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Keywords

IPO, Stock markets, Finance and growth, Creative destruction, Innovation, R&D

Disciplines

Business Intelligence | Corporate Finance | Finance and Financial Management | Management Information Systems

Comments

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Public entrants, public equity finance and creative destruction[#]

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Abstract

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JEL classification: D92; G10; G32; O30

Keywords: IPO; Stock markets; Finance and growth; Schumpeterian creative destruction; Innovation; R&D

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1. Introduction

What role do stock markets play in facilitating the process of creative destruction? In this study, we explore the importance of public equity finance for the R&D investment of new public entrants in the U.S. high-tech sector and evaluate the impact these entrants have on existing incumbents. Surprisingly, little attention has been paid to the economic impact of new public firms and their use of public equity finance, perhaps due to misleading aggregate statistics suggesting that the stock market is not an important source of finance in the U.S. economy. In fact, the entry of new public firms and the use of public equity finance, although highly volatile, increased tremendously in the 1980s and 1990s. Furthermore, access to public equity may be essential for most young high-tech firms, who typically have limited access to debt and small or negative internal finance.

We focus on public entry between 1970 and 2004 in six of the largest SIC three-digit high-tech industries in U.S. manufacturing: drugs, office and computing equipment, communications equipment, electronic components, industrial measuring and control instruments and medical instruments. In 2000, based on value added figures, electronic components (e.g., semiconductors) was the largest U.S. manufacturing industry, drugs was third, instruments was fifth and communications equipment was sixth. NSF figures show that in 2000 the six high-tech industries accounted for around 47% of manufacturing R&D and almost 30% of the total R&D of all firms in the U.S. economy. More importantly for our study, between 1970 and 2004, initial public offerings created over 1900 newly public firms in these six industries.

Our first objective is to explore the importance of public equity finance for new entrant R&D, the main investment for high-tech firms and the pivotal investment for creative destruction. We use GMM to estimate dynamic R&D models that include measures of internal and external finance. A large literature examines the link between internal finance and physical investment, but comparatively few studies consider R&D and even fewer evaluate the role of external finance. We are aware of no studies that focus on the link between R&D and external finance for firms immediately following their IPO, a crucial time in the firm's life-cycle when investment opportunities are likely high relative to internal funds. For the full sample of new public entrants between 1970 and 2004, we find a strong positive link between public stock issues and R&D when entrants are relatively new (first fifteen years following the IPO), but no link between internal or external finance and R&D for established entrants or incumbents, consistent with these firms having ample internal finance. In addition, we find a stronger link between stock issues and new entrant R&D in more recent entry cohorts, consistent with the rising importance of public equity in recent years (e.g., Brown and Petersen, 2009). Finally, the recent Nasdaq "bubble period" (e.g., Bradley et al., 2008) generated a remarkable boom and bust in the availability of public equity in the late 1990s and early 2000s. We re-estimate the model for narrow periods encompassing this volatility (e.g., 1998-2002) and continue to find a strong link between public equity finance and new entrant R&D. We also find that the dramatic swings in equity finance availability during this period are accompanied by a corresponding boom and bust in R&D for new entrants but not established entrants or incumbents. Together, these results suggest that the availability of public equity finance has a substantial impact on the R&D of public entrants in the years immediately following their IPO.

The second objective is to explore the importance of public entrants for "creative destruction." While there are several studies of the long-run *financial* performance of IPOs (e.g., Ritter, 1991; Loughran and Ritter, 1995; Gompers and Lerner, 2003), we are aware of no other studies that examine the long-run *economic* impact of new public firms. We divide the sample into seven five-year entry cohorts and present evidence on each cohort's impact over time. We find that rates of R&D investment for entrants are much greater than those of surviving incumbents, and R&D intensity rises rapidly over time with each successive entry cohort. In addition, in five of the six industries, incumbents lose most of their market share of sales and R&D. We also find substantial differences in economic impact across the seven entry cohorts, which is consistent with the dramatic variation in IPO numbers and use of public equity finance over time. We show that cohorts of IPOs that enter during periods of depressed stock prices (e.g., 1975-1979, 2000-2004) have comparatively small economic impact, while the four entry cohorts in the 1980s and 1990s each have substantial economic impact. We also report regressions indicating a strong link between a cohort's share of sales and R&D and its use of public equity finance. Finally, we show that a substantial number of individual entrants make very heavy use of public equity and quickly become leading firms, overtaking many of the largest incumbents. Finally, the aggregate impact of public entrants in the six industries is large: by 2000, entrants cumulatively account for approximately 29% of the total public-firm R&D in manufacturing and 24% of the R&D in the entire economy.

Our findings have several implications, discussed in more detail at the end of the study. First, our findings are relevant for the long-standing debate on the role of the stock market for corporate investments (e.g., Morck et al., 1990; Baker et al. (BSW), 2003). Second, our findings suggest that stock market crashes (e.g., 1974-1975, 2001-2002) and the associated declines in equity availability can lead to a sharp decline in innovative effort by equity-dependent firms and a stagnation of the process of creative destruction. This finding has obvious implications for the 2008-2009 crash in stock prices, which was accompanied by the near disappearance of IPOs and follow-up stock issues for young, high-tech firms. Third, given the central role that R&D and creative destruction play in modern theories of economic growth (e.g., Aghion and Howitt, 1998), our findings provide new micro-level evidence useful for understanding the strong connection between financial market development and economic growth widely documented at the macro level (e.g., Beck and Levine, 2004). Finally, while we have documented a dramatic episode of creative destruction, our findings differ in important respects from Schumpeter's (1942) description of creative destruction. Schumpeter (1942) emphasized that large established firms, relying on *internal* finance, are the primary force of innovation and creative destruction. In contrast, our study shows that in recent decades thousands of public entrants, relying heavily on *external* public equity finance, are the primary source of creative destruction in the high-tech sector.

2. Background

2.1. High-tech manufacturing industries

Autos, steel, and to a lesser extent airplanes and petroleum refining were the leading manufacturing industries for much of the 20th century, and a small number of original incumbents (e.g., GM and Boeing) dominated these industries for most of this period. In the second half of the 20th century, a new group of high-tech manufacturing industries emerged: drugs (SIC 283), office and computing equipment (SIC 357), communications equipment (SIC 366), electronic components (SIC 367), measuring and control instruments (SIC 382) and medical instruments (SIC 384). These are the leading manufacturing industries listed in the U.S. Department of Commerce classification of high technology.[1] With one exception, the six industries appear in the Census back to at least 1947, but account for only 7.4% of manufacturing value added in 1970. By 2000, however, value added for the six industries is 18.9%, higher than the peak share of autos, steel, aircraft and petroleum refining. In 2000, based on industry sales and using information from the new NAICS (four-digit) classification system, electronic components is the largest manufacturing industry, drugs is third, instruments is fifth and communications equipment is sixth.[2]

In 1970, there are several large established incumbents in all six of the high-tech industries. For example, in the computer industry, IBM is the leading firm but there are several other major

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[1] United States Department of Commerce, "An Assessment of United States Competitiveness in High-Technology Industries," February, 1983. We do not consider the aerospace industry (in SIC 37), a high-tech industry in which the government supplies much of the R&D financing. There are no other large high-tech industries in SIC 28, 35, 36 or 38, and SICs 366, 367, 382 and 384 make up the bulk of the sales of their respective two-digit industries.

[2] Starting in 1997, the U.S. Census of Manufacturing is based on the NAICS classification system. Most of the industries have a close counterpart to the old SIC classification system. Drugs, computers, communications equipment, and electronic components are all separate NAICS industries. The two instrument industries are combined into a single industry (3345). Using the mapping of 4-digit SIC industries into 5-digit NAICS industries, we computed the valued added for the constituent parts of SIC 382 and SIC 384 that now appear in NAICS 3345. Based on these numbers, old SIC 382 plus old SIC 384 would be the 5th largest industry in 2000. These figures are also used to compute the 18.9% value added figure for the year 2000.

corporations active in the industry, including General Electric, RCA, Honeywell, DEC and Control Data. In the 1990s, U.S. world market share rises in most of these industries, and by 2000 the U.S. is the leading producer of drugs, communications equipment, office and computing equipment, semiconductors, and medical and scientific instruments.

2.2. The role of public equity finance

Public firms account for the vast majority of R&D and output in the U.S. high-tech sector and there are almost no major private high-tech firms. A plausible reason is that the external capital supplied by public equity markets is crucial for the development of young high-tech firms given their limited access to other sources of finance. Internal equity finance is no doubt less costly than public equity, but internal cash flow is typically small and often negative for young high-tech firms. Debt finance has several disadvantages compared to equity finance for high-tech firms: i) debt accentuates problems of financial distress, ii) the nature of the debt contract is poorly suited for the uncertainty and skewness of returns associated with high-tech investment, and iii) R&D has very limited collateral value that should greatly restrict the use of debt, since risky firms typically must pledge collateral to obtain debt finance (Berger and Udell, 1990). While venture capital has emerged as an important source of early-stage financing, and may often be essential if a start-up firm is to reach the point of going public, it is designed to last for a relatively brief period (e.g., 3 to 4 years), and VC injections are typically small compared to public equity finance (see, for example, Table 8).

This discussion suggests a potentially important role for public equity finance in the financing of high-tech investment. Fama and French (2004, p. 229) state that becoming a public firm is "the point of entry that gives firms expanded access to equity capital, allowing them to emerge and grow." Nevertheless, stock issues are typically viewed as unimportant as a source of finance. One reason is misleading aggregate statistics showing that *net* external equity issues are small in the U.S. economy. Because large firms often use stock buybacks as a way to distribute earnings to shareholders, aggregate net new equity figures (which include buybacks) are often small and can be negative (see Brealey and Myers, 2000, Table 14.1). Looking only at the aggregate net equity figure, however, obscures the fact that many firms early in their life-cycle make extensive use of stock issues, as we show later in the paper. Over the last three decades, there has been a sharp upward trend in the issuance of stock, particularly for young firms listed on the Nasdaq.[3] The creation of the Nasdaq (1971) and the National Marketing System (1980s) are major improvements in public equity markets, particularly for the entrants in our sample, who typically have no other choice given the listing requirements of the NYSE and AMEX (see the discussion in Brown and Petersen, 2009).

We summarize the financing of young high-tech firms as follows: internal finance is typically small and often negative, debt is essentially unavailable, and VC financing is limited in scope, suggesting that public equity is the key marginal source of finance. If firms have no close substitute for public equity finance, there are a number of testable predictions, including: i) the availability of public finance should impact the R&D investment of new entrants, but ii) equity finance should not matter for incumbents and established entrants who typically have sufficient internal funds. A related prediction is that booms and busts in the availability of equity will lead to corresponding fluctuations in R&D investment for recent entrants but not established firms. Finally, the availability of public equity should impact the rate at which entrants innovate and grow, and hence the speed and extent of creative destruction.

2.3. Related literature

The findings in a number of papers suggest the potential for stock markets to play an important role for new firms seeking to challenge established incumbents. For example, Rajan and Zingales (1998) show that financial development is particularly beneficial to the creation of new firms. They also provide evidence of a life-cycle in the pattern of financing for U.S. manufacturing firms: firms rely very heavily on public equity finance in the decade following the

[3] Jay Ritter (http://bear.cba.ufl.edu/ritter/seoall.html) identifies 1082 seasoned offerings in the 1970s, 2468 offerings in the 1980s, and 4867 offerings in the 1990s.

IPO, but this reliance fades over time. BSW (2003) label firms as "equity dependent" if they need *external* equity to finance marginal investments and they show that stock prices have a stronger impact on the investment of these firms. A growing empirical literature finds that measures of the degree of stock market development are positively correlated with economic growth (see Levine (2005) for a survey). In particular, Beck and Levine (2004) find that stock market development has an economically large impact on growth, and Wurgler (2000) and Pang and Wu (2008) find that countries with better developed financial markets (including stock markets) are better at reallocating capital from declining sectors to growing industries.

Perhaps the most important channel through which stock markets can foster the process of creative destruction is the financing of R&D. Yet compared to the large empirical literature examining the financing of physical investment, relatively few studies explore the financing of R&D (see Hall (2002) for a review of this literature). Furthermore, only a couple of these studies consider the role of external equity finance for R&D. Muller and Zimmerman (2008) show that for small- and medium-sized private German companies, higher equity-to-assets ratios are associated with higher R&D intensity. Brown et al. (BFP, 2009) explore whether fluctuations in the supply of internal and external equity finance can explain the U.S. aggregate R&D boom in the 1990s. They examine only the 1990 to 2004 period and, more importantly, they do not consider the financing of firms with persistent negative cash flows, which excludes a large fraction of newly public entrants from their study. Brown and Petersen (2009) study the implications of rising R&D and increasing use of external equity for investment-cash flow sensitivities, but they do not focus on public entrants nor do they examine the behavior of R&D during the equity finance boom/bust of 1998-2002. Our methodology also differs significantly from Brown and Petersen (2009): we use a structural Euler equation to model the dynamics of R&D investment, and we estimate the model with a systems GMM estimator that has been shown to improve on the finite-sample bias and asymptotic imprecision of the "difference" GMM estimator used in both BFP (2009) and Brown and Petersen (2009). Most importantly, none of these studies evaluate the economic impact of public entry or consider the role that public equity availability plays in the process of creative destruction.

3. IPOs over time and across industries

3.1. The data

We focus on initial public offerings in U.S. manufacturing between 1970 and 2004. Our primary source for the year and dollar size of IPOs is Thompson Financial's SDC New Issues database. We then match this list of IPOs to the publicly traded firms in Compustat, which reports information (e.g., finance and R&D) typically not available to the researcher in other entry studies. Compustat has coverage for approximately 93% of the IPO firms identified in the SDC database. We only include firms if Compustat reports a primary SIC code within manufacturing (SIC 2000-3999) and a U.S. incorporation code. We do not include spin-offs or carve-outs in the set of IPOs, nor do we include mergers that create a new firm. While the number of spin-offs is not large, some large firms have been created through spin-offs in recent years: for example, AT&T spun off Lucent Technologies in 1996, and Hewlett Packard spun off Agilent in 1999. Since these firms are ex-divisions of major incumbents we treat them separately from the "public entrants" throughout the study. The final dataset contains 3596 newly public firms.[4]

For all of the results, we examine the high-tech industries separately, and only pool the six industries if there are no outlier industries. For some issues that we believe are of secondary importance, we briefly summarize the findings but do not report the results in a table. In all such cases, tables are available on request. We typically provide information on different cohorts of

[4] An additional 187 firms went public in a non-manufacturing sector, but at some point in their lives were primarily manufacturing firms. We do not include them in the initial count of IPOs, but we do allow them to enter our data in the years they were primarily in manufacturing. Similarly, firms entering in a manufacturing industry and subsequently leaving are dropped once the primary SIC code reported by Compustat is outside of manufacturing.

entrants, similar to the approach in Dunne et al., 1988). In most cases we divide the entrants into seven five-year cohorts, beginning with 1970-1974 and ending with 2000-2004.

3.2. IPOs by three-digit industry

Table 1 reports the breakdown of IPOs for the six high-tech industries in our study. The last two rows report the total number of high-tech IPOs and their share of all manufacturing IPOs for a given time period. At the start of 1970 there are a large number of publicly traded *incumbents* in the six high-tech industries (254), accounting for 14% of all public manufacturing firms. There are 254 IPOs in the 1970-1974 cohort but only 42 IPOs between 1975 and 1979, following the 1974-75 crash (and subsequent stagnation) in stock prices. Following the recovery of stock prices, high-tech IPOs explode in the 1980s (627) and the 1990s (869). High-tech IPO numbers, however, fall sharply in the 2000-2004 period (261), following the crash in Nasdaq prices in 2001-2002. (Most of the IPOs in 2000-2004 occur in 2000 prior to the Nasdaq bust.) The second to the last column shows that there are 1931 IPOs in the six high-tech industries between 1970 and 2004, which account for 54% of manufacturing IPOs during the 35 year period. This is a remarkable share, as there are more than 130 three-digit SIC industries in U.S. manufacturing. The final column reports that at the end of 2004, the six high-tech industries contain 1532 surviving public firms, or 48% of the publicly traded firms in manufacturing.[5] Because of the pattern of IPOs in the 1980s and 1990s, nearly one-half of public firms in manufacturing are now concentrated in just a few industries.

3.3. Characteristics of the IPO

We briefly summarize the key characteristics of the public entrants in our sample at the time of the IPO. Firms are typically very young at the time they go public, with a median age of

[5] While not reported in the table, of the 1532 firms in existence in 2004, 59 are surviving incumbents, 1034 are surviving IPOs from the period 1970-2004, and 439 are "other" firms, which are new public firms in Compustat not identified as IPOs. These firms include spinoffs and best effort offerings and are described at the start of section six. "Other" firms generally account for only a small share of economic activity.

around six years in both the 1980s and 1990s.[6] Firms are generally small at the time of the IPO, with a median employment of around 80 workers. Firms use almost no debt, with a median leverage ratio of close to zero at the time of the IPO during the 1990s and 2000s. Finally, the size of IPO proceeds increases sharply over time: the median IPO rises from $6.36 million (in 2000 dollars) for the 1970-74 cohort to $27.57 million for the 1995-1999 cohort, highlighting increasing importance of the first infusion of public equity.

4. Public equity finance and R&D

We begin our exploration of the role of public equity with information on its relative importance as a source of finance. We then provide regression results for an R&D investment model augmented with key sources of finance. We conclude by examining entrant and incumbent R&D during the recent Nasdaq bubble.

4.1. Investment and financing after the IPO

Table 2 reports information on post-IPO investment and financing for three different groups of IPOs: 1970-1979, 1980-1989 and 1990-2004. For each group, we provide separate information for the first two five-year intervals following the IPO (t=1 to t=5 and t=6 to t=10). The goal is to provide facts on the relative importance of public equity finance as a source of funds immediately after the IPO, and to explore how the role of equity finance for public entrants changes over time. All investment and financing variables in Table 2 are cumulative: we sum the annual values over the respective five-year periods and scale by beginning of period firm assets. The mean values are Winsorized at the 1% level to avoid undue influence of extreme values. Since we sum over each five-year period, we report numbers only for firms that survive all five years of the particular interval in question.[7] To measure internal equity finance we add

[6] Most of the age data is graciously provided by Laura Field and Jay Ritter (see Field and Karpoff, 2002 and Loughran and Ritter, 2004).

[7] Note that this restriction means that the results for the t=6 to t=10 period for the final entry cohorts include only entrants between 1990 and 1994 that survived to t=10.

R&D investment to the firm's reported cash flow because R&D is treated as an expense and we want a measure of internal equity finance gross of all investment expenditures (e.g., Himmelberg and Petersen, 1994).

The R&D ratios over the first five-year period following the IPO rise sharply across the periods; for example, the median ratio increases from 0.23 for the 1970s IPOs to 1.01 for the 1990-2004 IPOs (the pattern for the means is similar). The physical investment ratios are similar to the R&D ratios for the 1970s IPOs, but the physical investment ratios do not rise across periods, and therefore the final cohorts of high-tech public entrants do far more R&D than physical investment. The medians for total investment (R&D plus physical investment) rise sharply over time due entirely to the rise in R&D. The median values of cumulative new total debt are near zero, while the means of debt are modest compared to the mean of total investment. Cumulative gross cash flows are comparatively large in the first set of IPOs, but fall substantially in the final set and are only a small fraction of total investment. The importance of stock issues as a source of funds increases substantially across the entry cohorts. While median cumulative stock issues are modest for the 1970s and 1980s IPO cohorts, the mean value for stock issues in each of the first five-year intervals is roughly the same as cash flow. By the final set of IPOs (1990-2004), median stock issues are considerably larger than median cash flow and mean stock issues are many times larger than cash flow in both five-year intervals following the IPO. The last two rows show that gross cash flow is frequently negative and high-tech firms rarely pay dividends. Furthermore, the fraction of gross cash flow observations that are negative rises steeply over time: the share of negative cash flow observations during the first five-year interval increases from 0.11 for 1970-1979 entrants to 0.41 for 1990-2004 entrants. This increase in the frequency of negative cash flows is consistent with the sharp decline in median and mean cash flows for the final group of entrants.

The numbers in Table 2 show that the importance of public equity as a source of finance for newly public high-tech firms grows dramatically over time, from relatively modest figures in the 1970s to very large values (compared to cash flow or total investment) by the 1990s. Given that debt finance is typically small, the numbers suggest that by the 1980s, public equity finance is the main external form of finance and presumably the key marginal form of finance for newly public high-tech firms. Indeed, the financial features of high-tech entrants we document in Table 2 (e.g., negative cash flows, low incremental debt capacity) match the characteristics of firms that BSW (2003) identify as "equity-dependent." Thus, we expect that for the high-tech cohorts of the 1980s, and especially for the cohorts of the 1990s, variation in access to public equity finance will be an important determinant of firm-level investment in R&D.

4.2. R&D model

We formally examine the link between R&D and public stock issues with a dynamic investment model developed by Bond and Meghir (1994) to study the role of financial effects for physical investment. Bond and Meghir (1994) derive an Euler equation for optimal capital accumulation with adjustment costs for imperfectly competitive firms. Bond and Meghir (1994) focus on fixed investment, but an analogous estimating equation based on the Euler condition can be derived for R&D (also see BFP, 2009). One complication is that the stock of R&D (the analog of the stock of fixed capital used in investment studies) is not reported by the firm and can only be crudely approximated; we therefore scale all regression variables by the book value of total assets, which follows the approach in a number of other studies (e.g., BSW, 2003; BFP, 2009). To examine the link between R&D and public equity finance we add current period and lagged new share issues to the baseline Euler specification. We also add current period cash flow to examine and control for internal equity finance and contemporaneous sales as an additional control for demand. With these modifications, the estimating equation is:

$$
\begin{aligned}
\left(RD/TA\right)_{j,t} = {} & \beta_1\left(RD/TA\right)_{j,t-1} + \beta_2\left(RD/TA\right)^2_{j,t-1} + \beta_3\left(B/TA\right)^2_{j,t-1} + \beta_4\left(SALES/TA\right)_{j,t} + \\
& \beta_5\left(SALES/TA\right)_{j,t-1} + \beta_6\left(GCF/TA\right)_{j,t} + \beta_7\left(GCF/TA\right)_{j,t-1} + \beta_8\left(STK/TA\right)_{j,t} \\
& + \beta_9\left(STK/TA\right)_{j,t-1} + d_{i,t} + \alpha_j + \nu_{j,t}
\end{aligned} \tag{1}
$$

where *RD* is research and development spending for firm *j* in period *t*, *TA* is the beginning-of-period stock of firm assets, *SALES* is firm revenue, *B* is the stock of firm debt, *GCF* denotes gross cash flow and *STK* is net funds raised from new share issues. The variable d_{it} is a time-specific effect defined at the industry level, *i*, which controls for industry-specific changes in technological opportunities over time that could affect the firm-level demand for R&D. The variable α_j is a firm-specific effect that captures firm-level differences in technology, managerial quality, and a variety of other time-invariant factors that may impact R&D. The parameters in equation (1) can be interpreted as functions of the structural parameters of the original optimization problem presented in Bond and Meghir (1994).[8]

We obtain consistent estimates of equation (1) with a system GMM estimator that jointly estimates a regression of equation (1) in differences with the regression in levels (Arellano and Bover, 1995; Blundell and Bond, 1998). This method uses lagged levels as instruments for the regression in differences and lagged differences as instruments for the regression in levels, and can improve on the finite-sample bias and asymptotic imprecision of the difference GMM estimator used in other recent studies that estimate dynamic R&D models (e.g., BFP, 2009; Brown and Petersen, 2009). We treat all right-hand side variables as potentially endogenous and use lagged levels dated *t*-2 to *t*-4 as instruments for the regression in differences, and lagged differences dated *t*-1 for the regression in levels. Despite excluding lags beyond *t*-4 from the instrument set, the estimation approach we use generates a relatively large number of instruments compared to the number of firms in several of the different sub-samples we study. We therefore "collapse" the instrument matrix as discussed in Roodman (2009).[9] To assess instrument validity

[8] The structural model predicts a positive coefficient on lagged R&D and a negative coefficient on the squared term. The magnitude of the coefficients will depend on discount and depreciation rates, but both coefficients should slightly exceed one in absolute value. The lagged sales-to-asset ratio has a positive coefficient under imperfect competition that goes to zero as the elasticity of demand faced by the firm approaches the competitive value. The lagged debt-assets ratio allows for bankruptcy costs and a tax advantage to debt. The lagged gross cash flow-asset ratio appears in the specification without financing constraints, but it has a negative sign.

[9] Our findings are robust to alternative lags for the instruments, including beginning the instruments at *t*-3 (instead of *t*-2) and extending the lags to either *t*-5 or *t*-6. In addition, if we do not collapse the instrument set there are no qualitative changes in our findings.

we report a Hansen *J*-test of over-identifying restrictions and an *m2* test for second-order autocorrelation in the first-differenced residuals, which, if present, can render the GMM estimator inconsistent. We also report a difference-in-Hansen test that evaluates the validity of the additional instruments required for systems estimation (i.e., the instruments used in the levels equation). These tests indicate no problems with instrument validity or specification. Finally, we report chi-squared tests that the sum of the financial variables is significantly different from zero. We trim the upper and lower tails of all regression variables at the 1% level.

4.3. Results by firm type and entry cohort

In Table 3 we report regression results for both new public entrants and existing incumbents. Incumbents likely do not face binding financing constraints and we therefore expect small or zero coefficients on all financial variables. In contrast, based on the arguments in Section 2 and the figures in Table 2, entrants are likely dependent, at the margin, on external equity for a period of time following the IPO. Eventually, however, dependence on stock issues should fade as entrants become established and capable of generating sufficient cash flow to fund all investment. The figures in Rajan and Zingales (1998) suggest that most firms do not raise substantial sums of equity once they reach 15 years after the IPO. We therefore divide entrants into two groups: we define public entrants to be "new entrants" for the first fifteen years following the IPO and "established entrants" thereafter. (We also considered cutoffs at 10 and 20 years beyond the IPO and the results are very similar.) We expect substantial stock coefficients for new entrants and relatively unimportant stock coefficients for established entrants. We also report separate results for the IPOs groupings reported in Table 2. The increasing importance of stock issues documented in Table 2 and the substantial improvements in equity markets during our sample period (see the discussion in Brown and Petersen, 2009) suggest the potential for an increasing link between stock issues and R&D over time.

The first three columns in Table 3 report results for the full time period: all IPOs are grouped together and we switch entrants to the "established" category after 15 years. For both new and established entrants, the coefficient on lagged R&D tends to be close to one (consistent with the underlying model), while the coefficient on lagged R&D squared is always negative, but somewhat smaller (in absolute value) than expected. For established entrants and incumbents, coefficient estimates on both cash flow and stock issues are small and insignificant, as expected if they no longer face binding financing constraints. For the new entrants, cash flow coefficients are also insignificant, likely due to the very large fraction of negative cash flow observations for these firms (e.g., Allayannis and Mozumdar, 2004; Guariglia, 2008). Most importantly for our study, the coefficient estimate on contemporaneous stock issues is quantitatively large (0.229) and statistically significant (as is the sum of stock coefficients).

The next three columns report results for new entrants grouped by the year of their IPO. The coefficients on cash flow are, once again, typically small and always insignificant. We are particularly interested in the pattern of stock coefficients across the different entry cohorts. For the 1970s IPOs, the contemporaneous stock coefficient is positive (0.080) but statistically insignificant. For the 1980s IPOs, the contemporaneous coefficient is 0.115 (sum is 0.085) and the estimates are highly significant. For the final entry cohorts (1990-2004), the contemporaneous coefficient is 0.263 (sum is 0.234) and the estimates are also highly significant. Thus, there is a substantial increase in the estimated link between stock issues and new entrant R&D over time.

Overall, Table 3 indicates that that public equity has an important impact on the level of R&D investment by newly public high-tech entrants. Furthermore, based on the sharp rise in the estimated stock coefficients, it appears that the role of the stock market for R&D investment by newly public firms has grown sharply over time. This interpretation is supported by the fact that we find no significant link between stock issues and R&D for established entrants or incumbents, who should be beyond the point in their life-cycle where high-cost public equity is required to finance the marginal investment.

4.4. Further analysis: The Nasdaq "bubble"

A strong test of causality would be to examine the behavior of public entrant R&D during a time when access to public equity finance disappeared. The closest "natural experiment" we have is the Nasdaq bubble period. The Nasdaq Index jumped from 1,574 at the start of 1998 to 4,186 by the start of 2000, briefly broke 5,000 in 2000, but began a swift decent at the end of 2000, reaching approximately 1,100 in August 2002. The bubble and its collapse generated a remarkable boom and bust in the availability and use of public equity finance, permitting additional tests of its importance.

An extensive literature shows that stock-market mispricing can lower the cost of external equity finance and increase the availability of public equity. For example, Morck et al. (1990) note that for firms facing financing constraints, overpriced equity lowers the cost of capital and may allow constrained firms the opportunity to issue shares and increase investment. 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." BSW (2003) find that the investment of "equity-dependent" firms is especially sensitive to stock prices.

Collectively, the public entrants we study exhibit a pronounced boom and bust in equity usage that lines up well with the view that firms exploited mispricing in the Nasdaq by issuing new shares. Between 1998 and 2000, total public equity issues by the new high-tech entrants in our sample rises over 420 percent from $7.96 billion to $41.52 billion (in 2000 dollars). Following the collapse in the Nasdaq prices, total stock issues by new entrants falls dramatically, equaling $6.88 billion in 2002 before a modest recovery in 2003 and 2004.

Given the extremely large variation in public equity issues, it is important to check whether our regression results hold up for narrow windows around the Nasdaq bubble. The final regression in Table 3 (column seven) examines the narrow window 1998-2002, where we use years prior to 1998 as instruments (the findings are similar for other windows, such as 1997-2003). For new entrants, the sum of the estimates for current and lagged cash flow is positive but small (0.063) and statistically insignificant. In contrast, the coefficient estimates for stock issues is large (sum is 0.235) and statistically significant. Thus, the stock coefficients for the narrow window 1998-2002 are very similar to the coefficients discussed earlier for IPOs in the final period.

The large swing in equity issues, together with the quantitatively important coefficient estimate on stock issues, generates two predictions. First, if the availability of public equity finance matters for new entrant R&D, then the extremely large variation in public equity should have resulted in a boom and bust in R&D investment for new entrants. We note that large fluctuations in R&D are not common, as R&D is widely known to be highly persistent at both the firm and aggregate levels. The second prediction is that R&D by established entrants and incumbent firms, who are not equity dependent, should be stable. New entrant investment in R&D does in fact exhibit a boom and bust pattern. For example, the median R&D-to-asset ratio among new entrants is 0.158 in 1998, only slightly below the median for the decade of the 1990s (0.161). By 2000, at the peak of the Nasdaq bubble, the median ratio jumps to 0.210, a 33 percent increase over the 1998 figure. By 2002, the median ratio falls to 0.140, a 33 percent decline from the 2000 figure and well below the median ratio for the 1990s. The average R&D ratios (Winsorized at the 1% level) exhibit even larger percentage changes during this period: the averages for 1998, 2000, and 2002 are 0.238, 0.382 and 0.226. At both the mean and the median, the R&D ratio in 2000 is statistically different from the values in 1998 and 2002.[10]

For incumbents and established entrants, on the other hand, there is no evidence of a boom and bust pattern. The median R&D-to-assets ratio among incumbents actually *falls* between 1998 and 2000 (0.089 to 0.073), and is largely unchanged between 2000 and 2002 (0.073 to 0.068). Similarly, the median R&D ratios for established entrants for 1998, 2000 and 2002 are relatively stable (0.101, 0.112 and 0.102).

[10] The z-values from Wilcoxon tests of median differences are 5.16 for 1998-2000 and -6.61 for 2000-2002. The t-statistic for mean differences is 7.00 for 1998 to 2000 and -7.29 for 2000 to 2002.

These findings provide strong evidence of a link between the supply of public equity finance and new entrant R&D. The lack of an R&D boom and bust for incumbents and established entrants strongly suggests that sudden technological demand shocks for R&D are not driving our results: it seems implausible that demand shocks will impact only entrants. Instead, this evidence is consistent with major supply shifts in public equity finance that enable entrants to sharply increase R&D in the late 1990s, but entrants are then forced to curtail R&D when equity finance largely disappears after 2000. These results strengthen our overall case that access to public equity finance is important for the R&D investment of public entrants.

5. Public entrants and creative destruction

The findings presented so far suggest the potential for recent public entrants to have a major impact on the high-tech sector. In particular, our results show the creation of a very large number of new public firms that receive heavy funding from the stock market, and this funding has a substantial impact on R&D, the type of investment most relevant for creative destruction. The rest of the paper explores the economic impact of these new entrants.

In the tables that follow, we trace the impact of each entry cohort over the period 1970-2004. We do not label entrants as "new" and "established" (which we did for purposes of testing for financing constraints); rather, we seek to measure the complete impact of each of the seven cohorts (similar to Dunne et al., 1988). We also report results for the drug industry separately. The reason the drug industry is an outlier is straightforward: drug companies in the U.S. must go through protracted clinical trials and often go public before completing the trials and securing FDA approval for their first product. As a consequence, these firms often have little or no sales for many years after the IPO.

5.1. R&D intensity by cohort

Table 4 reports median R&D-to-sales ratios for entry cohorts and incumbents in selected years. We find no meaningful differences across the high-tech industries except for drugs, which is excluded from Panel A and reported separately in Panel B. In Panel A, moving down the diagonal, new cohorts are generally more R&D intensive over time, culminating with the year 2000, where the 1995-1999 cohort has a median R&D-to-sales ratio of 0.180, three times larger than the median R&D ratio of the initial cohort in 1975. This pattern is consistent with the regression results and the greater availability of equity finance in the 1980s and 1990s. Moving along the rows, R&D ratios generally rise over time for each cohort. It is interesting, however, that median R&D ratios in 2004 are lower than those in 2000 in all cohorts but one, consistent with the decline in equity availability in 2001-2003. Incumbent R&D ratios also rise somewhat over time, but they lag well behind the R&D intensities of all entry cohorts. The much higher R&D intensities of new entrants is consistent with a process of creative destruction driven by innovation.

Panel B reports values for the drug industry. We do not report figures for the first two cohorts because of the small number of observations. Median R&D ratios are very high and are probably not especially informative given the fact that entrants often have little or no sales for many years after the IPO.

5.2. Share of sales

Table 5 reports the share of sales accounted for by incumbents and entry cohorts over time. Each firm's sales is assigned to a single three-digit industry, and then an aggregate sales figure is computed for the set of five high-tech industries (Panel A) and drugs (Panel B). Diversification is a potential problem as the largest firms are often diversified across multiple three-digit industries. However, for our application, diversification is not likely to be a significant issue, because when high-tech firms diversify, most of their sales are contained within the *set* of the five high-tech industries that make up Panel A of Table 5. We do, however, have a direct way of checking on possible problems created by diversification. Beginning in the late 1990s, Compustat regularly reports each firm's sales disaggregated into its main four-digit SIC industries (business segment data). We use these numbers to compute share of sales of entrants and incumbents for 2000 and 2004. These numbers should be very accurate and provide a check on our other figures. A check of these numbers shows that they are nearly identical to those reported in Table 5.[11]

For completeness, Table 5 reports the share of sales for "other" firms, who are firms that have no Compustat coverage prior to 1970 and are not identified as IPOs. Fama and French (2004) also document a sizable number of new listings in CRSP that do not show up in their IPO data base, and they believe many of these firms are "best effort" offerings of firms that are typically very small and may not trade initially on the major exchanges. We examine all large "other" firms to see if they should be reclassified as incumbents or IPO firms. The large "other" firms are almost exclusively spinoffs, such as Lucent and Agilent. As is apparent in the tables, "other" firms account for only a small share of economic activity in all years except 2000.[12]

Starting with the high-tech firms in Panel A, there are a number of interesting findings. First, going down the diagonal, the cohorts entering in years with relatively depressed stock prices – 1970-1974, 1975-1979 and 2000-2004 – have the lowest initial market share of sales. The four cohorts of the 1980s and 1990s – periods of generally robust stock prices – have the largest initial shares of sales. Second, moving along the rows, market shares of most cohorts rise over time. This result differs from the key finding in Dunne et al. (1988) showing that new cohorts lose market share fairly rapidly over time.[13] Third, and most importantly, incumbents lose a great deal of market share to new public entrants. By 2000, entrants account for almost

[11] Since segment sales are reported at the four-digit level, we aggregate across four-digit industries to compute a segmented sales figure for each firm at the three-digit level. If segmented data was missing for a firm, we used the firm level sales figure reported on the Compustat's Industrial Annual database and placed the entire amount in the firm's primary industry (this was seldom necessary). Using sales figures from this segmented data base, IPO cohort shares in 2000 are virtually identical (e.g., starting with the 1970-1974 cohort, the shares are 0.072, 0.009, 0.114, 0.132, 0.100 and 0.057), while incumbent's share of sales falls to 37% and "other" firms share increases slightly (to 0.146).

[12] The market share of "other" firms is small until 2000, where three large spinoffs drive the share to nearly 13%. Spinoffs Lucent, Agilent and Avaya accounted for almost 60% of the total sales in the "others" category in 2000.

[13] The explanation for the difference is likely due to multiple factors, including the fact that high-tech *public* entrants had high survival rates and very high real growth rates in the last two decades. In addition, the Dunne et al. (1988) study covers the time period 1963 to 1982, and our study shows that the impact of new public entrants is fairly small in the 1970s, even for high-tech industries.

48% of high-tech sales, while incumbent market share is just 38.6% (37.0% using business segment data).[14] Incumbent loss of market share is largest in the 1990s, the period of greatest availability of public equity, and most of this market share goes to the four entry cohorts of the 1980s and 1990s. By 2004, however, incumbents experience a modest rebound in their market share.[15] This temporary stabilization of market share of incumbents stands in contrast to the sharp loss of market share in the 1990s and suggests that the decline in the availability of public equity after 2000 greatly slowed the process of creative destruction by sharply curtailing R&D investment, the entry of new firms, and the expansion of previous entry cohorts.

Panel B explores the drug industry, which has over four hundred public entrants, concentrated heavily in 1990s. Yet as of 2004, incumbents have a market share just under eighty percent. We believe the main reasons are the length of clinical trials and the fact that most entry was relatively recent.

To briefly explore the association between incumbent loss of market share and public equity, we run simple descriptive regressions relating the evolution of cohort and firm shares of sales to sources of finance. The data points for the cohort level regressions are the share of sales figures (at five-year intervals) as shown in Panel A of Table 5. Let *j* stand for the cohort or firm and *t* represent a particular period (e.g., 1975, 1980, etc.). The left-hand side variable is $\Delta SALES_{jt}$, which is the change in *share* of sales between period *t* and *t*-1 for cohort or firm *j*, while the right-hand side variables are the flows of finance ($CASHFLOW_{jt}$, $STOCK_{jt}$, and $DEBT_{jt}$) raised by the cohort or firm in the corresponding five-year period. Table 7 reports the regression results for the five high-tech industries. Panel A shows that at the cohort level only public equity issues are positively (and significant at the 6% level) associated with $\Delta SALES_{jt.}$

[14] For Tables 5 and 6, we leave IBM in industry SIC 357 through 2000, even though IBM's primary SIC code changes to 737 (which is outside of manufacturing) in 1998. Because IBM is a very large incumbent, allowing IBM to switch would significantly increase the reported market shares of IPO firms.
[15] Much of the rebound is the acquisition of Compaq (of the cohort 1980-1984) by Hewlett-Packard in 2002. When we recompute the numbers without this acquisition, the incumbent's share of sales in 2004 is virtually unchanged compared to the 2000 figure.

This is consistent with the fact that the cohorts in the 1980s and 1990s have the sharpest gains in share of sales as well as the largest IPOs and the heaviest use of follow-up equity. At the firm level (Panel B) all sources of finance are positively associated with $\Delta SALES_{jt}$, though the magnitude of the coefficient estimate on stock issues is more than twice as large as the coefficient on new debt and almost twenty times larger than the coefficient on cash flow.

5.3. Share of R&D

Table 6 reports the shares of R&D for the entry cohorts and the incumbents over time. The findings in Table 6 are similar to those in Table 5. First, in Panel A, the three cohorts from periods with depressed stock prices (1970s and 2000-2004) have substantially lower shares of R&D than the cohorts of the 1980s and 1990s. Second, cohort shares of R&D tend to rise over time. Third, by 2000, new public entrants' share of R&D is 51.8% and incumbent's share is only 32%, less than their share of sales. Most of the incumbent's loss of R&D share occurs in the 1990s and no loss occurs in the period 2000-2004, consistent with Table 5. Panel B is also broadly consistent with the findings in the corresponding panel in Table 5, though public entrants in the drug industry account for a larger share of R&D than sales by the end of the sample period.

We run a descriptive regression exploring the link between sources of finance and changes in the share of R&D identical to the regressions for $\Delta SALES_{jt}$ discussed above. The data points for the cohort level regressions are now the share of R&D figures as shown in Panel A of Table 6. The regression results are reported in the second column of Table 7. Once again, the results show that only public equity issues are positively associated (and statistically significant) with $\Delta R\&D_{jt}$ at the cohort level, and while both cash flow and stock issues are positively associated with $\Delta R\&D_{jt}$ at the firm level, the coefficient estimate on stock issues is more than fifteen times larger. A comparison of the estimated coefficients for stock issues across the two columns in Table 7 indicates a stronger relationship between share of R&D and public equity than between share of sales and public equity, consistent with the equity-dependent nature of R&D. While the findings in Table 7 are only descriptive regressions, they support our argument that public equity finance played a significant role in the process of creative destruction in the high-tech sector.

5.4. Leading firms and public equity usage

It is possible that the sheer volume of entry caused a substantial amount of creative destruction without any individual entrant ever becoming a leading firm. We thus briefly consider whether a significant number of individual high-tech public entrants displaced incumbents as leading producers. In Table 8 we present detailed information for the top ten firms in 2000 (based on sales) in two of the largest and most important industries: office and computing equipment (Panel A) and electronic components (Panel B).

In Panel A, by 2000, new public entrants, mostly founded in the 1980s, have displaced most of the original leading incumbents in office and computing equipment. While incumbents Hewlett-Packard and IBM have the largest sales, Compaq and Dell are close behind.[16] With the exception of Xerox, the rest of the leading firms in office and computing equipment – Cisco, Sun Microsystems, Gateway, EMC, and Apple – are all new public entrants. Five of the seven entrants receive significant VC financing. Most of the IPOs are large, with four over $90 million. Most entrants make heavy use of follow-up equity financing, with Cisco raising nearly $2.82 billion and Compaq raising $1.16 billion.[17]

Electronic components (Panel B) is an even better example of an industry where entrants rapidly displaced the leading incumbents. By 2000, Intel and Solectron are the two leading firms, ahead of Texas Instruments and Motorola (also semiconductor producers), the leading

[16] By 2003, Dell has the world's largest market share (approximately 15%) of personal computers despite Hewlett-Packard's purchase of Compaq in 2002 (Wall Street Journal, 5/12/2004).

[17] We recognize the life-cycle feature of new equity financing and measure the magnitude of new equity financing in the period of a firm's life-cycle when it is a net seller of equity. To do this we sum net new equity finance until we reach a year in which the firm is a net buyer of equity (i.e., until net new share issues are negative). We then compare this value to the value generated by summing net equity finance over all years following the IPO (or, for incumbents, all the years between 1970 and 2000). We report the larger of the two values in Table 8. Stopping at the first time the firm is a net buyer of equity has the potential to greatly understate the firm's use of equity finance, as firms may have a year or more when both sales and purchases of equity are quite small, resulting in a small negative values for net new share issues. All financing figures are expressed in 2000 dollars.

firms of the late 1960s and 1970s. Five of the six entrants received venture capital. All six entrants make heavy use of follow-up public equity, with four firms raising over $1 billion. In addition to the two industries shown in Table 8, many new public entrants are also leading firms in the other four high-tech industries.

6. Implications: The stock market and creative destruction

There is a long standing interest in the connection between the stock market and corporate investment. Most of this interest focuses on whether stock prices influence corporate investment in fixed capital. Some early, well-known studies such as Morck et al. (1990) and Blanchard et al. (1993) conclude that the stock market plays only a limited role in investment decisions.[18] More recently, BSW (2003) rank U.S. firms according to "equity dependence" and find that the investment of equity-dependent firms is more sensitive to Tobin's Q, supporting the existence of an "equity finance channel." While our approach differs from these studies – we focus on stock *issues* rather than stock prices – our results support the importance of an equity finance channel for new public entrants.

Another implication of our study is that public equity markets and public entrants are important inputs for, and agents of, creative destruction. While our findings are in most ways an excellent example of Schumpeter's (1942) perspective on competition as a "process of creative destruction," there are two major differences. Schumpeter (1942) envisioned entrants to be large established firms with the deep pockets needed to finance innovation and argued (p. 101) that large-scale establishments "not only arise in the process of creative destruction, but in many cases of decisive importance they provide the necessary form for that achievement." He (1942, p. 106) describes the large established firm as "the most powerful engine of economic progress" and he is generally pessimistic about the ability of markets made up of small firms to be

[18] Similarly, Wang et al. (2009) report that firm investment in China does not significantly respond to stock prices; they speculate this may be because stock prices in China contain very little extra information about future profitability.

innovative. This view, however, differs from Schumpeter (1912), where he argues that entrepreneurs in the form of new firms embodying new innovative ideas are the key instruments of creative destruction. Thus, while our findings that new public entrants are the main agents of creative destruction in the U.S. high-tech sector differ from Schumpeter (1942), they are more consistent with the early (and less widely appreciated) views of Schumpeter on creative destruction.[19] In addition, our findings suggest that recent entrants rely extensively on external equity to finance innovation, which runs strongly counter to the views expressed in Schumpeter (1942) on the on the need for self-finance.

Our findings also suggest that the state of development of a country's equity markets may play an important role in determining the quantity and quality of a country's public entrants, and therefore the performance of its high-tech sector.[20] A plausible explanation for part of the recent low rate of firm formation in France, Germany and Italy is past problems in equity markets. In Europe there is much public policy discussion concerning both the low numbers of high-tech public entrants and the lack of VC and follow-up equity financing.[21] This lack of finance may explain why Germany, France and Italy have comparatively few public entrants in the last two decades and lag far behind the U.S. in high-tech production in the 1980s and 1990s.[22]

Underdeveloped equity markets, accompanied by a lack of new entrants, may also have a significant impact on a country's rate of economic growth. Several studies, summarized in

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[19] We thank an anonymous referee for pointing out the different views expressed in Schumpeter (1912). See Bertocco (2008) for more discussion on Schumpeter's views about financial development and innovation.

[20] Undeveloped stock markets will likely also retard the R&D activity of new entrants. For example, Ughetto (2009) shows that small Italian firms rely almost exclusively on internal finance for funding R&D; even though Italy is a bank-based system, banks in Italy appear unwilling to supply financing for R&D.

[21] See, for example, the European Commission (1998) and Bottazzi and Da Rin (2002) for a review of venture capital in Europe as well as a summary of the European Commission's conclusions on lack of private and public equity. Furthermore, follow-up equity financing for small high-tech firms is much lower in Europe compared to the U.S. (European Commission, 1998).

[22] According to Loughran et al. (1994, updated in 2004 at http://bear.cba.ufl.edu/ritter/Int.pdf), for the entire economy, France had 571 IPOs between 1983-2000, Germany had 407 between 1978-1999 and Italy 181 between 1985-2001. This contrasts with the more than 6600 IPOs in the U.S. economy between 1980-2000 (SDC New Issues Data Base). In the period 1980-1998, Germany, France and Italy experienced declines of between 33% and 41% in high-tech world market shares (The National Science Foundation, Science and Engineering Indicators, 2002, Chapter 6).

Aghion and Howitt (2006), advance a "Schumpeterian Paradigm" of economic growth characterized by creative destruction through the entry of new innovators and the exit of former innovators. Aghion and Howitt (2006) argue that, given the low rate of entry and turnover in many European countries, the Schumpeterian Paradigm can readily explain the productivity gap between the U.S. and Europe. Thus, by showing the strong link between public equity markets, innovation and creative destruction, our findings provide micro-level evidence useful for understanding the strong connection between financial market development and economic growth widely documented at the macro level (e.g., Beck and Levine, 2004).

Finally, our results suggest that even temporary crashes in stock prices and the associated declines in equity availability can have a negative longer-run impact on an economy's economic performance by lowering the intangible investment of public entrants and slowing the process of creative destruction. As noted above, R&D investment by entrants falls sharply in 2001 and 2002. In addition, the entry cohorts that span periods dominated by depressed stock prices have comparatively little economic impact; in particular, the process of creative destruction stagnates during 1975-1979 and 2000-2004.

7. Conclusions

We provide new evidence on the role that public stock markets play in facilitating the process of creative destruction. We explore the importance of new public firms and public equity finance for R&D and creative destruction in the U.S. high-tech sector. Public equity finance, largely ignored in the literature, is an increasingly important source of finance in the 1980s and 1990s and is typically the main form of finance for high-tech entrants early in their life-cycle. Our estimates from a dynamic investment model show that public equity has a statistically significant and economically important impact on entrant R&D. In contrast, no such relationship exists for established entrants and incumbents, who arguably are not equity-dependent. Additional evidence on the causal link between public equity finance and entrant

R&D emerges from the recent bubble in the Nasdaq that generated enormous variation in stock issues. We find that only equity-dependent entrants experience a boom and bust in R&D investment during the 1998-2002 period. Together, these results suggest that shifts in the availability of public equity finance have a substantial impact on the R&D of new public entrants.

Our study also documents a dramatic episode of creative destruction in the high-tech sector. In all industries but drugs, the flood of new entrants causes incumbents to lose most of their pre-1970 share of sales and R&D, with the largest losses coming in the 1990s. Descriptive regressions show that the evolution of cohort shares of sales and R&D are closely tied to new equity finance but not to other forms of finance. In addition, a substantial number of individual new public firms rapidly became leading firms in their respective industries. While our study provides an impressive example of creative destruction, there are important differences from Schumpeter's (1942) description: new public firms, relying heavily on external public equity, are the primary source of creative destruction in recent years.

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Table 1
IPOs in high-tech manufacturing industries: 1970 – 2004.

	# of Firms at Beginning of 1970 (Incumbents)	1970-1974	1975-1979	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	1970-2004	# of Firms at End of 2004
Three-digit industry code										
SIC 283	35	11	3	44	55	136	122	94	465	446
SIC 357	42	41	16	106	77	78	81	20	419	219
SIC 366	32	27	6	51	33	44	63	28	252	204
SIC 367	63	21	3	40	35	51	67	52	269	230
SIC 382	59	18	4	46	27	26	43	25	189	171
SIC 384	23	14	10	68	45	73	85	42	337	262
Total	254	132	42	355	272	408	461	261	1931	1532
High-tech share of all manufacturing	0.14	0.27	0.54	0.62	0.47	0.51	0.59	0.75	0.54	0.48

The table reports the number of existing and IPO firms in high-tech manufacturing during 1970-2004. The high-tech industries are pharmaceuticals (SIC 283), office and computing equipment (SIC 357), communications equipment (SIC 366), electronic components (SIC 367), industrial measuring and control instruments (SIC 382), and surgical instruments (SIC 384). Incumbents are firms with coverage in Compustat at the beginning of 1970.

Table 2
Investment and financing after the IPO for newly public high-tech firms.

		IPO entry cohort					
		1970-1979		1980-1989		1990-2004	
		t=1 to t=5	t=6 to t=10	t=1 to t=5	t=6 to t=10	t=1 to t=5	t=6 to t=10
cumulative R&D / initial assets							
	median	0.23	0.27	0.48	0.48	1.01	0.89
	mean	0.39	0.41	0.71	0.72	1.59	1.73
cumulative physical investment / initial assets							
	median	0.28	0.29	0.31	0.21	0.25	0.17
	mean	0.59	0.47	0.46	0.36	0.48	0.40
cumulative total investment / initial assets							
	median	0.53	0.56	0.83	0.73	1.33	1.13
	mean	1.00	0.87	1.17	1.09	2.04	2.16
cumulative new total debt (net) / initial assets							
	median	0.06	0.07	0.03	0.00	0.01	0.00
	mean	0.37	0.18	0.23	0.10	0.32	0.27
cumulative gross cash flow / initial assets							
	median	0.46	0.68	0.54	0.64	0.28	0.28
	mean	0.68	0.91	0.70	0.73	0.38	0.16
cumulative new stock issues (net) / initial assets							
	median	0.05	0.14	0.23	0.09	0.86	0.47
	mean	0.64	0.40	0.76	0.59	1.82	1.98
Share of observations with negative gross cash flow		0.11	0.05	0.23	0.20	0.41	0.38
Share of observations with positive dividends		0.20	0.28	0.03	0.08	0.01	0.04

The table reports cumulative investment and financing activity for surviving high-tech IPOs in the first two five-year intervals following the IPO. The year in which the firm conducts its IPO is t = 0. Investment and financing values are summed over each of the five-year intervals (t=1 to t=5 and t=6 to t=10) and then scaled by the book value of assets at the start of the interval (i.e., the end of t=0 for the first interval and the end of t=5 for the second interval). Only the firms surviving until the end of the period are included in the reported values. Ratios are Winsorized at the 1% level.

Table 3
GMM estimates of the R&D-stock issue sensitivity for public entrants and incumbents.

	New entrants	Established entrants	Incumbents	New entrants	New entrants	New entrants	New entrants
	Full sample period (1970-2004)			1970s IPOs	1980s IPOs	1990-2004 IPOs	1998-2002 sample period
Dependent variable: $(RD/TA)_t$							
$(RD/TA)_{t-1}$	0.973***	1.025***	0.781***	1.227***	1.078***	1.057***	1.097***
	(0.258)	*(0.280)*	*(0.088)*	*(0.373)*	*(0.212)*	*(0.342)*	*(0.409)*
$(RD/TA)_{t-1}^2$	-0.499***	-0.969	-0.326	-0.862	-0.518***	-0.558***	-0.559**
	(0.150)	*(0.852)*	*(0.380)*	*(0.869)*	*(0.145)*	*(0.202)*	*(0.256)*
$(B/TA)_{t-1}^2$	-0.069	-0.030	-0.028	-0.042	-0.393**	-0.109	-0.101
	(0.127)	*(0.028)*	*(0.024)*	*(0.097)*	*(0.197)*	*(0.166)*	*(0.186)*
$(SALES/TA)_t$	-0.014	0.034	0.030*	-0.013	0.095*	-0.091	-0.004
	(0.045)	*(0.032)*	*(0.018)*	*(0.037)*	*(0.052)*	*(0.074)*	*(0.100)*
$(SALES/TA)_{t-1}$	-0.054***	-0.030	-0.031**	-0.022	-0.046**	-0.049**	-0.070*
	(0.015)	*(0.022)*	*(0.012)*	*(0.024)*	*(0.021)*	*(0.021)*	*(0.038)*
$(GCF/TA)_t$	-0.004	0.032	0.046	0.067	-0.142	0.146	-0.037
	(0.101)	*(0.068)*	*(0.060)*	*(0.072)*	*(0.133)*	*(0.140)*	*(0.190)*
$(GCF/TA)_{t-1}$	0.046	-0.001	0.022	0.016	0.009	0.039	0.100*
	(0.029)	*(0.037)*	*(0.029)*	*(0.037)*	*(0.041)*	*(0.036)*	*(0.060)*
$(STK/TA)_t$	0.229***	-0.021	-0.056	0.080	0.115***	0.263***	0.269***
	(0.063)	*(0.053)*	*(0.058)*	*(0.076)*	*(0.029)*	*(0.088)*	*(0.074)*
$(STK/TA)_{t-1}$	-0.027***	-0.002	0.010	-0.009	-0.030***	-0.029**	-0.034*
	(0.011)	*(0.036)*	*(0.010)*	*(0.025)*	*(0.009)*	*(0.014)*	*(0.017)*
M1 (p-value)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
M2 (p-value)	0.295	0.419	0.178	0.188	0.183	0.635	0.714
Hansen *J*-test (p-value)	0.865	0.574	1.000	1.000	0.860	0.865	0.913
Diff-Hansen (p-value)	0.926	0.201	1.000	1.000	0.627	0.943	0.724
GCF Chi2 (p-value)	0.644	0.509	0.060	0.226	0.254	0.167	0.698
STK Chi2 (p-value)	0.004	0.665	0.402	0.469	0.005	0.016	0.003
Observations	10741	1087	3363	1194	4726	4821	2844
Firms	1509	226	206	124	516	869	938

Estimation is with systems GMM using lagged levels dated t-2 through t-4 as instruments for the equation in differences and lagged differences dated t-1 for the equation in levels. Fixed firm and industry-specific time effects are included in all regressions. Public entrants are considered "new" for the first fifteen years following the IPO and "established" thereafter. Outliers in first-differences are trimmed at the 1% level. Standard errors robust to heteroskedasticity and with-in firm serial correlation are reported in parenthesis. GCF Chi2 and STK Chi2 are chi-squared tests that the sum of the cash flow and stock issue coefficients equal zero. Statistical significance at the ten, five and one percent level is noted by *, ** and ***.

Table 4
Median R&D-to-sales ratios for IPO cohorts and incumbents over time.

	1975	1980	1985	1990	1995	2000	2004
Panel A: Five high-tech industries							
IPO cohort							
1970 – 1974	0.059	0.059	0.085	0.086	0.095	0.101	0.091
1975 – 1979		0.065	0.099	0.083	0.091	0.085	0.080
1980 – 1984			0.093	0.081	0.076	0.097	0.089
1985 – 1989				0.096	0.087	0.107	0.126
1990 – 1994					0.121	0.131	0.124
1995 – 1999						0.180	0.166
2000 – 2004							0.168
Incumbents	0.033	0.037	0.055	0.051	0.053	0.062	0.055
Panel B: Drugs (SIC 283)							
IPO cohort							
1970 – 1974							
1975 – 1979							
1980 – 1984			0.284	0.347	0.226	0.175	0.195
1985 – 1989				0.916	1.125	0.626	0.856
1990 – 1994					1.682	1.239	1.182
1995 – 1999						1.756	2.242
2000 – 2004							2.758
Incumbents	0.043	0.048	0.074	0.089	0.094	0.104	0.142

The table reports the median R&D-to-sales ratio for IPO cohorts and incumbents in selected years. The five high-tech industries in Panel A are from three-digit SIC industries 357, 366, 367, 382 and 384. Incumbents are firms with coverage in Compustat at the beginning of 1970. No ratios are reported for the first two cohorts in Panel B due to a limited number of observations.

Table 5
Share of sales accounted for by IPO cohorts over time.

	1975	1980	1985	1990	1995	2000	2004
Panel A: Five high-tech industries							
IPO cohort							
1970 – 1974	0.029	0.035	0.037	0.039	0.073	0.078	0.079
1975 – 1979		0.015	0.022	0.025	0.018	0.009	0.013
1980 – 1984			0.072	0.096	0.140	0.118	0.036
1985 – 1989				0.054	0.079	0.131	0.144
1990 – 1994					0.078	0.097	0.118
1995 – 1999						0.053	0.066
2000 – 2004							0.031
Incumbents	0.941	0.913	0.820	0.733	0.571	0.386	0.433
Others	0.030	0.037	0.049	0.052	0.042	0.129	0.080
Panel B: Drugs (SIC 283)							
IPO cohort							
1970 – 1974	0.010	0.012	0.012	0.015	0.016	0.024	0.016
1975 – 1979		0.003	0.003	0.001	0.002	0.002	0.001
1980 – 1984			0.010	0.021	0.036	0.046	0.070
1985 – 1989				0.004	0.004	0.009	0.014
1990 – 1994					0.024	0.024	0.041
1995 – 1999						0.018	0.020
2000 – 2004							0.026
Incumbents	0.967	0.978	0.946	0.944	0.884	0.849	0.778
Others	0.023	0.008	0.028	0.015	0.035	0.027	0.034

The table reports the share of total sales accounted for by IPOs, incumbents and other firms in selected years. The five high-tech industries in Panel A are from three-digit SIC industries 357, 366, 367, 382 and 384. Incumbents are firms with coverage in Compustat at the beginning of 1970. Others are newly listed firms in Compustat not identified IPOs (such as spinoffs).

Table 6
Share of R&D accounted for by IPO cohorts over time.

	1975	1980	1985	1990	1995	2000	2004
Panel A: Five high-tech industries							
IPO cohort							
1970 – 1974	0.037	0.055	0.062	0.058	0.083	0.097	0.121
1975 – 1979		0.026	0.035	0.043	0.028	0.008	0.014
1980 – 1984			0.080	0.100	0.118	0.084	0.053
1985 – 1989				0.067	0.087	0.087	0.098
1990 – 1994					0.098	0.143	0.137
1995 – 1999						0.099	0.091
2000 – 2004							0.055
Incumbents	0.936	0.881	0.781	0.695	0.551	0.320	0.331
Others	0.027	0.037	0.043	0.036	0.036	0.162	0.099
Panel B: Drugs (SIC 283)							
IPO cohort							
1970 – 1974	0.012	0.007	0.006	0.012	0.011	0.012	0.007
1975 – 1979		0.000	0.001	0.000	0.000	0.000	0.000
1980 – 1984			0.030	0.057	0.091	0.074	0.095
1985 – 1989				0.032	0.030	0.019	0.028
1990 – 1994					0.083	0.070	0.089
1995 – 1999						0.094	0.055
2000 – 2004							0.061
Incumbents	0.967	0.988	0.934	0.887	0.761	0.695	0.640
Others	0.021	0.005	0.029	0.013	0.023	0.036	0.025

The table reports the share of total R&D spending accounted for by IPOs, incumbents and other firms in selected years. The five high-tech industries in Panel A are from three-digit SIC industries 357, 366, 367, 382 and 384. Incumbents are firms with coverage in Compustat at the beginning of 1970. Others are newly listed firms in Compustat not identified as IPOs (such as spinoffs).

Table 7
Sources of finance and the impact of public entrants: OLS regression estimates.

	Dependent Variable	
	Change in share of sales$_{t,t-1}$	Change in share of R&D$_{t,t-1}$
Panel A: Cohort level		
Cohort funds from cash flow$_{t,t-1}$	-0.012	-0.005
	(0.029)	(0.026)
Cohort funds from stock issues$_{t,t-1}$	0.278*	0.543***
	(0.143)	(0.130)
Cohort funds from debt issues$_{t,t-1}$	-0.056	-0.526
	(0.341)	(0.309)
Observations	28	28
Adj. R^2	0.12	0.40
Panel B: Firm level		
Firm funds from cash flow$_{t,t-1}$	0.020***	0.032***
	(0.002)	(0.002)
Firm funds from stock issues$_{t,t-1}$	0.376***	0.557***
	(0.033)	(0.034)
Firm funds from debt issues$_{t,t-1}$	0.160***	-0.026
	(0.032)	(0.033)
Observations	1275	1275
Adj. R^2	0.25	0.38

The dependent variables are measured as the change in cohort (Panel A) or firm (Panel B) share of sales and R&D between the years reported in Tables 5 and 6 (i.e., 1975, 1980…2004). The independent variables are the cumulative flows of finance raised by the cohort (Panel A) or firm (Panel B) over the corresponding five-year interval. The sample is public entrants in the five high-tech industries that comprise Panel A of Tables 5 and 6. Estimation is by OLS.

Table 8
Leading firms in selected industries in 2000.

Company	IPO Year	Segment Sales	Venture Capital	IPO Proceeds	New Equity Finance (Post-IPO)
Panel A: Office and computing equipment (SIC 357)					
Hewlett-Packard	Incumbent	41,165.00			1,025.04
IBM	Incumbent	37,811.00			4,623.88
Compaq	1983	35,038.00	18.98	102.43	1,164.51
Dell	1988	31,888.00	32.47	39.71	403.65
Cisco	1990	18,928.00	21.10	62.28	2,817.89
Xerox	Incumbent	17,156.00			2,316.36
Sun Microsystems	1986	11,971.00	56.29	90.84	638.57
Gateway	1993	9,600.60		148.66	150.71
EMC	1986	8,872.82	0.44	58.62	654.10
Apple	1980	7,983.00	18.17	189.65	34.78
Panel B: Electronic components (SIC 367)					
Intel	1971	27,297.00	26.77	28.72	1,234.23
Solectron	1989	14,137.50	11.25	14.25	1,607.86
Texas Instruments	Incumbent	10,267.00			1,708.14
SCI Systems	Incumbent	8,342.58			114.29
Motorola	Incumbent	7,876.00			4,045.92
Lucent Technologies	Spinoff	6,953.00			3,057.04
Micron Technology	1984	6,278.40	12.42	43.99	1,300.48
Advanced Micro Devices	1972	4,644.19	6.70	32.25	1,208.53
Sanmina	1993	3,911.56	13.59	26.14	687.64
Jabil Circuit	1993	3,558.32		19.89	803.76

All values are in millions of 2000 dollars. The level of segment sales in 2000 is from Compustat's line of business data. The amount of venture capital received is from Venture Economics. IPO proceeds are taken from the SDC New Issues database. Post-IPO new equity finance is from Compustat, where new equity finance is the sum of net equity issues until the firm becomes a net buyer of its equity (see the discussion in section 5.4). Compaq merged with Hewlett-Packard in 2002 and SCI Systems merged with Sanmina in 2001.