Financing Innovation and Growth: Cash Flow, External Equity and the 1990s R&D Boom

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James R. Brown, Department of Economics, Montana State University
(jrbrown@montana.edu)

Steven M. Fazzari, Washington University in St. Louis
(fazz@wustl.edu)

Bruce C. Petersen, Washington University in St. Louis
(petersen@wustl.edu)

Abstract

The financing of R&D is a potentially important channel that connects finance and economic growth, but there is no direct evidence that financial effects are large enough to impact aggregate R&D. U.S. firms finance R&D from volatile sources: cash flow and stock issues. We estimate dynamic R&D models for high-tech firms and find significant effects of cash flow and external equity for young, but not mature, firms. The financial coefficients for young firms are large enough that finance supply shifts can explain most of the dramatic 1990s R&D boom, which implies a significant connection between finance, innovation and growth.

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Does finance cause growth? A large empirical literature, surveyed by Levine (2005), establishes a strong connection between broad measures of financial development and economic growth. Questions remain, however, about the channels through which finance may matter. One potentially important channel is the financing of R&D, a critical input for growth in modern economies. R&D is particularly interesting not only because of the knowledge spillovers it creates--a major feature of endogenous growth models--but also because R&D may be difficult to finance with external sources (e.g., Arrow 1962).[1] While a small number of empirical studies suggest that some firms face financing constraints for R&D (see Hall 2002), there is no direct micro evidence that these financial effects are large enough to matter for aggregate R&D. This paper fills that gap: we identify financial factors for young, high-tech firms that can explain a significant portion of the dramatic 1990s boom, and subsequent decline, in U.S. R&D.

In the U.S., young publicly-traded firms in high-tech industries finance R&D investment almost entirely with internal or external equity (that is, cash flow or public share issues). For these firms, information problems, skewed and highly uncertain returns, and lack of collateral value likely make debt a poor substitute for equity finance. Furthermore, these firms typically exhaust internal finance and issue stock as their marginal source of funds. If these firms face binding financing constraints, then shifts in the supply of either internal or external equity finance should lead to changes in R&D. If such firms undertake a large fraction of aggregate R&D, then changes in the availability of finance may have macroeconomic significance. In particular, booms (or busts) in the availability of equity finance should lead to booms (or busts) in R&D.

We argue that the U.S. has recently experienced a finance-driven cycle in R&D. From 1994 to 2004, there was a dramatic boom, and subsequent decline, in R&D: the ratio of privately financed, industrial R&D to GDP rose from 1.40 percent in 1994 to an all-time high of 1.89 percent in 2000 before declining to an average of 1.70 percent from 2002 to 2004. As we will show, just seven high-tech industries (drugs, office equipment and computers, electronic components, communication equipment, scientific and medical instruments, and software) accounted for virtually all of the 1990s U.S. R&D boom

[1] Recent efforts to incorporate financing into models of endogenous growth, include King and Levine (1993), De la Fuente and Marin (1996), Morales (2003), Aghion, Howitt, and Mayer-Foulkes (2005), and Aghion, Angeletos, Banerjee, and Manova (2005).

(see figure 1 below). More important, virtually all of the boom was accounted for by young firms (publicly traded for less than 15 years) in these industries (see figure 2 below).

From 1994 to 2004, there was also a dramatic boom and bust in both cash flow and external equity finance in these industries. Internal finance (cash flow) for publicly traded firms increased from \$89 billion in 1993 to \$231 in 2000, and then collapsed in 2001 and 2002. External public equity finance rose from \$24 billion in 1998 to \$86 billion in 2000, but then plummeted by 62 percent in 2001.

The central question in this paper is whether supply shifts in both internal and external equity finance can explain a significant part of the 1990s boom and subsequent decline in aggregate R&D. To our knowledge, this is the first study to examine whether finance supply shifts explain large fluctuations in R&D. We use a Generalized Method of Moments procedure to estimate dynamic R&D investment models with panel data from 1,347 publicly traded firms in the seven high-tech industries from 1990 to 2004. For mature firms, the point estimates for both cash flow and external equity finance are statistically insignificant and quantitatively unimportant. For young firms, however, the point estimates for the equity finance variables are quantitatively large and highly significant. Furthermore, the financial coefficients are large enough that the financial cycles for young, high-tech firms alone can explain about 75 percent of the *aggregate* R&D boom and subsequent decline.

Our interpretation of the results is that shifts in the *supply* of internal and external equity finance in the 1990s relaxed financing constraints that restricted R&D for young firms. Of course, new technological opportunities during this period also could have led to a *demand* shift for R&D. To identify the supply effect, our approach accounts for demand in a variety of ways. First, the structural specification controls for expectations that might affect investment demand. Second, the results do not change in any significant way when we include industry-level time dummies that control for all time-varying demand shocks at the industry level. Third, although demand shocks presumably affected all firms in these industries, we find significant financial effects for young firms only, which is inconsistent with the view that the financial effects proxy for an unobserved demand shift. Finally, the R&D boom and bust was confined entirely to young firms, consistent with the supply interpretation.

Our findings have implications for several important economic issues. First, shifts in the supply of equity finance may have driven much of the R&D boom, which was likely important for the surge in labor productivity beginning in the late 1990s. Second, because the corporate tax system affects after-tax cash flow, our findings identify a potentially important channel through which business tax policies affect R&D investment. Third, while the large literature on finance and economic growth has good reasons to focus on debt and credit constraints, our results suggest that more attention should be given to equity finance, particularly for models that emphasize innovation. Finally, although empirical studies on finance and growth have examined the potential impact of stock market development, they typically do not emphasize (or test for) the stock market as a *source* of finance. Our evidence suggests that stock markets can be an important source of funds, which has implications for the debate about the relative merits of bank-based versus market-based financial systems.

I. R&D and Equity Finance

A. The 1990s R&D Boom and Subsequent Decline

The 1990s boom and decline after 2000 in U.S. R&D spending is likely without precedent. According to the National Science Foundation survey, aggregate privately financed R&D rose smoothly from 1953 through 1969 until a sluggish period in the early 1970s. There were then three distinct waves of R&D growth. The annualized trough-to-peak real growth rate in the final wave, 1994-2000, was 9.2 percent, greatly exceeding the growth rates of the first two waves.[2] As a result, the R&D-GDP ratio hit an all-time peak of 1.89 percent in 2000, 35 percent greater than the 1994 figure. In 2001, however, the R&D-GDP ratio declined modestly (to 1.86) and then fell sharply (to 1.72) in 2002. The 2002 decline, as noted in the NSF report, was the largest single-year absolute and percentage reduction in the R&D-GDP ratio since the survey began in 1953.

Unlike other types of investment, R&D is highly concentrated in the seven high-tech industries listed in the introduction. Figure 1 plots R&D investment in billions of 2000 dollars (solid line) for all publicly traded firms listed in Compustat from 1980 to 2004.[3] The dotted line is the leve1 of R&D for all firms *excluding* those in the seven high-tech industries. Three facts stand out. First, the high-tech share of R&D grew significantly in the past quarter century, reaching more than two thirds in recent years.

[2] The respective growth rates of the first two waves were 6.8 percent (1975-1986) and 5.4 percent (1987-1992). See *National Patterns of R&D Resources,* National Science Foundation (annual series).
[3] Public firms undertake nearly all of U.S. R&D: the sum of R&D for public firms tracked by Compustat was equal to 90.1 percent of total industrial R&D reported by the NSF for 2003.

Second, there is a sharp acceleration in economy-wide R&D starting in 1994 and ending in 2000. Third, the seven high-tech industries account for virtually all of the cycle in R&D between 1994 and 2004.

Figures 2a-2c present aggregated R&D and financing data for publicly traded firms in the seven high-tech industries. Figure 2a shows R&D for all firms while figures 2b and 2c provide separate data for young firms (publicly traded for 15 years or less) and mature firms (publicly traded for more than 15 years). Figures 2b and 2c suggest that young high-tech firms accounted for nearly all of the 1990s R&D boom and subsequent decline. This fact is central to our paper. To estimate the boom quantitatively, we fit a geometric trend from 1980 to 1993 to real R&D for both young and mature firms. The trend annual growth rates are 7.5 percent for mature firms and a remarkably high 11.8 percent for young firms. We then project post-1993 R&D with the estimated trend and define the boom as the difference between actual R&D and the projected trend. For the six years from 1996 through 2001, the level of young firm R&D averaged *65 percent* above the trend that already incorporated almost 12 percent annual growth. In 2002, however, this boom came to an abrupt end. R&D dropped so rapidly that it fell below the trend by 2003 and 2004. In contrast to this dramatic cycle, mature-firm R&D after 1993 continued to grow almost exactly at the trend rate.

The existing literature has little to say about the potential causes of an aggregate boom in R&D. In particular, an R&D boom is more difficult to explain than a boom in fixed investment because R&D likely has a substantial gestation period before it becomes productive.[4] Therefore, periods of high *cyclical* demand will have little or no impact on R&D. We argue below, however, that shifts in the supply of R&D finance can explain the emergence and end of an R&D boom. The financing hypothesis also makes sharp predictions about why the boom and bust is concentrated in young firms.

B. Financing R&D: The Role of Internal and External Finance

Financing constraints, if they exist, may restrict R&D much more than other forms of investment. Reasons include the lack of collateral value for the R&D "capital" and firms' need to protect proprietary information, even from potential investors. Compared to the vast literature testing for the presence of financing constraints on capital investment, relatively little research focuses on R&D. An excellent review of the existing literature appears in Hall (2002). Some studies find evidence suggesting that firms

[4] See Griliches (1979, p. 101); Ravenscraft and Scherer (1982) report mean gestation lags of four to six years.

in the U.S. and other countries face financing constraints for R&D, including Hall (1992), Himmelberg and Petersen (1994), Mulkay, Hall and Mairese (2001), and Bond, Harhoff, and Van Reenen (2003). Previous studies have not, however, explored the implications of financing constraints for aggregate R&D. Nor have previous studies typically examined the role of public equity as a source of finance.

Hall (2002, p. 12) concludes that “the capital structure of R&D-intensive firms customarily exhibits considerably less leverage than that of other firms,” an observation confirmed in our data. There are several reasons why young, high-tech firms obtain little or no debt finance. First, the structure of a debt contract is not well suited for R&D-intensive firms with uncertain and volatile returns (see Stiglitz 1985, p. 146). Second, adverse selection problems (Stiglitz and Weiss, 1981) are more likely in high-tech industries due to the inherent riskiness of investment. Third, debt financing can lead to *ex post* changes in behavior (moral hazard) that are likely more severe for high-tech firms because they can more easily substitute high-risk for low-risk projects. Fourth, the expected marginal cost of financial distress rises rapidly with leverage for young high-tech firms because their market value depends heavily on future growth options that rapidly depreciate if they face financial distress (Cornell and Shapiro, 1988). Finally, the limited collateral value of intangible assets should greatly restrict the use of debt: risky firms typically must pledge collateral to obtain debt finance (Berger and Udell, 1990).

Equity finance has several advantages over debt for young high-tech firms (e.g., Carpenter and Petersen, 2002). For both internal and external equity finance, shareholders share in upside returns, there are no collateral requirements, and additional equity does not magnify problems associated with financial distress. In addition, internal equity finance does not create adverse selection problems. Internal and external equity finance are not, however, perfect substitutes. Public stock issues incur sizeable flotation costs, and new share issues may require a “lemons premium” due to asymmetric information (Myers and Majluf 1984). Brealey and Myers (2000, p. 423) write that “[m]ost financial economists now interpret the stock price drop on equity issue announcements as an information effect.” Nevertheless, because of the other advantages of equity finance over debt, together with the nearly total absence of debt financing, external equity finance is the more relevant substitute for internal cash flow for young, high-tech firms. In spite of its potential advantages, public equity finance has been largely ignored in the literature.[5]

This discussion suggests that there is a financing hierarchy for R&D that consists almost entirely of internal and external equity finance, at least for young firms. (This is surely not the case for capital investment with collateral value, for which debt presumably plays a more important role.) The least-cost form of finance is internal cash flow. When cash flow is exhausted and debt is not an option, firms must turn to new share issues. The supply schedule for external equity finance is likely to be upward sloping because information asymmetries become more severe as the amount of funds raised increases. One reason is that quasi-insiders will likely have better information about the firm's true prospects and therefore demand smaller lemons premia than the typical supplier of finance. In addition, in recent years, there are usually just a few analysts that specialize in tracking any given young, high-tech firm. Evidence from Asquith and Mullins (1986, table 7) is consistent with an upward sloping supply curve for external equity. They find that the announcement-day excess return for new share issues falls with the size of the planned issue: the more funds raised, the larger the percentage loss in firm market value.

C. *Shifts in the Supply of Internal and External Equity Finance*

In the mid and late 1990s, there was a strong boom in corporate income, the largest component of internal finance. Economy-wide profits, however, stagnated in 2000 and collapsed in 2001 (falling 87 percent in the Census Bureau *Quarterly Financial Reports*). This economy-wide experience mirrors the behavior of the aggregated cash flow data for the industries in our study. For young high-tech firms it is apparent from figure 2b that there was a dramatic boom in cash flow beginning in 1994. For the six years from 1995 through 2000, cash flow averaged 90 percent above the value predicted by the 1980-1993 exponential trend. After 2000, young-firm cash flow collapses. Mature firms also experience a significant cash flow boom beginning in 1994.

It has been widely documented that corporate income (and therefore internal equity finance) is highly volatile. One explanation is the fact that labor costs are quasi-fixed so that shocks to other costs or

[5] One reason may be the very low aggregate net equity statistics (see Brealey and Myers, 2000, table 14.1). These statistics, however, greatly understate the importance of public equity issues because mature firms often use large stock buybacks to distribute earnings to shareholders. Many firms make extensive use of follow-up stock issues early in their life cycle (e.g., Rajan and Zingales, 1998). Brown (2006), Fama and French (2005), and Frank and Goyal (2003) present facts on the increasing use of public equity.

revenues lead to disproportionate changes in profits. Goldin (2000) argues that 20th century labor markets changed from spot markets to markets with substantial investments in human capital, labor hoarding, and job security. The 1990s internal finance boom was likely the result of a number of favorable, but temporary, shocks to nominal interest rates, oil prices, and exchange rates combined with quasi-fixed labor costs particularly for highly skilled workers, the preponderance of employees at high-tech firms.

In addition to the major shifts in cash flow, fluctuations in the supply of *external* equity for the high-tech industries were also dramatic during this period. Figures 2a-2c provide information for net public equity issues with negative issues (buybacks) set to zero. Between 1994 and 1996, young firms collectively increased their net stock issues by nearly 200 percent. Starting from this high base, young firms again increased stock issues by nearly 265 percent between 1998 and 2000. In 2000, net stock issues by young firms in the seven high-tech industries were so large that they accounted for nearly half of net issues in the entire economy. Between 2000 and 2002, however, young-firm stock issues then fell by more than 83%. Almost all of the young high-tech firms trade on the NASDAQ. The large swings in stock issues line up well with the dramatic swing in NASDAQ stock prices between 1995 and 2002.[6]

This correspondence between cycles in share issues and stock prices was probably not a coincidence. Many financial economists have argued that there was mispricing, even a bubble, in the NASDAQ in the late 1990s.[7] An extensive literature shows that stock-market mispricing can lower the cost of external equity finance and increase the availability and use of public equity. For example, Morck, Shleifer, and Vishney (1990, p. 160) note that overpriced equity lowers the cost of capital and may allow financially constrained firms the opportunity to issue shares and increase investment. Baker and Wurgler (2000) find that firms are more likely to issue equity when stock prices are high, and Loughran and Ritter (1995, p 46) state that their "evidence is consistent with a market where firms take advantage of transitory windows of opportunity by issuing equity, when, on average, they are substantially overvalued." Baker, Stein and Wurgler (2003, p. 970), argue "that those firms that are in need of external equity finance will have investment that is especially sensitive to the non-fundamental

[6] The NASDAQ Index jumped from 1,574 at the start of 1998, to over 5,000 in 2000, only to bottom out at approximately 1,100 in August, 2002.
[7] For example, Bond and Cummins (2000, p. 100) conclude that there are "serious anomalies in the behavior of share prices" in the 1990s. See Chen, Hong and Stein (2002), Wurgler and Zhuravskaya (2002), Kumar and Lee (2006), and Sadka and Scherbina (2007) for explanations of persistent mispricing on stock markets.

component of stock prices." In addition, a number of studies report evidence that mispricing affects investment, particularly for equity-dependent firms.[8]

A key implication of this research for our work is that mispricing changes the cost of equity capital and shifts the supply curve for external equity. Many public firms in the late 1990s likely enjoyed overpriced (or less underpriced) stock, which lowered their cost of external equity finance. Thus, in the mid and late 1990s, there were arguably major rightward shifts in the supply of both *internal* and *external* equity finance, and these shifts reversed sharply (at least temporarily) after 2000.

D. Empirical Predictions for R&D and Equity Finance

To motivate the empirical hypotheses we test, consider first the effect of changes in the supply of equity finance on young high-tech firms. As we will show, these firms typically exhaust their internal cash flow, make negligible use of debt, and raise substantial funds from new share issues. These facts suggest that their marginal source of finance is external equity. In the context of the financing hierarchy discussed earlier, consider two possible equity supply shifts. First, an increase in the supply of low-cost *internal* equity finance (cash flow) shifts the *entire* hierarchy of finance to the right. The consequence is a lower marginal cost of finance for any quantity of external finance raised. Second, a reduction in the cost of *external* equity shifts the rising portion of the financing hierarchy downward, also reducing the marginal cost of finance for firms that use external funds. Thus, for firms that initially exhaust internal finance, we predict that either of these supply shifts should increase the optimal quantity of R&D.

In contrast, mature firms often have cash flow (or buffer stocks of cash) in excess of demand for investment, and do not depend on stock (or debt) issues. In this case, increases in the supply of either internal or external equity finance should not affect the marginal cost of funds and hence should not change R&D. In addition, mature firms, because of established track records (see Gertler, 1988 and Oliner and Rudebusch, 1992), may find that external finance (both debt and stock), should they seek it, is a very close substitute for internal finance. Thus, we predict there should be heterogeneity across young and mature firms in how R&D responds to changes in the supply of internal and external finance. This

[8] See Chirinko and Schaller (2001), Baker, Stein and Wurgler (2003), Polk and Sapienza (2004), and Gilchrist, Himmelberg, and Huberman (2005).

kind of heterogeneity has been widely used to test for the existence of financing constraints and helps us to empirically identify shifts in supply of finance.[9]

We note that for a constrained firm, an additional dollar of finance should result in less than an additional dollar of R&D. First, firms have other uses of funds besides R&D, including physical investment and working capital. Second, R&D likely has high adjustment costs, as documented in several empirical studies.[10] Most R&D investment is payment to highly skilled technology workers. Skilled R&D workers often require a great deal of firm-specific knowledge and training. When confronted with high adjustment costs, a firm that is unsure about the permanence of a positive supply shift in finance is likely to conserve some of its new equity finance so that it will have future resources to maintain its initial increase in R&D. Symmetrically, a firm faced with declining financial resources will likely cut back slowly on R&D. This point implies that firms should smooth R&D to some degree relative to temporary finance shocks.

II. Empirical Specification and Estimation

To test the impact of internal and external equity finance on R&D we modify an investment model from Bond and Meghir (1994) and Bond, et al. (2003). This specification is based on the dynamic optimization "Euler condition" for imperfectly competitive firms that accumulate productive assets with a quadratic adjustment cost technology. The advantage of a structural approach is that it controls for expectations. A major challenge facing empirical work on financing constraints has been to separate the influence of variables that measure access to finance from their possible role as proxies for expected future profitability. The Euler equation estimation approach eliminates terms in the solution to the optimization problem that depend on unobservable expectations, such as the shadow value of capital, and it replaces expected values of observable variables with actual values plus an error orthogonal to pre-determined instruments. If firms do not face financing constraints, Bond, et al. (2003, p. 153) write that, "under the maintained structure, the model captures the influence of current expectations of future

[9] Kaplan and Zingales (1997) criticize heterogeneity tests. Bond, et al. (2003, p. 154) argue, however, that it "remains the case in [the Kaplan-Zingales] model that a firm facing no financial constraint (no cost premium for external finance) would display no excess sensitivity to cash flow," in which case the Kaplan-Zingales criticism of heterogeneity tests does not apply.

[10] Hall, Griliches, and Hausman (1986) and Bernstein and Nadiri (1989) find that adjustments costs for R&D are considerably higher than for capital investment.

profitability on current investment decisions; and it can therefore be argued that current or lagged financial variables should not enter this specification merely as proxies for expected future profitability."

In the model from Bond and Meghir (1994) designed to study fixed investment, firm profits are a function of the physical capital stock and capital adjustment costs are a quadratic function of the ratio of capital investment to the capital stock. To apply the model to R&D, it would be natural to consider profits as a function of the accumulated stock of R&D. Measurement of the R&D stock, however, is fraught with difficulties. The absence of a long time-series of R&D expenditures makes perpetual inventory methods for stock computations infeasible and the depreciation rate for an intangible asset like R&D is hard to determine. We therefore use firms' stock of total assets as a scale factor in the regressions and assume that adjustment costs of R&D are quadratic in the ratio of R&D to total assets. This approach has precedents in the literature. Baker, Stein, and Wurgler (2003), for example, also use total assets as a scale variable in firm-level regressions for both physical capital and R&D.

The Euler equation leads to this empirical specification in the absence of financing constraints:

$$(1) \qquad rd_{j,t} = \beta_1 rd_{j,t-1} + \beta_2 rd^2_{j,t-1} + \beta_3 cf_{j,t-1} + \beta_4 s_{j,t-1} + d_t + \alpha_j + \nu_{j,t}$$

where $rd_{j,t}$ is research and development spending for firm j in period t, and $s_{j,t}$ is firm sales, and $cf_{j,t}$ denotes gross cash flow, the flow of internal funds defined consistently with previous literature on finance and R&D.[11] All variables are scaled by the beginning-of-period stock of firm assets. The model includes firm effects (α_j) and time effects (d_t). The firm effects control for all time-invariant determinants of R&D at the firm level. Bond and Meghir (1994) include aggregate time dummies to control for, among other things, movements in the aggregate cost of capital and tax rates. We take this approach a step further and also report regressions with time dummies at the three-digit industry level to control for industry-specific changes in technological opportunities that could affect the demand for R&D. We assume the random error term ($\nu_{j,t}$) follows a firm-specific MA(1) process.

The parameters in this equation can be interpreted as functions of the structural parameters of the original optimization problem. The structural model from Bond and Meghir (1994) implies that β_1 and β_2 will slightly exceed one in absolute value. The lagged sales-to-asset ratio has a positive coefficient under

[11] See Hall (1992) and Himmelberg and Petersen (1994). Because R&D is treated as a current expense for accounting purposes, the *cf* variable adds R&D expenses to the standard measure of net cash flow (after-tax earnings plus depreciation allowances).

imperfect competition. The lagged gross cash flow-asset ratio appears in the specification without financing constraints, but it has a negative sign. In addition, a significant advantage of the Bond and Meghir (1994) approach is that the empirical specification, although generated from an explicit optimization problem, has a form that corresponds to an intuitive, dynamic R&D regression.[12]

To explore the role of financing constraints on R&D we add variables that correspond to the firm's access to both internal and external equity. The modified regression equation is:

$$\begin{aligned} rd_{j,t} &= \beta_1 rd_{j,t-1} + \beta_2 rd^2_{j,t-1} + \beta_3 s_{j,t} + \beta_4 s_{j,t-1} \\ &\quad + \beta_5 cf_{j,t} + \beta_6 cf_{j,t-1} + \beta_7 stk_{j,t} + \beta_8 stk_{j,t-1} + d_t + \alpha_j + \nu_{j,t} \end{aligned} \qquad (2)$$

We add contemporaneous gross cash flow, the standard measure of internal equity financing in the financing constraint literature. We also add contemporaneous sales as an additional control for firm demand and to avoid possible omitted variable bias on β_5 due to the correlation between sales and cash flow. While cash flow effects have been widely explored in the literature, few studies have considered external equity. We include contemporaneous and lagged values of funds raised by new stock issues scaled by beginning-of-period total assets ($stk_{j,t}$). Bond and Meghir (1994) include similar variables in capital investment regressions. As discussed in section I, we split the data into young and mature firms. The baseline Euler equation 1 should best describe R&D for mature firms and the financing variables in equation 2 should have stronger effects for young firms if financing constraints are important for R&D.

We estimate these equations with the first-difference GMM approach developed by Arellano and Bond (1991) for dynamic panel models with lagged dependent variables.[13] We treat all right-hand side variables as potentially endogenous and use lagged levels dated t-3 and t-4 as instruments. As discussed in Bond, et al. (2003, p. 159), instruments must be lagged at least three years if the error term follows a firm-specific MA(1) process. The use of lagged instruments also mitigates concerns about measurement error in the total assets scale variable. Finally, our approach allows for heteroskedasticity and any arbitrary pattern of within-firm serial correlation.

[12] Bond, Harhoff, and Van Reenen (2003) make a similar point.
[13] For early examples of dynamic panel techniques applied to issues of financial development and economic growth, see Beck, Levine and Loayza (2000) and Beck and Levine (2004).

III. Data Description and Sample Characteristics

A. Industries and Construction of Sample

The two-digit SIC industries 28, 35, 36, 37, 38, and 73 contain virtually the entire U.S. high-tech sector. Many of the three-digit industries in this group, however, are not considered high tech and we exclude them from our study. [14] In addition, aerospace, the high-tech part of SIC 37, has very few firms and much of its R&D is funded by the U.S. government. Excluding aerospace, by far the largest three-digit high-tech industries are drugs (SIC 283), office and computing equipment (SIC 357), communications equipment (SIC 366), electronic components (SIC 367), scientific instruments (SIC 382) medical instruments (SIC 384) and software (SIC 737). In 2004, these industries collectively included about 80 percent of all publicly traded firms in their two-digit industries. As shown in figure 1, these industries accounted for a very large share of aggregate R&D undertaken by all publicly traded firms.

We construct an unbalanced panel of publicly traded firms in these industries from the Compustat database during 1990-2004. We exclude firms incorporated outside of the U.S. and firms with no stock price data. We require firms to have at least six R&D observations, and we exclude firms if the *sum* of their cash flow-assets ratio over the sample is less than zero (discussed in more detail below). We trim outliers in all key variables at the one-percent level.[15] After imposing these restrictions, the regression sample consists of 1,347 firms that account for over 90 percent the public-firm R&D in these industries.

The definition of "young" and "mature" firms is based on the number of years since the firm's first stock price appears in Compustat, which is typically the year of the firm's initial public offering. Consistent with the definition used for figures 2b and 2c, a firm is classified as young for the 15 years following the year it first appears in Compustat and mature thereafter. (Our results are similar for cutoffs of 10 or 20 years, as discussed further in section V.B.)

We are particularly interested in the R&D investment of young firms. Figure 3 shows the share of R&D in the sample accounted for by the young firms over time. Note that the young-firm share is substantial, averaging 33.8 percent for the sample period. Also, there is much variation in the share of aggregate R&D accounted for by young firms. Starting from a low of 21.7 percent, the share peaks at

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[14] See "An Assessment of United States Competitiveness in High-Technology," United States Department of Commerce, February 1983 for a list of three-digit high-tech industries.

[15] Our results are robust to changes in the outlier rule to exclude either the 0.5 percent or 2.0 percent tails.

45.7 percent in 1998 and then falls to 26.1 percent by 2004, consistent with the fact that young firms account for all of the recent cycle in high-tech R&D.

B. Descriptive Statistics

Figure 4 plots the median R&D-assets ratio (the dependent variable for our regressions) for the firms in the regression sample. For young firms, this ratio rose by 43 percent between 1990 to 1999 and then fell precipitously in 2001. For mature firms, median R&D intensity largely follows a smooth upward trend with little, if any, cycle. The basic pattern for young and mature firms is similar at the mean and 75th and 90th percentiles, though the boom-bust pattern for young firms is magnified. Thus, R&D *intensity* for young firms has a cyclical pattern like the aggregate data in figure 2b.

Table I provides descriptive statistics for the regression variables and the sources of finance for the sample firms. For firms in the sample, R&D far exceeds capital expenditure (*capex*). Furthermore, young firms have higher R&D intensities than mature firms (and the differences are highly significant). In contrast, the sales-asset ratios for young and mature firms are similar. Turning to the sources of finance, the cash flow ratio is slightly larger for young firms. For young firms (but not mature firms) the mean of the cash flow ratio is substantially smaller than the sum of the R&D and capital spending ratio means, implying that young firms must obtain significant funds from an external source. This source is new stock issues. For young firms, the mean of the ratio of stock issues to assets (0.268) is larger than the cash flow ratio.[16] In contrast, for mature firms, the mean of the stock issues ratio is only 0.021. New debt finance is near zero for both young and mature firms. While not reported, virtually no young firm ever pays a dividend.

There is significant boom-bust variation in the key financial statistics. For example, for young firms, the mean of the stock issues ratio for 1995-2000 is 0.351, while the mean of the stock ratio for 2001-2004 is only 0.070. In addition, for young firms, the mean of the cash flow ratio in the 1995-2000 period is 0.246 while the mean of this ratio in the 2001-2004 period is only 0.136.

The final statistics in table I report the share of finance from each source relative to total finance raised (the sum of internal cash flow, external public equity issues, and new debt). For young firms, the mean share of gross cash flow is 65.9 percent, the mean of public equity issues is 32.0 percent, and the

[16] For young firms, median new stock issues is close to zero. This arises because high issue costs make public equity issues lumpy, so firms raise large sums in some years and have no issues in others.

mean of debt finance is just 1.5 percent. For mature firms, the mean of gross cash flow is 91.6 percent, the mean of public equity finance is 6.8 percent, and the mean of debt finance is 1.9 percent. Clearly, debt finance is usually trivial for both types of firms and thus we ignore debt for the remainder of the paper. For young firms, public equity finance is important, and a large fraction of these firms must rely on public equity as their marginal source of finance. If external equity requires a cost premium, as discussed in section I, these firms will face binding financing constraints and fluctuations in the supply of both internal cash flow and external public equity finance could significantly impact their R&D. The mature firms, however, are in a different situation. Few mature firms make significant use of external finance and clearly internal cash flow is usually their marginal source of funds. Firms in our mature sample are therefore not likely to face binding financing constraints. For these firms, equity finance supply shifts should make little or no difference to R&D.

As noted above, we exclude any firm—young or mature—for which the sum of its gross cash flow ratios over the sample is negative. Notice that we do not exclude firms simply because they have some negative gross cash flow observations—rather we exclude firms for which the *sum* of these observations is negative. These are almost always very small startup companies. Summary statistics for these firms (together with the pooled sample used in our study) appear in Table IA in the appendix. For the negative cash flow firms, just 25 percent of the cash flow observations are positive (compared to 85 percent in the rest of the sample). In 1990, 1997 and 2004, these firms account for just 0.8 percent, 3.2 percent and 4.3 percent of aggregate R&D in the high-tech industries. Their median cash flow ratio is -0.172 (the mean is -4.669). The mean stock ratio is 10.663. The cash flow share is negative while external public equity finance accounts for over 100 percent of total financing. The small size of these firms often leads to ratios that are highly variable and very large (in absolute value), which could give them disproportionate impact on the results. Considering how unimportant these firms are for aggregate R&D, we exclude them from our primary sample, but report their regression results in section V.D.

IV. Econometric Results

A. Pooled Sample Estimates

Table II presents GMM coefficient estimates and standard errors for the 1990-2004 sample of high-tech firms. We report separate regressions with aggregate and industry-level time dummies. The first two columns give the baseline Euler equation specification (equation 1 from section II). The p-values for the m1 statistic indicate first-order autocorrelation in the errors, which is expected with first-difference estimation. The m2 statistics do not reject the null of no second-order autocorrelation. The Sargan test rejects the validity of the instruments in the regression with aggregate time dummies, but does not reject with industry-level time dummies. The third and fourth columns report pooled regressions with the financial variables. The results strongly indicate the impact of both internal and external equity finance on R&D. Contemporaneous gross cash flow and contemporaneous new stock issues both have a statistically significant positive effect. The Sargan tests do not reject instrument validity. We note, however, that the dynamic effects of lagged R&D and its square are well below the theoretical values of approximately one and negative one predicted by the structural model from Bond and Meghir (1994). We will make more progress in understanding these results by splitting the sample.

B. Comparison of Young and Mature Firms

Table III presents regressions for young and mature firm sub-samples with aggregate and industry-level time dummies. For the mature firms, none of the financial variables have significant effects in either regression, with the exception of a small coefficient for lagged cash flow. For both cash flow and new stock issues, chi-square tests do not reject the hypothesis that the sum of the current and lagged coefficients equals zero. In addition, the estimated dynamics conform reasonably well with the Euler equation predictions for the mature firms (coefficients on rd_{t-1} and rd_{t-1}^2 close to one in absolute value). These results are consistent with the summary statistics that imply the absence of binding financing constraints in the mature-firm sample.

For young firms, in contrast, the results are strongly consistent with the presence of binding financing constraints. For these firms, the contemporaneous gross cash flow and stock effects are statistically significant. Furthermore, the point estimates (between 0.148 and 0.166) suggest a similar and economically important effect of internal and external equity finance on R&D. While the positive and statistically significant coefficient on the lagged dependent variable implies persistence of R&D, the coefficients on the lag and lag squared of the R&D ratio do not conform to the structural model proposed in Bond and Meghir (1994). This outcome is expected if young firms face financing constraints because the structural Euler equation is derived under the assumption of perfect capital markets.

Comparison of the regressions with aggregate and industry time dummies shows that our results are not much affected by unobserved industry technology shocks or other time-varying industry-level variables correlated with R&D investment opportunities. If a correlation of financial variables with investment opportunities were an important source of bias, then the financial coefficients should decline substantially when we include industry-level time dummies.

Four main features of the regression results and the evidence discussed previously, taken together, support our hypothesis that the 1990s R&D boom and subsequent contraction were driven to a significant degree by shifts in the supply of internal and external equity finance. First, there was a boom and bust in equity finance that was closely correlated with the dramatic R&D cycle. Second, our summary statistics imply that financing constraints, if they exist, should be binding only for young firms. Third, the aggregate R&D cycle is confined entirely to young firms, consistent with the equity supply interpretation. Finally, and most important, the regressions identify significant effects of internal and external equity finance on R&D for young firms, but not mature firms, in specifications that control for R&D demand in a variety of ways.

C. Quantitative Implications

The estimates in table III suggest that young firms invest approximately 15 percent of additional equity funds in R&D. As discussed in section I, we expect the magnitude of these coefficients to be substantially less than one. The fact that the cash flow and stock coefficient estimates are close in magnitude is consistent with the financing constraint interpretation. Once inside the firm, financial resources are fungible and an additional dollar of equity finance should have a similar effect on R&D regardless of whether it comes from internal or external sources.

Can the effects estimated here for young firms explain a substantial portion of the 1990s R&D boom? While a structural answer to this question is beyond the scope of our study, we can use the results in table III to perform a simple, but suggestive, calculation. As described earlier, we projected the exponential 1980-1993 trend in aggregate R&D in the seven high-tech industries for all young firms. We then defined the amount of "boom" R&D, for 1994 through 2000, as the difference between actual and trend values. We used the same procedure to define "boom" amounts of gross cash flow and new stock issues. These calculations were done just for young firms because there is evidence of an R&D boom and significant financial effects only for young firms. With these definitions and the estimated model from table III (with industry time dummies) the cash flow and stock issue booms explain 72 percent of the 1994-2000 R&D boom in the seven high-tech industries. From 2001 to the end of the sample in 2004, the bust in both internal and external finance explains 78 percent of the reduction in R&D. In both the boom and bust periods, cash flow accounts for just under two thirds of the changes in R&D predicted by the financial variables, with the remainder explained by new share issues. Because the recent cycle in R&D for the U.S. economy is concentrated almost entirely in young firms from the industries we study, this calculation suggests that the financial effects have important macroeconomic implications.

D. Was the Level of R&D Excessive in the Late 1990s?

Our interpretation of the evidence presented here is that relaxed financing constraints in the 1990s allowed young high-tech firms to raise R&D investment closer to the level consistent with perfect capital markets. In addition, due to spillovers created by R&D, the *socially* optimal level of R&D may be even greater than what is privately optimal.[17] An alternative possibility is that young firms invested excessively in R&D--possibly even compared to the social optimum--to cater to irrational investors who focused on the high NASDAQ valuations in the late 1990s and wanted to see more R&D in these firms. Three pieces of evidence, however, are inconsistent with this alternative interpretation of our findings.

First, recall that figure 2c shows little or no boom in R&D for mature firms and mature firms have no significant financial effects in the regressions. If young firms responded excessively to high stock prices, why did mature firms not behave similarly? One possibility is that stock market valuations did not rise much for mature firms. Between 1990 and 1999, however, the average Tobin's *q* for mature firms rose 78 percent. While this figure is less than the young firm increase (122 percent), one would have expected some mature firm financial effects on R&D if the primary source of these effects were an attempt to impress irrational investors with excessive R&D activity.

[17] A large body of evidence indicates that R&D spillovers can be substantial (see the reviews in Griliches, 1992 and Jaffe, 1996). Jones and Williams (1998) link the theoretical models of new growth theory to the empirical findings in the productivity literature and report (p. 1121) that the "optimal R&D spending as a share of GDP is more than two to four times larger than actual spending."

The behavior of capital investment also seems inconsistent with the alternative view. Firms that seek to cater to irrational investors would likely expand physical investment at least as much as R&D.[18] The evidence indicates, however, that the rise in capital investment for young firms was roughly half as large as the boom we documented in R&D.[19] Furthermore, using a parallel regression specification, the financial coefficients for capital investment were substantially smaller than in the R&D regressions. There is a small positive (but insignificant) cash flow effect and a significant contemporaneous stock effect for young firms in the capital spending regressions, but the coefficient (0.045) on the stock variable is only 30 percent of the corresponding effect for R&D. These results are consistent with the view (e.g., Hall 2002) that financing constraints bind more tightly on R&D than physical investment.

A more direct test for excessive R&D is to examine the effect of corporate governance on behavior of firms. Gompers, Ishii and Metrick (GIM, 2003) construct an index of corporate governance by summing 24 different governance indicators (a high index indicates high management power and weak shareholder rights). They find a positive relationship between the index and capital expenditures (and acquisitions), which is consistent with higher agency costs for firms with weak corporate governance. We computed the average GIM index for each firm during our sample period. If the shifts in supply of finance led to excessive R&D, then we would expect to see a stronger relationship between finance and R&D in firms with a high GIM index. The results, however, suggest the opposite: we find a stronger relationship between R&D and cash flow in firms with *low* GIM values.[20]

V. Alternative Tests and Robustness

We explored a wide variety of alternative specifications and a number of different estimation approaches. The interpretation we give to the baseline results reported above is largely unchanged in these regressions. This subsection summarizes a few of the most interesting results.

[18] Unlike R&D (which is expensed), capital investment does not reduce current profits. Also, as previously discussed, there is substantial evidence of lower adjustment costs for capital investment than R&D, so temporarily ramping up capital investment is relatively less costly.

[19] Starting in 1990, the median capital investment-assets ratio rises 23.6 percent to its peak, while the R&D ratio rises 42.6 percent to its peak.

[20] Cash flow effects are largest in the quartile of firms with the lowest GIM index; the difference between the cash flow effect of this quartile and the highest GIM quartile is significant at the 6 percent level.

A. Financial Variables and Expectations

The structural specification and the industry-level time dummies control for expectations and demand factors. Moreover, the heterogeneity we obtain in the results for financial variables across young and mature firms helps assure that the financial variables in the regressions are not simply proxies for expectations. Nonetheless, we pursued two additional sets of tests that add confidence to the interpretation we offer for the results above.

First, we included various measures of Tobin's q as an additional proxy for expectations that might affect R&D demand. The use of q to account for investment demand is widely employed in the financing constraint literature. We included both beginning-of-period q as is common in the literature, and, in a particularly strong test, we included end-of-period q that conveys all contemporaneous information available from the stock market. The financial results changed very little.[21]

Second, following the lead of Bond, et al. (2003), we estimated simple forecasting equations for future profits for both the young and mature firms. These OLS regressions predict cash flow from the first and second lags of R&D, sales, capital expenditure, and cash flow. Not surprisingly, in these reduced-form regressions, cash flow lags have some forecasting power for future cash flow. Importantly, however, cash flow appears to be a better proxy for future profitability in mature firms.[22] Since our structural R&D specification finds no significant cash flow effect for mature firms, the forecasting results provide additional confidence that the significant cash flow coefficients we identify for young firms are not due simply to cash flow signaling expected future profits.

B. Alternative Sample Split Criteria

To explore how the results are affected with the choice of the classification criterion for the young and mature firm subsamples, we changed the sample split criterion to both 10 years and 20 years. The results are consistent with the interpretation we give to our baseline results with the 15-year cutoff. The financial variables have somewhat stronger effects in a sub-sample of firms that have been public for 10 or fewer years. The contemporaneous gross cash flow coefficient rises to 0.176 and the

[21] The gross cash flow and stock coefficients for the young firms dropped by 0.016 to 0.034 in various regressions, but remained highly significant. The financial variable coefficients for mature firm regressions changed negligibly.
[22] Conditional on the other variables, a one dollar increase in both current and lagged cash flow predicts a 20 cent increase in next year's cash flow for young firms but a 46 cent increase in future cash flow for mature firms.

contemporaneous stock coefficient is almost identical for this sub-sample. If we re-define the mature firms to be public for at least 20 years, financial effects remain insignificant.

In addition, we considered two other frequently used criteria (e.g., Gilchrist and Himmelberg, 1995) for splitting the sample according to firms *a priori* likelihood of facing financing constraints: presence of a bond rating and payout ratio (dividends plus stock buybacks divided by total assets). For the firms with either no bond rating or low payout (less than one percent of assets), we obtain cash flow and stock coefficients similar in magnitude and significance to those for young firms reported in table III. The financial coefficients for the "unconstrained" firm groups in the alternative sample splits are also very similar to the results for mature firms in table III.[23]

C. System GMM Estimation

Our benchmark regressions are estimated with the first-difference GMM method used in much of the related literature. A "system" GMM estimator recently developed by Arellano and Bover (1995) and Blundell and Bond (1998) has been applied to the study of finance and growth by Beck, Levine and Loayza (2000) and Beck and Levine (2004). This system approach can both improve asymptotic efficiency and reduce estimation bias in finite samples. This estimation method, however, requires additional moment restrictions to hold in the data, specifically there must be no correlation between the differences in the right-hand side variables and the firm fixed effects. Furthermore, Blundell and Bond (1998) show that the benefits of the system approach rise as the AR1 coefficient for the regression variables approaches unity.

We estimated the regressions reported in table III with the system GMM technique and the financial effects are quite similar. The contemporaneous cash flow effect for the young firms is larger (0.199) than in table III and highly significant, while neither contemporaneous nor lagged cash flow is significant for mature firms. The contemporaneous stock coefficient estimate for young firms from the system GMM regression (0.124) is slightly lower than in table III, but remains highly significant. The contemporaneous stock coefficient for mature firms becomes marginally significant, but half the size of

[23] The results are available on request. There is no statistically or economically significant stock effect for either bond-rated or high-payout firms. Furthermore, contemporaneous cash flow coefficients are near zero and insignificant. As was the case in Table III, the lagged cash flow coefficient is positive for bond-rated and positive-payout firms. These lagged coefficients are slightly larger than the corresponding coefficient for mature firms in Table III, but a chi-squared test does not reject the null of no effect for the high-payout case.

the value for young firms. For young firms, the Sargan test rejects the validity of the additional instruments needed for system GMM, suggesting that the necessary moment conditions for this approach are not satisfied in our data. Furthermore, we found that the first-order autocorrelation of our variables was far from the near-unit-root case for which the benefits of the system estimator are most pronounced, especially for the young-firm sample. We therefore conclude that the first-difference GMM estimation approach is most appropriate for our primary results.[24]

D. Negative Cash Flow Firms

In section III, we discussed the characteristics of the "negative cash flow" firms that we exclude from the primary regression sample. The *sum* of the gross cash flow-assets variable for these firms is negative over the entire sample. The gross cash flow regression coefficients are negative (although not highly significant) for this sub-sample. This result is not surprising since these firms have not reached the stage at which internal equity is a source of funds. They must obtain all financing from outside equity (see appendix table IA for summary statistics for these firms). It is therefore also not surprising that the young firms in this sub-sample have a positive and significant coefficient on the stock variable (0.079, standard error of 0.019). Recall that these firms account for a trivial amount of aggregate R&D.

E. Results for Firms Outside of High Tech

Figure 1 shows that the 1990s boom in R&D investment was confined almost entirely to the seven high-tech industries that are the focus of our study. It is therefore interesting to examine the summary statistics and regression results for all other young publicly traded firms covered by Compustat. The summary statistics for other firms (with positive R&D) are very different from the numbers reported in table I for the high-tech industries. For other young firms, the overall median R&D-to-asset ratio is low (0.030) compared to the median figure in table I (0.137 for young high-tech firms), consistent with the fact that firms outside high-tech have relatively low demand for R&D. In addition, the sum of the median R&D and capital spending ratios for all other firms (0.077) is much lower than their median cash flow (0.132), suggesting that the typical young firm outside of high tech may not face binding financing constraints. We estimated dynamic R&D regressions for these firms and find that financing effects are

[24] Bond et al. (2003) consider the first-difference and system GMM estimators and prefer the first-difference approach, also on the basis of the AR1 properties of the regression variables.

small (and generally insignificant) compared to those reported in table III.[25] These results are consistent with both the summary statistics (indicating no binding financing constraints) and the absence of a finance-driven R&D boom beyond the seven high-tech industries.

VI. Economic Implications

Our interpretation of the empirical findings presented here is that a major shift in the availability of internal and external equity finance relaxed financing constraints for a large number of young high-tech companies in the mid and late 1990s which contributed significantly to the aggregate R&D boom. Furthermore, finance shifts help explain the reversal of R&D growth in 2001-2004. We briefly consider some of the implications of these findings in this section.

A. The R&D Boom and Labor Productivity

At the micro level, many studies have found a strong relationship between R&D investment and labor productivity. If R&D is an important determinant of technical change, the 1990s R&D boom should have had an impact, with some lag, on the 1990s revival of labor productivity growth. Indeed, non-farm labor productivity growth began to rise in 1996, two to three years after the beginning of the R&D boom. The high-tech industries responsible for the recent R&D boom include the chief information technology industries, frequently cited as critical to the recent productivity revival (see, for example, Jorgenson, 2001). Our findings therefore suggest that the boom in internal and external equity finance may have contributed to robust productivity growth in the "new economy" era.

B. Corporate Income Taxation and the Supply of Internal and External Equity Finance

The U.S. currently has the second highest corporate income tax among OECD countries.[26] Compared to other types of investment, corporate tax rates should have a disproportionate impact on R&D, because R&D is financed mainly with equity and equity income is not protected from the corporate tax. This point implies that the standard cost-of-capital channel through which corporate taxation affects investment will be more significant for R&D than for fixed capital investment. Fixed capital is usually

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[25] There is a relatively small and marginally significant coefficient for current stock issues in young, non-high-tech firms of 0.053 (0.025).

[26] Over the last six years, most OECD nations (but not the U.S). have substantially reduced their rate of corporate income taxation. In addition, a number of countries have implemented an R&D tax credit. While the U.S. has had an R&D credit since 1981, it is not permanent and not as generous as tax credits in other countries.

financed in part by debt that has returns shielded from taxation. In addition, the presence of financing constraints on R&D introduces a potentially more significant, but less studied, channel through which business taxation affects R&D. Business tax payments reduce after-tax cash flow, which therefore reduce the quantity of internal equity finance. Our regression results imply that lower cash flow reduces R&D for constrained firms (young firms in this study) independently of any effect on the marginal cost of capital. This argument suggests that business tax policies have larger effects on R&D than predicted by conventional models without financial constraints.

C. Growth and Finance: External Equity as a Source of Finance?

Levine (2005) surveys the enormous macroeconomic literature that studies finance and growth, and one of his main conclusions (p. 3) is that "better functioning financial systems ease external financing constraints." Most recent efforts (see the introduction) to introduce financing constraints into the modern endogenous growth literature focus on the role of intermediation and debt finance.[27] While the historical absence of public equity finance in most countries certainly justifies analysis of debt, recently stock market capitalization has grown tremendously in both developed and developing countries (see Rousseau and Wachtel, 2000). Our findings show that stock markets can be an important source of finance, suggesting that it may be useful for growth models focusing on innovation and financing constraints to consider the role of both debt and equity finance.

A growing empirical literature finds that measures of the degree of stock market development are positively correlated with growth (e.g., Atje and Jovanovic, 1993; Levine and Zervos, 1998; Arestis, Demetriades and Luintel, 2001; Rousseau and Wachtel, 2000; and Beck and Levine, 2002 and 2004). In particular, Beck and Levine (2004), using dynamic panel data techniques, find that both stock market and bank development have an economically large impact on economic growth. These studies, however, do not emphasize equity markets as an important *source* of finance, but rather that stock markets provide exit options for investors, more liquidity, or better information.[28] Likewise, these studies do not include

[27] Exceptions that consider stock markets include Levine (1991) and Bencivenga, Smith, and Starr (1995).
[28] Perhaps one reason for the lack of emphasis on stock markets as a source of finance is the finding that liquidity measures (such as trading volume) are significant for growth while measures of stock market capitalization typically are not. (See Levine 2005; an exception is Arestis, Demestraides, and Luintel 2001). Stock market capitalization, however, is an imperfect proxy for new stock issues. In addition, most studies examine data from the late 1970s through the early 1990s, predating most of the recent surge in the development of stock markets and the use of external equity finance.

measures of equity issues as indicators for the importance of equity markets. Our findings suggest that future empirical tests should consider the possibility that stock markets contribute to economic growth by directly funding innovation, particularly for young companies.

A country with closed equity markets can obtain a significant new source of equity finance--foreign investors--by liberalizing its stock markets. Bekaert, Harvey and Lundblad (2005, page 4) argue that "equity market liberalization directly reduces financing constraints in the sense that more foreign capital becomes available, and foreign investors could insist on better corporate governance, which indirectly reduces the cost of internal and external finance." Their empirical findings show that equity market liberalization is associated with a substantial increase in economic growth. These results, along with our findings that link equity finance to R&D, suggest that equity market liberalization may have a disproportionate impact on a country's rate of intangible investment and innovation.

D. Bank-Based Versus Market-Based Financial Systems

In his survey of the growth-finance nexus, another of Levine's (2005) main conclusions is that "the degree to which a country is bank-based or market-based does not matter much." Some studies, however, have found evidence that a country's financial architecture may matter (see Tadesse, 2002, for example). Our findings also suggest that the financial architecture may make a difference. In the U.S. during the 1980s and 1990s, thousands of young high-tech firms obtained a tremendous amount of finance from various external equity markets. These new entrants had very high levels of R&D investment. In contrast, during this same period, bank-based economies such as Germany and France had comparatively less success in creating new high-tech firms, and their world share of high-tech production has fallen substantially, exactly the opposite of the U.S.

VII. Summary

This paper explores whether supply shifts in finance can explain a significant portion of the 1990s R&D boom and subsequent decline. We examine firm-level, panel data for 1,347 publicly traded, high-tech firms from 1990-2004. Using a GMM procedure to estimate dynamic R&D models, we find very sharp differences when we disaggregate the data into young and mature firms. For mature firms, the point estimates for the financial variables are quantitatively unimportant and statistically insignificant. For young firms, variables that measure access to both internal and external equity finance have significant effects, both statistically and economically. These findings, together with the fact that there was no boom in R&D for mature firms, are consistent with a shift in supply of finance and are difficult to explain with a demand-side story. The financial effects for the young, high-tech firms alone are large enough to explain most of the 1994-2004 aggregate R&D cycle.

These results contribute to the understanding of the link between finance and economic growth. A number of recent endogenous growth models incorporate capital market imperfections to provide a theoretical foundation for a causative finance-growth link. A large literature demonstrates that broad macroeconomic indicators of financial development correlate with economic growth across countries, and significant progress has been made to establish causation in this relationship. Our work complements these findings by using microeconomic data to look more deeply at a key mechanism that connects finance and growth. Focusing on the dramatic 1990s R&D boom, we uncover an empirical effect of finance on R&D, the key innovative activity in most modern models of endogenous growth. These results provide further support for the view that finance, financial development, and the institutional structure of financial markets are important factors driving economic growth.

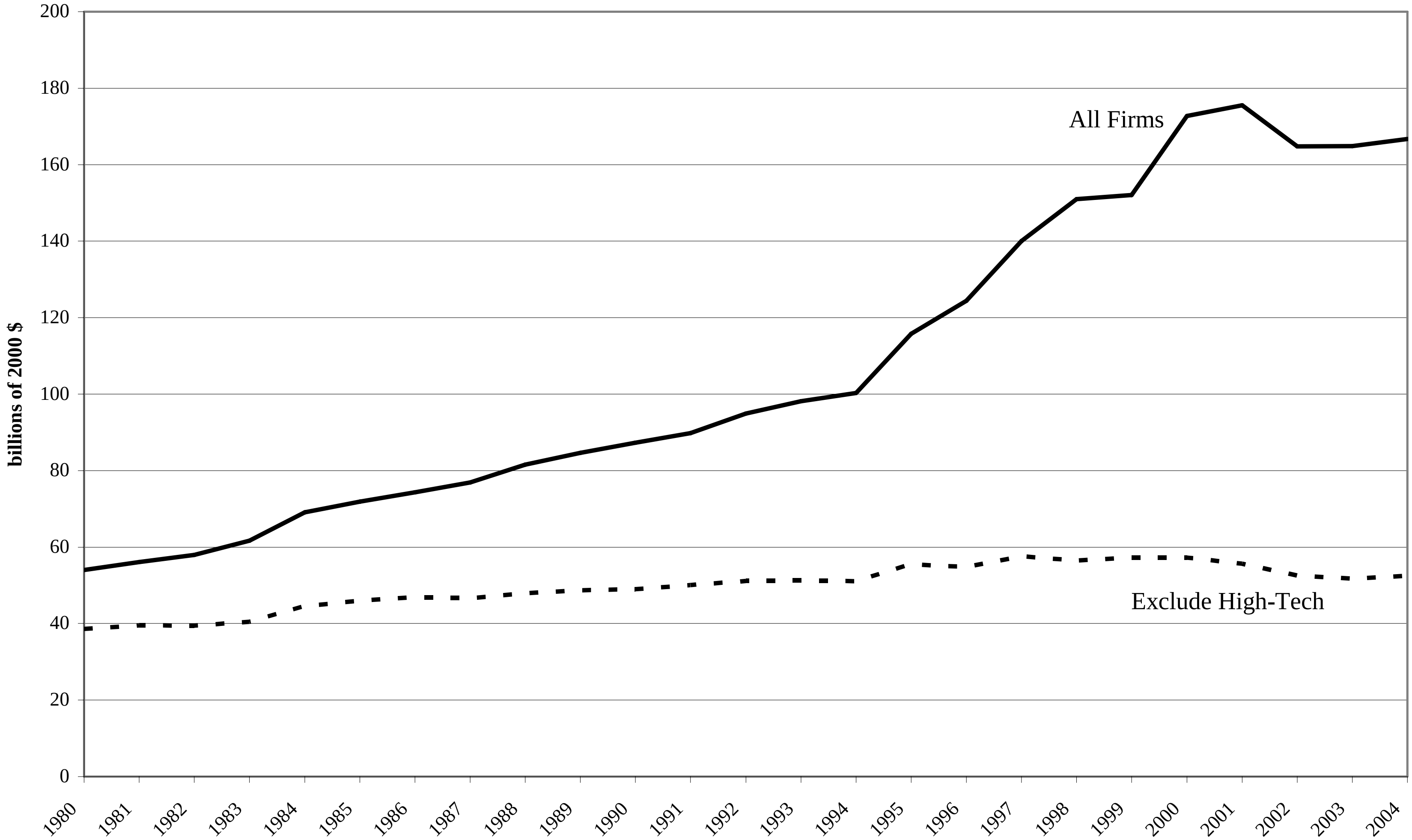

Figure 1. Economy-Wide R&D Investment. The solid line plots the sum of R&D for all publicly traded companies with coverage in Compustat (financial firms and utilities are excluded) over time. The dashed line plots the sum of R&D for firms in all industries *except* the seven high-tech industries with SIC codes 283, 357, 366, 367, 382, 384 and 737.

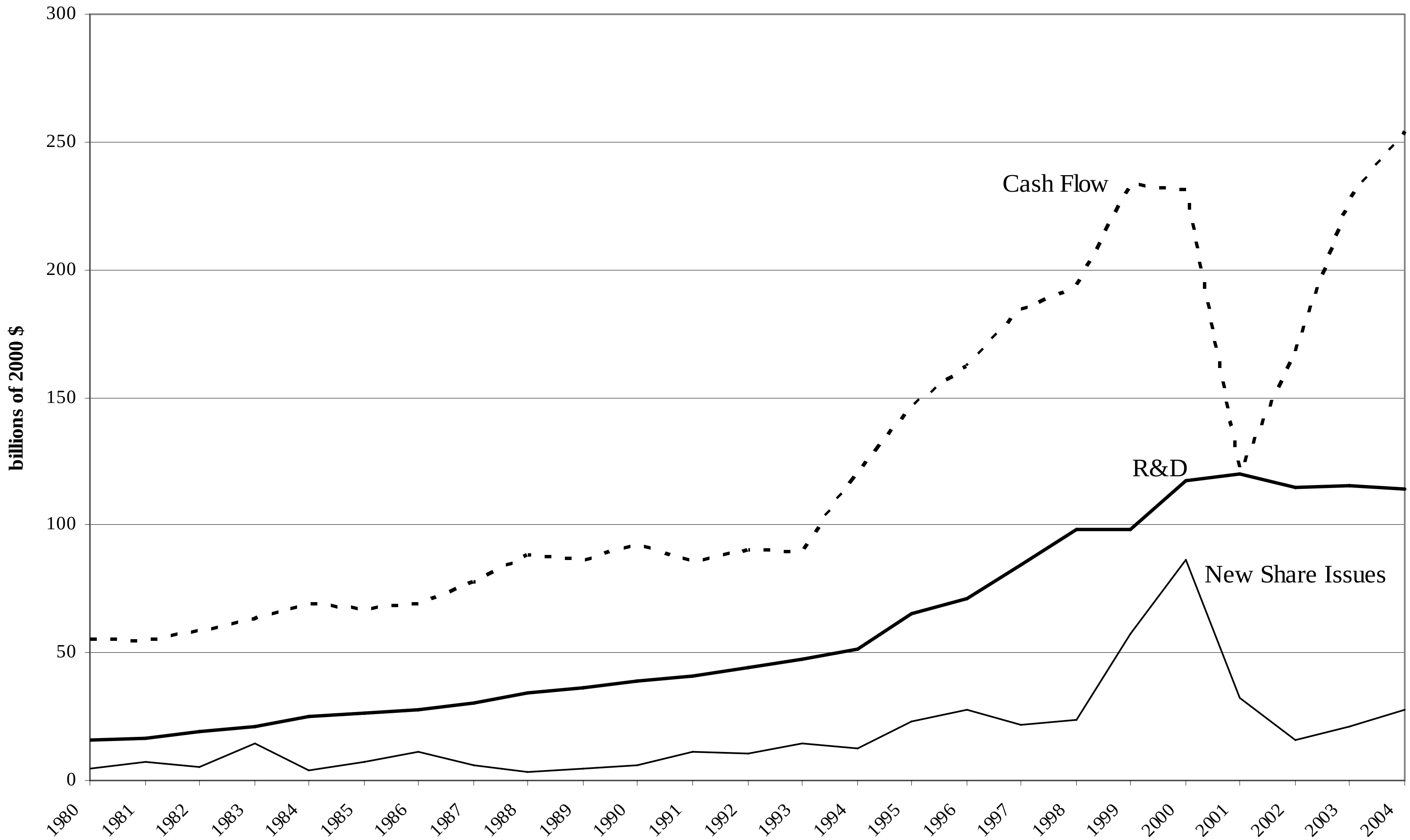

Figure 2a. High-Tech R&D, Cash Flow and New Share Issues (All Firms). The sample is all publicly traded companies in high-tech industries 283, 357, 366, 367, 382, 384 and 737 with coverage in Compustat. The heavy line plots the sum of R&D for all high-tech firms, the dashed line plots the sum of gross cash flow, and the thin line plots the sum of net new stock issues with stock buybacks set equal to zero.

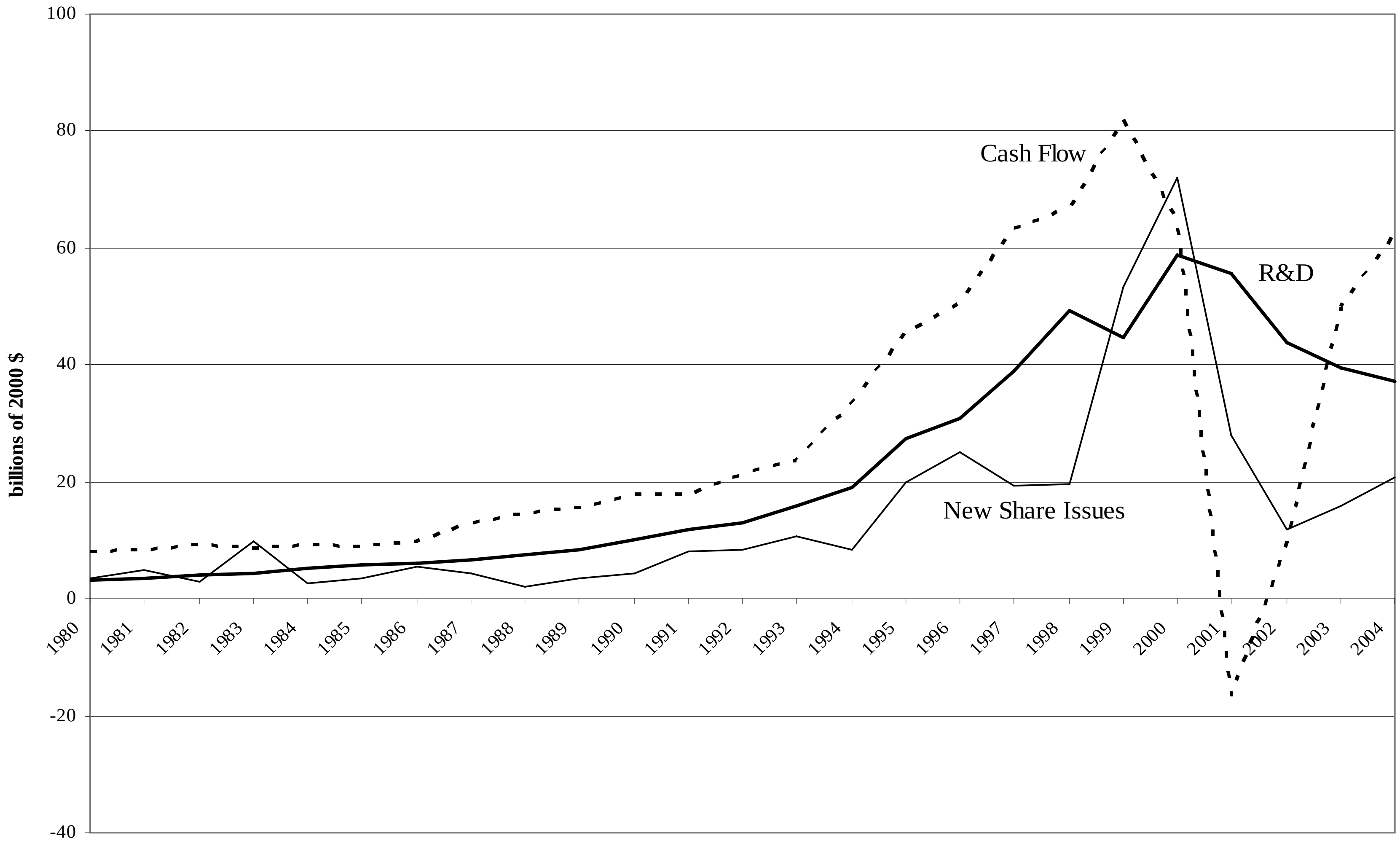

Figure 2b. High-Tech R&D, Cash Flow and New Share Issues (Young Firms). The sample is all young, high-tech firms with coverage in Compustat. A firm is classified as young for the first 15 years following the year it first appears in Compustat with a stock price. The high-tech industries are SICs 283, 357, 366, 367, 382, 384 and 737. The heavy line plots the sum of R&D for all young high-tech firms, the dashed line plots the sum of gross cash flow, and the thin line plots the sum of net new stock issues with stock buybacks set equal to zero.

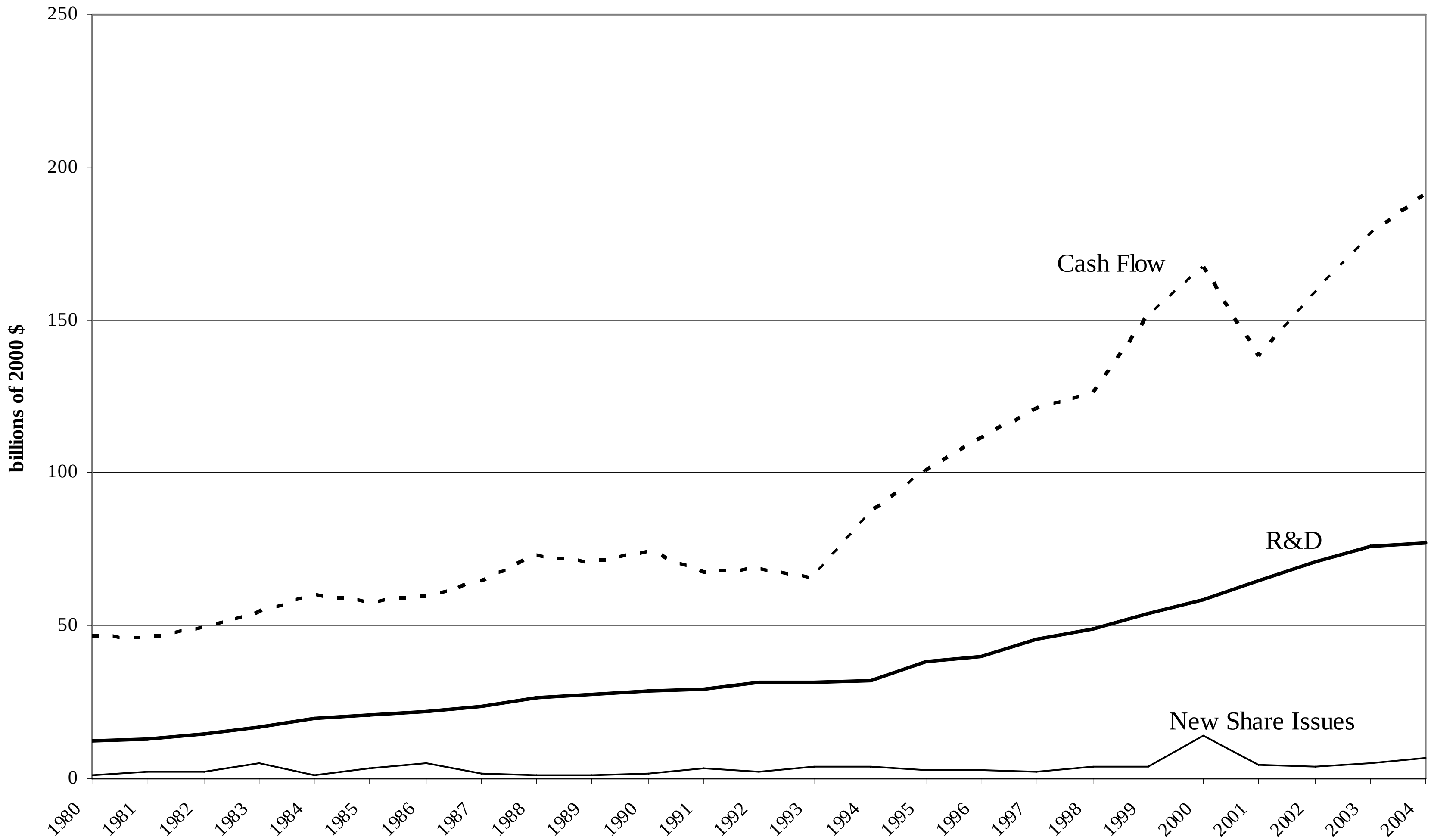

Figure 2c. High-Tech R&D, Cash Flow and New Share Issues (Mature Firms). The sample is all mature, high-tech firms with coverage in Compustat. A firm is classified as mature if it is more than 15 years after the year it first appears in Compustat with a stock price. The high-tech industries are SICs 283, 357, 366, 367, 382, 384 and 737. The heavy line plots the sum of R&D for all mature high-tech firms, the dashed line plots the sum of gross cash flow, and the thin line plots the sum of net new stock issues with stock buybacks set equal to zero.

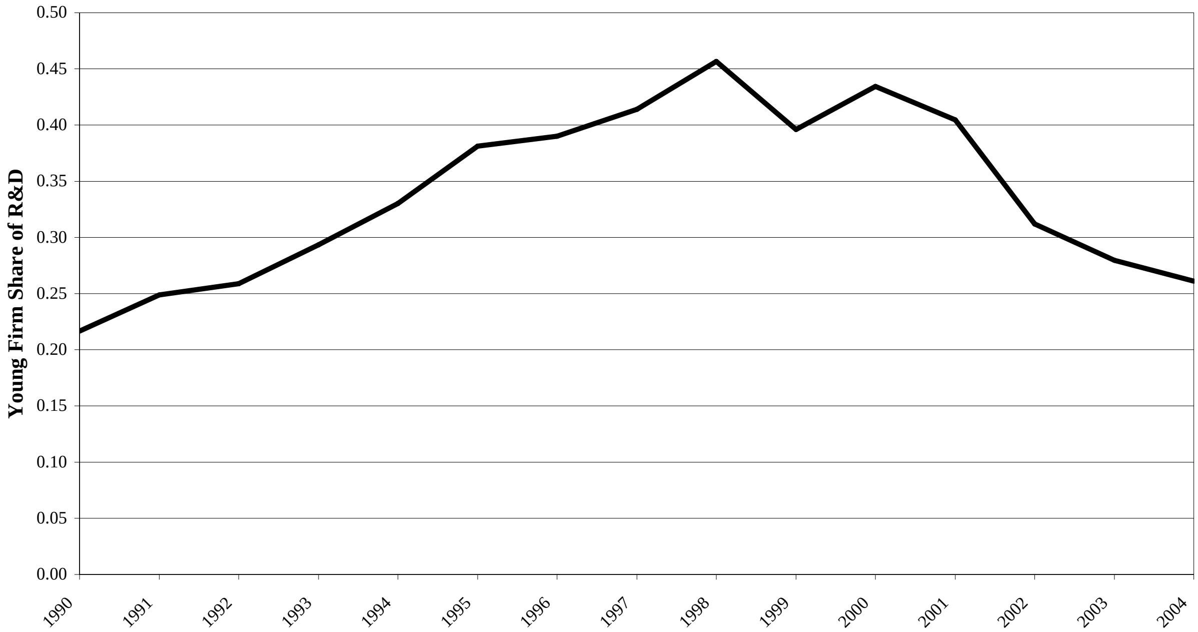

Figure 3. Young Firm Share of Total R&D (Regression Sample). The line plots the share of regression sample R&D accounted for by young firms over time. A firm is classified as young for the first 15 years following the year it first appears in Compustat with a stock price. The regression sample is described in section III.A of the paper.

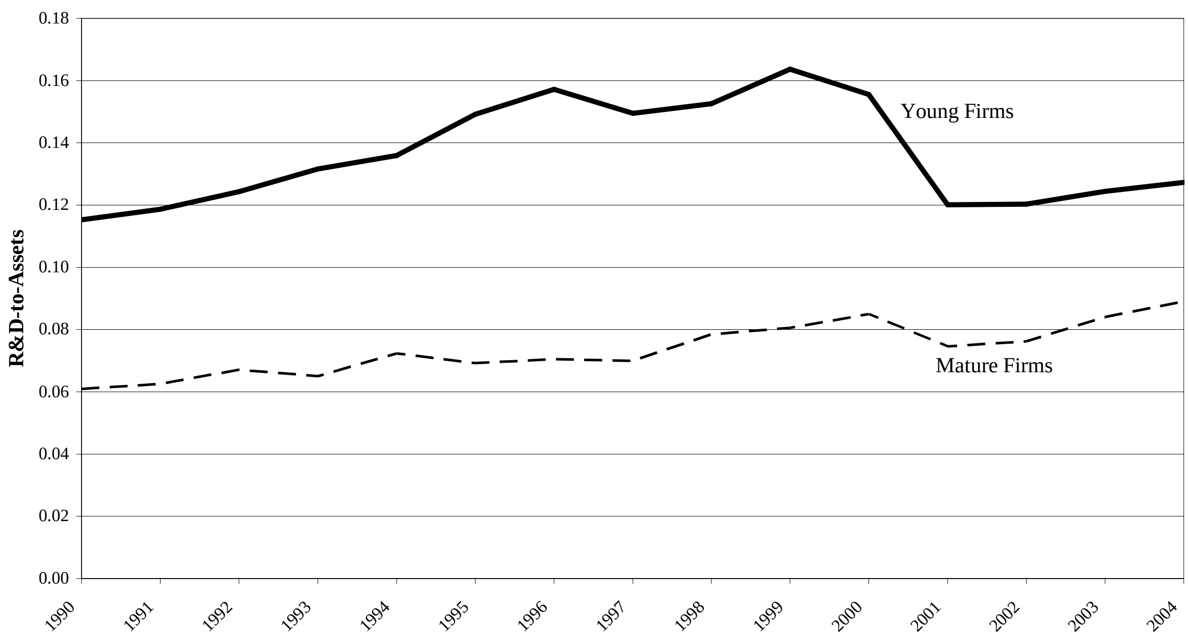

Figure 4. Median R&D-to-Assets Ratios (Regression Sample). The solid line plots the median R&D-to-assets ratio for young firms in the regression sample over time, and the dashed line plots the median R&D-to-assets ratio for mature firms. A firm is classified as young for the first 15 years following the year it first appears in Compustat with a stock price, and mature thereafter. The regression sample is described in section III.A of the paper.

Table I
Sample Descriptive Statistics

The regression sample is constructed from publicly traded high-tech firms with coverage in the Compustat database during 1990-2004. We exclude firms incorporated outside of the U.S., firms with no stock price data, and firms without at least six R&D observations. We also exclude firms if the sum of their cash flow-assets ratio over the sample period is less than or equal to zero. All variables are scaled by beginning-of-period total assets. Outliers in all variables are trimmed at the one-percent level. Young firm observations are those less than or equal to 15 years from the initial appearance of a stock price in Compustat; mature firm observations are more than 15 years from the appearance of a stock price. The final column reports p-Values for tests that the mean and median values differ across young and mature firms. By three-digit SIC code, the high-tech industries are: 283, 357, 366, 367, 382, 384 and 737.

Variable and Statistic	Full Sample	Young Firms	Mature Firms	Difference (p-Value)
rd_t				
Mean	0.170	0.194	0.098	0.000
Median	0.116	0.137	0.074	0.000
Std. Dev.	0.217	0.240	0.100	
90th Percentile	0.350	0.395	0.186	
$capex_t$				
Mean	0.064	0.069	0.049	0.000
Median	0.041	0.042	0.039	0.000
Std. Dev.	0.149	0.171	0.042	
90th Percentile	0.130	0.143	0.102	
s_t				
Mean	1.212	1.227	1.167	0.000
Median	1.083	1.076	1.099	0.145
Std. Dev.	0.993	1.095	0.597	
90th Percentile	2.122	2.213	1.837	
cf_t				
Mean	0.205	0.217	0.172	0.000
Median	0.185	0.194	0.166	0.000
Std. Dev.	0.369	0.398	0.261	
90th Percentile	0.457	0.495	0.347	
stk_t				
Mean	0.204	0.268	0.021	0.000
Median	0.006	0.010	0.001	0.000
Std. Dev.	1.160	1.338	0.155	
90th Percentile	0.427	0.643	0.050	
dbt_t				
Mean	0.009	0.009	0.007	0.515
Median	0.000	0.000	0.000	0.655
Std. Dev.	0.344	0.394	0.113	
90th Percentile	0.061	0.058	0.067	

Table I (Continued)
Sample Descriptive Statistics

Variable and Statistic	Full Sample	Young Firms	Mature Firms	Difference (p-Value)
Sum Cash Flow / Net Finance				
Mean	0.686	0.659	0.916	0.000
Median	0.731	0.692	0.957	0.000
Std. Dev.	0.399	0.421	0.627	
90^{th} Percentile	1.139	1.110	1.357	
Sum New Stock / Net Finance				
Mean	0.289	0.320	0.068	0.000
Median	0.219	0.247	0.027	0.000
Std. Dev.	0.367	0.381	0.419	
90^{th} Percentile	0.807	0.850	0.484	
Sum New Debt / Net Finance				
Mean	0.021	0.015	0.019	0.820
Median	0.000	-0.001	0.000	0.002
Std. Dev.	0.182	0.194	0.382	
90^{th} Percentile	0.229	0.230	0.378	

Table II
Dynamic R&D Regressions: Pooled Results

Dynamic R&D regressions on the sample of high-tech firms described in Table I are estimated with GMM in first differences to eliminate firm effects. Level variables dated *t-3* and *t-4* are used as instruments. Aggregate or industry–specific year dummies are included in all regressions (as indicated in the table). Standard errors robust to heteroskedasticity and with-in firm serial correlation appear below point estimates. The statistics *m1* and *m2* test the null of no first- and second-order autocorrelation in the first-differenced residuals. The *cf Chi2* statistic is a Chi-square test of the null that sum of the current and lagged cash flow coefficients is zero; *stk Chi2* is the corresponding test for stock issues. *Sargan* is a test of the null that that the overidentifying restrictions are valid.

Dependent Variable: rd_t

Variable	Baseline Euler Equation		Euler Equation with Financial Variables	
rd_{t-1}	0.808 *(0.215)*	0.789 *(0.200)*	0.380 *(0.134)*	0.403 *(0.130)*
rd_{t-1}^2	-0.400 *(0.139)*	-0.384 *(0.130)*	-0.145 *(0.076)*	-0.153 *(0.075)*
s_t			-0.020 *(0.018)*	-0.007 *(0.018)*
s_{t-1}	-0.007 *(0.016)*	-0.013 *(0.017)*	-0.015 *(0.009)*	-0.022 *(0.009)*
cf_t			0.170 *(0.041)*	0.158 *(0.040)*
cf_{t-1}	-0.015 *(0.045)*	-0.004 *(0.045)*	0.001 *(0.016)*	0.006 *(0.016)*
stk_t			0.151 *(0.017)*	0.149 *(0.017)*
stk_{t-1}			-0.018 *(0.004)*	-0.017 *(0.004)*
Time Dummies	Aggregate	Industry-Level	Aggregate	Industry-Level
m1 (p-value)	0.000	0.000	0.000	0.000
m2 (p-value)	0.401	0.311	0.249	0.345
cf Chi2 (p-value)			0.000	0.000
stk Chi2 (p-value)			0.000	0.000
Sargan (p-value)	0.002	0.889	0.138	1.000
Observations	12,248	12,248	12,224	12,224

Table III
Dynamic R&D Regressions for Separate Young and Mature Firm Samples

Dynamic R&D regressions on the samples of young and mature high-tech firms described in Table I are estimated with GMM in first differences to eliminate firm effects. Level variables dated *t-3* and *t-4* are used as instruments. Aggregate or industry–specific year dummies are included in all regressions (as indicated in the table). Standard errors robust to heteroskedasticity and with-in firm serial correlation appear below point estimates. The statistics *m1* and *m2* test the null of no first- and second-order autocorrelation in the first-differenced residuals. The *cf Chi2* statistic is a Chi-square test of the null that sum of the current and lagged cash flow coefficients is zero; *stk Chi2* is the corresponding test for stock issues. *Sargan* is a test of the null that that the overidentifying restrictions are valid.

Dependent Variable: rd_t

Variable	Mature Firms		Young Firms	
rd_{t-1}	0.632	0.626	0.382	0.392
	(0.179)	*(0.172)*	*(0.137)*	*(0.130)*
rd_{t-1}^2	-0.831	-0.830	-0.142	-0.144
	(0.277)	*(0.226)*	*(0.077)*	*(0.074)*
s_t	0.049	0.048	-0.023	-0.006
	(0.016)	*(0.015)*	*(0.020)*	*(0.019)*
s_{t-1}	-0.031	-0.031	-0.015	-0.023
	(0.011)	*(0.010)*	*(0.010)*	*(0.009)*
cf_t	-0.015	-0.005	0.166	0.150
	(0.032)	*(0.031)*	*(0.044)*	*(0.043)*
cf_{t-1}	0.041	0.040	0.003	0.012
	(0.020)	*(0.018)*	*(0.017)*	*(0.017)*
stk_t	0.031	0.034	0.148	0.148
	(0.029)	*(0.030)*	*(0.017)*	*(0.017)*
stk_{t-1}	-0.010	-0.010	-0.019	-0.017
	(0.011)	*(0.011)*	*(0.004)*	*(0.004)*
Time Dummies	Aggregate	Industry-Level	Aggregate	Industry-Level
m1 (p-value)	0.000	0.000	0.000	0.000
m2 (p-value)	0.795	0.880	0.294	0.432
cf Chi2 (p-value)	0.382	0.212	0.000	0.000
stk Chi2 (p-value)	0.539	0.470	0.000	0.000
Sargan (p-value)	0.633	1.000	0.103	1.000
Observations	3,393	3,393	8,831	8,831

Appendix

Variable Definitions with Compustat Data Codes

rd_t: Research and development expense (data46) in period *t* divided by the book value of total assets (data6) at the beginning of period *t.*

$capex_t$: Capital expenditures (data128) in period *t* divided by the book value of total assets (data6) at the beginning of period *t.*

s_t: Net sales (data12) in period *t* divided by the book value of total assets (data6) at the beginning of period *t.*

cf_t: Gross cash flow in period *t* divided by the book value of total assets (data6) at the beginning of period *t*, where gross cash flow is defined as (after-tax) income before extraordinary items (data18) plus depreciation and amortization (data14) plus research and development expense (data46).

stk_t: Net cash raised from stock issues in period *t* divided by the book value of total assets (data6) at the beginning of period *t*, where net cash from stock issues is equal to the sale of common and preferred stock (data108) minus the purchase of common and preferred stock (data115).

dbt_t: Net new long-term debt in period *t* divided by the book value of total assets (data6) at the beginning of period *t*, where net new long-term debt is equal long-term debt issuance (data111) minus long-term debt reduction (data114).

Appendix Table IA: Summary Statistics for Firms with Negative Sum of cf

		Negative Cash Flow Firms	**Sample Firms**
Firms		633	1347
Share cf Observations Positive	mean	0.25	0.85
	median	0.24	0.90
Share of Aggregate R&D	1990	0.008	0.992
	1997	0.032	0.968
	2004	0.043	0.957
Sales (millions of dollars)	mean	21.89	478.80
	median	5.27	55.18
rd	mean	0.844	0.170
	median	0.190	0.116
cf	mean	-4.669	0.205
	median	-0.172	0.185
stk	mean	10.663	0.204
	median	0.067	0.006
dbt	mean	-0.034	0.009
	median	0.000	0.000
Sum Cash Flow / Net Finance	mean	-0.134	0.686
	median	-0.275	0.731
Sum New Stock / Net Finance	mean	1.117	0.289
	median	1.199	0.219
Sum New Debt / Net Finance	mean	0.044	0.021
	median	0.004	0.000

References

Aghion, Philippe, George-Marios Angeletos, Abhijit Banerjee, and Kalina Manova. 2005. "Volatility and Growth: Credit Constraints and Productivity-Enhancing Investment," mimeo.

Aghion, Philippe, Peter Howitt, and David Mayer-Foulkes. 2005. "The Effect of Financial Development on Convergence: Theory and Evidence," *Quarterly Journal of Economics*, 120, 173-222.

Arellano, Manuel and Stephen R. Bond. 1991. "Some Specification Tests for Panel Data: Monte Carlo Evidence and an Application to Employment Equations*," Review of Economic Studies,* 58, 277-98.

Arellano, Manuel and Olympia Bover. 1995. "Another Look at the Instrumental-Variable Estimation of Error-Components Models," *Journal of Econometrics*, 68, 29-52.

Arrow, Kenneth J. 1962. "Economic Welfare and the Allocation of Resources for Invention," in *The Rate and Direction of Inventive Activity: Economic and Social Factors,* R. R. Nelson ed., Princeton, New Jersey: Princeton University Press, 609-625.

Arestis, Philip, Panicos O. Demetriades and Kul B. Luintel. 2001. "Financial Development and Economic Growth: The Role of Stock Markets," *Journal of Money Credit and Banking*, 33, 16-41.

Asquith, Paul and David W. Mullins. 1986. "Equity Issues and Offering Dilution," *Journal of Financial Economics*, 15, 61-89.

Atje, Raymond, and Boyan Jovanovic. 1993. "Stock Markets and Development," *European Economic Review*, 37, 632-640.

Baker, Malcolm, Stein, Jeremy and Wurgler, Jeffrey. 2003. "When Does the Market Matter? Stock Prices and the Investment of Equity-Dependent Firms," *Quarterly Journal of Economics*, 118(3), pp. 969-1005.

Baker, Malcolm and Jeffrey Wurgler. 2000. "The Equity Share in New Issues and Aggregate Stock Returns," *Journal of Finance*, 55, 2219-2257.

Beck, Thorsten and Ross Levine. 2002. "Industry Growth and Capital Allocation: Does Having a Market- or Bank-Based System Matter?", *Journal of Financial Economics,* 64, 147-180.

Beck, Thorsten and Ross Levine. 2004. "Stock Markets, Banks and Growth: Panel Evidence," *Journal of Banking and Finance*, 28, 423-442.

Beck, Thorsten, Ross Levine, and Norman Loayza. 2000. "Finance and the Sources of Growth," *Journal of Financial Economics*, 58, 261-300.

Bekaert, Geert, Harvey R. Campbell, and Christian Lundblad, 2001 "Emerging Equity Markets and Economic Development," *Journal of Development Economics*, 66, 465-504.

Bekaert, Geert, Harvey R. Campbell, and Christian Lundblad, 2005. "Does Financial Liberalization Spur Growth?" *Journal of Financial Economics*, 77, 3-55.

Bencivenga, Valerie R., Bruce D. Smith, and Ross M. Starr. 1995. "Transactions Costs, Technological Choice, and Endogenous Growth," *Journal of Economic Theory*, 67, 153-77.

Berger, Allen N. and Gregory F. Udell. 1990. "Collateral, Loan Quality, and Bank Risk," *Journal of Monetary Economics*, 25, 21-42.

Bernstein Jeffery I. and M. Ishaq Nadiri. 1989. "Rate of Return on Physical and R&D Capital and Structure of the Production Process: Cross Section and Time Series Evidence," in B. Raj, ed), *Advances in Econometrics and Modelling,* Dordrecht Kluwer Academic Publishing, 169-185.

Blundell, Richard and Stephen Bond. 1998. "Initial Conditions and Moment Restrictions in Dynamic Panel Data Models," Journal of Econometrics, 87, 115-143.

Bond, Stephen R. and Jason G. Cummins. 2000. "The Stock Market and Investment in the New Economy: Some Tangible Facts and Some Intangible Fictions." *Brookings Papers on Economic Activity*, 61-108.

Bond, Stephen, Julie Ann Elston, Jacques Mairesse, and Benoît Mulkay. 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, Stephen, Dietmar Harhoff, and John Van Reenen. 2003. "Investment, R&D and Financial Constraints in Britain and Germany," Institute for Fiscal Studies Working Paper 99/5.

Bond, Stephen and Costas Meghir. 1994. "Dynamic Investment Models and the Firm's Financial Policy," *Review of Economic Studies*, 61, 197-222.

Brealey, Richard A. and Stewart C. Myers. 2000. *Principles of Corporate Finance, sixth edition* Boston, MA: Irwin McGraw-Hill.

Brown, James R. 2006. "R&D, Debt Capacity and New Equity Finance Following the IPO," working paper, Montana State University.

Carpenter, Robert E. and Bruce C. Petersen. 2002. "Capital Market Imperfections, High-Tech Investment, and New Equity Financing," *The Economic Journal*, 112, 54-72.

Chen, Joseph; Harrison Hong, and Jeremy C. Stein. 2002. "Breadth of Ownership and Stock Returns," *Journal of Financial Economics,* 66 , 171-205.

Chirinko, Robert S. and Huntley Schaller. 2001. "Business Fixed Investment and 'Bubbles:' The Japanese Case," *American Economic Review*, 91, 663-680.

Cornell, Bradford and Alan C. Shapiro. 1988. "Financing Corporate Growth," *Journal of Applied Corporate Finance*, 1, 6-22.

De la Fuente, Angel and Jose M. Marin. 1996. "Innovation, Bank Monitoring and Endogenous Financial Development," *Journal of Monetary Economics*, 269-301.

Fama, Eugene F. and Kenneth R. French. 2005. "Financing Decisions: Who Issues Stock?" *Journal of Financial Economics*, 76, pp. 549-582.

Frank, Murray Z. and Vidhan K. Goyal. 2003. "Testing the Pecking Order Theory of Capital Structure," *Journal of Financial Economics*, 67, pp. 217-248.

Gilchrist, Simon and Charles P. Himmelberg. 1995. "Evidence on the Role of Cash Flow, " *Journal of Monetary Economics*, 36, pp. 541-572.

Gilchrist, Simon, Charles Himmelberg, and Gur Huberman. 2005. "Do Stock Price Bubbles Influence Corporate Investment?" *Journal of Monetary Economics*, 52, 805-27.

Gertler, Mark. 1988. "Financial Structure and Aggregate Economic Activity: An Overview," *Journal of Money, Credit, and Banking*, 20, 559-596.

Goldin, Claudia. 2000. "Labor Markets in the Twentieth Century," in S. Engerman and R. Gallman, eds., *The Cambridge Economic History of the United States*, Vol. 3. New York: Cambridge University Press, Chapter 10, 549-624.

Gompers, Paul A., Ishii, Joy L. and Andrew Metrick. 2003. "Corporate Governance and Equity Prices, *Quarterly Journal of Economics*, pp. 107-15

Griliches, Zvi. 1979. "Issues in Assessing the Contribution of Research and Development to Productivity Growth," *Bell Journal of Economics*, 10, pp. 92-116.

Griliches, Zvi. 1992. "The Search for R&D Spillovers," *Scandinavian Journal of Economics*, 94, S29-S47.

Hall, Bronwyn H. 1992. "Investment and Research and Development at the Firm Level: Does the Source of Financing Matter?" NBER Working Paper, number 4096.

Hall, Bronwyn H. 2002. "The Financing of Research and Development." *Oxford Review of Economic Policy*, 18, 35-51.

Hall, Bronwyn H., Zvi Griliches, and Jerry A. Hausman. 1986. "Patents and R&D: Is There a Lag?" *International Economic Review*, 27, 265-83.

Himmelberg, Charles P. and Petersen, Bruce 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.

Jaffe, Adam B. 1996. *Economic Analysis of Research Spillovers – Implications for the Advanced Technology Program*, Washington, D.C.: Advanced Technology Program, National Institute of Standards and Technology, U.S. Department of Commerce.

Jones, Charles and John C. Williams. 1998. "Measuring the Social Return to R&D." *Quarterly Journal of Economics*, 113, 1119-1135.

Jorgenson, Dale W. 2001. "Information Technology and the U.S. Economy," *American Economic Review*, 91, 1-32.

Kaplan, Steven N. and Luigi Zingales. 1997. "Do Investment-Cash Flow Sensitivities Provide Useful Measures of Financing Constraints?" *Quarterly Journal of Economics*, 112, 169-215.

King, Robert G. and Ross Levine. 1993. "Finance, Entrepreneurship and Growth: Theory and Evidence," *Journal of Monetary Economics*, 32, 513-542.

Kumar, Alok and Charles M. C. Lee. 2006. "Retail Investor Sentiment and Return Comovements," *Journal of Finance*, 61, pp. 2451-2486.

Levine, Ross. 1991. "Stock Markets, Growth, and Tax Policy," *Journal of Finance*, 46, 1445-1465.

Levine, Ross. 2005. "Finance and Growth: Theory and Evidence." in *Handbook of Economic Growth,* P. Aghion and S. Durlauf, eds., Amsterdam: North-Holland Elsevier Publishers.

Levine, Ross. and Sara Zervos. 1998. "Stock Markets, Banks, and Economic Growth", *American Economic Review*, 88, 537-558.

Loughran, Tim, and Jar R. Ritter. 1995. "The New Issues Puzzle," *The Journal of Finance*, 50, 23-51.

Morales, Maria. 2003. "Financial Intermediation in a Model of Growth Through Creative Destruction," *Macroeconomic Dynamics*, 7, 363-393.

Morck, Randall, Andrei Shleifer, and Robert Vishny. 1990. "The Stock Market and Investment: Is the Market a Sideshow?" *Brookings Papers on Economic Activity*, 1990:2, 157-202.

Mulkay, Benoit, Bronwyn H. Hall, and Jacques Mairesse, 2001. "Investment and R&D in France and in the United States," in *Investing Today for the World of Tomorrow* Deutsche Bundesbank, ed., Dresden: Spring Verlag.

Myers, Stewart C. and Nicholas S. Majluf. 1984. "Corporate Financing and Investment Decisions When Firms have Information that Investors Do Not," *Journal of Financial Economics*, 13, 187-221.

Oliner, Stephen D. and Glenn D. Rudebusch. 1992. "Sources of Financing Hierarchy for Business Investment," *Review of Economics and Statistics*, 74, 643-654.

Polk, Christopher K. and Paola Sapienza. 2004. "Real Effects of Investor Sentiment," 6th Annual Texas Finance Festival (July).

Rajan, Raghuram G. and Luigi Zingales. 1998. "Financial Dependence and Growth," *American Economic Review*, 88, 559-586.

Ravenscraft, David and F. M. Scherer. 1982. "The Lag Structure of Returns to Research and Development," *Applied Economics*, 14, pp. 603-620.

Rousseau, Peter and Paul Wachtel. 2000. "Equity Markets and Growth: Cross-Country Evidence on Timing and Outcomes, 1980-1995," *Journal of Banking and Finance*, 24, 1933-1957.

Sadka, Ronnie and Anna Scherbina. 2007. "Analyst Disagreement, Mispricing, and Liquidity," *Journal of Finance*, forthcoming.

Stiglitz, Joseph. 1985. "Credit Markets and Capital Control," *Journal of Money, Credit and Banking*, 17, 133-52.

Stiglitz, Joseph E. and Andrew Weiss. 1981. "Credit Rationing in Markets with Imperfect Information," *American Economic Review*, 71, 393-410.

Tadesse, Solomon. 2002. "Financial Architecture and Economic Performance: International Evidence" *Journal of Financial Intermediation*, 11, 429-454.

Wurgler, Jeffrey and Ekaterina Zhuravskaya. 2002. "Does Arbitrage Flatten Demand Curves for Stocks?" *Journal of Business*, 75, pp. 583-608.