titman, Sheridan (1994).

[12]We define $\Delta RD_{t+1} = (RD_{t+1} - RD_t)/TA_t$ and $\Delta FixInv_{t+1} = (Inv_{t+1} - Inv_t)/TA_t$.

[13]As a robustness check, Section 4.2.3 presents a set of regressions which we carry out for separate categories. Regression results obtained from this investigation provide further support for our main hypothesis.

[14]A firm is considered in the manufacturing sector if its two-digit US Standard Industrial Classification (SIC) code is in the 20–39 range. The database provides this code for non-US firms as well.

[15]In total, 104 firms have been removed.

[16]We cannot carry out this exercise for the UK and German subsamples as information on new equity issuance is only available for US companies.

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Table 1: Descriptive statistics: All firms, 1989–2007

Panel A: US

Variable	μ	σ	Median	N
Cash	0.144	0.176	0.070	17,813
Cash Flow	0.067	0.127	0.089	17,813
R&D	0.048	0.077	0.019	17,813
Fixed Investment	0.052	0.041	0.042	17,813
Short Term Debt	0.024	0.054	0.000	17,813

Panel B: Germany

Variable	μ	σ	Median	N
Cash	0.086	0.101	0.049	2,306
Cash Flow	0.080	0.096	0.087	2,306
R&D	0.013	0.035	0.000	2,306
Fixed Investment	0.068	0.049	0.058	2,306
Short Term Debt	0.109	0.111	0.068	2,306

Panel C: UK

Variable	μ	σ	Median	N
Cash	0.113	0.134	0.071	3,202
Cash Flow	0.077	0.119	0.097	3,202
R&D	0.020	0.054	0.000	3,202
Fixed Investment	0.060	0.044	0.051	3,202
Short Term Debt	0.073	0.083	0.045	3,202

Note: All figures are calculated as ratios to the firm's total assets. μ and σ represent mean and standard deviation respectively. N is the number of firm-years.

Table 2: Robust two-step GMM estimates of $\Delta Cash$

	US	Germany	UK
	(1)	(2)	(3)
ΔCash_{t-1}	-0.089**	-0.195***	-0.207***
	(0.038)	(0.049)	(0.071)
Cash Flow$_t$	0.246***	0.269***	0.126**
	(0.039)	(0.055)	(0.055)
ΔRD_{t+1}	0.671***	0.511***	0.856**
	(0.184)	(0.190)	(0.404)
ΔFix. Investment$_{t+1}$	0.219**	0.088	0.056
	(0.107)	(0.072)	(0.164)
ΔNWC_t	-0.247***	-0.121***	-0.323***
	(0.063)	(0.044)	(0.100)
ΔShort Term Debt$_t$	-0.100	0.008	-0.326***
	(0.090)	(0.065)	(0.102)
Firm-years	17,813	2,306	3,202
Firms	2,006	352	505
Instruments	335	391	237
J	337.669	312.251	213.486
J pvalue	0.162	0.987	0.536
AR(2) pvalue	0.251	0.238	0.705
Test $\gamma_{\Delta RD} = \gamma_{\Delta FixInv}$, pvalue	0.040	0.033	0.064

Notes: Two-step GMM-SYS estimates of $\Delta Cash$ are reported with robust standard errors in parentheses. Time fixed effects and a constant term are included in all specifications. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Robust two-step GMM estimates of $\Delta Cash$: Firm Size interactions

	US		Germany		UK	
	(1)	(2)	(3)	(4)	(5)	(6)
ΔCash_{t-1}	-0.071*	-0.098**	-0.165**	-0.133**	-0.233***	-0.203***
	(0.043)	(0.042)	(0.065)	(0.059)	(0.059)	(0.076)
Small $\times$ CF$_t$	0.209***	0.191***	0.185*	0.202***	0.142***	0.185**
	(0.045)	(0.047)	(0.097)	(0.065)	(0.051)	(0.073)
Medium $\times$ CF$_t$	0.171***	0.152***	0.126**	0.183***	0.209***	0.249***
	(0.039)	(0.055)	(0.060)	(0.055)	(0.072)	(0.081)
Large $\times$ CF$_t$	0.076	0.027	0.080	0.136**	0.090	0.129
	(0.089)	(0.051)	(0.094)	(0.060)	(0.071)	(0.120)
ΔRD_{t+1}	0.464**		0.371*		0.412*	
	(0.185)		(0.200)		(0.219)	
ΔFix. Investment$_{t+1}$	0.359***		-0.069		-0.017	
	(0.130)		(0.103)		(0.102)	
ΔNWC_t	-0.289***	-0.302***	-0.037	-0.073	-0.316***	-0.349***
	(0.061)	(0.060)	(0.063)	(0.050)	(0.073)	(0.095)
ΔShort Term Debt$_t$	-0.167*	-0.227**	-0.001	0.024	-0.263***	-0.285***
	(0.092)	(0.091)	(0.084)	(0.068)	(0.072)	(0.110)
Small $\times$ ΔRD_{t+1}		0.510**		0.636*		0.889**
		(0.210)		(0.349)		(0.432)
Medium $\times$ ΔRD_{t+1}		0.338		0.080		0.019
		(0.275)		(0.189)		(0.837)
Large $\times$ ΔRD_{t+1}		0.676		-0.028		-0.239
		(0.493)		(0.199)		(0.448)
Small $\times$ ΔFInv_{t+1}		0.346*		-0.003		0.252
		(0.180)		(0.113)		(0.201)
Medium $\times$ ΔFInv_{t+1}		-0.125		0.178		0.223
		(0.158)		(0.111)		(0.198)
Large $\times$ ΔFInv_{t+1}		0.221		0.075		-0.442
		(0.136)		(0.208)		(0.445)
Firm-years	17,813	17,813	2,306	2,306	3,202	3,202
Firms	2,006	2,006	352	352	505	505
Instruments	361	520	194	409	497	209
J	363.345	524.516	171.063	293.772	446.868	161.801
J pvalue	0.155	0.150	0.484	1.000	0.810	0.857
AR(2) pvalue	0.443	0.166	0.414	0.604	0.329	0.631

Notes: Two-step GMM-SYS estimates of $\Delta Cash$ are reported with robust standard errors in parentheses. Time fixed effects and a constant term are included in all specifications. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Robust two-step GMM estimates of $\Delta Cash$: Dividend Status interactions

	US		Germany		UK	
	(1)	(2)	(3)	(4)	(5)	(6)
ΔCash$_{t-1}$	-0.081*	-0.125**	-0.193***	-0.211***	-0.256***	-0.190**
	(0.042)	(0.062)	(0.049)	(0.056)	(0.055)	(0.092)
No Div $\times$ CF$_t$	0.193***	0.191***	0.258***	0.253**	0.214*	0.158*
	(0.038)	(0.048)	(0.091)	(0.112)	(0.122)	(0.094)
Div $\times$ CF$_t$	0.117***	-0.089	0.215***	0.222**	0.167***	0.086
	(0.040)	(0.090)	(0.070)	(0.094)	(0.064)	(0.077)
ΔRD$_{t+1}$	0.533***		0.475**		0.574*	
	(0.177)		(0.192)		(0.333)	
ΔFix. Investment$_{t+1}$	0.217**		0.081		0.039	
	(0.109)		(0.081)		(0.091)	
ΔNWC$_t$	-0.220***	-0.372***	-0.155***	-0.050	-0.404***	-0.248
	(0.057)	(0.113)	(0.050)	(0.046)	(0.079)	(0.178)
ΔShort Term Debt$_t$	-0.134	-0.073	-0.073	-0.030	-0.403***	-0.210
	(0.095)	(0.160)	(0.052)	(0.075)	(0.088)	(0.197)
No Div $\times$ ΔRD$_{t+1}$		0.525**		1.766***		1.115***
		(0.263)		(0.650)		(0.357)
Div $\times$ ΔRD$_{t+1}$		1.018		0.001		-1.576
		(0.643)		(0.306)		(1.182)
No Div $\times$ ΔFInv$_{t+1}$		0.376		-0.501		0.940
		(0.231)		(0.398)		(0.644)
Div $\times$ ΔFInv$_{t+1}$		0.140		0.025		0.260
		(0.205)		(0.085)		(0.182)
Firm-years	17,813	17,813	2,306	2,306	3,202	3,202
Firms	2,006	2,006	352	352	505	505
Instruments	349	174	380	194	334	362
J	353.093	128.674	288.255	150.975	294.859	37.902
J pvalue	0.145	0.884	0.997	0.850	0.749	0.796
AR(2) pvalue	0.300	0.273	0.298	0.236	0.192	0.583

Notes: Two-step GMM-SYS estimates of $\Delta Cash$ are reported with robust standard errors in parentheses. Time fixed effects and a constant term are included in all specifications. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.