1-2013

R&D sensitivity to asset sale proceeds: New evidence on financing constraints and intangible investment

Ginka Borisova
Iowa State University, ginka@iastate.edu

James R. Brown
Iowa State University, jrbrown@iastate.edu

R&D sensitivity to asset sale proceeds: New evidence on financing constraints and intangible investment

Abstract
We examine the intersection between corporate divestitures of tangible assets and investment in intangible capital (R&D) to provide new tests for the impact financing constraints have on real activity. A positive R&D sensitivity to asset sale proceeds indicates binding financing constraints since cash inflows from tangible asset sales are negatively correlated with productivity shocks and not otherwise connected to intangible investment via non-financial channels. Using a variety of estimation approaches, we document a strong, positive link between cash inflows from fixed asset sales and corporate R&D investment, but only among firms most likely facing binding financing constraints. These results offer robust evidence that financing frictions impact the increasingly important yet understudied intangible corporate investments that drive innovative activity, and they highlight a previously unexplored but potentially valuable use of proceeds from fixed asset divestitures.

Keywords
Financing constraints, Corporate divestitures, R&D, Innovation

Disciplines
Business Administration, Management, and Operations | Corporate Finance | Fashion Business | Finance and Financial Management | Management Information Systems

Comments
This is an accepted manuscripts of an article from *Journal of Banking & Finance,* 2013 37(1); 159-173. DOI: 10.1016/j.jbankfin.2012.08.024. Posted with permission.

R&D sensitivity to asset sale proceeds: New evidence on financing constraints and intangible investment[#]

Ginka Borisova[*], James R. Brown

Department of Finance, College of Business, Iowa State University, Ames, IA 50011, USA

This version: August 20, 2012

Abstract

We examine the intersection between corporate divestitures of tangible assets and investment in intangible capital (R&D) to provide new tests for the impact financing constraints have on real activity. A positive R&D sensitivity to asset sale proceeds indicates binding financing constraints since cash inflows from tangible asset sales are negatively correlated with productivity shocks and not otherwise connected to intangible investment via non-financial channels. Using a variety of estimation approaches, we document a strong, positive link between cash inflows from fixed asset sales and corporate R&D investment, but only among firms most likely facing binding financing constraints. These results offer robust evidence that financing frictions impact the increasingly important yet understudied intangible corporate investments that drive innovative activity, and they highlight a previously unexplored but potentially valuable use of proceeds from fixed asset divestitures.

JEL classification: G31; G32
Keywords: Financing constraints; Corporate divestitures; R&D; Innovation

---

* Corresponding author. Tel.: +1 515 294 3709; fax: +1 515 294 3525.
E-mail addresses: ginka@iastate.edu (G. Borisova), jrbrown@iastate.edu (J.R. Brown).

We thank Arnie Cowan, Chris Koehn, Jason Lunn, Bill Megginson, Bruce Petersen, Mark Power, Jun Zhou, and participants at the 2011 Midwest Finance Association and Financial Management Association meetings for helpful comments and suggestions.

1. Introduction

A fundamental concern in modern finance research is evaluating the impact that financing frictions have on real corporate activity. One key challenge facing financing constraint studies is distinguishing financing effects from other explanations that can also generate finance-investment correlations. In particular, several studies raise concerns about the widely used method – pioneered by Fazzari, Hubbard, and Petersen (1988) – of drawing inference about financing constraints from fixed investment-cash flow sensitivities, in part because of the difficulty of adequately controlling for productivity shocks.[1] As a consequence, a number of recent studies use alternative approaches to identify constraints that do not hinge on standard investment-cash flow regressions (e.g., Almeida, Campello, and Weisbach, 2004; Hovakimian and Titman, 2006; Rauh, 2006; Fee, Hadlock, and Pierce, 2009). Although these efforts, taken together, provide strong evidence that financing constraints "matter", they offer limited evidence on the different firm policies most affected by capital market imperfections. Notably, the majority of this literature continues to focus almost exclusively on fixed capital investment, thereby overlooking the effects financing constraints have on other firm activities, some of which are critical to firm- and economy-wide growth and might be even more susceptible to financing difficulties.

In this paper, we make progress on identifying the presence of binding financing constraints, and on understanding how finance affects non-traditional real firm activities, by focusing on both a *source* and *use* of funds ignored in almost all prior studies. Specifically, our primary tests are based on the sensitivity of firm investment in intangible capital (research and

[1] For example, see Kaplan and Zingales (1997), Erickson and Whited (2000), Alti (2003), Moyen (2004), and Chen and Chen (2011). Fazzari, Hubbard, and Petersen (2000) provide a defense of the investment-cash flow methodology, and several studies improve on standard measures of Tobin's Q in order to better control for investment opportunities, including Gilchrist and Himmelberg (1995) and Carpenter and Guariglia (2008).

development (R&D)) to the cash proceeds generated by the sale of tangible fixed assets. This approach builds on the insight in Hovakimian and Titman (2006) that a *fixed investment* response to asset sale proceeds provides relatively clean evidence of financing frictions because asset sale proceeds (unlike cash flow and other financial variables) are not positively associated with investment opportunities. We argue that examining the link between asset sale proceeds and *intangible* investment offers an even stronger test of financing constraints because there is no obvious alternative to a financing channel that connects fixed asset sales and corporate R&D investment. Not only are cash inflows from asset sales negatively correlated with proxies for investment opportunities (*Q* and sales growth) and other financing sources (cash flow and new stock/debt issues), as Hovakimian and Titman (2006) note, but asset sale proceeds are also negatively correlated with both contemporaneous and future investment in R&D. Thus, there appears to be no systematic information about R&D investment opportunities in asset sale proceeds, in which case a positive R&D-asset sales sensitivity cannot readily be dismissed based solely on inadequate demand control. Furthermore, while equipment replacement can potentially rationalize a positive connection between asset sale proceeds and *fixed investment*, there is no corresponding mechanical link between the sale of tangible assets and firm spending on R&D.

In addition to providing a sharper test of binding financing constraints, studying the link between asset sales and R&D offers novel and particularly relevant evidence on where capital market imperfections are likely to have the most important effects in modern firms. Although a vast number of studies apply numerous alternative tests to evaluate how access to finance affects fixed investment[2], empirical evidence on the impact of financing frictions on R&D investment is

[2] A non-exhaustive list of examples includes Fazzari, Hubbard, and Petersen (1988), Bond and Meghir (1994), Gilchrist and Himmelberg (1995), Hubbard, Kashyap, and Whited (1995), Hovakimian and Titman (2006), Rauh (2006), Almeida and Campello (2007), Ağca and Mozumdar (2008), Ascioglu, Hegde, and McDermott (2008),

remarkably limited and the findings are far from conclusive. The lack of attention to R&D is surprising, both because there are strong theoretical reasons to think that intangible investments like R&D are more susceptible to financing difficulties than other types of investment (e.g., Himmelberg and Petersen, 1994; Hall and Lerner, 2010)[3], and because corporate spending on R&D has increased sharply over the past three decades and now substantially exceeds fixed investment in a large fraction of US firms. Figure 1 plots the levels of R&D and fixed investment in our sampled firms. In contrast to the steep rise in R&D expenditures, particularly among younger firms, fixed investment has declined steadily and is now a much less significant use of funds. This shift toward R&D investment indicates that it is increasingly important to look beyond capital expenditures to understand how financing frictions influence real investment decisions in modern firms. Furthermore, R&D is a key input for innovation, an important determinant of productivity growth, and a central feature of the endogenous growth literature (e.g., Romer, 1990; Aghion and Howitt, 1992). Evidence that financing constraints impact corporate R&D spending can therefore provide insights into the causal channels that connect finance and economic growth.

Focusing on the intersection between tangible divestitures and intangible investment is also of interest because there is little direct evidence that firms use asset sales proceeds to support corporate investment. Asset sales can provide valuable (albeit limited) funding for innovative firms facing a high cost of external funds, in part because information asymmetry often contributes to these firms' financing frictions and fixed assets may be easier to value than

---

Guariglia (2008), Carpenter and Guariglia (2008), and Lewellen and Lewellen (2010). Hubbard (1998) and Stein (2003) review portions of this literature.

[3] Notably, R&D projects are difficult to finance with debt because they offer little or no collateral value and often have skewed and highly variable returns (Solt, 1993; Garlappi, 2004). Additionally, information asymmetry associated with R&D investment projects is potentially severe, in part because firms have incentives to maintain secrecy from competitors, increasing the cost of external funds (Kamien and Schwartz, 1978; Myers and Majluf, 1984).

the overall firm. This is not to say that fixed asset sales represent a major source of funding for intangible investment; nor does it suggest that R&D financing considerations are the primary motivation for fixed asset divestitures. Rather, at the margin, firms facing binding financing constraints should *optimally* use some fraction of the cash inflows generated by fixed asset divestitures for value-enhancing investments that would otherwise be foregone due to high financing costs.[4] Although the financing potential from asset sales has long been discussed (e.g., Shleifer and Vishny, 1992; Lang, Poulsen, and Stulz, 1995), and several studies show that divestitures often follow periods when liquidity concerns are pronounced (e.g., Ofek, 1993; Campello, Graham, and Harvey, 2010), we are aware of no evidence linking asset sales and investment in intangible capital.

Our tests are based on a broad sample of Compustat firms between 1980 and 2008. Our investment regressions are in the spirit of Fazzari, Hubbard, and Petersen (1988) and the related literature but differ in three important ways: i) we add cash proceeds from asset sales as a source of finance, ii) we control for the potential confounding impact funds raised from new stock and debt issues have on R&D, and iii) we include changes in net working capital to control for firm efforts to keep R&D smooth by managing liquid assets.[5] We use both instrumental variables regressions employing the generalized method of moments (GMM) estimator and a switching model (estimated via maximum likelihood) that endogenously sorts firms into constrained and

[4] Supporting the plausibility of asset sale proceeds being used for intangible investment, reports from the press suggest that, along with more commonly cited uses such as debt repayment, firms sometimes explicitly point to R&D funding as a use of asset sale proceeds. To cite a couple of examples: "Pharmacia AB will sell all its office and industrial properties in Uppsala and Umea to raise capital for investments in research and development as well as marketing" (Journal of Commerce, Nov. 14, 1988); "MagneTek, Inc. sells drive products business to Yaskawa…Proceeds will be used for R&D, acquisitions, and debt reduction" (PR Newswire, Jan. 29, 2001).

[5] Most spending on R&D consists of wages to skilled labor (e.g., scientists, software developers, and engineers), so cutting R&D often means releasing workers with a great deal of firm-specific knowledge. As a consequence, firms have strong incentives to avoid large swings (particularly large cuts) in R&D spending. See Hall and Lerner (2010) for a more complete discussion of R&D adjustment costs and Brown and Petersen (2011) for recent evidence that firms use reserve stocks of cash to smooth R&D.

unconstrained groups. In each case we find a strong, positive R&D response to cash inflows from asset sales, but *only* in the groups of firms most likely to face binding financing constraints.

Overall, our findings offer strong evidence that capital market frictions have important real effects. In particular, since R&D investment in unconstrained firms is completely insensitive to cash inflows from asset sales, our approach avoids the Kaplan and Zingales (1997) critique of studies that compare the *relative* magnitude of positive investment-finance sensitivities across *all* firms to identify financing constraints. Furthermore, the robust relation we identify between cash proceeds from asset sales and R&D investment in constrained firms is consistent with quantitatively important effects from financing frictions, regardless of whether it is driven by firms specifically choosing to finance R&D via fixed asset sales or by them channeling the additional capital provided via unrelated divestitures into R&D.[6] Thus, there is much less concern in this setting that the simultaneity of the investment and financing decisions will bias the inferences we can make about the *reasons* for a positive finance-investment relation.[7]

Our findings contribute to an emerging literature that looks beyond the intersection of fixed capital investment and internally generated cash flow to evaluate the real consequences of financing constraints.[8] In particular, the evidence on how financing frictions affect R&D

[6] Hovakimian and Titman (2006) make a similar point about the link between asset sale proceeds and new capital spending.

[7] Nonetheless, our main findings are based on an instrumental variables approach that explicitly addresses the potential endogeneity of the asset sale decision.

[8] A number of different approaches have been used to test for financing constraints. Many studies following Fazzari, Hubbard, and Petersen (1988) use *Q*-models of investment to establish a link between fixed investment and cash flow, particularly among firms most likely, *a priori*, to face binding constraints. Bond and Meghir (1994), Hubbard, Kashyap, and Whited (1995), Bond, Elston, Mairesse, and Mulkay (2003), and Guariglia (2008) estimate structural Euler equations and/or error correction models and find evidence consistent with financing constraints in fixed investment for some firms. Almeida, Campello, and Weisbach (2004) focus on the cash flow sensitivity of investment in financial assets (cash reserves). As noted above, Hovakimian and Titman (2006) study the link between asset sales and capital expenditures. Rauh (2006) finds that exogenous variation on internal funds caused by mandatory pension contributions affects corporate investment in fixed capital. Almeida and Campello (2007) introduce a new test for financing constraints based on the idea that asset tangibility impacts the extent to which

consists primarily of a small number of conflicting studies on the R&D-cash flow sensitivity. For example, Hall (1992) and Himmelberg and Petersen (1994) document a positive link between R&D investment and internal cash flow, particularly among smaller firms. More recently, Brown, Fazzari, and Petersen (2009) and Brown and Petersen (2009) find a positive relation between both internal and external equity finance and young-firm R&D spending in the US, and Martinsson (2010) and Brown, Martinsson, and Petersen (2012) document similar connections among new firms in parts of Europe. On the other hand, several studies find that finance is relatively unimportant for R&D, including a recent study by Chen and Chen (2011) that reports no evidence of a significant R&D-cash flow sensitivity in recent years.[9] By considering an internal source of finance not contaminated by demand-side effects, our study offers novel and more conclusive evidence that financing frictions do affect firm investment in R&D.

2. Data and sample characteristics

2.1. Sample construction

To construct the sample, we start with all surviving and non-surviving firms with a US incorporation code and coverage in the Compustat database at any time over 1980-2008. We exclude firms outside of manufacturing (SIC codes 20-39) and services (SIC 73) since most

---

firms can raise external finance to fund additional investment in *tangible* assets and show that their approach is not appropriate for R&D investment. Fee, Hadlock, and Pierce (2009) identify financing constraints by examining the intersection between advertising expenditures by multinational firms and the level of their foreign cash flow.

[9] Bhagat and Welch (1995) and Ryan and Wiggins (2002) actually find some evidence of a *negative* relation between the levels of operating cash flow and R&D investment in US firms. However, they measure cash flow *net* of R&D expenditures (which can be highly negative for R&D intensive firms early in their lifecycle when internally generated cash flows are often insufficient to fully fund their substantial R&D expenses), and they do not control for firm use of external finance which can bias inference about the importance of finance for R&D (Brown, Martinsson, and Petersen, 2012). Rauh (2006) examines R&D when estimating how investment responds to exogenous shocks to internal funds caused by mandatory pension contributions. However, the "natural experiment" approach he employs may not be very informative about financing constraints on R&D because high adjustment costs can limit the R&D response to transitory finance shocks. Indeed, Rauh (2006) finds strong evidence that capital spending responds to cash shortfalls but no evidence of an R&D response.

R&D takes place in these sectors. Our sample, therefore, includes the three-digit SIC high-tech industries (283, 357, 366, 367, 382, 384, and 737) that account for the majority of US R&D (see Brown, Fazzari, and Petersen, 2009). We then eliminate any firm without at least one positive asset sale and four positive R&D observations during the sample period. Most of the eliminated firms do not report *any* information on R&D expenses (i.e., R&D is reported as 'missing' rather than 'zero'). Specifically, across all firms in the industries and time period we study that have at least four years of Compustat data, 27% report no positive R&D observations whatsoever, while only 9% report between one and three years of R&D. Requiring four years of reported R&D expenses is important for our study because: i) our focus on the potential for a positive R&D-asset sale sensitivity is only relevant for firms with active R&D programs, and ii) some of our estimation approaches require both differenced and lagged values of regression variables.[10] Finally, we exclude all firm-years in which merger and acquisition activity accounts for 50% or more of sales and any firm-years in which sales, the book value of assets, or gross property, plant, and equipment are less than or equal to zero. The final sample consists of 3,156 firms and 36,923 firm-year observations. Appendix A contains detailed variable definitions.

2.2. Financial constraint subsamples

We rely on widely used criteria to sort firms into *ex ante* constraint groupings. Our primary *ex ante* constraint split is based on firm age, which follows a number of recent studies (e.g., Brown, Fazzari, and Petersen, 2009; Fee, Hadlock, and Pierce, 2009; Hadlock and Pierce, 2010). As these studies note, age is an especially attractive way to sort firms because it is less

[10] The main results are qualitatively similar if we relax the restriction that requires four R&D observations, insist on at least one "big" asset sale during the period (e.g., at least 1% of the book value of assets), look only at high-tech firms (like Brown, Fazzari, and Petersen, 2009), or focus only on firms in manufacturing (like Hovakimian and Titman, 2006).

endogenous than other commonly used sorting criteria, and there are several reasons to expect that younger firms face more severe financing frictions than older firms. In particular, young firms are more likely to suffer from especially severe information problems and are in a phase of their lifecycle when investment opportunities often exceed internally generated funds. We define firm age as the number of years since the firm first appears in Compustat with a stock price. We then find an average age for each firm over the sample period and classify firms as "young" if their average age is 10 years or less and as "mature" if it is 20 years or more. Additionally, we confirm that our findings are robust to alternative cutoff points, such as considering firms young if their average age is 15 years or less and mature otherwise or sorting firms into young and mature categories based on how their average age compares to the sample median age.

We also sort firms based on size and dividend payout. Our main size split considers firms "small" if their average net sales during the sample period fall in the bottom quartile of sampled firms, and "large" if average sales are in the top quartile. Dividing the sample in this way prevents firms of roughly equivalent sizes (on either side of the median) from being classified in different categories and helps handle the skewed distribution of firm size, where the median sales value is only $83 million. We show that our primary results are similar if we sort based on sample median sales or use assets instead of sales to measure firm size. This approach is based on the idea that smaller firms are more likely to face binding financing constraints than larger firms (e.g., Gilchrist and Himmelberg, 1995; Almeida, Campello, and Weisbach, 2004). Finally, we sort firms based on average payout ratios over the sample period, following the logic in Fazzari, Hubbard, and Petersen (1988) that constrained firms should be less likely to have positive dividends. As with age and size, we explore alternative approaches for identifying constrained (unconstrained) firms, such as the presence of a non-positive (positive) average overall net payout ratio (which accounts for stock issues and buybacks in addition to dividends) or an average dividend payout in the bottom (top) quartile of the sample distribution.

2.3. Descriptive statistics

Table 1 reports descriptive statistics for the full sample and separately for the young and mature subsamples. We provide descriptive statistics for the small/large and low payout/high payout subsamples in Tables B1 and B2, respectively, in Appendix B. These statistics are very similar in all key respects to the young/mature statistics reported in Table 1. All investment and financing variables are scaled by the beginning-of-period book value of total assets, and all ratios are winsorized at the 1% level. Since our sample is comprised entirely of firms with positive R&D spending, R&D values for both young and mature firms are much higher than those reported in studies that examine a broader set of industries and firms (and often set missing R&D values to zero). Young firms have much higher *Q* values (reflecting greater investment opportunities) than their older counterparts. On the financing side, cash flow and stock issues are the most important sources of finance for the firms in our sample. Not surprisingly, cash flow is smaller and stock issues are larger, on average, in the young firms than in the mature firms. New long-term debt issues and changes in net working capital are relatively small for both types of firms. Similarly, the overall level of indebtness (long-term and short-term) is low for both young and mature firms. For all of the firm characteristics in Table 1, the mean values are statistically different between young and mature firms at the 1% level, and the median values are statistically different for all variables except the change in net working capital.

These statistics highlight the potential for young firms to face binding financing constraints. In particular, young firms have substantial R&D investment opportunities relative to internal funds, and they rely, at the margin, on costly external stock issues. In contrast, mature firms have lower *Q* values and appear capable of easily covering annual R&D spending with internally generated cash flows. If so, we expect only the young (constrained) firms to use some fraction of asset sale proceeds for R&D investment. Like Hovakimian and Titman (2006), we do not require that the asset sale meet a minimum size threshold, and as a result our sample includes a number of firm-years with very small values for asset sales. We also treat asset sale proceeds like other sources of finance and focus on the gross proceeds that fixed asset divestitures make available for all investment, rather than the net or residual amount that remains after new spending on fixed capital. The magnitude of these gross cash inflows from asset sales in our sample is similar to that in Hovakimian and Titman (2006) (the average ratios they report are slightly larger because they scale by net fixed assets rather than by total assets). Asset sales are positive (i.e., non-zero) in approximately 42% of all observations (we set asset sale proceeds to zero in years when Compustat reports a missing value). In the years with positive asset sales, the average sale is 1.06% of existing total assets (first column of Table 1) and 18.69% of existing net property, plant, and equipment (not tabulated).[11] Thus, asset sales are not a large source of funds for either young or mature firms, but when R&D-reporting firms sell assets, they often sell a significant fraction of existing fixed assets. Mature firms have larger stocks of fixed assets than young firms and are *more likely* to have positive asset sales (51% of firm-years versus 38% for young firms), ensuring that our tests will not be skewed by a disproportionate lack of asset sales in the groups of firms we classify as 'unconstrained'.

[11] For comparison, in the years with positive asset sales, funds from new debt issues are, on average, 1.53% of existing total assets, and new stock issues generate 5.08% of total assets.

2.4. *Time series changes in R&D and capital spending*

Figure 1 shows how the relative importance of R&D and fixed capital investment changes for the firms in our regression sample during the 1980-2008 period.[12] We plot the average (winsorized) R&D- and capital spending-to-assets ratios separately for young and mature firms.[13] In 1980 capital spending is substantially larger than R&D for both young and mature firms. However, R&D ratios increase sharply during the sample period, while capital spending ratios decline. The increase in R&D spending is particularly pronounced among young firms, and although their R&D intensity declines sharply in 2001 and never fully recovers, the young-firm R&D ratio at the end of the sample period is roughly four times higher than the corresponding fixed investment ratio (0.144 vs. 0.038). For mature firms the increase in R&D intensity is steadier, and by the end of our sample the average R&D ratio is over twice as large as capital spending (0.093 vs. 0.040). In sum, R&D spending is now the primary investment for a large fraction of publicly-traded US firms. Given that the nature of R&D should make it even more susceptible to financing frictions than fixed investment, the evidence in Figure 1 suggests that focusing only on capital expenditures may vastly understate the influence that financing constraints have on investment in modern firms.

[12] By construction our sample only includes firms that report positive R&D expenditures. Thus, the figure shows the relative importance of R&D investment among positive R&D firms. However, the trends are very similar (though the R&D magnitudes are slightly smaller) if we include all listed firms in the manufacturing and services industries during this period. The trends are also similar if we look at median levels rather than averages.

[13] For this figure we want to report information for the full sample of firms, so we classify firms as young for the first fifteen years they appear in Compustat with a stock price and as mature thereafter.

2.5. Correlation coefficients

Table 2 shows the correlation between asset sales, two proxies for growth opportunities (*Q* and sales growth), key financial variables (cash flow and new stock/debt issues), and investment in R&D and fixed capital. The first column shows that funds from asset sales are negatively correlated with the proxies for growth opportunities (consistent with Hovakimian and Titman, 2006), with the financial variables, and, notably, with R&D. Capital spending is the only variable positively correlated with funds from asset sales, perhaps because both fixed assets and the absolute magnitude of asset sales are larger in firms with relatively high capital spending ratios, and because some asset sales are almost surely associated with equipment replacement. The correlations show that by examining the link between asset sales and R&D, we can test for financing constraints and avoid a key critique of studies that focus on investment-finance sensitivities (Fazzari, Hubbard, and Petersen, 1988): namely, that because controls for investment demand are imperfect, a positive link between finance and investment may simply reflect the fact that financial variables contain information about the profitability of investment.

2.6. Alternative sale motivation

Although Table 2 shows negative correlations of asset sales with R&D investment and sales growth, we further examine the changes in R&D and sales following divestitures to confirm that shifts in product demand cannot rationalize a positive relation between R&D and asset sale proceeds in financially constrained firms. One possibility is that unobserved shifts in demand lead constrained firms to simultaneously dispose of tangible assets in unprofitable business lines and increase R&D spending on new product development. In this case we would expect to find larger absolute increases in R&D spending and sales in the years after constrained firms sell assets. The financing constraint explanation, on the other hand, assumes that cash inflows from asset sales allow R&D spending to be higher than it would have otherwise been; in fact, the primary impact of the sale proceeds may be to limit the decline in intangible investment spending. The results in Table 3 show that R&D spending tends to grow *slower* for constrained firms in the years following asset sales – for young firms, R&D growth rates are 3-4% lower (significant at the 1% level) in the first two years following an asset sale than in the years following no divestitures. Similarly, constrained firms (young, small, and low payout) experience lower growth in sales in the years following a divestiture compared to years without an asset sale. We find exactly the same pattern if we examine longer periods (i.e., three, four, and five years) following the asset sale. These results are not consistent with constrained firms systematically selling assets while shifting toward more profitable product development.[14]

3. Empirical approach

3.1. R&D investment regressions

To examine whether R&D investment is sensitive, at the margin, to cash inflows from fixed asset sales we include the cash proceeds from the sale of property, plant, and equipment (AssetSales) in a standard dynamic investment model that includes controls for both investment opportunities and the availability of key sources of R&D financing. Our baseline empirical model takes the following form:

[14] Specifically, our point is not that R&D is unrelated to new product development, but that firms do not appear to be *systematically* switching from tangible production to intangible production in order to capitalize on new growth options. If we have poor controls for R&D profitability, then such switching could potentially generate a positive connection between R&D and asset sale proceeds even in the absence of financing constraints. The evidence in Table 3 is inconsistent with this alternative explanation, as is the fact that we find a positive connection between asset sales and R&D in constrained firms only.

$$RD_{j,t} = \alpha_1 RD_{j,t-1} + \alpha_2 RD^2_{j,t-1} + \alpha_3 Q_{j,t-1} + \alpha_4 AssetSales_{j,t} + \alpha_5 CashFlow_{j,t} + \alpha_6 StkIssues_{j,t} + \alpha_7 DbtIssues_{j,t} + \alpha_8 \Delta NWC_{j,t} + d_t + f_j + \nu_{j,t}, \quad (1)$$

where $RD_{j,t}$ is R&D spending for firm *j* in period *t*. In the baseline specification we control for investment opportunities with the beginning-of-period market-to-book ratio (Tobin's *Q*), but results are similar if we use sales growth instead of *Q*. The other financing sources include current period cash flow, funds from new stock and new debt issues, and the period change in net working capital.[15] While it is standard to include cash flow in regressions of this type, few studies control for the use of external finance and the potential for the stock of working capital to be an important source of R&D finance. However, recent studies show that R&D is sensitive to the funds from stock issues (e.g., Brown, Fazzari, and Petersen, 2009) and that firms actively manage their liquid assets to keep investment smooth in the face of transitory finance shocks (e.g., Fazzari and Petersen, 1993; Brown and Petersen, 2011), suggesting that failure to control for these variables can cause misleading inference about the importance of financing constraints for R&D.[16] In addition, some theoretical critiques of conventional investment-cash flow regressions (e.g., Moyen, 2004) are based on the idea that external finance is correlated with cash flow but omitted from the regression.

Our primary results also include a set of year (d_t) and firm (f_j) fixed effects. The firm effects control for all unobserved time-invariant determinants of R&D at the firm level, such as managerial, technological, and industry characteristics, while the year fixed effects control for

[15] Following Himmelberg and Petersen (1994), we measure cash flow gross of both R&D and capital expenditures. Since R&D is expensed, this entails adding R&D expenses to the standard measure of net cash flow (after-tax income before extraordinary items plus depreciation).
[16] For example, the correlations in Table 2 show that asset sale proceeds are negatively correlated with cash flow, stock issues, and debt issues. Thus, declines in these key financial variables can cause R&D to fall precisely in the years when asset sale proceeds are positive, in which case the primary importance of asset sale funds may be to mitigate the fall in R&D. If so, a regression with no controls for other financing sources will show a negative relation between asset sales and R&D when, in fact, the *ceteris paribus* relation is positive.

any aggregate shocks that might impact the demand for R&D, such as changes in the cost of capital or macroeconomic fluctuations. We show in Section 4.3 that our findings are robust to using industry-specific year effects in place of the aggregate year dummies. In all regressions, standard errors are calculated with clustering at the firm level and are thus robust to within-firm serial correlation.

We include both lagged R&D and lagged R&D-squared in the regression model, consistent with the approach in several studies that model the dynamics of R&D, as reviewed by Hall and Lerner (2010). However, including lagged R&D in a regression with a firm fixed effect introduces the potential for dynamic panel bias in a standard within-firm estimator (Nickell, 1981). We address this concern by using a GMM estimator specifically designed to deal with dynamic panel bias. We report initial results using a difference GMM estimator that first-differences equation (1) to remove the firm fixed effect and then uses lagged levels of the regression variables as instruments for the differenced regression equation (Arellano and Bond, 1991). However, the difference GMM estimator is subject to potentially severe finite-sample biases due to weak instruments when the dependent variable is highly persistent (Blundell and Bond, 1998). Given the highly persistent nature of R&D investment, we thus focus primarily on the results from a system GMM estimator that addresses the weak instrument problems of difference GMM by jointly estimating a regression of equation (1) in differences and in levels, using lagged levels as instruments for the regression in differences and lagged differences as instruments for the regression in levels (Arellano and Bover, 1995; Blundell and Bond, 1998). In addition to addressing dynamic panel bias, this approach also accounts for the simultaneity and potential endogeneity of the financing and investment decisions. Several recent studies use similar approaches to address endogeneity concerns in situations where no obvious external instruments are present (e.g., Beck and Levine, 2004; Guariglia, 2008; Carpenter and Guariglia, 2008; Faulkender, Flannery, Hankins, and Smith, 2011). In addition, by instrumenting with lagged values, this approach provides a tractable yet relatively robust and efficient way to address concerns about measurement error in investment equations like those we estimate (Almeida, Campello, and Galvao, 2010).

3.2. *Endogenous switching regressions*

In addition to using GMM to estimate equation (1) separately for constrained and unconstrained subsamples of firms, we also use an endogenous switching regression following Hovakimian and Titman (2006) and Almeida and Campello (2007). The primary advantage of this approach is that it does not require an *ex ante* split of firms into constrained and unconstrained groupings. Rather, it simultaneously estimates: i) the likelihood that a firm is in constrained or unconstrained regimes based on a vector of firm characteristics, and ii) separate R&D regressions for firms in the different regimes. Both Hovakimian and Titman (2006) and Almeida and Campello (2007) provide detailed discussions of this estimation approach. Briefly, we simultaneously estimate the following set of equations via maximum likelihood:

$$RD_{1j,t} = \beta_1 RD_{j,t-1} + \beta_2 RD^2_{j,t-1} + \beta_3 Q_{j,t-1} + \beta_4 AssetSales_{j,t} + \beta_5 CashFlow_{j,t} + \beta_6 StkIssues_{j,t} + \beta_7 DbtIssues_{j,t} + \beta_8 \Delta NWC_{j,t} + \omega_j + \psi_t + e_{1j,t} \quad (2)$$

$$RD_{2j,t} = \chi_1 RD_{j,t-1} + \chi_2 RD^2_{j,t-1} + \chi_3 Q_{j,t-1} + \chi_4 AssetSales_{j,t} + \chi_5 CashFlow_{j,t} + \chi_6 StkIssues_{j,t} + \chi_7 DbtIssues_{j,t} + \chi_8 \Delta NWC_{j,t} + \omega_j + \psi_t + e_{2j,t} \quad (3)$$

$$y^*_{j,t} = \gamma_1 Q_{j,t-1} + \gamma_2 Age_{j,t-1} + \gamma_3 Size_{j,t-1} + \gamma_4 Cash_{j,t-1} + \gamma_5 StDebt_{j,t-1} + \gamma_6 LtDebt_{j,t-1} + \gamma_7 DivDummy_{j,t-1} + u_{jt}. \quad (4)$$

Equations (2) and (3) allow the determinants of R&D to differ across firms endogenously sorted into constrained and unconstrained regimes. The structural equations mirror the baseline specification in equation (1), and include both firm and year fixed effects (ω_j and ψ_t). Our focus is the potential for asset sales to have a different impact on R&D in constrained firms than in unconstrained firms (i.e., for β_4 to differ from χ_4). Equation (4) is the selection equation that sorts firms into constrained and unconstrained regimes in each period *t*. Unlike the *ex ante* constraint groupings which are based on one firm characteristic, equation (4) uses multiple firm characteristics to determine the likelihood a firm is in the constrained or unconstrained regime. The set of firm characteristics that determines the likelihood of being in one regime or the other is similar to that used by Hovakimian and Titman (2006) and includes both firm size and firm age, which Hadlock and Pierce (2010) find to be especially important predictors of the extent of financing constraints. Actual R&D by firm *j* at time *t* is given by:

$$RD_{j,t} = RD_{1j,t} \text{ if } y^*_{j,t} < 0 \quad (5)$$

$$RD_{j,t} = RD_{2j,t} \text{ if } y^*_{j,t} >= 0,$$

where $y^*_{j,t}$ is a latent variable that measures the likelihood that the firm is in either the first or the second regime in each period.

3.3. *Empirical predictions*

We expect a positive link, at the margin, between funds from asset sales and R&D for firms that face binding financing constraints. It is important to emphasize that the financing constraint hypothesis predicts a positive R&D-asset sales link for constrained firms *only*: unconstrained firms would have no need to use asset sale proceeds for R&D investment. This prediction is valuable for a number of reasons. In particular, to the extent that asset sales have a positive impact on R&D in constrained firms but no impact in unconstrained firms, our tests for the influence of financing frictions bypass the Kaplan and Zingales (1997) critique of drawing inference about financing constraints from the relative magnitude of finance-investment sensitivities.[17] In addition, the absence of investment sensitivity to asset sales in unconstrained firms is not consistent with overinvestment due to agency problems, a commonly proposed alternative to the financing constraint explanation: if overinvestment problems are at play, the positive R&D-asset sales link should be concentrated in large, more mature companies with limited R&D growth opportunities and abundant free cash flow, i.e., the unconstrained firms.

4. Results

4.1. Baseline regressions

Table 4 reports baseline estimates of the sensitivity of R&D investment to cash flows from asset sales using the full sample. In column (1) we pool all firm-year observations and estimate OLS regressions with controls for year fixed effects. In column (2) we estimate a within-firm regression that controls for yearly and firm-specific fixed effects. In each initial regression the coefficient estimate on asset sales is positive and statistically significant, ranging from 0.102 in the within-firm regression to 0.126 in the OLS regression.

The other estimates are consistent with our expectations. In particular, the coefficient on lagged R&D is large and highly significant, showing substantial persistence in R&D spending at the firm level. We do note, however, that the coefficient on lagged R&D falls substantially

[17] Kaplan and Zingales (1997) show that among financially constrained firms it is possible for the firms that face relatively less severe financing frictions to exhibit higher investment-cash flow sensitivities. However, as Bond, Elston, Mairesse, and Mulkay (2003) point out, even in the KZ framework, investment by firms that do not face binding financing constraints is not sensitive to fluctuations in the availability of funds for investment. Bond, Elston, Mairesse, and Mulkay (2003) also note (p. 154) that "Kaplan and Zingales's example is derived in a model with no adjustment costs of any type; to the best of our knowledge, the robustness of their result has not been demonstrated in more realistic settings with adjustment costs or other impediments to capital-stock adjustment."

(from 0.923 to 0.509) when we include the firm fixed effects, which is consistent with the downward bias induced by estimating a dynamic regression with a firm fixed effect (Nickell, 1981). The coefficient on lagged R&D-squared is negative and significant, consistent with both theoretical investment models that include quadratic adjustment cost technologies (e.g., Bond and Meghir, 1994) and other studies that model the dynamics of R&D (e.g., Brown, Fazzari, and Petersen, 2009). *Q* is positively associated with R&D spending, consistent with its role as a proxy for investment opportunities. Cash flow, stock issues, and debt issues generally share a positive link with R&D spending, as expected if firms face binding financing constraints, but also potentially consistent with financial variables containing information about the profitability of investment. Finally, the negative coefficient on changes in net working capital shows that firms use their liquid assets to smooth R&D investment.

In the remainder of Table 4, we report GMM estimates of equation (1). As discussed above, the GMM estimators rely on lagged values of the regressors to deal with both dynamic panel bias and potential endogeneity. Column (3) reports results from difference GMM estimation, where lagged levels of all explanatory variables dated t-3 and t-4 are used as instruments for equation (1) in differences. The coefficient estimate on asset sales remains positive and statistically significant and increases sharply (to 0.495) relative to the OLS and within-firm estimates in columns (1) and (2). In addition, an $m3$ test for third-order autocorrelation in the first-differenced residuals and a Hansen J-test indicate no problems with instrument validity. In column (4) we estimate the same regression, this time including lagged levels dated t-2 in the instrument set for asset sales. The results are very similar to those in column (3), but they improve on two key dimensions: 1) the coefficient estimate on asset sales is more precisely estimated, and 2) the Hansen J-test improves. However, the $m2$ test reported at the bottom of column (4) indicates that we reject the null of no second-order autocorrelation in the first-differenced residuals, in which case lagged levels dated *t*-2 are not valid instruments (Arellano and Bond, 1991). Another cause for concern with both of the difference GMM regressions is that the coefficient on lagged R&D falls substantially *below* the within-firm estimate. As Bond, Elston, Mairesse, and Mulkay (2003) note, this result suggests that the finite-sample biases associated with a persistent dependent variable in difference GMM estimation are of practical importance, since the (unbiased) GMM estimate on the lagged dependent variable should fall between the OLS and within-firm estimates. We therefore turn to system GMM in columns (5) and (6).

Column (5) reports results from system GMM estimation where lagged levels dated *t*-3 to *t*-4 are employed as instruments for equation (1) in differences, and the lagged difference dated *t*-2 is used to instrument equation (1) in levels. Relative to the difference GMM estimates in columns (3) and (4), the coefficient estimate on asset sales increases in both magnitude (to 0.707) and precision. Furthermore, the coefficient estimate on lagged R&D is now 0.895, which lies above the within-firm estimate and indicates substantial persistence in R&D, as expected. In column (6) we adjust the instrument set for asset sales to include lagged levels dated *t*-2 to *t*-4 in the differenced regression and the lagged difference dated *t*-1 in the levels regression. The *m*2 test in column (6) indicates no second-order autocorrelation in the first-differenced residuals and hence no concern with including more recent lags of asset sales in the instrument set.[18] Once again, including more recent lags in the instrument set for asset sales improves both the precision of the estimate on AssetSales_t and the overall Hansen *J*-test, but otherwise does not change any of our inferences.

---

[18] If we use lagged levels starting at *t*-2 for *all* of the regressors, the Hansen test for instrument validity deteriorates considerably, though the coefficient estimates are qualitatively similar.

To get a sense for the economic magnitude of the coefficient estimate on asset sales, we consider the implied impact that an average asset sale has on R&D investment. As discussed above, the average asset sale is approximately 1.06% of existing assets. The estimates in column (6) of Table 4 indicate than such a divestiture would increase the R&D to assets ratio by approximately 0.0072, which equals 6.9% of the sample mean R&D intensity. This economic magnitude is only slightly less than the predicted impact that an average *stock issue* would have on R&D.[19]

We note that, despite the improvement we get in column (6) from using more recent lags to instrument for asset sales, the Hansen *J*-test marginally rejects the null hypothesis that the overidentifying restrictions are valid. Nonetheless, going forward we focus primarily on the estimates using the system GMM approach in column (6) since i) the system GMM estimates explicitly deal with the potential endogeneity of the asset sale decision, ii) these estimates are more efficient and less biased than the difference GMM results, and iii) the tests for instrument validity improve substantially in the alternative samples and approaches we examine further below.[20] As we show below, the inferences we draw from the GMM estimates about the asset sales-R&D connection are unaffected if we follow the approach in Hovakimian and Titman (2006) and use an endogenous switching model that controls for firm fixed effects but that does not otherwise address the potential endogeneity of the asset sale decision.

4.2. Financial constraint subsamples

In Table 5 we split firms based on age, size, and payout ratio and report separate estimates of the asset sales-R&D link for these *ex ante* constraint groupings. We report three

[19] The estimates indicate than an average stock issue would increase R&D intensity by 8.8% of the sample mean.
[20] We thank the referee for encouraging us to focus on the GMM results.

different panels of results, each using a different approach for sorting firms into constrained and unconstrained groups. In each panel, for both the constrained and unconstrained subsamples, we report coefficient estimates from the system GMM method discussed above, standard errors, *p*-values from *m2* and Hansen *J*-tests, and observation counts. Below these, we also report a *p*-value from a test of the null hypothesis that the coefficients on asset sales are equal in the constrained and unconstrained groups.[21]

In the first panel of Table 5, we report results using our primary constraint groupings where firms are considered: i) young (constrained) if their average age is 10 years or less and mature (unconstrained) if it is 20 years or more, ii) small (constrained) if their average sales fall in bottom quartile of the sample and large (unconstrained) if they have sales in the top quartile, and iii) low payout (constrained) if their average dividend payout over the sample period is zero and high payout (unconstrained) if the average ratio is positive. For each approach of sorting firms, we find a positive and statistically significant connection between asset sales and R&D only in the constrained subsamples. The coefficient estimates on asset sales are generally similar across the alternative groups of constrained firms, ranging from 0.679 in the small firm subsample to 0.737 in the young firm subsample. In addition, the final row in Panel 1 shows that coefficient estimates across the constrained and unconstrained groups are statistically different.

In the second panel, we use different definitions of young, small, and low payout to sort firms. Specifically, we consider a firm young if its average age is 15 years or less and mature otherwise; a firm is considered small if its average sales are equal to or fall below the sample median and large if its average sales are above the median; and a firm has a low payout ratio if its average net payout (dividends plus stock buybacks minus stock issues) is non-positive, and

[21] To perform this test we estimate a single regression where all variables are interacted with a dummy variable indicting financial constraint status. We then report the *p*-value from a test that the coefficient on the constrained firm*asset sales interaction is equal to zero.

has a high payout ratio otherwise. As in Panel 1, the coefficient estimates on asset sales are positive and statistically significant in the constrained firm groupings only. Further, none of the coefficient estimates for unconstrained firms are statistically different from zero. We can reject the null that the coefficients across the constrained and unconstrained groups are equal at the 10% and 1% level in the age and payout regressions, respectively, but not in the size regressions. The lack of significance using the median size split is not entirely surprising given the highly skewed distribution of firm size in our sample: since the median sales value is only $83 million, this sample split puts a number of firms that are 'small' by most measures into the unconstrained group.

In the final panel of Table 5, we define a firm as young if its age is at or below the median age of other sampled firms and as mature otherwise; a firm is considered small if its assets are equal to or fall below the median for the sample and large otherwise; and firms are assigned to the low payout ratio group if their average dividend payout falls in the bottom quartile for the sample and to the high payout group if their average dividend payout is in the top quartile. The estimates using these sorting criteria are very similar to the estimates in Panels 1 and 2: the coefficients on $AssetSales_t$ are only statistically significant for the constrained groups and are larger than the corresponding point estimates for the unconstrained groups. Significance tests show that the difference between coefficients is significant at the 5% level for the dividend split and marginally insignificant for the age and size splits.

Taken together, the findings in Table 5 provide important insights into the relation between financing constraints, R&D, and asset sales. First, they show a positive sensitivity of R&D investment to a source of financing uncorrelated with investment opportunities. Second, as expected, the positive R&D-asset sales sensitivity we identify exits *only* in the groups of firms most likely to face binding financing constraints. Thus, we are not basing inference about financing frictions on the monotonicity of positive investment-finance sensitivities across classifications of constrained firms.

4.3. Robustness checks

In Table 6 we report robustness checks of the sample and empirical specification. In each case we report results for the full sample of firms in the column labeled "All", as well as separate results for *ex ante* constraint splits using the age, size, and dividend payout splits we used in Panel 1 of Table 5. First, we use sales growth rather than *Q* to proxy for investment opportunities. This approach addresses the potential concern that our findings are simply an artifact of measurement error in *Q* (Erickson and Whited, 2000).[22] As the results in Panel 1 show, the findings using sales growth are very similar to the results using *Q* reported in Tables 4 and 5. In particular, in the full sample we continue to find a positive and statistically significant connection between asset sale proceeds and firm R&D investment, and for each constraint split this sensitivity exists for constrained firms only. Next, we drop data from years 2007 and 2008 to confirm that our findings are not being unduly influenced by the effects of the recent financial crisis. The results in Panel 2 show that we obtain very similar results if we exclude the crisis years. The only notable change is that we obtain a marginally significant coefficient on asset sales in the mature firm regression, but the magnitude is small (0.166) and statistically different from the much larger young-firm estimate (0.703). Finally, in Panel 3 we control for time-varying investment opportunities at the industry level by including industry-year fixed effects, as in Carpenter and Petersen (2002), Guariglia (2008), and Brown, Fazzari, and Petersen (2009).

[22] Almeida, Campello, and Weisbach (2004) use a similar approach (p. 1979): "One way to check directly whether the use of the standard *Q* measure in the basic regressions is somehow contributing to our empirical findings is to replace it with another proxy relating future and current investment opportunities."

We continue to find a positive, statistically significant connection between asset sales and R&D in the full sample and all of the constrained subsamples, and smaller and statistically insignificant coefficients in all of the unconstrained regressions. Furthermore, in all regressions the coefficient estimates for constrained firms are statistically different from the unconstrained firm at the 5% level or better.

4.4. Endogenous switching regressions

As a final check of robustness, we follow the approach that Hovakimian and Titman (2006) use to evaluate the fixed investment sensitivity to asset sale proceeds. In Table 7 we report the results from an endogenous switching regression that does not rely on any *a priori* classification schemes. In the first two columns, we focus on contemporaneous asset sales as we have done in prior tables. In the last two columns, we follow Hovakimian and Titman (2006) and use the sum of asset sale proceeds over *t*-1 to *t*+1 as the key dependent variable ($\sum AssetSales_{t-1,t,t+1}$). Panel 1 reports separate regression results for the endogenously determined unconstrained and constrained regimes (equations (2) and (3)), while Panel 2 reports the selection regression (equation (4)). For both measures of asset sale proceeds, we find a strong positive link between funds from asset sales and R&D in the constrained regime only, whereas the coefficient estimates on asset sale proceeds in the unconstrained regime is near zero and actually slightly negative. Also, across the board, the other financial variables are more important for the constrained regime than the unconstrained one, and though still statistically significant, the estimates on financial variables for unconstrained firms are quantitatively small.

5. Conclusions

We provide new evidence on the influence financing frictions have on real investment decisions by examining how corporate R&D spending responds to cash inflows generated by the sale of fixed assets. This is a particularly valuable way to evaluate financing constraints because asset sales provide cash that firms facing financing frictions can use to finance investment, yet unlike most financial variables, asset sales are not positively correlated with productivity shocks. As a result, a positive asset sales-R&D link is not simply an artifact of poor controls for investment demand. In addition, while equipment replacement might rationalize a positive link between asset sales and fixed investment spending, it cannot explain such a relation between asset sales and R&D.

We use a variety of specifications and estimation approaches to examine the link between the funds from asset sales and R&D investment. Most importantly, we use *ex ante* firm characteristics and an endogenous switching model to identify financially constrained firms and find a positive asset sales-R&D link *only* in the constrained groups. Thus, any alternative to financing constraints would have to explain why the proceeds from asset sales have a positive impact on R&D spending in constrained firms only. In particular, these findings are not an artifact of measurement error in Q, our approach is not subject to the Kaplan and Zingales (1997) critique of investment-cash flow studies, and our results are not consistent with constrained firms divesting assets and re-focusing because of shifts in consumer demand. Overall, our study provides robust evidence that financing frictions have economically important effects on key corporate investment decisions.

Our study is one of relatively few to test for financing constraints on intangible corporate investment activities. Although fixed investment has received much more attention, there are several reasons to expect that intangible investments like R&D are particularly susceptible to financing difficulties (e.g., information problems and limited collateral value). Yet prior studies that do examine R&D offer mixed and inconclusive evidence, at best, that financing frictions influence firm-level spending on R&D (Hall and Lerner, 2010). Our results clearly indicate that financing constraints impact R&D investment in smaller, younger, and low payout firms. These findings are of particular interest because R&D is an increasingly critical investment and a key input for innovation and productivity growth in modern economies. In this way, our study offers new insights into the causal micro-level mechanisms that link finance and broad measures of economic growth. Our results indicate that financial market developments that mitigate financing constraints would increase R&D investment in growing firms, which should, in turn, spur innovation and lead to higher overall economic growth. These findings also suggest that public policy efforts to foster financial market access by liberalizing capital markets and providing stronger legal protections for outside suppliers of capital can have an especially pronounced effect on innovation and intangible investment. In addition, our findings suggest policies that increase the funds available for intangible investment – such as lower effective corporate tax rates for R&D-intensive firms or government loan guarantees to finance innovative projects – can be growth-enhancing. Such efforts could be especially important for countries with less developed capital markets where financing constraints on R&D are likely especially severe.

We also provide novel evidence that firms use funds from corporate divestitures for new investment spending. Several studies advance a "financing hypothesis" to explain corporate divestitures, but this literature has not considered whether firms use asset sale proceeds to support intangible investments that are particularly susceptible to financing difficulties.

Although funding from divestitures is necessarily limited, the use of cash inflows from asset sales for intangible investment can be valuable because asset sales tend to be negatively correlated with other financing sources and because the information problems that plague R&D-intensive firms need not affect the property they choose to sell (Shleifer and Vishny, 1992). This suggests that fixed asset divestitures may be especially valuable to innovative firms during recessions and other periods when liquidity concerns are particularly pronounced. Furthermore, our findings are also relevant for the literature that studies how companies use the proceeds from asset sell-offs (e.g., Lang, Poulsen, and Stulz, 1995; Borisova, John, and Salotti, 2012). Our study shows that funds from the sale of fixed assets can support a key intangible investment in firms facing binding financing constraints.

Appendix A

Variable definitions (with Compustat variable names in parentheses).

Age_{t-1}: The natural log of the number of years that the company has been publicly traded at the beginning of period t.

$AssetSales_t$: Cash proceeds from sales of property, plant, and equipment (SPPE) in period t divided by beginning of period book value of total assets (AT).

$Capex_t$: Capital expenditures (CAPX) in period t divided by beginning of period book value of total assets.

$Cash_{t-1}$: The level of cash and short-term investments (CHE) at the beginning of period t divided by book value of total assets from the previous period.

$CashFlow_t$: Cash flow in period t divided by beginning of period book value of total assets, where cash flow is defined as (after-tax) income before extraordinary items (IB) plus depreciation and amortization (DP) plus research and development expense (XRD).

$DbtIssues_t$: Net long-term debt issued in period t divided by beginning of period book value of total assets, where net new long-term debt is equal to long-term debt issued (DLTIS) minus long-term debt reduction (DLTR).

Div $dummy_{t-1}$: A binary variable that takes a value of one if the company paid out dividends (DVC) in period t-1, zero otherwise.

Long-term $debt_{t-1}$: Total long-term debt (DLTT) at the beginning of period t divided by book value of total assets from the previous period.

$NetPPE_t$: Net property, plant, and equipment (PPENT) in period t divided by beginning of period book value of total assets.

ΔNWC_t: The change in net working capital between the beginning and end of period t, calculated as the difference between current assets (ACT) and current liabilities (LCT), divided by beginning of period book value of total assets.

Q_{t-1}: Market value of assets divided by book value of total assets in period t-1, where market value of assets is equal to the market value of common shares outstanding (PRCC_F*CSHO) plus the book value of assets (AT) minus the book value of equity (CEQ) minus deferred taxes (DEFTAXB).

$R\&D_t$: Research and development expense (XRD) in period t divided by beginning of period book value of total assets.

$SalesGwth_{t, t-1}$: Log change in net sales (SALE) between period t and t-1.

$Size_{t-1}$: The natural log of the book value of assets in 2005 dollars at the beginning of period t.

Short-term $debt_{t-1}$: Debt in current liabilities (DLC) at the beginning of period t divided by book value of total assets from the previous period.

$StkIssues_t$: Net cash raised from stock issues in period t divided by beginning of period book value of total assets, where net cash from stock issues is equal to the sale of common and preferred stock (SSTK) minus the purchase of common and preferred stock (PRSTKC).

Appendix B

Table B1
Descriptive statistics for small and large firms. The sample is R&D reporting firms in manufacturing (SIC 2000-3999) and services (SIC 7300-7399) with coverage in the Compustat database over 1980-2008. The table shows mean, median, and standard deviation values for the subsamples of small and large firms. A firm is defined as small if its average sales fall in the bottom quartile for the sample, and large if its average sales are in the top quartile. $R\&D_t$ is research and development expense; $AssetSales_t$ represents the funds from positive (non-zero) sales of property, plant, and equipment; Q_t is the ratio of the market and book value of assets, where the market value of assets is calculated as the sum of the market value of equity and book value of assets minus the book value of equity minus deferred taxes; $CashFlow_t$ is the sum of income before extraordinary items, depreciation and amortization, and research and development; $StkIssues_t$ represents the net cash raised from stock issues; $DbtIssues_t$ is net new long-term debt issued; ΔNWC_t is the change in net working capital between the beginning and end of period t, calculated as the difference between current assets and current liabilities; Long-term $debt_t$ is total long-term debt; Short-term $debt_t$ is debt in current liabilities; and $NetPPE_t$ is the property, plant, and equipment in period t. Fraction of positive $AssetSales_t$ is share of firm-year observations with non-zero cash proceeds from sales of property, plant, and equipment. All variables (except Q) are scaled by beginning of period total assets and all ratios are winsorized at the 1st and 99th percentiles.

	Small firms			Large firms			Mean test	Median test
	Mean	Median	St. dev.	Mean	Median	St. dev.	*p*-value	*p*-value
$R\&D_t$	0.2007	0.1174	0.2299	0.0530	0.0308	0.0632	0.000	0.000
$AssetSales_t$	0.0158	0.0030	0.0296	0.0081	0.0040	0.0133	0.000	0.000
Q_t	3.9631	2.3245	4.2110	1.8260	1.4508	1.2962	0.000	0.000
$CashFlow_t$	-0.1294	-0.0051	0.4897	0.1600	0.1470	0.1252	0.000	0.000
$StkIssues_t$	0.2662	0.0069	0.5541	0.0013	0.0000	0.0968	0.000	0.000
$DbtIssues_t$	0.0322	0.0000	0.1700	0.0184	-0.0003	0.1101	0.000	0.000
ΔNWC_t	0.0407	-0.0145	0.5044	0.0281	0.0129	0.1392	0.0158	0.000
Long-term $debt_t$	0.1518	0.0185	0.2957	0.2037	0.1740	0.1860	0.000	0.000
Short-term $debt_t$	0.2295	0.0234	1.5724	0.0471	0.0263	0.0707	0.011	0.000
$NetPPE_t$	0.1828	0.1274	0.1743	0.3184	0.2926	0.1694	0.000	0.000
Fraction of positive $AssetSales_t$		0.2753			0.5019			
Count		6,904			10,292			

Table B2

Descriptive statistics for low and high payout firms. The sample is R&D reporting firms in manufacturing (SIC 2000-3999) and services (SIC 7300-7399) with coverage in the Compustat database over 1980-2008. The table shows mean, median, and standard deviation values for subsamples of low payout and high payout firms. A firm is defined as low payout if its average dividend payout is zero and as high payout otherwise. $R\&D_t$ is research and development expense; $AssetSales_t$ represents the funds from positive (non-zero) sales of property, plant, and equipment; Q_t is the ratio of the market and book value of assets, where the market value of assets is calculated as the sum of the market value of equity and book value of assets minus the book value of equity minus deferred taxes; $CashFlow_t$ is the sum of income before extraordinary items, depreciation and amortization, and research and development; $StkIssues_t$ represents the net cash raised from stock issues; $DbtIssues_t$ is net new long-term debt issued; ΔNWC_t is the change in net working capital between the beginning and end of period t, calculated as the difference between current assets and current liabilities; Long-term $debt_t$ is total long-term debt; Short-term $debt_t$ is debt in current liabilities; and $NetPPE_t$ is the property, plant, and equipment in period t. Fraction of positive $AssetSales_t$ is share of firm-year observations with non-zero cash proceeds from sales of property, plant, and equipment. All variables (except Q) are scaled by beginning of period total assets and all ratios are winsorized at the 1st and 99th percentiles.

	Low payout firms			High payout firms			Mean test	Median test
	Mean	Median	St. dev.	Mean	Median	St. dev.	*p*-value	*p*-value
$R\&D_t$	0.1539	0.1007	0.1775	0.0518	0.0310	0.0645	0.000	0.000
$AssetSales_t$	0.0120	0.0023	0.0247	0.0094	0.0035	0.0176	0.000	0.000
Q_t	2.8974	1.8070	3.1336	1.7046	1.3495	1.2230	0.000	0.000
$CashFlow_t$	0.0276	0.1038	0.3759	0.1453	0.1415	0.1348	0.000	0.000
$StkIssues_t$	0.1569	0.0066	0.4221	0.0097	0.0000	0.1221	0.000	0.000
$DbtIssues_t$	0.0274	0.0000	0.1570	0.0127	-0.0008	0.1081	0.000	0.000
ΔNWC_t	0.0539	0.0099	0.4009	0.0284	0.0151	0.1619	0.000	0.000
Long-term $debt_t$	0.1606	0.0460	0.2662	0.1747	0.1398	0.1837	0.000	0.000
Short-term $debt_t$	0.1290	0.0176	0.9653	0.0541	0.0253	0.0951	0.000	0.000
$NetPPE_t$	0.1990	0.1536	0.1664	0.2940	0.2705	0.1663	0.000	0.000
Fraction of positive $AssetSales_t$		0.3498			0.4936			
Count		19,107			17,801			

References

Ağca, Ş., Mozumdar, A., 2008. The impact of capital market imperfections on investment-cash flow sensitivity. Journal of Banking and Finance 32, 207-216.

Aghion, P., Howitt, P., 1992. A model of growth through creative destruction. Econometrica 60, 323-351.

Almeida, H., Campello, M., 2007. Financial constraints, asset tangibility, and corporate investment. Review of Financial Studies 20, 1429-1460.

Almeida, H., Campello, M., Galvao, A., 2010. Measurement errors in investment equations. Review of Financial Studies 23, 3279-3328.

Almeida, H., Campello, M., Weisbach, M., 2004. The cash flow sensitivity of cash. Journal of Finance 59, 1777-1804.

Alti, A., 2003. How sensitive is investment to cash flow when financing is frictionless? Journal of Finance 58, 707-722.

Arellano, M., Bond, S., 1991. Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. Review of Economic Studies 58, 277-297.

Arellano, M., Bover, O., 1995. Another look at the instrumental variable estimation of error-components models. Journal of Econometrics 68, 29-51.

Ascioglu, A., Hegde, S.P., McDermott, J.B., 2008. Information asymmetry and investment-cash flow sensitivity. Journal of Banking and Finance 32, 1036-1048.

Beck, T., Levine, R., 2004. Stock markets, banks, and growth: Panel evidence. Journal of Banking and Finance 28, 423-442.

Bhagat, S., Welch, I., 1995. Corporate research & development investments: International comparisons. Journal of Accounting and Economics 19, 443-470.

Blundell, R., Bond, S., 1998. Initial conditions and moment restrictions in dynamic panel data models. Journal of Econometrics 87, 115-143.

Bond, S., Elston, J.A., Mairesse, J., Mulkay, B., 2003. Financial factors and investment in Belgium, France, Germany, and the United Kingdom: A comparison using company panel data. Review of Economics and Statistics 85, 153-165.

Bond, S., Meghir, C., 1994. Dynamic investment models and the firm's financial policy. Review of Economic Studies 61, 197-222.

Borisova, G., John, K., Salotti, V., 2012. The value of financing through cross-border asset sales: Shareholder returns and liquidity. Working paper, Iowa State University.

Brown, J., Fazzari, S., Petersen, B., 2009. Financing innovation and growth: Cash flow, external equity, and the 1990s R&D boom. Journal of Finance 64, 151-185.

Brown, J., Martinsson, G., Petersen, B., 2012. Do financing constraints matter for R&D? European Economic Review, forthcoming.

Brown, J., Petersen, B., 2009. Why has the investment-cash flow sensitivity declined so sharply? Rising R&D and equity market developments. Journal of Banking and Finance 33, 971-984.

Brown, J., Petersen, B., 2011. Cash holdings and R&D smoothing. Journal of Corporate Finance, 17, 694-709.

Campello, M., Graham, J.R., Harvey, C.R., 2010. The real effects of financial constraints: Evidence from a financial crisis. Journal of Financial Economics 97, 470-487.

Carpenter, R.E., Guariglia, A., 2008. Cash flow, investment, and investment opportunities: New tests using UK panel data. Journal of Banking and Finance 32, 1894-1906.

Carpenter, R.E., Petersen, B., 2002. Is the growth of small firms constrained by internal finance? Review of Economics and Statistics 84, 298-309.

Chen, H., Chen S., 2011. Investment-cash flow sensitivity cannot be a good measure of financial constraints: Evidence from the time series. Journal of Financial Economics 103, 393-410.

Erickson, T., Whited, T., 2000. Measurement error and the relationship between investment and Q. Journal of Political Economy 108, 1027-1057.

Faulkender, M., Flannery, M.J., Hankins, K.W., Smith, J.M., 2011. Cash flows and leverage adjustments. Journal of Financial Economics 103, 632-646.

Fazzari, S., Hubbard, R., Petersen, B., 1988. Financing constraints and corporate investment. Brookings Papers on Economic Activity 1, 141-195.

Fazzari, S., Hubbard, R., Petersen, B., 2000. Investment-cash flow sensitivities are useful: A comment on Kaplan and Zingales. Quarterly Journal of Economics 115, 695-705.

Fazzari, S.M. and Petersen, B.C., 1993. Working capital and fixed investment: New evidence on financing constraints. Rand Journal of Economics 24, 328-342.

Fee, C., Hadlock, C., Pierce, J., 2009. Investment, financing constraints, and internal capital markets: Evidence from the advertising expenditures of multinational firms. Review of Financial Studies 22, 2361-2392.

Garlappi, L., 2004. Risk premia and preemption in R&D ventures. Journal of Financial and Quantitative Analysis 39, 843-872.

Gilchrist, S., Himmelberg, C., 1995. Evidence on the role of cash flow for investment. Journal of Monetary Economics 36, 541-572.

Guariglia, A., 2008. Internal financial constraints, external financial constraints, and investment choice: Evidence from a panel of UK firms. Journal of Banking and Finance 32, 1795-1809.

Hadlock C., Pierce, J., 2010. New evidence on measuring financial constraints: Moving beyond the KZ index. Review of Financial Studies 23, 1909-1940.

Hall, B.H., 1992. Investment and research and development at the firm level: Does the source of financing matter? Working paper, NBER, Number 4096.

Hall, B.H., Lerner, J., 2010. The financing of R&D and innovation. In: Hall, B.H., Rosenberg, N. (Eds.), Handbook of the Economics of Innovation, Vol. 1. North-Holland, Amsterdam.

Himmelberg, C.P., Petersen, B.C., 1994. R&D and internal finance: A panel study of small firms in high-tech industries. Review of Economics and Statistics 76, 38-51.

Hovakimian, G., Titman, S., 2006. Corporate investment with financial constraints: Sensitivity of investment to funds from voluntary asset sales. Journal of Money Credit and Banking 38, 357-374.

Hubbard, G., 1998. Capital market imperfections and investment. Journal of Economic Literature 36, 193-227.

Hubbard, G., Kashyap, A.K., Whited, T., 1995. Internal finance and firm investment. Journal of Money, Credit and Banking 27, 683-701.

Kamien, M., Schwartz, N., 1978. Self-financing of an R&D project. American Economic Review 68, 252-261.

Kaplan, S., Zingales, L., 1997. Do investment-cash flow sensitivities provide useful measures of financing constraints? Quarterly Journal of Economics 112, 169-215.

Lang, L., Poulsen, A., Stulz, R., 1995. Asset sales, firm performance, and the agency costs of managerial discretion. Journal of Financial Economics 37, 3-37.

Lewellen, J., Lewellen, K., 2010. Investment and cash flow. Working paper, Dartmouth College.

Martinsson, G., 2010. Equity financing and innovation: Is Europe different from the United States? Journal of Banking and Finance 34, 1215-1224.

Moyen, N., 2004. Investment–cash flow sensitivities: Constrained versus unconstrained firms. Journal of Finance 59, 2061-2092.

Myers, S., Majluf, N., 1984. Corporate financing and investment decisions when firms have information that investors do not have. Journal of Financial Economics 13, 187-221.

Nickell, S., 1981. Biases in dynamic models with fixed effects. Econometrica 49, 1417-1426.

Ofek, E., 1993. Capital structure and firm response to poor performance: An empirical analysis. Journal of Financial Economics 34, 3-30.

Rauh, J., 2006. Investment and financing constraints: Evidence from the funding of corporate pension plans. Journal of Finance 59, 33-71.

Romer, P., 1990. Endogenous technological change. Journal of Political Economy 98, S71-S102.

Ryan, H., Wiggins, R.A., 2002. The interactions between R&D investment decisions and compensation policy. Financial Management 31, 5-29.

Shleifer, A., Vishny, R.W., 1992. Liquidation values and debt capacity: A market equilibrium approach. Journal of Finance 47, 1343-1366.

Solt, M.E., 1993. SWORD financing of innovation in the biotechnology industry. Financial Management 22, 173-187.

Stein, J., 2003. Agency, information and corporate investment. In: Constantinides, G.M., Harris, M., Stulz, R. (Eds.), Handbook of the Economics of Finance, Vol. 1A. North-Holland, Amsterdam.

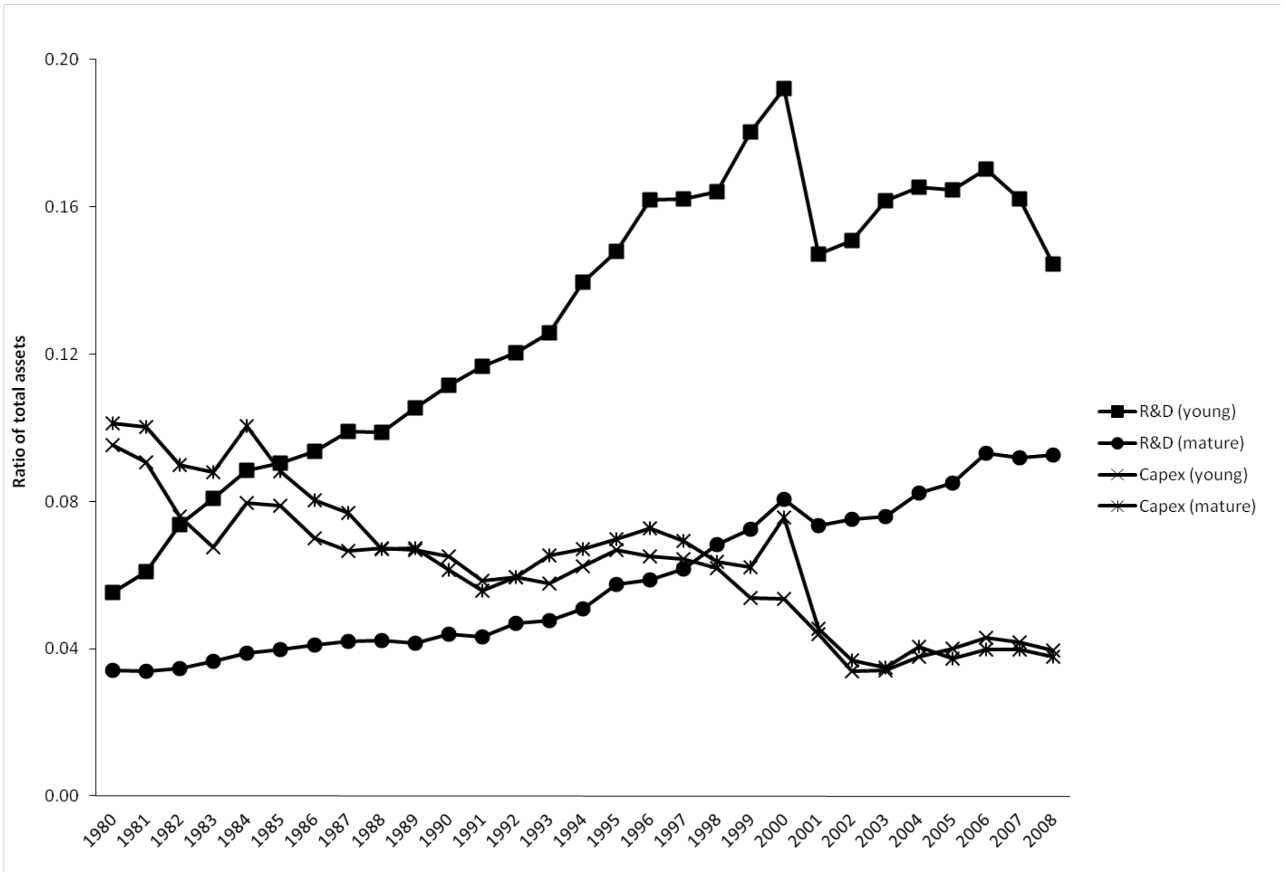

Fig. 1. R&D spending compared to capital expenditures. The figure shows (winsorized) average annual investment in R&D and physical capital for 3,156 publicly traded companies in manufacturing (SIC 2000-3999) and services (SIC 7300-7399) with coverage in Compustat from 1980-2008. All values are scaled by the total assets of the firm. We show spending differences between young and mature firms. Firms are classified as "young" for the first fifteen years they appear in Compustat with a stock price and as "mature" thereafter.

Table 1

Descriptive statistics. The sample is R&D reporting firms in manufacturing (SIC 2000-3999) and services (SIC 7300-7399) with coverage in the Compustat database over 1980-2008. The table shows mean, median, and standard deviation values for the full sample and subsamples of young and mature firms. A firm is defined as young if its average age is 10 years or less, and as mature if it is 20 years or more. $R\&D_t$ is research and development expense; $AssetSales_t$ represents the funds from positive (non-zero) sales of property, plant, and equipment; Q_t is the ratio of the market and book value of assets, where the market value of assets is calculated as the sum of the market value of equity and book value of assets minus the book value of equity minus deferred taxes; $CashFlow_t$ is the sum of income before extraordinary items, depreciation and amortization, and research and development; $StkIssues_t$ represents the net cash raised from stock issues; $DbtIssues_t$ is net new long-term debt issued; ΔNWC_t is the change in net working capital between the beginning and end of period t, calculated as the difference between current assets and current liabilities; Long-term $debt_t$ is total long-term debt; Short-term $debt_t$ is debt in current liabilities; and $NetPPE_t$ is the property, plant, and equipment in period t. Fraction of positive $AssetSales_t$ is share of firm-year observations with non-zero cash proceeds from sales of property, plant, and equipment. All variables (except Q) are scaled by beginning of period total assets and all ratios are winsorized at the 1st and 99th percentiles.

	Full sample			Young firms			Mature firms			Mean test	Median test
	Mean	Median	St. dev.	Mean	Median	St. dev.	Mean	Median	St. dev.	*p*-value	*p*-value
$R\&D_t$	0.1046	0.0569	0.1446	0.1460	0.0924	0.1742	0.0433	0.0277	0.0520	0.000	0.000
$AssetSales_t$	0.0106	0.0031	0.0210	0.0108	0.0020	0.0232	0.0092	0.0041	0.0160	0.000	0.000
Q_t	2.3202	1.5276	2.4793	2.8204	1.8072	2.9761	1.5962	1.3164	1.0280	0.000	0.000
$CashFlow_t$	0.0844	0.1292	0.2921	0.0350	0.1065	0.3659	0.1398	0.1383	0.1112	0.000	0.000
$StkIssues_t$	0.0858	0.0016	0.3238	0.1463	0.0057	0.4073	0.0003	0.0000	0.0824	0.000	0.000
$DbtIssues_t$	0.0203	-0.0002	0.1358	0.0276	0.0000	0.1558	0.0120	-0.0010	0.0986	0.000	0.000
ΔNWC_t	0.0416	0.0135	0.3098	0.0499	0.0094	0.3860	0.0178	0.0114	0.1281	0.000	0.249
Long-term $debt_t$	0.1674	0.0964	0.2302	0.1594	0.0445	0.2619	0.1878	0.1625	0.1728	0.000	0.000
Short-term $debt_t$	0.0929	0.0221	0.6985	0.1184	0.0143	0.9968	0.0568	0.0308	0.1010	0.000	0.000
$NetPPE_t$	0.2448	0.2128	0.1729	0.1989	0.1527	0.1664	0.3176	0.2944	0.1581	0.000	0.000
Fraction of positive $AssetSales_t$		0.4190			0.3849			0.5098			
Count		36,923			16,169			9,926			

Table 2

Correlation coefficients for key variables. The table displays the Pearson correlation coefficients for the full sample described in Table 1. $AssetSales_t$ represents the funds from sales of property, plant, and equipment. Q_{t-1} is the ratio of the market and book value of assets, where the market value of assets is calculated as the sum of the market value of equity and book value of assets minus the book value of equity minus deferred taxes. $SalesGwth_{t,\ t-1}$ is the log change in net sales between period t and t-1. $CashFlow_t$ is the sum of income before extraordinary items, depreciation and amortization, and research and development. $StkIssues_t$ represents the net cash raised from stock issues. $DbtIssues_t$ is net new long-term debt issued. $R\&D_t$ is research and development expense. $Capex_t$ represents capital expenditures. All variables (except Q) are scaled by beginning of period total assets and all ratios are winsorized at the 1^{st} and 99^{th} percentiles. *p*-values of statistical significance of the correlations are presented in parentheses.

	$AssetSales_t$	Q_{t-1}	$SalesGwth_{t,\ t-1}$	$CashFlow_t$	$StkIssues_t$	$DbtIssues_t$	$R\&D_t$	$Capex_t$
$AssetSales_t$	1.0000							
Q_{t-1}	-0.0362	1.0000						
	(0.0000)							
$SalesGwth_{t,\ t-1}$	-0.0355	0.1281	1.0000					
	(0.0000)	(0.0000)						
$CashFlow_t$	-0.0254	-0.3229	0.1611	1.0000				
	(0.0000)	(0.0000)	(0.0000)					
$StkIssues_t$	-0.0102	0.4890	0.1181	-0.3734	1.0000			
	(0.0491)	(0.0000)	(0.0000)	(0.0000)				
$DbtIssues_t$	-0.0393	0.1499	0.0921	-0.1438	0.0357	1.0000		
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)			
$R\&D_t$	-0.0247	0.5129	0.0895	-0.1975	0.5230	0.1285	1.0000	
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)		
$Capex_t$	0.0844	0.1359	0.1933	0.1467	0.1538	0.1954	0.0589	1.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	

Table 3
R&D investment and sales growth following asset sales. The table shows comparisons of the average annual change in one-year and two-year R&D and sales growth between firm-years of constrained firms in which an asset is sold and those without an asset sale. R&D growth over one and two years is defined as the log change in R&D spending between period t+1 and t and between period t+2 and t, respectively. Sales growth over one and two years is defined as the log change in net sales between period t+1 and t and between period t+2 and t, respectively. Financially constrained firms are defined based on age, size, and payout. A firm is defined as young (constrained) if its average age is 10 years or less, and as mature if it is 20 years or more; a firm is considered small (constrained) if its average sales fall in the bottom quartile for the sample, and large if its average sales are in the top quartile; a firm has a low payout ratio (constrained) if its average dividend payout is zero, and has a high payout ratio otherwise. *** and ** denote significance at the 1% and 5% level of significance, respectively.

		Young	Small	Low payout
R&D growth 1 year ahead	Asset Sale(s): Yes	0.023	-0.077	0.017
	Asset Sale(s): No	0.056	0.0004	0.059
	Difference	-0.033***	-0.0774***	-0.042***
R&D growth 2 years ahead	Asset Sale(s): Yes	0.074	-0.075	0.068
	Asset Sale(s): No	0.113	0.004	0.117
	Difference	-0.039***	-0.079***	-0.049***
Sales growth 1 year ahead	Asset Sale(s): Yes	0.044	-0.017	0.046
	Asset Sale(s): No	0.079	0.042	0.075
	Difference	-0.035***	-0.059***	-0.029***
Sales growth 2 years ahead	Asset Sale(s): Yes	0.106	0.026	0.112
	Asset Sale(s): No	0.156	0.073	0.147
	Difference	-0.050***	-0.047	-0.035**

Table 4

R&D sensitivity to asset sale proceeds. The table shows the baseline regression results from estimating ordinary least squares (OLS), firm fixed effects (Firm FE), dynamic GMM (Diff-GMM), and system GMM (Sys-GMM) regressions on the full sample described in Table 1. The OLS regression includes year fixed effects, while the Firm FE estimation includes both firm and year fixed effects. The Diff-GMM estimation in Model 3 uses lagged values dated t-3 and t-4 of the right-hand side variables as instruments in the baseline difference regression. Model 4 uses the same instrument set, except for $AssetSales_t$ where lagged values dated t-2 to t-4 are used. The Sys-GMM estimation in Model 5 uses lagged levels dated t-3 and t-4 of the right-hand side variables as instruments for the regression equation in first differences and lagged differences dated t-2 of the right-hand side variables as instruments for the equation in levels. Model 6 uses the same instrument set, except for $AssetSales_t$ where lagged levels dated t-2 to t-4 and lagged differences dated t-1 are used. The table also presents *m2 (m3)* tests of second (third)-order autocorrelation and *J*-tests of instrument validity. The dependent variable in all models is the current level of research and development expense ($R\&D_t$). $AssetSales_t$ represents the funds from sales of property, plant, and equipment. $R\&D_{t-1}$ is $R\&D_t$ from the previous period. $R\&D^2_{t-1}$ is the lagged square of $R\&D_t$. Q_{t-1} is the ratio of the market and book value of assets, where the market value of assets is calculated as the sum of the market value of equity and book value of assets minus the book value of equity minus deferred taxes. $CashFlow_t$ is the sum of income before extraordinary items, depreciation and amortization, and research and development. $StkIssues_t$ represents the net cash raised from stock. $DbtIssues_t$ is net new long-term debt. ΔNWC_t is the change in net working capital between the beginning and end of period t, calculated as the difference between current assets and current liabilities. All variables (except Q) are scaled by beginning of period total assets and all ratios are winsorized at the 1st and 99th percentiles. Standard errors are displayed in parentheses below the estimated coefficients and are clustered at the firm level. ***, **, and * denote significance at the 1%, 5%, and 10% level of significance, respectively.

	OLS (1)	Firm FE (2)	Diff-GMM (3)	Diff-GMM (4)	Sys-GMM (5)	Sys-GMM (6)
$AssetSales_t$	0.1260***	0.1019***	0.4953**	0.4844**	0.7065***	0.6811***
	(0.0375)	(0.0385)	(0.2522)	(0.2060)	(0.2652)	(0.2245)
$R\&D_{t-1}$	0.9229***	0.5090***	0.2694***	0.2643***	0.8948***	0.8888***
	(0.0152)	(0.0245)	(0.0897)	(0.0883)	(0.0530)	(0.0515)
$R\&D^2_{t-1}$	-0.3598***	-0.2249***	-0.1998**	-0.1920**	-0.3882***	-0.3820***
	(0.0227)	(0.0244)	(0.0783)	(0.0777)	(0.0594)	(0.0578)
Q_{t-1}	0.0049***	0.0075***	0.0087***	0.0089***	0.0060***	0.0063***
	(0.0005)	(0.0007)	(0.0021)	(0.0020)	(0.0019)	(0.0019)
$CashFlow_t$	0.0191***	0.0142*	0.0653***	0.0606***	-0.0191	-0.0174
	(0.0057)	(0.0073)	(0.0242)	(0.0234)	(0.0173)	(0.0171)
$StkIssues_t$	0.1128***	0.1114***	0.1300***	0.1288***	0.1057***	0.1069***
	(0.0066)	(0.0066)	(0.0176)	(0.0172)	(0.0180)	(0.0175)
$DbtIssues_t$	0.0562***	0.0638***	0.1105***	0.1136***	0.0937***	0.0969***
	(0.0065)	(0.0064)	(0.0338)	(0.0334)	(0.0357)	(0.0347)
ΔNWC_t	-0.0223***	-0.0157***	-0.0054	-0.0046	-0.0086	-0.0064
	(0.0058)	(0.0056)	(0.0172)	(0.0168)	(0.0164)	(0.0159)
Constant	-0.0072***	0.0216***				
	(0.0016)	(0.0028)				
Observations	36923	36923	33322	33322	36923	36923
Number of firms	3156	3156	3135	3135	3156	3156
R-squared	0.7086	0.3447				
m2				0.000		0.482
m3			0.982		0.020	
J			0.278	0.438	0.065	0.096

Table 5

R&D-asset sale sensitivity in constrained and unconstrained firms. The table shows the regression results from estimating system GMM regressions with year and firm fixed effects for subsamples of firms based on age, size, and payout ratio. The dependent variable is the current level of research and development expense ($R\&D_t$). The table displays coefficient estimates for the main variable of interest, $AssetSales_t$, which represents the funds from sales of property, plant, and equipment. The other explanatory variables are omitted from the table for brevity and include $R\&D_{t-1}$, $R\&D^2_{t-1}$, Q_{t-1}, $CashFlow_t$, $StkIssues_t$, $DbtIssues_t$, and ΔNWC_t. In Panel 1 a firm is defined as young (constrained) if its average age is 10 years or less, and as mature if it is 20 years or more; a firm is considered small (constrained) if its average sales fall in the bottom quartile for the sample, and large if its average sales are in the top quartile; a firm has a low payout ratio (constrained) if its average dividend payout is zero, and has a high payout ratio otherwise. In Panel 2 a firm is defined as young (constrained) if its average age is 15 years or less, and as mature if it is greater than 15 years; a firm is considered small (constrained) if its average sales are equal to or fall below the median sales for the sample, and large if they are above the median; a firm has a low payout ratio (constrained) if its average net payout is non-positive, and has a high payout ratio otherwise. In Panel 3 a firm is defined as young (constrained) if its average age is equal to or falls below the median age for the sample, and as mature otherwise; a firm is considered small (constrained) if its average assets are equal to or fall below the median for the sample, and large otherwise; a firm has a low payout ratio (constrained) if its average dividend payout falls in the bottom quartile for the sample, and has a high payout ratio if it falls in the top quartile. The Sys-GMM estimation uses lagged levels dated t-3 and t-4 of the right-hand side variables as instruments for the regression equation in first differences and lagged differences dated t-2 of the right-hand side variables as instruments for the equation in levels, except for $AssetSales_t$ where lagged levels dated t-2 to t-4 and lagged differences dated t-1 are used. The panels also present an *m2* test of second-order autocorrelation in residuals in { }, followed by a *J*-test of instrument validity and the number of observations (*N*) in each model. *p*-value shows the significance of the test for differences in the coefficient on $AssetSales_t$ across constrained and unconstrained firms. All variables (except Q) are scaled by beginning of period total assets and all ratios are winsorized at the 1st and 99th percentiles. In all panels standard errors are displayed in parentheses below the estimated coefficients and are clustered at the firm level. *** and ** denote significance at the 1% and 5% level of significance, respectively.

	Financial Constraints Criteria		
	Age	Size	Payout ratio
1.			
constrained	0.7369***	0.6787**	0.7282***
	(0.2503)	(0.2748)	(0.2598)
m2, J, N	{0.891, 0.131, 16169}	{0.512, 0.293, 6904}	{0.473, 0.296, 19107}
unconstrained	0.1379	0.0074	-0.0872
	(0.1030)	(0.1012)	(0.1380)
m2, J, N	{0.197, 1.000, 9926}	{0.873, 0.287, 10292}	{0.263, 0.004, 17801}
p-value	(0.027)	(0.018)	(0.013)
2.			
constrained	0.6596***	0.5699**	0.8099***
	(0.2418)	(0.2419)	(0.2514)
m2, J, N	{0.525, 0.086, 24710}	{0.104, 0.210, 16833}	{0.417, 0.249, 23202}
unconstrained	0.1941	0.1574	-0.0635
	(0.1310)	(0.2287)	(0.0781)
m2, J, N	{0.488, 0.565, 12213}	{0.027, 0.001, 20090}	{0.033, 0.010, 13706}
p-value	(0.091)	(0.207)	(0.002)
3.			
constrained	0.7285***	0.6023**	0.7282***
	(0.2586)	(0.2417)	(0.2598)
m2, J, N	{0.966, 0.076, 18639}	{0.448, 0.178, 16938}	{0.473, 0.296, 19107}
unconstrained	0.2239	0.1652	0.0186
	(0.2498)	(0.2407)	(0.1054)
m2, J, N	{0.326, 0.000, 18284}	{0.480, 0.001, 19985}	{0.183, 0.753, 10216}
p-value	(0.161)	(0.152)	(0.030)

Table 6

R&D investment and asset sales: Robustness checks. The table shows several robustness checks of the baseline regression model. The dependent variable is the current level of research and development expense ($R\&D_t$). Results are presented for the full sample (All) and for subsamples of financially constrained firms based on age, size, and payout ratio. A firm is defined as young (constrained) if its average age is 10 years or less, and as mature if it is 20 years or more; a firm is considered small (constrained) if its average sales fall in the bottom quartile for the sample, and large if its average sales are in the top quartile; a firm has a low payout ratio (constrained) if its average dividend payout is zero, and has a high payout ratio otherwise. The table displays coefficient estimates for the main variable of interest, $AssetSales_t$, which represents the funds from sales of property, plant, and equipment. The other explanatory variables are omitted from the table for brevity and include $R\&D_{t-1}$, $R\&D^2_{t-1}$, Q_{t-1}, $CashFlow_t$, $StkIssues_t$, $DbtIssues_t$, and ΔNWC_t. In Panel 1 Q_{t-1} is replaced by $SalesGwth_{t,t-1}$ which is the log change in net sales between period t and t-1. In Panel 2 the years of 2007 and 2008 are excluded to avoid the Financial Crisis. In Panel 3 industry-year fixed effects are included to control for investment opportunities. The Sys-GMM estimation uses lagged levels dated t-3 and t-4 of the right-hand side variables as instruments for the regression equation in first differences and lagged differences dated t-2 of the right-hand side variables as instruments for the equation in levels, except for $AssetSales_t$ where lagged levels dated t-2 to t-4 and lagged differences dated t-1 are used. The panels also present an *m2* test of second-order autocorrelation in residuals in { }, followed by a *J*-test of instrument validity and the number of observations (*N*) in each model. *p*-value shows the significance of the test for differences in the coefficient on $AssetSales_t$ across constrained and unconstrained firms. All variables (except Q) are scaled by beginning of period total assets and all ratios are winsorized at the 1st and 99th percentiles. In all panels standard errors are displayed in parentheses below the estimated coefficients and are clustered at the firm level. ***, **, and * denote significance at the 1%, 5%, and 10% level of significance, respectively.

1. Replace Q with sales growth					
	All		Age	Size	Payout ratio
		constrained	0.7827***	0.8521**	0.7038**
			(0.2622)	(0.3380)	(0.2947)
	0.5789**	*m2, J, N*	{0.263, 0.136, 16555}	{0.588, 0.467, 7379}	{0.622, 0.196, 19692}
	(0.2531)				
m2, J, N	{0.527, 0.080, 37836}	unconstrained	0.0603	0.1538	0.0814
			(0.1111)	(0.1449)	(0.1626)
		m2, J, N	{0.084, 1.000, 10081}	{0.733, 0.330, 10495}	{0.157, 0.003, 18129}
		p-value	(0.011)	(0.049)	(0.077)
2. Crisis years are excluded					
	All		Age	Size	Payout ratio
		constrained	0.7034***	0.5879**	0.6200**
			(0.2521)	(0.2711)	(0.2638)
	0.5633**	*m2, J, N*	{0.240, 0.117, 14858}	{0.213, 0.284, 6417}	{0.067, 0.271, 17668}
	(0.2248)				
m2, J, N	{0.062, 0.122, 34574}	unconstrained	0.1662*	0.0278	-0.0785
			(0.1007)	(0.0999)	(0.1452)
		m2, J, N	{0.231, 0.956, 9450}	{0.390, 0.203, 9630}	{0.161, 0.009, 16891}
		p-value	(0.048)	(0.043)	(0.037)
3. Industry-year FE					
	All		Age	Size	Payout ratio
		constrained	0.7701***	0.5465**	0.8340***
			(0.239)	(0.274)	(0.260)
	0.7926***	*m2, J, N*	{0.887, 1.000, 16169}	{0.608, 1.000, 6904}	{0.659, 1.000, 19107}
	(0.2305)				
m2, J, N	{0.668, 0.921, 36923}	unconstrained	0.1564	0.1317	-0.0680
			(0.098)	(0.106)	(0.152)
		m2, J, N	{0.242, 1.000, 9926}	{0.718, 1.000, 10292}	{0.396, 0.998, 17801}
		p-value	(0.022)	(0.044)	(0.005)

Table 7

Regime switching regressions. Panel 1 shows the regression results from estimating R&D investment regime switching regressions. The second pair of results augments the baseline model by including future and lagged values of asset sales. The regression includes both firm and year fixed effects. The dependent variable is the current level of research and development expense ($R\&D_t$). $AssetSales_t$ represents the funds from sales of property, plant, and equipment. The sum of coefficients ($\sum AssetSales_{t-1,t\ t+1}$) is reported with the p-value from an F-test that the sum is equal to zero. $R\&D_{t-1}$ is $R\&D_t$ from the previous period. $R\&D^2_{t-1}$ is the lagged square of $R\&D_t$. Q_{t-1} is the ratio of the market and book value of assets, where the market value of assets is calculated as the sum of the market value of equity and book value of assets minus the book value of equity minus deferred taxes. $CashFlow_t$ is the sum of income before extraordinary items, depreciation and amortization, and research and development. $StkIssues_t$ represents the net cash raised from stock issues. $DbtIssues_t$ is net new long-term debt issued. ΔNWC_t is the change in net working capital between the beginning and end of period t, calculated as the difference between current assets and current liabilities. Panel 2 displays the estimation of the selection equation where the dependent variable takes a value of one for Regime 1 (Unconstrained), and zero otherwise. Age_{t-1} is the natural log of the number of years since the company has been publicly traded. $Size_{t-1}$ is the natural log of the book value of assets in 2005 dollars. Short-term $debt_{t-1}$ is debt in current liabilities. Long-term $debt_{t-1}$ is total long-term debt. $Cash_{t-1}$ is the level of cash and short-term investments scaled by beginning of period total assets. Div $dummy_{t-1}$ takes a value of one if the company paid out dividends during the period, and zero otherwise. All variables (except Q) are scaled by beginning of period total assets and all ratios are winsorized at the 1^{st} and 99^{th} percentiles. Standard errors are displayed in parentheses below the estimated coefficients (except for ($\sum AssetSales_{t-1,t,t+1}$) and are clustered at the firm level. *** and ** denote significance at the 1% and 5% level of significance, respectively.

	1. R&D investment regressions			
	Regime 1 (Unconstrained)	Regime 2 (Constrained)	Regime 1 (Unconstrained)	Regime 2 (Constrained)
$AssetSales_t$	-0.0094**	0.3310***		
	(0.0040)	(0.0957)		
$\sum AssetSales_{t-1,t,t+1}$			-0.0092	0.5219***
			(0.1549)	(0.0008)
$R\&D_{t-1}$	0.9843***	0.7837***	0.9937***	0.7805***
	(0.0017)	(0.0243)	(0.0018)	(0.0258)
$R\&D^2_{t-1}$	-0.2077***	-0.2714***	-0.2712***	-0.2767***
	(0.0040)	(0.0268)	(0.0040)	(0.0288)
Q_{t-1}	-0.0001***	0.0050***	-0.0003***	0.0048***
	(0.00006)	(0.0007)	(0.00006)	(0.0007)
$CashFlow_t$	0.0142***	0.0340***	0.0160***	0.0390***
	(0.0005)	(0.0076)	(0.0006)	(0.0082)
$StkIssues_t$	0.0105***	0.1380***	0.0110***	0.1400***
	(0.0006)	(0.0084)	(0.0006)	(0.0089)
$DbtIssues_t$	0.0053***	0.1000***	0.0051***	0.0994***
	(0.0006)	(0.0118)	(0.0006)	(0.0123)
ΔNWC_t	-0.0041***	-0.0290***	-0.0043***	-0.0318***
	(0.0005)	(0.0078)	(0.0005)	(0.0082)
N	24923	11906	22988	10834

	2. Selection equation	
Age_{t-1}	0.1594***	0.1563***
	(0.0053)	(0.0055)
$Size_{t-1}$	0.1636***	0.1584***
	(0.0028)	(0.0029)
Short-term $debt_{t-1}$	-0.0051***	-0.0031***
	(0.00004)	(0.00004)
Long-term $debt_{t-1}$	-0.1936***	-0.1463***
	(0.0179)	(0.0186)
$Cash_{t-1}$	-1.3767***	-1.3453***
	(0.0120)	(0.0125)
Q_{t-1}	-0.1988***	-0.2008***
	(0.0013)	(0.0013)
Div $dummy_{t-1}$	0.8133***	0.8148***
	(0.0114)	(0.0119)
Constant	0.0618***	0.0828***
	(0.0165)	(0.0168)
N	36829	33822
p-value of the model	0.0000	0.0000