Patents, Innovation, and Performance of Venture Capital-backed IPOs

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Abstract

We study the predictive power of patents on the long-run performance of venture capital (VC)-backed initial public offerings (IPOs). We show that VC-backed IPOs that have at least one patent at the time of the IPO substantially outperform other VC-backed IPOs, with 3-year buy-and-hold market-adjusted returns of -7.1% vs. -23.3%. On average, VC-backed IPOs without patents perform similarly to non-VC-backed IPOs. We also report that VC-backed IPOs from 1981-1998 outperformed other IPOs, but the pattern has reversed for IPOs from 1999-2006. Although a smaller proportion of non-VC-backed IPOs possess patents, those with patents also outperform those without patents.

Keywords: Initial public offerings, Venture capital, Patents, Innovation, Long-run performance

JEL: G14 G24 G30

1. Introduction

Innovation is vital to companies' productivity, future profitability, and competitive advantages, and is an important driver of economic growth and social welfare (Griliches, 1992; Hall, 1996). Recent literature shows that venture capital (VC) plays a favorable effect in nurturing high growth startups (Gompers, 1995), yields higher valuation and positive changes in operating performance (Chemmanur, Simonyan, and Tehranian, 2013), and spurs innovation (Kortum and Lerner, 2000). For example, Kortum and Lerner show that increases in VC activities in an industry are associated with significantly higher patenting rates. Chemmanur, Loutskina, and Tian (2014) show that corporate VC has even stronger ability in nurturing innovation due to technology fit and tolerance for failure. Governments around the world have been eager to encourage VC activity with the aim of boosting innovation (Lerner, 2012).

Brav and Gompers (1997), Chan, Cooney, Kim, and Singh (2008), and Field and Lowry (2009) find that VC-backed initial public offerings (IPOs) significantly outperform non-VC-backed IPOs, and that VC-backed IPOs do not significantly underperform benchmarks matched by size and book-to-market ratio.[1] They argue that most IPOs are young, high growth companies, which are prone to information asymmetry and agency problems. Since VCs specialize in identifying, evaluating, and nurturing these types of firms, they posit that VC-backed IPOs are on average better quality companies than non-VC-backed companies. If the market fails to incorporate the importance of venture capital in the pricing of IPOs, VC investment will predict long-run stock price outperformance. Since VC-backed IPOs are renowned for innovation, we focus on VC-

[1] Brav and Gompers (1997) use IPOs from 1975-1992, and both Chan, Cooney, Kim, and Singh (2008) and Field and Lowry (2009) use IPOs from 1980-2000.

backed IPOs and investigate the effects of innovation, as measured by the possession of patents, for their long-run stock price performance, although we also study the impact of patents on the returns of non-VC-backed IPOs.

Many papers document the long-run underperformance of IPOs in the U.S. and elsewhere. The evidence on the long-run performance of IPOs can be summarized as follows: On average, IPOs have low returns in the three years after the IPO, measured from the first closing market price. The low returns are due to both successful market timing effects (Greenwood and Hanson, 2012) and abnormal performance relative to the market. The IPO universe, however, is intensive in small growth stocks with high capital expenditures, high R&D expenditures, and weak profitability, all of which have been shown to explain cross-sectional patterns in stock returns generally (Bessembinder and Zhang, 2012). Thus, one question is whether, after one controls for more general known cross-sectional effects, does knowing whether or not a stock is a recent IPO contain any incremental return predictability effect? A second question is whether there are reliable cross-sectional effects in IPO abnormal performance.

We use patent grants prior to the IPO as a proxy for innovation for a comprehensive sample of 2,254 VC-backed IPOs from 1981-2006. A firm is classified as a VC-backed IPO with patents if it has at least one patent grant before the IPO date; otherwise, it would be classified as without patents. We collect firms' patent grant information before the IPO from the NBER's patent database, which contains the USPTO grant date for all patent filings that were subsequently granted between January 1, 1976 and December 31, 2006. The NBER database reports patents on the basis of company names at the time of the patent grant, and many buyout-backed IPOs and spinoffs have changed their names or

made acquisitions prior to the IPO, resulting in a lower correlation between holding patents that are material to their business and what is reported in the NBER database. This is a second important reason why we focus on VC-backed IPOs.

We acknowledge that patents are not a perfect measure of innovation (for example, many inventions are protected as trade secrets, such as the formula for Coca-Cola), but patents remain the most important and direct measure of the quality and extent of firms' innovations (Griliches, 1990). They are valuable materialized innovation outputs and are actively traded in intellectual property markets. Lerner, Sorensen, and Stromberg (2011) state that the use of patents as a measure of innovative activity is widely accepted in the literature. Alternatively, we could use R&D capital to proxy for innovation, with R&D capital being the sum of unamortized past R&D expenditures. However, R&D expenditures from several years before the IPO are unlikely to be observable for most IPOs.[2] Patent grants are readily available from the United States Patent and Trademark Office (USPTO)'s website, regardless of whether a company is private or public.

We find that patents strongly and positively predict the long-run performance of VC-backed IPOs. Within the class of VC-backed IPOs, firms with pre-IPO patents granted substantially outperform various benchmarks, whereas those without patents do not. The outperformance is both economically and statistically strong. The Fama-French 3-factor model alphas for value-weighted calendar-time portfolios are 74 basis points per month for VC-backed IPOs with patents versus 31 basis points per month for those without patents. The average 3-year market-adjusted buy-and-hold return is -7.1% for VC-backed IPOs with patents, versus -23.3% for those without patents (and -24.2% for

[2] For example, R&D expenses from fiscal years 3 to 7 years before the IPO are needed to calculate R&D capital in the innovation efficiency measure of Hirshleifer, Hsu and Li (2012). Most young firm IPOs, however, do not report audited financial statements from fiscal years that are more than 3 years old.

non-VC-backed IPOs). Moreover, patents also positively predict the long-run price performance of non-VC-backed IPOs, as reported in Panels D and E of Table 4.

Patents are more important for large than small VC-backed firms, i.e, the value-weighted results are stronger than the equally weighted results. Among VC-backed firms with patents, those having low citations show even stronger outperformance than others. Moreover, when we include the R&D ability factor of Cohen, Diether, and Malloy (2013) in multifactor regressions, our findings remain qualitatively unchanged. This result indicates that VC-backed IPOs with patents outperform, other IPOs don't, and this pattern is not likely to be driven by the more general relation between R&D and stock returns.

This paper adds to an extensive literature documenting cross-sectional patterns in the long-run performance of IPOs.[3] Brav and Gompers (1997) find that VC-backed IPOs do not underperform the market or comparable firms. Carter, Dark and Singh (1998) show that IPOs with high-prestige underwriters do not underperform. Teoh, Welch, and Wong (1998) report that IPOs with low discretionary accruals do not underperform. Chan et. al. (2008) examine discretionary accruals, VC-backing, and underwriter prestige, and report results confirming the findings of the original authors. Krishnan, Ivanov, Masulis, and Singh (2011) report that the long-run returns on VC-backed IPOs from 1996-2002 are positively related to the reputation of the VC firms, as measured by the prior market share of IPOs that a VC firm has conducted. Cao and Lerner (2009) find that buyout-backed IPOs do not underperform the market on average. Ritter (2011) reports that

[3] Ritter (1991), Lerner (1994), Loughran and Ritter (1995, 2000), Baker and Wurgler (2000), and Hirshleifer (2001) discuss a behavioral explanation for poor performance subsequent to equity offerings. They argue that stock prices periodically diverge from fundamental values, and that managers and investment bankers take advantage of overpricing by selling stock to overly optimistic investors.

issuers with pre-IPO annual sales of more than $50 million do not reliably underperform the market, whereas smaller issuers have average 3-year buy-and-hold market-adjusted returns of -35.2%. Brau, Couch, and Sutton (2012) show that IPOs without acquisition activity within a year of going public do not underperform. We show that our results are robust to the inclusion of many of these predictors, suggesting that patent possession is a new and previously undetected predictor for the cross-section of the long-run performance of IPOs.

In addition to analyzing the effect of patents on the long-run performance of IPOs, we also document an important pattern related to VC-backed IPOs. Specifically, the superior performance of VC-backed IPOs relative to other IPOs, first documented by Brav and Gompers (1997), has reversed during the 1999-2000 bubble period and later. For 1981-1998, VC-backed IPOs have produced average 3-year buy-and-hold market-adjusted returns of -10.7%, versus -28.7% for non-VC-backed IPOs. In contrast, for 1999-2006, VC-backed IPOs have underperformed the market by -36.2% over three years, versus -2.8% for non-VC-backed IPOs.

This paper contributes to the growing literature on how investors fail to fully incorporate relevant public information about innovations.[4] The future cash flows from innovation can be long deferred, highly uncertain, and difficult to project. Hall (1993) and Hall and Hall (1993) suggest that investors therefore might be myopic in pricing the future cash flows from innovations, leading to undervaluation. Huberman and Regev (2001) and Hirshleifer, Hsu, and Li (2012) show that investors with limited attention may

[4] Previous studies identify many innovation measures with predictive power for future stock returns, including the R&D capital to market value ratio (Lev and Sougiannis, 1996; Chan, Lakonishok, and Sougiannis, 2001; Guo, Lev, and Shi, 2006; Li, 2011), R&D growth (Eberhart, Maxwell, and Siddique, 2004; Lev, Sarath, and Sougiannis, 2005; Hsu, 2009), patents and citations (Deng, Lev, and Narin, 1999; Gu, 2005; Hsu, 2009), innovation efficiency (Hirshleifer, Hsu, and Li, 2013), and innovation ability (Cohen, Diether, and Malloy, 2013).

fail to reflect innovation information into stock prices, leading to undervaluation.[5] Cohen, Diether, and Malloy (2013) document that investors do not correctly price the innovation ability of firms in translating R&D into future sales, and a long-short portfolio strategy based on the past track records of innovation ability earns abnormal returns of roughly 11% per year. Most of the existing research, however, focuses on mature public firms and does not separately examine the entrepreneurial young startup and high-growth firms that characterize VC-backed IPO firms. We posit that VC-backed IPOs with patents are undervalued, whereas VC-backed IPO firms without patents are overvalued at the time of the IPO. An alternative interpretation is that investors are overoptimistic about the prospects of firms that have not demonstrated an ability to convert R&D expenditures into patentable products. If either interpretation is correct, the initial misvaluation should manifest itself in long-run abnormal returns.

2. Data, Sample and Methods

We collect returns on common stocks listed on the New York Stock Exchange (NYSE), American Stock Exchange (Amex), and NASDAQ from CRSP, and accounting data of the issuing firms from COMPUSTAT. We obtain the IPO date, offer price, and underpricing from the Thomson-Reuters Securities Data Company (SDC) new issues database from 1981 to 2006, with numerous fill-ins of missing data and corrections based upon information from Dealogic for 1990-2006, the Graham Howard-Todd Huxster set of IPO prospectuses from 1975-1996 given to Jay Ritter, EDGAR for 1996-2006, and other sources. We exclude closed-end funds, Real Estate Investment Trusts, banks and S&Ls,

[5] Merton (1987), Hirshleifer and Teoh (2003), Peng and Xiong (2006), DellaVigna and Pollet (2009), and Hirshleifer, Lim, and Teoh (2009), among others, analyze how limited investor attention affects stock prices and can cause market underreaction.

American Depository Receipts, unit offerings, limited partnerships, and IPOs with proceeds below $1.5 million, an offer price of under $5 per share, or companies not listed on CRSP within six months of the IPO date.

An IPO is classified as venture capital-backed based upon venture funding information from Thomson-Reuters VentureXpert database, with numerous alterations based upon inspection of the prospectuses. The VentureXpert database provides information on buyout and venture capital firms and their investments, but it does not differentiate between venture capital financing and growth capital financing. We classify 318 growth capital-backed IPOs from 1981-2006, which comprise about 10% of what the VentureXpert database classifies as VC-backed IPOs, as non-VC-backed IPOs. The main criteria for classifying an IPO with a financial sponsor as growth capital-backed rather than venture capital-backed is whether the company is investing in tangible assets and/or growing primarily through acquisitions, in which case we classify the IPO as growth capital-backed.[6] The classification procedure leaves us with a final sample of 2,254 VC-backed IPOs and 4,568 non-VC-backed IPOs from 1981-2006.

A VC-backed IPO is classified as possessing a patent if it has at least one patent granted before the IPO date; otherwise, it is classified as without patents. We retrieve the patent grants information from the latest version of the National Bureau of Economic Research (NBER) patent database that was initially created by Hall, Jaffe, and Trajtenberg (2001). The NBER patent database provides detailed information on more than three million patents that were granted by the United States Patent and Trademark

[6] See Ritter (2014) for further details. A list of companies that we identify as growth capital-backed can be found on his website. Most growth capital-backed IPOs are in industries such as health care services, restaurants, retailing, airlines, and garbage collection, for which patents are unimportant. Very few are in technology industries, and none are in biotech.

Office (USPTO) from January 1, 1976 to December 31, 2006. The database provides detailed information on patent assignee (owner) names, the number of patents, the number of citations received by each patent, a patent's application year, a patent's grant date, and a patent's 3-digit technology class, etc.

We match the NBER patent database to VC-backed companies using GVKEY and CUSIP identifiers. Following the innovation literature, we set the number of patents to zero for companies that have no patent information available from the NBER patent database. While patents protection starts from the application dates and innovation begins once they appear (Hall, Jaffe, and Trajtenberg, 2001), it takes on average two years for a patent to be granted by USPTO. To avoid the look-ahead bias due to patent application-grant lag, following Hirshleifer, Hsu, and Li (2013), we hence date all patents by their grant date instead of application date. In robustness tests, we use the year of the patent filing and assume at least a two year lag prior to the grant date and find qualitatively consistent results, which are available in the Appendix Table A2.

In Table A1 of the Appendix that accompanies this paper, we report patent information from both the NBER patent database and the IPO prospectus for some example firms (all table numbers with an "A" prefix appear in the Appendix). The comparison shows that, although the NBER patent database summarizes the patent information quite well on average, the correlation with what is reported in IPO prospectuses is far from perfect. This is one reason why we use a simple 0-1 classification scheme.[7]

[Insert Table 1 Here]

[7] One reason for a correlation of less than 1.0 is that a firm may have recently acquired another firm that had patent applications, but the NBER dataset would list them under the acquired company's name.

Table 1 presents the distribution of the sample by year. The table reports, by year, the number of VC-backed IPOs and the total number of successful patent grants over the five calendar years either prior to, or after, the IPO year by these newly listed companies. The last column shows, by year, the number of VC-backed IPOs that have at least one patent grant prior to the IPO date.

This table highlights the increase in VC-backed IPO activities in the 1990s. The number of VC-backed firms going public hit a peak in 1999 and 2000 during the tech bubble. The time series suggest that VCs are more likely to take portfolio companies public when public market valuations are high, consistent with Lerner (1994). There is a strong pattern of persistence in innovation: pre-IPO patent grants have a correlation coefficient of 0.73 with post-IPO patent grants. The results indicate that VC-backed companies that have patents before the IPO will continue to file patents and maintain innovation after the IPO.[8] Table 1 does not report patent grants over event years +1 to +5 for IPOs from 2002 to 2006 due to the increasing missing observation problem (i.e., the NBER patent database only contains data for patents granted before the end of 2006).

The NBER patent database does not contain information about patents that were subsequently denied. Hall, Jaffe, and Trajtenberg (2001) show that it takes about two years after the filing to grant a patent. For successful patents filed in calendar year t during the late 1990s, about 85% are granted by the end of calendar year t+2 after the filing year, and about 95% by the end of calendar year t+3. We hence focus on patents that have been successfully granted before the IPO, which are always publicly known before the IPO, to avoid the look-ahead bias associated with patent applications that are

[8] Bernstein (2012) and Ferreira, Manso, and Silva (2014) provide evidence on the impact of going public on firms' innovation activities.

ultimately successful.

[Insert Figure 1 Here]

Figure 1 shows the average number of new subsequently successful patent filings and patent grants per firm per event year over the 11 event years centered on the calendar year of the IPO. The solid line depicts the yearly average number of new patent filings; and the dashed line shows the yearly average number of new patent grants.

According to the solid line of Figure 1, perhaps not surprisingly, we observe a steep uptrend in the average number of successful patent filings per firm per event year. On average, in event year -3 there are 0.6 new subsequently successful patent filings, and in year +3 there are 2.3 new successful patent filings for the surviving firms, with the (not shown) cumulative number rising to about 16 by the end of event year +5. The dashed line indicates a similar uptrend for the average number of patent grants, with an average of 0.3 and 1.6 in event years -3 and +3, respectively. Patents are counted until the end of calendar year 2006 due to the data availability of the NBER patent database.[9] In unreported results, we observe a similar, but much steeper, uptrend for the subset of 594 VC-backed IPOs that have at least one patent grant before the IPO.

3. Patents and VC-backed IPOs Performance

A. Firm Characteristics and Accounting Performance

In Table 2, we summarize the firm characteristics and accounting performance for the VC-backed IPOs with and without patents. Table 2 reports the sample means of

[9] When a firm is acquired/merged/spun-off, the NBER patent database assigns its patents to the new owner. At present it does not track ownership changes when patents are sold independently of their initial assigned owners.

variables computed for the fiscal year in which the IPO occurred, and one, two, three, four, and five years after the IPO.[10] 2,198 of the 2,254 VC-backed issuing firms have financial information in COMPUSTAT for the fiscal year in which the IPO occurred, with the sample size falling to 1,270 five years after the IPO due to delistings. All variables using levels rather than flows are computed using data at the end of the fiscal year, as reported by COMPUSTAT.

[Insert Table 2 Here]

Surprisingly, Table 2 shows that the mean market value of VC-backed IPOs without patents falls during fiscal year +1 after the IPO. This drop is largely due to the large number of highly valued VC-backed IPOs during 1999-2000 that collapsed in price after March 2000. Table 2 shows that VC-backed IPOs with patents have mean R&D-to-assets and R&D-to-sales ratios about 40% higher than VC-backed firms without patents.[11] The patterns in Table 2 show a downtrend in the R&D-to-sales ratio from the IPO year to five years after the IPO, while the R&D-to-assets ratio is relatively stable. The mean R&D-to-sales ratio of 0.55 to 0.97 in various years is high because many biotech firms have ratios far above 1.00. In unreported results, we find that the median R&D-to-sales ratio is about 0.21 for VC-backed IPOs with patents and about 0.14 for those VC-backed IPOs without patents in the IPO year. Those with patents have smaller CAPEX/assets than those without at the IPO year and one year after, then they share similar levels afterwards. Consistent with Chemmanur, Simonyan, and Tehranian (2013), VC-backed IPOs with or

[10] We Winsorize all variables at the 1% and 99% percentiles to eliminate outliers, and set missing values to zero before calculating the means.

[11] The higher average R&D-to-sales ratio relative to the R&D-to-assets ratio is partly due to the low revenue of most biotech stocks in the IPO year and subsequent years. For example, for the VC-backed biotech IPOs with patents, the average sales in the IPO year is only $35 million, and the median sales is even smaller ($6 million), generating a high average R&D-to-sales ratio of 1.90. We observe the same pattern for VC-backed biotech IPOs without patents, too.

without patents both have negative profitability on average after the IPO, whether measured in terms of operating income-to-assets or net income-to-assets (ROA).[12]

B. Underpricing

An extensive literature on IPOs finds sizeable positive average returns on the first day of trading. Megginson and Weiss (1991) show that U.S. VC-backed IPOs have lower first-day returns than non-VC-backed IPOs during 1983 through 1987, which they attribute to the VC certification role in reducing information asymmetry between investors and issuing firms. Evidence from recent years suggests that U.S. VC-backed IPOs are more underpriced than other IPOs. Liu and Ritter (2011) report that during 1993-2008 VC-backed IPOs with subsequent coverage from an all-star analyst affiliated with a lead underwriter are underpriced by 21% more (e.g., 31% vs. 10%) than non-VC-backed IPOs, but other VC-backed IPOs are not reliably underpriced more or less than non-VC-backed IPOs.[13]

[Insert Table 3 Here]

Table 3 reports the summary statistics of the first-day returns for the VC-backed IPOs with and without patents. The average first-day return for those without patents during the period January 1981 to December 2006 is 32.0%, a level slightly higher than the 25.2% for VC-backed IPOs with patents. The September 1998 to June 2000 internet bubble had a striking effect on first day returns for both VC-backed IPOs with or without patents, which reached average levels of 92.3% and 95.6%, respectively, during this

[12] Appendix Table A3 summarizes the characteristics and accounting performance for the VC-backed IPOs with and without patents sorted on size or book-to-market ratio. VC-backed IPOs in large size or value terciles (high book-to-market ratio) have better profitability than those in small size or growth terciles (low book-to-market ratio).

[13] Liu and Ritter (2011, column 1 of Table 5) report a coefficient of 2.88 on a VC dummy and 18.03 on an interaction of a VC dummy and an all-star analyst dummy, giving a total effect of 20.91% in an underpricing regression.

bubble period. In general, there is little difference in the distribution of first-day returns between the two categories of VC-based IPOs.

C. Firm Level Stock Performance

Brav and Gompers (1997) find that equally weighted portfolios of VC-backed IPOs from 1975-1992 outperform non-VC-backed IPOs during the three years after issuing. In this section, we present firm level analyses of long-run performance of VC-backed IPOs with and without patents from 1981-2006. Later on, we will show that the results are qualitatively similar when weighting each time period equally, rather than each IPO equally.

In examining IPO long-run performance, we employ various performance measures that have been used in the literature. These measures include buy-and-hold returns (raw and market-adjusted returns), monthly returns (raw and market-adjusted), Fama-French (1993) 3-factor alphas, and Fama-French (2014) 5-factor alphas.[14] If the sample firm gets delisted, the performance measures are calculated up to the delisting date.

The average buy-and-hold raw returns and monthly raw returns are computed on the basis of monthly stock returns over 24, 36, 48, and 60 calendar months starting from the closing price on the last trading day of the IPO month, and do not include the first-day return or returns until the end of the IPO calendar month. The average buy-and-hold market-adjusted returns and monthly market-adjusted returns are adjusted by subtracting the compound return on the CRSP value-weighted NYSE/Amex/Nasdaq index. All returns include capital gains and dividends.

[14] The Fama-French factor portfolios are themselves partly composed of new issues, and the small size, high growth, low profitability, and high investment portfolios may have a high proportion of recent IPOs, so there is a "factor contamination" problem that biases the estimated intercept towards zero, as discussed in Loughran and Ritter (2000).

In calculating Fama-French 3-factor alphas, for each firm we regress monthly firm excess returns on the Fama and French three factors for 24, 36, 48, and 60 months after the IPO,

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_i\left(R_{m,t} - R_{f,t}\right) + s_i SMB_t + h_i HML_t + e_{i,t}.$$

where $R_{i,t} - R_{f,t}$ is the return on stock i in excess of the risk-free interest rate (the one-month Treasury bill rate) at time *t*; $R_{m,t} - R_{f,t}$ is the value-weighted market return of all NYSE/Amex/Nasdaq firms minus the risk-free rate at time *t*; SMB_t is the difference between the return on small- and big-capitalization firms; and HML_t is the difference between the return on high and low book-to-market stocks, with the factor returns downloaded from Ken French's website.

We calculate Fama-French 5-factor alphas by regressing the excess returns on the Fama-French five factors, which include the Fama-French three factors plus the profitability factor and the investment factor,

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_i\left(R_{m,t} - R_{f,t}\right) + s_i SMB_t + h_i HML_t + m_i RMW_t + n_i CMA_t + e_{i,t},$$

where the profitability factor RMW_t, is the difference between the return on robust and weak operating profitability firms; and the investment factor CMA_t, is the difference between the return on conservative and aggressive investment firms, both of which help to explain the stock returns of IPO firms (Lyandres, Sun and Zhang, 2008; Hou, Xue, and Zhang, 2014; Fama and French, 2014). If a sample firm gets delisted, the IPO returns and the corresponding benchmark returns are calculated using data up to the delisting date. When available, we include the firm's delisting return.

[Insert Table 4 Here]

Panels A and B of Table 4 summarize the equally weighted average long-run raw

and abnormal returns in the five years following the IPOs of 1,660 VC-backed IPOs without patents and 594 VC-backed IPOs with patents, respectively. In Panel A, VC-backed IPOs without patents deliver an average raw buy-and-hold return of 12.1% over three years, and perform similarly to the non-VC-backed IPOs in Panel C of Table 4.[15] In contrast, Panel B shows that VC-backed IPOs with patents deliver a substantially higher average raw buy-and-hold return of 28.2% over three years. When the buy-and-hold return is adjusted by the compounded value-weighted market return, the outperformance of VC-backed IPOs with patents relative to those without patents is 16.2% (-23.3% vs. -7.1%) after three years, in terms of average buy-and-hold market-adjusted returns.

Moreover, all of the average monthly Fama-French 3-factor alphas of VC-backed IPOs without patents are negative in the five years after the IPO, ranging from a monthly average of -0.38% in the first year to a monthly average of -0.17% in the first five years, in Panel A. By comparison, Panel B shows that all of the average monthly Fama-French alphas of VC-backed IPOs with patents are positive, ranging from 0.21% to 0.52%, including an average of 0.47% per month in the first five years. Therefore, VC-backed IPOs with patents substantially outperform those without patents by 0.64% per month (-0.17% vs. +0.47%) in the five years after the IPO in terms of Fama-French 3-factor alphas when each IPO is weighted equally. The Fama-French 5-factor alphas, which control for the Fama-French three factors plus the profitability and investment factors, also show that VC-backed IPOs with patents outperform those without patents, by 0.51% per month in their first five years after the IPO. When average monthly market-adjusted returns are used, the results are similar.

[15] If a stock is delisted before the end of a T-month buy-and-hold return period, the return is calculated up until the delisting date. The sample size for the 60-month buy-and-hold returns is thus just as large as for the 24-month buy-and-hold returns.

Panel C of Table 4 reports the equally weighted average long-run performance of 4,568 non-VC-backed IPOs in the five years after the IPO. Panel C shows that, consistent with the literature, non-VC-backed IPOs underperform. The average buy-and-hold market-adjusted return is -16.1% two years after the IPO, and increases to -35.5% five years after the IPO. In addition, all the average monthly Fama-French 3-factor alphas of non-VC-backed IPOs are negative, ranging from -0.43% to -0.49%. The average monthly Fama-French 5-factor alphas also show underperformance, ranging from -0.06% to -0.23%, although the point estimates are close to zero.[16]

In Panels D and E of Table 4, we show that patents also have a positive effect on the long-run price performance of non-VC-backed IPOs, though the economic scales are smaller. Among the 4,568 non-VC-backed IPOs, 561 of them are classified as having at least one patent grant before the IPO; while the other 4,007 issuers are classified as non-VC-backed IPOs without patents.[17] Those IPOs with patents outperform those without patents by 13.8% (-26.1% vs. -12.3%) in terms of average 3-year buy-and-hold market-adjusted returns, and 0.70% per month (-0.50% vs. +0.20%) in terms of Fama-French 3-factor alphas in the three years after the IPO when each IPO is weighted equally.

Finally, in Panels F of Table 4, we report the long-run performance of 6,822 IPO firms. They deliver an average raw buy-and-hold return of 14.1% to 34.0% over the two to five years after the IPOs. Consistent with Ritter and Welch (2002), the IPOs

[16] Our results are robust to alternative classifications of VC-backed IPOs with and without patents. For example, we find similar patterns in Appendix Table A2, where we date patents by application year and an issuing firm is classified as with patents if it has at least one successful patent filing up to event year -3 prior to the IPO year. The three year lag is utilized to account for the patent application-grant lag.

[17] It is somewhat surprising that only 561 out of 4,568 non-VC-backed IPOs have patents, given that over 1,000 are spinoffs or buyout-backed. Partly, the low count reflects the fact that the NBER database does not include patents from before 1976, and also because of name changes associated with mergers and spinoffs. Because the NBER patent dataset does not adjust for name changes or sales of patents, we have undoubtedly undercounted the number of IPOs with patents.

substantially underperform the market. For example, they suffer large negative buy-and-hold market-adjusted returns of -22.7% and negative average monthly market-adjusted return of -0.64% in the three years after the IPO. After we control for the well-known size and value effects, the IPOs still underperform and have a negative average monthly Fama-French 3-factor alpha of -0.30%. However, the negative long-run abnormal returns of IPOs are largely explained when investment and profitability factors are added. The IPOs actually generate a slightly positive average monthly Fama-French 5-factor alpha of 0.07% in the three years after the IPO.

These findings are consistent with Bessembinder and Zhang (2013), who show that the long-run returns of IPOs can be explained by controlling for firm characteristics such as idiosyncratic volatility, prior returns, and illiquidity in addition to size and book-to-market. It should be noted, however, that the alphas are biased towards zero due to the "factor contamination" problem discussed in Loughran and Ritter (2000). Specifically, because in some periods many recent IPOs are in the small firm portfolio of SMB, the growth firm portfolio of HML, the high investment firm portfolio of CMA, and the unprofitable firm portfolio of RMW, low returns on IPOs are affecting the factor returns.

In summary, the overall evidence from Table 4 suggests that VC-backed IPOs with patents strongly outperform VC-backed IPOs without patents and non-VC-backed IPOs for almost all performance measures. However, VC-backed IPOs without patents perform similarly to non-VC-backed IPOs, and both underperform the market. Patents also have a positive effect on non-VC-backed IPOs but with smaller economic magnitude: those with patents outperform those without patents, but underperform VC-backed IPOs with patents generally. Although the firm characteristics such as investment and operating

profitability help to explain the long-run underperformance of IPOs in general, they cannot explain the outperformance of VC-backed IPOs with patents.

Patents are important for high-tech firms while they may not be equally important in non-high-tech sectors. We thus classify all VC-backed IPOs into non-high-tech, high-tech, and biotech groups according to standard industry classification (SIC) codes at the IPO.[18] The average three-year long-run performance results of non-high-tech, high-tech, and biotech industries after the IPO are reported in Table 5. Panel A of Table 5 reports the results for VC-backed IPOs without patents, while Panel B reports the results for those VC-backed IPOs with patents.

[Insert Table 5 Here]

Table 5 shows that the innovation leads to outperformance in all three sectors, especially in the high-tech sector, no matter what performance measure is used. For example, using 3-year market-adjusted buy-and-hold returns, the VC-backed IPOs with patents outperform those without patents by 5.2%, 26.1%, and 13.8% for non-high-tech, high-tech, and biotech firms, respectively.

D. Subperiod Firm Level Performance

This subsection refines the firm level stock price performance results reported in the previous section by assessing the 3-year long-run performance of VC-backed IPOs with and without patents in different subsample periods and cohort years. This analysis is motivated by the evidence that IPO long-run performance varies across time. Loughran and Ritter (2000), among others, find that IPO performance is particularly poor following

[18] An IPO's industry is determined by its primary 3-digit SIC code at the IPO. High-tech industries are classified as belonging to SIC codes 481 (telecommunications), 365-369 (electronic equipment), 482-489 (communication services), 357 (computer hardware), and 737 (computer software). Biotech industries are defined as those belonging to SIC codes 283 and 874 (biological products, genetics, pharmaceuticals, and biological research). All other industries are non-high-tech.

hot IPO markets.

Table 6 reports the average firm level three-year stock performance measures for IPOs from four subperiods: 1981-1989, 1990-1998, 1999-2000, and 2001-2006. Panels A and B of Table 6 report the subperiod results for 1,660 and 594 VC-backed IPOs without and with patents, respectively, based on at least one patent grant before the IPO. Panel C reports the subperiod results for all 2,254 VC-backed IPOs. Panel D reports the subperiod results for 4,568 non-VC-backed IPOs.

[Insert Table 6 Here]

Consistent with the literature, the long-run abnormal performance of IPOs varies over time. Panels A and B show that, among VC-backed IPOs, firms with patents strongly outperform firms without patents during all but the 2001-2006 periods. VC-backed IPOs with patents generate sizable positive Fama-French 3-factor alphas and Fama-French 5-factor alphas across every subperiod except for IPOs from 2001-2006.

Brav and Gompers (1997) show that VC-backed IPOs from 1975-1992 outperform non-VC-backed IPOs, and that VC-backed IPOs do not significantly underperform size- and book-to-market-matched benchmarks, although both categories underperform relative to the market. Consistent with their findings, taking an IPO-weighted average of the 1981-1989 and 1990-1998 numbers, the average market-adjusted 3-year buy-and-hold return is -10.8% for VC-backed IPOs in Panel C and -28.7% for non-VC-backed IPOs in Panel D. However, the weighted average market-adjusted 3-year buy-and-hold return for the VC-backed IPOs from 1999-2006 is -36.2% in Panel C; in Panel D, the average 3-year buy-and-hold market-adjusted return for the non-VC-backed IPOs from 1999-2006 is -2.7%. Thus, for 1999-2006, VC-backed IPOs have underperformed non-VC-backed

IPOs when 3-year buy-and-hold market-adjusted returns are used, although the reversal is not strong when 3-factor or 5-factor regression alphas are used as a measure of performance.[19] In other words, the pattern that Brav and Gompers documented has reversed for IPOs from 1999-2006.

Table 7 presents average 3-year buy-and-hold returns for VC-backed IPOs with and without patents over each cohort year, with the returns starting from the closing price on the last trading day of the calendar month of the IPO. For every VC-backed IPO, we calculate the 36-month buy-and-hold return and the compounded market benchmark return, and report the average (equal-weighted in Panel A and market capitalization-weighted in Panel B) returns for the cohort year. If a sample firm gets delisted, the IPO returns and the corresponding benchmark returns are calculated using data up to the delisting date. Also reported is the wealth relative, calculated as

$$Wealth\ Relative = \sum\left(1 + R_{i,T}\right) / \sum\left(1 + R_{bench\ i,T}\right),$$

where $R_{i,T}$ is the buy-and-hold return on IPO i for holding period of length T and $R_{bench\ i,T}$ is the benchmark buy-and-hold return on the value-weighted market portfolio of all NYSE/Amex/Nasdaq firms over the same period. Wealth relatives as a measure of performance were first introduced by Ritter (1991), and are identical to public market equivalents when the benchmark return is the market return, as in Kaplan and Schoar (2005).

[19] For VC-backed IPOs from 1999-2000, Panel B of Table 6 reports an average monthly 3-factor alpha of +1.42% for 105 VC-backed IPOs with patents, while at the same time reporting an average 3-year buy-and-hold market-adjusted return of -25.4%. The reason for the difference in abnormal performance is that the multifactor model estimates a high factor loading (slope coefficient) on the market factor and a very negative factor loading on the book-to-market factor. During the March 2000 to March 2003 period, the market excess return was strongly negative and the HML factor return was strongly positive. Ritter and Welch (2002, Table V) report a similar difference in the abnormal returns for the bubble period IPOs using these alternative benchmarks.

[Insert Table 7 Here]

Table 7 shows that the average 3-year buy-and-hold returns and wealth relatives have large variations over time. These results are largely consistent with the results in Ritter and Welch (2002). Nevertheless, VC-backed IPOs with patents substantially outperform those VC-backed IPOs without patents. In Panel A of Table 7, when weighting each VC-backed IPO equally, the average 3-year wealth relative for the 594 with patents is 0.95, versus only 0.83 for the 1,660 without. In Panel B of Table 7, we weight each IPO employing inflation-adjusted market values for each cohort year, and find that those with patents show significantly better performance, with an average wealth relative of 1.14, in contrast to only 0.64 for those without patents.

E. Calendar-time Portfolio Performance

The firm level performance measures in event time suffer from cross-sectional correlation, which is why we have not reported statistical significance measures in Tables 1-7. In this subsection, we report calendar-time long-run performance of VC-backed IPOs with and without patents, weighting each time period equally rather than weighting each IPO equally.[20] We form monthly portfolios of VC-backed IPOs with and without patents by including all issues that were undertaken in the three years previous to the month of the observation. We then calculate the monthly excess returns, defined as monthly returns of the equal- or value-weighted return of these portfolios less the risk-free rate (the one-month Treasury bill rate). The calendar-time portfolios are rebalanced every month, and the value weights are based on the previous month's month-end market values of the issuing firms.

[20] A disadvantage of the calendar-time approach is that it tends to underestimate the level of underperformance when the magnitude of abnormal underperformance is positively correlated with issuing activity (Loughran and Ritter, 2000).

[Insert Table 8 Here]

Panel A of Table 8 reports Fama-French 3-factor time-series regression results for calendar-time portfolios of VC-backed IPOs with and without patents for the 347 months from February 1981 to December 2009. Unless there is an early delisting, an IPO is included in a portfolio for the 36 calendar months after listing. The equally weighted calendar-time portfolio of VC-backed IPOs with patents significantly outperforms; the alpha is 0.52% per month, which is economically sizable and statistically significant, with a *t*-statistic of 2.18. When those with patents are value-weighted, the outperformance is even stronger, with a monthly Fama-French alpha of 0.74%, and a *t*-statistic of 2.15. Abnormal returns of 0.74% per month correspond to approximately 9% per year.

By comparison, for both the equally and value-weighted calendar-time portfolios of VC-backed IPOs without patents, the Fama-French 3-factor alphas are insignificantly different from zero, suggesting that those without patents in general perform as well as other firms with similar characteristics. As a benchmark, the last two columns of Table 8 show that both the equally and value weighted portfolios of non-VC-backed IPOs significantly underperform, with a monthly Fama-French alpha of -0.41% and -0.19%, respectively. Table 8 weights each calendar month equally, whereas the average alphas reported in Table 4 weight each IPO equally. Nevertheless, a comparison of the Fama-French alphas in the two tables leads to similar conclusions.

Next, we examine whether the outperformance of VC-backed IPOs with patents is captured by existing innovation-related effects in the cross-section of mature public firms. Specifically, we augment the Fama-French 3-factor model with the innovation ability factor (IAH) of Cohen, Diether, and Malloy (2013), who document that the innovation

ability of firms in translating R&D into future sales growth is a positive predictor for the cross-section of stock returns. The IAH factor is the return difference between a portfolio of stocks with high R&D and high innovation ability and a portfolio of stocks with high R&D and low innovation ability.

Panel B of Table 8 shows that our findings generally remain unchanged by the inclusion of the innovation ability factor. All the factor loadings on the innovation factor are economically small (less than 0.05 in absolute value). The inclusion of the innovation factor has little impact on the abnormal returns of VC-backed IPOs. For example, the value-weighted portfolio of innovation VC-backed IPOs still generates abnormal return of 0.71% per month, with a t-statistic of 2.03. We thus conclude that our findings are distinct from existing innovation-related patterns in the literature such as those reported in Cohen, Diether, and Malloy (2013) and Hirshleifer, Hsu, and Li (2013).[21]

In summary, the empirical evidence heretofore indicates that investors fail to fully incorporate the value-relevant information of patents and innovation at the point of the IPO, resulting in underreaction and return predictability. Furthermore, this predictability remains even after controlling for a more general innovation ability factor.

In the Appendix Table A4, we study the effects of patent citations on the predictive power of innovation, and classify the 594 VC-backed IPOs with patents into low and high citations groups based on cumulative citations received prior to the IPO.[22] Patent citations reflect the technology or economic significance of patents (e.g., Trajtenberg, 1990). Financial analysts, media and investors also pay a lot of attention to high impact

[21] In unreported results, we find that our findings are robust to the inclusion of additional factors such as a momentum factor or an investment factor.

[22] We collect each patent's pre-IPO citation data manually, because the number of citations received by each patent in the NBER patent database is counted until the end of 2006, which subjects the cumulative counts to a look-ahead bias for IPOs from before 2007.

inventions. High-citations patents hence are more salient and less uncertain to investors. The psychology literature shows that, due to the limited attention, investors will underreact more to information that is less salient and with higher uncertainty (see Hirshleifer, Hsu, and Li (2013) and the references therein), indicating that the positive predictive ability of innovation will be stronger for those low-citation patents.

Table A4 shows that, while both low and high citations portfolios of VC-backed IPOs with patents have positive abnormal returns, the low citations portfolio performs much better. For example, the monthly Fama-French alpha is 1.09% for the value-weighted low citations portfolio, while it is only -0.05% for the corresponding high citations portfolio. The evidence suggests that investors underestimate the economic importance of patents, and especially those patents that have not generated many citations at the time of going public. These findings are consistent with our premise that patents with low citations are less salient and more uncertain, so that they are more likely to be ignored by the market.

Size and the book-to-market ratio are important firm characteristics related to long-run performance. In a further robustness check, Table A5 reports the performance of calendar-time portfolios of VC-backed IPOs formed on the basis of market capitalization and the book-to-market ratio, following Brav and Gompers (1997). Table A5 shows that the alphas are highest for the portfolios of larger companies and value companies, and VC-backed IPOs with patents consistently outperform those without patents across all three size and book-to-market groups. For example, the Fama-French alphas of the value-weighted portfolios of VC-backed IPOs with patents are as high as 0.96% and 2.13% per month for the large size and value groups, respectively.

4. Cross-sectional differences across VC-backed IPOs

In this section, we employ multivariate cross-sectional regressions to further assess the positive effect of patents on VC-backed IPOs' long-run performance in the three years after going public. Table 9 reports the regression results for the sample of 2,254 VC-backed IPOs from 1981 to 2006. The dependent variables for Columns (1) to (3) in Table 9 are the monthly Fama-French 3-factor alphas estimated by running firm-specific time-series regressions of monthly firm excess returns on the Fama and French factors for 36 months after the IPO. The dependent variables for Columns (4) to (6) are the 3-year buy-and-hold market-adjusted returns.

The variable of interest is the patent dummy, which is equal to one when the firm has at least one patent grant before the IPO, and zero otherwise. The sample size falls to 2,042 when we include various alternative determinants of IPO return performance such as the logarithm of inflation-adjusted sales (in millions of dollars of 2006 purchase power), book-to-market equity ratio (BE/ME), debt-to-total assets ratio, cash-to-sales ratio, research and development (R&D) expenses-to-sales ratio, patent grants at the IPO year relative to R&D expenditures ratio, underpricing, logarithm of IPO firm age at the IPO, and underwriter reputation (measured on a 0 to 9 scale, with 9 high).[23] All the accounting variables are computed using data at the end of the fiscal year of the IPO in COMPUSTAT. Variables are Winsorized at the 1% and 99% levels, and the 5% and 99%

[23] The book-to-market equity ratio is calculated as the book value of equity divided by the market value of common equity at the end of the fiscal year of the IPO, which would bias the BE/ME coefficient downwards. To avoid losing firm-year observations when calculating ratios with a zero in the denominator, we add a small positive number to the actual values of sales and R&D expenditures when their values are equal to zero. Following Field and Karpoff (2002) and Loughran and Ritter (2004), IPO firm age is defined as the calendar year of offering minus the calendar year of founding. The IPO founding dates and updated Carter and Manaster (1990) underwriter reputation rankings are available from Jay Ritter's website.

levels for R&D/Sales and Patents/R&D because more than 1% of the denominators are zero. All the regressions control for industry and year fixed effects. Standard errors are clustered at the industry and year levels (Petersen, 2009). Given that a number of the control variables are endogenous choices by the issuing firms and VCs, these regressions should be interpreted as indicative of correlation, not causation.

[Insert Table 9 Here]

According to Columns (1) to (3) of Table 9, VC-backed IPOs with patents experience significantly higher Fama-French alphas than those without patents over the three years after the IPO, even after including different sets of control variables. For example, the cross-sectional regression estimates in Column (1) show that the regression coefficient on the patent dummy is 0.55%, which is economically large and statistically significant, with a *t*-statistic of 2.37, when controlling for firm sales, book-to-market ratio, IPO year fixed effects, and industry fixed effects. In other words, VC-backed IPOs with patents on average outperform those without patents by 0.55% per month, or annually up to 7%, in terms of Fama-French alpha in the three years after the IPO.

Our results are generally unchanged, with the regression coefficients on patent dummy of 0.56% to 0.57% when we further control for additional firm characteristics such as capital structure (debt-to-market ratio), financing capacity (cash-to-sales ratio), innovation intensity (R&D expenses-to-sales ratio), innovation efficiency (patents-to-R&D expenses ratio), IPO firm age, and underwriter reputation, as presented in Columns (2) to (3).[24] Therefore, the predictive power of patents is not driven by these known

[24] In unreported results, we find that our findings are robust to the incorporation of VC reputation proxies such as VC firm age and VC's historical assets under management at the IPO (e.g., Nahata, 2008 and Krishnan, Ivanov, Masulis, and Singh, 2011), although the sample size drops by more than 50% due to missing information on VC characteristics.

determinants of the cross-section of stock returns in the literature.

The regression results in Columns (4) to (6) show that patents also positively predict a VC-backed IPO firm's buy-and-hold market-adjusted returns over the three years after the IPO. The outperformance associated with patents is both economically and statistically significant, regardless of the model specifications and controls. The coefficients on the patent dummy range from 27.7% to 34.6% for the 3-year buy-and-hold market-adjusted returns.[25]

The slope coefficients on the control variables are generally consistent with the previous literature. VC-backed companies with larger sales perform significantly better, which is consistent with Ritter (2011), who reports that long-run abnormal returns are much worse for IPOs with inflation-adjusted pre-IPO annual sales of below $50 million in terms of 2005 purchasing power. Consistent with Carter, Dark, and Singh (1998) and Chan, Cooney, Kim, and Singh (2008), we find that underwriter reputation is significantly positively associated with the long run abnormal returns of VC-backed IPOs. The book-to-market ratio has a marginally significantly positive effect on the long run abnormal performance, especially for the Fama-French alpha. The cash-to-sales ratio, R&D expenses-to-sales ratio, and patents-to-R&D expenses ratio have positive impacts, and the debt-to-assets ratio, underpricing, and firm age have negative impacts, while the explanatory power of all of them is statistically insignificant.

[25] In unreported results, we investigate the likelihood of having patent grants and its effects on post-issue three-year abnormal stock price performance using Heckman's two-stage selection regressions, to address the concern that the patenting activities may arise endogenously as a consequence of choices made by the issuing firms and VCs. The identifying instruments in the first-stage regressions include the industry-average R&D activity, operating performance, assets, book-to-market ratio, and debt-to-asset ratio for publicly traded firms measured at year -3 before IPO. In the second-stage regression, we show that the patent dummy is significantly and positively associated with IPO firm long-run performance, even though we include the inverse Mills ratio computed from the first-step probit regression as an additional control variable for selection bias.

5. Conclusions

In this paper, we examine the predictive ability of patents as a proxy for innovation on the long-run performance of VC-backed IPOs using a sample of 2,254 VC-backed U.S. IPOs from 1981 through 2006. We find that VC-backed IPOs with pre-IPO patent grants strongly outperform those VC-backed IPOs without patent grants in both cross-sectional and calendar-time analyses, with 3-year buy-and-hold market-adjusted returns of -7.1% vs. -23.3%. Outperformance associated with patents is especially strong in the high-tech sector, in patenting firms with low citations, and in large size or value (high book-to-market) terciles. In contrast, VC-backed IPOs without patents on average perform similarly to non-VC-backed IPOs. Although a smaller proportion of non-VC-backed IPOs have patents, those with patents also outperform those without patents.

The outperformance for VC-backed IPOs with patents remains virtually unchanged after we control for size, value, profitability, and investment factors. In addition, our findings are not driven by the existing innovation-related effects in the cross-section of stock returns. For example, the value-weighted calendar-time portfolio of VC-backed IPOs with patents earns a 9% annual abnormal return both in Fama-French 3-factor time-series regressions and after adding the innovation ability factor of Cohen, Diether, and Malloy (2013). In contrast, the alpha of the portfolio of VC-backed IPOs without patents is insignificantly different from zero. We also control for a large number of firm characteristics that may potentially affect IPO long-run performance in a cross-sectional multivariate regression framework. Our innovation proxy, a patent dummy, remains a strong positive predictor of long-run abnormal returns.

The empirical results of this research suggest that IPO investors do not fully comprehend the information content in patents, possibly because of the difficulty of evaluating the economic implications of such innovation information. This is especially relevant for patents that are not widely cited, since such value-relevant information is less salient and more uncertain. The results also suggest that for VC-backed IPOs, the ability to innovate is a key driver of long-run performance. Innovation measures such as patents therefore have important valuation implications in the capital market.

In addition to documenting that the possession of patents at the time of an IPO is an important predictor of subsequent returns for VC-backed IPOs, we also report that the positive abnormal performance of VC-backed IPOs has reversed in recent years. In particular, VC-backed IPOs from 1981-1998 outperformed other IPOs, but for IPOs from both the 1999-2000 internet bubble period and from 2001-2006, the pattern has reversed. VC-backed IPOs from 1999-2006 have produced average 3-year buy-and-hold market-adjusted returns of -36.2%, vs. -2.8% for non-VC-backed IPOs, in contrast to the 1981-1998 averages of -10.8% for VC-backed IPOs and -28.7% for non-VC-backed IPOs.

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Figure 1: Average number of patents for VC-backed IPOs before and after the IPO

The sample consists of 2,254 VC-backed IPOs between January 1981 and December 2006. The solid line reports the average number of new subsequently successful patent applications per firm per event year over [-5, +5] event years relative to the calendar year of the IPO for all the 2,254 VC-backed IPOs; the dashed line depicts the corresponding average number of new patent grants per firm per event year. There are 2,254 firms for event years -5 to -1, which decreases to 1,446 at event year +5. The averages for years +1 to +5 are conditional on the firm remaining as a publicly traded firm. Patent counts are calculated until the earlier of the event year +5 after the IPO, the delisting date, or December of 2006.

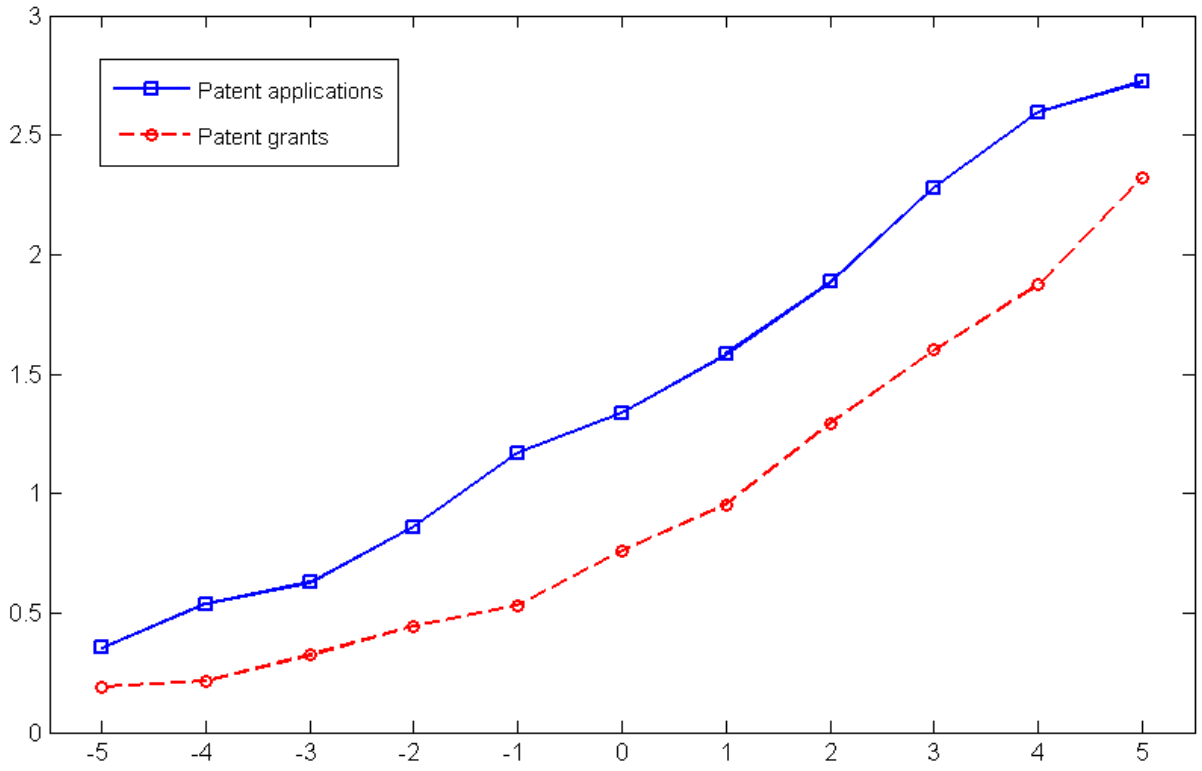

Table 1: Annual distribution for VC-backed IPOs and patent grants

The sample consists of 2,254 venture capital (VC)-backed initial public offerings (IPOs) between January 1981 and December 2006, with 318 growth capital-backed IPOs excluded. The table reports the annual number of VC-backed IPOs, and their patent grants over the five calendar years before and after the calendar year of the IPO. The last column shows the annual number of VC-backed IPOs with patents, which have at least one patent before the IPO. The patent grants data from 1976 to 2006 are from the NBER patent dataset, which contains information about all patents that were granted by the USPTO from January 1, 1976 to December 31, 2006. There are no requirements that a firm has to continue to exist for a full five-year window after the IPO. Patent grants after the IPO are measured until the earlier of the end of event year +5 or the delisting date. Year 0 is the calendar year in which the IPO occurred.

IPO year	Number of VC-backed IPOs	Patent grants of VC-backed IPOs from -5 to -1 years prior to the IPO year	Patent grants of VC-backed IPOs from +1 to +5 years after the IPO year	Number of VC-backed IPOs with patents
1981	53	31	80	12
1982	19	5	40	2
1983	105	88	302	25
1984	39	12	114	7
1985	30	2	31	2
1986	73	34	357	15
1987	63	19	266	14
1988	29	22	134	7
1989	30	23	128	11
1990	40	28	143	8
1991	98	101	675	27
1992	125	146	620	39
1993	166	205	1,016	50
1994	118	146	639	27
1995	161	202	1,150	49
1996	222	186	1,724	48
1997	104	94	1,219	24
1998	61	80	326	16
1999	259	188	1,421	38
2000	238	469	2,529	67
2001	22	44	318	12
2002	11	31	-	3
2003	20	148	-	10
2004	73	463	-	42
2005	43	170	-	19
2006	52	187	-	20
Total	2,254	3,124	13,232	594

Table 2: Mean accounting characteristics for VC-backed IPOs with and without patents

The sample consists of 2,254 VC-backed IPOs between January 1981 and December 2006. Among them, 2,198 have financial information in COMPUSTAT for the fiscal year during which the IPO occurred. The sample size falls to 1,270 five years after the IPO due to delistings. Panels A and B report the average values of financials for VC-backed IPOs without and with patents, respectively, based on at least one patent grant prior to the time of the IPO. The firm characteristics include the following: inflation-adjusted equity market capitalization (in millions of 2006 dollars), inflation-adjusted total assets (in millions of 2006 dollars), the ratio of book value to the market value of firm's equity, the ratio of operating income to assets, the ratio of net income to assets (ROA), the capital expenditures (CAPEX)-to-assets ratio, the debt-to-assets ratio, the long-term debt-to-assets ratio, the R&D-to-assets ratio, and the R&D-to-sales ratio. For all variables, fiscal year-end values reported in COMPUSTAT are used, which are the values for the fiscal year in which the IPO occurred, and one to five fiscal years after the IPO. For example, year +1 for Google, which went public on August 19, 2004 and which has a December 31 fiscal year, ends on December 31, 2005. All accounting variables are Winsorized at the 1% and 99% levels.

	IPO year	Year one	Year two	Year three	Year four	Year five
Panel A: VC-backed IPOs without patents						
Market value, $ millions	754	492	516	669	696	776
Total assets, $ millions	114	186	234	246	302	352
Book-to-market ratio	0.37	0.57	0.55	0.48	0.46	0.49
Operating income/assets	-4.9%	-10.2%	-10.0%	-7.1%	-5.5%	-4.6%
Net income/assets (ROA)	-11.3%	-23.4%	-27.7%	-21.5%	-17.4%	-16.1%
CAPEX/assets	7.0%	7.9%	6.4%	5.4%	5.1%	4.7%
Total debt/assets	8.7%	11.7%	13.5%	14.3%	14.5%	13.8%
Long-term debt/assets	6.4%	8.5%	9.6%	10.2%	10.4%	9.7%
R&D/assets	10.1%	13.9%	15.7%	16.3%	15.7%	15.3%
R&D/sales	0.58	0.62	0.59	0.46	0.43	0.42
Number of observations	1,604	1,486	1,294	1,133	997	863
Panel B: VC-backed IPOs with patents						
Market value, $ millions	405	438	432	533	630	584
Total assets, $ millions	100	145	151	190	228	287
Book-to-market ratio	0.32	0.46	0.53	0.47	0.47	0.46
Operating income/assets	-4.9%	-10.3%	-11.7%	-11.3%	-10.8%	-7.8%
Net income/assets (ROA)	-9.5%	-17.3%	-21.7%	-21.5%	-19.6%	-16.9%
CAPEX/assets	5.3%	6.6%	6.4%	5.5%	5.1%	4.9%
Total debt/assets	5.3%	6.6%	9.0%	10.4%	11.0%	11.5%
Long-term debt/assets	3.7%	4.5%	6.6%	7.5%	8.2%	8.8%
R&D/assets	13.9%	18.3%	20.3%	21.2%	20.2%	19.5%
R&D/sales	0.81	0.97	0.88	0.73	0.63	0.55
Number of observations	594	571	530	489	456	407

Table 3: Underpricing for VC-backed IPOs with and without patents

The sample consists of 2,254 VC-backed IPOs between January 1981 and December 2006. Underpricing is defined as the percentage first-day return, measured from the offer price to the closing price. The bubble period is from September 1998 to June 2000, and the normal period excludes the bubble period. The percentage starting below the offer price are those IPOs with negative first-day returns. Money left on the table is defined as the number of shares offered (not including overallotment shares) multiplied by the first day capital gain or loss per share.

IPO characteristics	Without patents	With patents
Average underpricing (equal weighted %)	32.0	25.2
Median underpricing (%)	11.1	9.4
Standard deviation (%)	61.5	48.1
Bubble period average (equal weighted %)	95.6	92.3
Normal period average (equal weighted %)	16.4	16.0
Percentage starting below offer price (%)	11.2	13.4
Average money left on the table ($ millions)	25.8	18.3
Number of issues	1,660	594

Table 4: Average raw and abnormal percentage returns for IPOs with and without patents

The sample consists of 2,254 VC-backed IPOs between January 1981 and December 2006. Panels A and B report the average raw and abnormal returns of 1,660 VC-backed IPOs without patents and 594 VC-backed IPOs with patents, respectively, based on at least one patent grant before the IPO. Panel C reports the results for 4,568 non-VC-backed IPOs. Panels D and E respectively report the results of 4,007 non-VC-backed IPOs without patents and 561 non-VC-backed IPOs with patents, based on at least one patent grant before the IPO. Panel F reports the results of all 6,822 IPOs. The equally weighted buy-and hold returns and monthly returns are computed on the basis of monthly stock returns ending 24, 36, 48, and 60 calendar months after the IPO and starting from the closing market price on the last trading day of the IPO month. The buy-and-hold market-adjusted returns and monthly market-adjusted returns are adjusted by the value-weighted (VW) NYSE/Amex/Nasdaq market index. FF3 alphas are the intercepts estimated by running firm-specific time-series regressions of monthly firm excess returns on the Fama-French three factors for 24, 36, 48, and 60 months after the IPO. FF5 alphas are the intercepts estimated using the Fama-French five factors as independent variables. If the sample firm gets delisted, the IPO returns and corresponding benchmark returns are calculated using data up to the delisting date. For example, a portfolio with two IPOs that were listed for, respectively, 60 and 25 months would equally weight the two buy-and-hold returns for the 60-month horizon, but the 60-month monthly average raw return would be the average of 85 observations. When available, we include the firm's delisting return.

Holding periods after the IPO (month)	Buy-and-hold raw return (%)	Buy-and-hold market-adjusted return (%)	Monthly raw return (%)	Monthly market-adjusted return (%)	Monthly FF3 alpha (%)	Monthly FF5 alpha (%)
Panel A: 1,660 VC-backed IPOs without patents						
24	13.3	-9.8	-0.04	-0.91	-0.38	0.01
36	12.1	-23.3	0.09	-0.74	-0.25	0.24
48	29.2	-21.2	0.46	-0.45	-0.19	0.31
60	34.4	-26.3	0.44	-0.46	-0.17	0.33
Panel B: 594 VC-backed IPOs with patents						
24	22.0	-3.3	0.83	-0.13	0.21	0.45
36	28.2	-7.1	0.97	0.14	0.39	0.77
48	42.6	-8.7	1.30	0.37	0.52	0.87
60	55.1	-2.9	1.26	0.35	0.47	0.84
Panel C: 4,568 Non-VC-backed IPOs						
24	13.5	-16.1	0.38	-0.75	-0.46	-0.23
36	20.7	-24.2	0.40	-0.70	-0.43	-0.07
48	25.7	-33.6	0.40	-0.69	-0.47	-0.06
60	31.0	-35.5	0.38	-0.68	-0.49	-0.07

Panel D: 4,007 Non-VC-backed IPOs without patents						
24	13.2	-16.3	0.33	-0.80	-0.51	-0.29
36	19.0	-26.1	0.33	-0.79	-0.50	-0.12
48	24.0	-35.4	0.32	-0.77	-0.54	-0.12
60	29.4	-41.1	0.30	-0.77	-0.55	-0.14
Panel E: 561 Non-VC-backed IPOs with patents						
24	15.0	-14.5	0.67	-0.40	-0.03	0.18
36	32.9	-12.3	0.95	-0.09	0.20	0.44
48	38.0	-23.0	0.97	-0.06	0.19	0.42
60	42.4	-30.8	0.97	-0.04	0.15	0.38
60	29.4	-41.1	0.30	-0.77	-0.55	-0.14
Panel F: 6,822 IPOs						
24	14.1	-13.3	0.30	-0.75	-0.38	-0.11
36	19.2	-22.7	0.38	-0.64	-0.30	0.07
48	27.8	-28.8	0.49	-0.54	-0.31	0.10
60	34.0	-33.5	0.47	-0.54	-0.31	0.10

Table 5: Three-year performance for VC-backed IPOs with and without patents categorized by non-high-tech, high-tech, and biotech industries

The sample consists of 2,254 VC-backed IPOs between January 1981 and December 2006, including 1,660 VC-backed IPOs without patents and 594 VC-backed IPOs with patents, respectively, based on at least one patent grant prior to the IPO. We further divide the sample firms into non-high-tech firms (607 firms without patents and 257 firms with patents), high-tech firms (1,053 firms without patents and 337 firms with patents), and biotech firms (163 firms without patents and 86 firms with patents). The buy-and-hold returns and monthly returns are computed on the basis of CRSP monthly stock returns over the 36 months starting from the end of the IPO month. The buy-and-hold market-adjusted returns and monthly market-adjusted returns are adjusted by the value-weighted (VW) NYSE/Amex/Nasdaq market index. FF3 alphas are the intercepts estimated by running firm-specific time-series regressions of monthly firm excess returns on the Fama-French three factors for 36 months after the IPO. FF5 alphas are the intercepts estimated using Fama-French five factors as independent variables. If the sample firm gets delisted, the IPO returns and corresponding benchmark returns are calculated using data up to the delisting date. When available, we include the firm's delisting return. All of the raw and abnormal percentage stock returns are the arithmetic average of VC-backed IPOs within a group.

	Non-high-tech	High-tech	Biotech
Panel A: VC-backed IPOs without patents			
Buy-and-hold 3-year raw return (%)	2.5	18.2	-1.9
Buy-and-hold 3-year market-adjusted return (%)	-35.5	-15.8	-32.4
Monthly raw return (%)	-0.41	0.47	0.75
Monthly market-adjusted return (%)	-1.24	-0.34	-0.04
Monthly FF3 alpha (%)	-0.93	0.17	0.10
Monthly FF5 alpha (%)	-0.64	0.66	0.50
Number of observations	607	1,053	163
Panel B: VC-backed IPOs with patents			
Buy-and-hold 3-year raw return (%)	7.9	43.8	20.2
Buy-and-hold 3-year market-adjusted return (%)	-30.3	10.3	-18.6
Monthly raw return (%)	0.47	1.35	1.01
Monthly market-adjusted return (%)	-0.42	0.56	0.09
Monthly FF3 alpha (%)	-0.24	0.89	0.16
Monthly FF5 alpha (%)	-0.02	1.37	1.16
Number of observations	257	337	86

Table 6: Three-year performance for VC-backed IPOs with and without patents grouped by subperiods

The sample consists of 2,254 VC-backed IPOs between January 1981 and December 2006. Panels A and B report the subperiod raw and abnormal three-year stock returns of, respectively, 1,660 VC-backed IPOs without patents and 594 VC-backed IPOs with patents. Panel C reports the subperiod returns for all 2,254 VC-backed IPOs. Panel D reports the subperiod returns for 4,568 non-VC-backed IPOs. The full sample is divided into four subsample periods based upon the year of the IPO: 1981 through 1989, 1990 through 1998, 1999 through 2000, and 2001 through 2006. The buy-and hold returns and monthly returns are computed on the basis of monthly stock returns ending 36 calendar months after the IPO and starting from the closing market price on the last trading day of the IPO month. The buy-and-hold market-adjusted returns and monthly market-adjusted returns are adjusted by the value-weighted (VW) NYSE/Amex/Nasdaq market index. FF3 alphas are the intercepts estimated by running firm-specific time-series regressions of monthly firm excess returns on the Fama-French three factors for 36 months after the IPO. FF5 alphas are the intercepts estimated using Fama-French five factors as independent variables. If the sample firm gets delisted, the IPO returns and corresponding benchmark returns are calculated using data up to the delisting date. When available, we include the firm's delisting return. All stock return measures are expressed in percentages.

Subperiod	N	Buy-and-hold 3-year return (%)	Market-adjusted 3-year BHR (%)	Monthly raw return (%)	Monthly market-adjusted return (%)	Monthly FF3 alpha (%)	Monthly FF5 alpha (%)
Panel A: 1,660 VC-backed IPOs without patents							
1981-1989	346	13.2	-32.8	-0.10	-1.15	-0.79	-0.22
1990-1998	807	53.3	-8.0	1.36	-0.09	0.15	0.69
1999-2000	392	-71.4	-50.6	-2.48	-2.03	-0.85	-0.52
2001-2006	115	9.4	-4.3	0.53	0.10	0.09	0.51
Panel B: 594 VC-backed IPOs with patents							
1981-1989	95	28.7	-15.7	0.83	-0.26	0.37	0.44
1990-1998	288	69.1	9.7	1.64	0.18	0.42	0.91
1999-2000	105	-52.1	-25.4	-0.09	0.68	1.42	1.91
2001-2006	106	-3.7	-28.0	0.36	-0.12	-0.45	-0.35
Panel C: 2,254 VC-backed IPOs							
1981-1989	441	16.5	-29.1	0.10	-0.96	-0.52	-0.10
1990-1998	1,095	57.5	-3.4	1.44	-0.02	0.39	0.82
1999-2000	497	-67.3	-45.3	-1.98	-1.46	-0.37	-0.01
2001-2006	221	3.1	-15.7	0.45	-0.01	-0.17	0.09
Panel D: 4,568 Non-VC-backed IPOs							
1981-1989	1,442	15.5	-29.6	0.32	-0.86	-0.55	-0.34
1990-1998	2,343	31.8	-28.1	0.69	-0.76	-0.44	0.02
1999-2000	343	-40.6	-19.7	-1.23	-0.63	-0.17	0.47
2001-2006	440	26.4	10.5	0.45	0.05	-0.21	0.13

Table 7: Three-year buy-and-hold performance for VC-backed IPOs with and without patents, by cohort year

The sample consists of 2,254 VC-backed IPOs between January 1981 and December 2006. Panels A and B report the subperiod raw and abnormal three-year stock returns of 1,660 VC-backed IPOs without patents and 594 VC-backed IPOs with patents, respectively, based on at least one patent grant prior to the IPO. Panels A and B respectively report the equally and value-weighted 3-year buy-and-hold returns and wealth relatives over the market index for VC-backed IPOs without and with patents, respectively, over each cohort year. For each cohort of IPOs that went public in a given calendar year, the buy-and-hold returns are calculated by compounding monthly stock returns for 36 months from the last trading day of the IPO month. If the sample firm gets delisted, the IPO returns and corresponding benchmark market returns are calculated using data up to the delisting date. Wealth relatives are calculated as $W_{i,T} = \sum(1 + R_{i,T}) / \sum(1 + R_{bench\ i,T})$, where $R_{i,T}$ is the buy-and-hold return on IPO i for holding period of length T (or shorter if there is an early delisting) and $R_{bench\ i,T}$ is the buy-and-hold return on the value-weighted NYSE/Amex/Nasdaq market index over the same period. The value weights are based on the market capitalization using the first-day closing prices in CRSP, and are converted into dollars of 2006 purchasing power using the Consumer Price Index. For IPOs with dual-class shares, we use post-issue shares outstanding for all share classes reported by SDC, with corrections. At the end of each panel, we report the corresponding equally or value-weighted average 3-year buy-and-hold returns and wealth relatives over the entire 1981-2006 sample period.

	VC-backed IPOs without patents				VC-backed IPOs with patents			
	Number of IPOs	IPO return (%)	Market return (%)	Wealth relatives	Number of IPOs	IPO return (%)	Market return (%)	Wealth relatives
Panel A: Equally weighted 3-year buy-and-hold returns								
1981	41	11.1	38.7	0.80	12	15.6	36.8	0.85
1982	17	-20.3	71.9	0.46	2	55.2	66.3	0.93
1983	80	2.1	54.2	0.66	25	7.7	55.9	0.69
1984	32	9.1	83.5	0.59	7	-16.5	85.8	0.45
1985	28	-31.0	47.6	0.47	2	-14.7	46.2	0.58
1986	58	23.1	37.2	0.90	15	54.8	39.2	1.11
1987	49	-3.6	19.7	0.81	14	6.6	21.0	0.88
1988	22	55.5	46.1	1.06	7	175.3	46.0	1.89
1989	19	129.5	32.9	1.73	11	22.1	32.5	0.92
1990	32	44.4	51.0	0.96	8	36.1	44.0	0.94
1991	71	4.0	31.0	0.79	27	31.3	30.1	1.01
1992	86	18.7	36.2	0.87	39	84.6	34.9	1.37
1993	116	60.4	51.7	1.06	50	54.2	50.8	1.02
1994	91	100.3	81.0	1.11	27	196.4	81.5	1.63
1995	112	25.9	82.6	0.69	49	14.9	85.2	0.62
1996	174	44.7	82.4	0.79	48	-11.1	81.7	0.49
1997	80	119.9	61.2	1.36	24	248.0	58.8	2.19
1998	45	73.6	16.2	1.49	16	82.2	16.1	1.57
1999	221	-64.9	-14.4	0.41	38	-27.5	-19.6	0.90
2000	171	-79.8	-29.0	0.28	67	-66.1	-30.7	0.49
2001	10	13.2	3.4	1.09	12	-25.9	3.4	0.72
2002	8	34.2	19.2	1.13	3	124.5	22.4	1.83
2003	10	131.3	46.8	1.58	10	-42.4	74.6	0.33
2004	31	20.4	43.5	0.84	42	13.4	43.3	0.79
2005	24	0.2	3.8	0.97	19	-8.5	11.5	0.82
2006	32	-39.9	-16.2	0.72	20	-21.8	-16.1	0.93
1981-2006	1,660	12.1	35.5	0.83	594	28.2	35.4	0.95

Panel B: Value-weighted 3-year buy-and-hold returns								
1981	41	31.0	40.0	0.94	12	38.0	41.3	0.98
1982	17	-43.3	66.3	0.34	2	47.5	66.3	0.89
1983	80	-25.9	56.2	0.47	25	-36.3	63.6	0.39
1984	32	-4.5	80.8	0.53	7	-4.6	84.7	0.52
1985	28	-29.4	48.6	0.47	2	-17.5	48.4	0.56
1986	58	80.1	36.4	1.32	15	64.1	38.4	1.19
1987	49	-4.7	20.9	0.79	14	0.8	21.1	0.83
1988	22	59.7	43.5	1.11	7	228.9	48.9	2.21
1989	19	149.2	33.2	1.87	11	-9.4	30.5	0.69
1990	32	86.8	50.3	1.24	8	86.7	43.6	1.30
1991	71	13.7	31.3	0.87	27	23.2	30.6	0.94
1992	86	36.4	35.5	1.01	39	83.7	36.7	1.34
1993	116	45.2	53.0	0.95	50	66.6	53.5	1.09
1994	91	124.4	83.5	1.22	27	265.3	84.8	1.98
1995	112	19.8	79.2	0.67	49	-13.3	83.5	0.47
1996	174	120.8	82.9	1.21	48	-35.7	87.3	0.34
1997	80	228.7	59.6	2.06	24	364.3	74.0	2.67
1998	45	153.0	16.2	2.18	16	16.7	12.3	1.04
1999	221	-82.3	-17.9	0.22	38	-54.0	-21.7	0.59
2000	171	-89.7	-30.7	0.15	67	-74.8	-30.6	0.36
2001	10	6.3	0.3	1.06	12	-39.8	0.8	0.60
2002	8	56.4	8.2	1.44	3	103.4	22.8	1.66
2003	10	100.1	46.0	1.37	10	-39.8	88.6	0.32
2004	31	27.0	39.4	0.91	42	273.5	47.0	2.54
2005	24	54.4	1.8	1.52	19	-18.9	10.7	0.73
2006	32	-51.6	-19.1	0.60	20	-31.9	-13.2	0.78
1981-2006	1,660	-35.6	0.8	0.64	594	33.9	17.3	1.14

Table 8: Time-series regressions for calendar-time portfolios of VC-backed IPOs with and without patents, and non-VC-backed IPOs

We form the equally and value-weighted monthly calendar-time portfolios of VC-backed IPOs without (N=1,660) and with patents (N=594), as well as non-VC-backed IPOs (N=4,568) by including all issues that were undertaken in the three years previous to the month of the observation. The calendar-time portfolios are rebalanced every month, and the value weights are based on the previous month's month-end market values of the issuing firms. RMRF is the value weighted market return on all NYSE/Amex/Nasdaq firms (RM) minus the risk free rate (RF), which is the one-month Treasury bill rate. SMB is the difference each month between the return on small firms and big firms. HML is the difference each month between the return on a portfolio of high book-to-market stocks and the return on a portfolio of low book-to-market stocks. IAH is the difference each month between the return on a portfolio of stocks with high R&D and high innovation ability and the return on a portfolio of stocks with high R&D and low innovation ability as in Cohen, Diether, and Malloy (2013). The sample period covers the 347 months between February 1981 and December 2009. White (1980) robust t-statistics are reported in parentheses.

	VC-backed IPOs without patents		VC-backed IPOs with patents		Non-VC backed IPOs	
	Equally weighted	Value-weighted	Equally weighted	Value-weighted	Equally weighted	Value-weighted
Panel A: Fama-French factors						
Alpha	-0.04%	0.31%	0.52%	0.74%	-0.41%	-0.19%
	(-0.06)	(0.97)	(2.18)	(2.15)	(-2.17)	(-1.79)
RMRF	1.44	1.53	1.13	1.20	1.25	1.19
	(19.34)	(16.22)	(16.66)	(12.34)	(23.54)	(47.26)
SMB	1.22	0.89	1.46	1.22	0.95	0.68
	(7.39)	(6.13)	(14.18)	(5.72)	(8.55)	(14.91)
HML	-0.74	-1.15	-0.92	-1.25	-0.03	-0.24
	(-6.53)	(-8.27)	(-10.68)	(-8.84)	(-0.29)	(-5.44)
R^2	0.80	0.78	0.82	0.72	0.83	0.89
Panel B: Fama-French and innovation ability factors						
Alpha	0.03%	0.33%	0.54%	0.71%	-0.36%	-0.19%
	(0.13)	(1.06)	(2.21)	(2.03)	(-1.80)	(-1.75)
RMRF	1.44	1.53	1.13	1.20	1.25	1.19
	(19.71)	(16.37)	(16.70)	(12.26)	(23.57)	(47.17)
SMB	1.22	0.89	1.46	1.23	0.94	0.68
	(7.49)	(6.16)	(14.18)	(5.73)	(8.94)	(14.96)
HML	-0.75	-1.16	-0.93	-1.24	-0.04	-0.24
	(-6.72)	(-8.37)	(-10.68)	(-8.94)	(-0.46)	(-5.44)
IAH	-0.04	-0.02	-0.02	0.03	-0.05	0.00
	(-1.04)	(-0.54)	(-0.45)	(0.55)	(-1.90)	(0.30)
R^2	0.80	0.78	0.82	0.72	0.84	0.89

Table 9: Multivariate regression analyses for VC-backed IPOs

The dependent variable for (1) to (3) is the monthly Fama-French 3-factor alpha estimated by running firm-specific time-series regressions of monthly firm excess returns on the Fama-French factors for 36 months after the IPO. The dependent variable for (4) to (6) is the 3-year buy-and-hold market-adjusted return adjusted by the value-weighted NYSE/Amex/Nasdaq market index. If the sample firm gets delisted, the IPO returns and corresponding benchmark returns are calculated using data up to the delisting date. We include a patent dummy equal to one when the firm has at least one patent grant before the IPO. The sample consists of 2,254 VC-IPOs between January 1981 and December 2006, which falls to 2,042 when we include control variables: the logarithm of inflation-adjusted sales (in millions of 2006 dollars), the book-to-market equity ratio (BE/ME), debt-to-total assets ratio, cash holding-to-sales ratio, research and development expenses-to-sales ratio, patent grants-to-R&D expenses ratio, underpricing, logarithm of firm age, in years, at the IPO, and underwriter reputation (measured on a 0 to 9 scale, with 9 high). All the accounting variables are computed using data at the end of the fiscal year of the IPO in COMPUSTAT. Variables are Winsorized at the 1% and 99% levels, and the 5% and 99% levels for R&D/Sales and Patents/R&D because more than 1% of the denominators are zero. Underpricing and the accounting ratios are measured as fractions. All the regressions control for industry and year fixed effects. A constant is always included in regressions although not reported. Below each regression coefficient, *t*-statistics are reported in parentheses with the standard errors of the regression coefficients clustered at the industry and year levels. *, **, and *** indicate significance at the 10%, 5%, and 1% confidence level, respectively.

	Monthly Fama-French alpha (%)			3-year buy-and-hold market-adjusted return (%)		
	(1)	(2)	(3)	(4)	(5)	(6)
Patent dummy	0.55**	0.56**	0.57**	27.7**	34.6**	34.3***
	(2.37)	(2.22)	(2.21)	(2.49)	(2.55)	(2.79)
Log(Sales)	0.21***	0.37***	0.27**	16.5***	18.7***	17.3***
	(2.76)	(3.34)	(2.38)	(5.07)	(3.71)	(3.02)
BE/ME	1.14*	1.13*	1.09*	10.5	8.7	12.5
	(1.80)	(1.81)	(1.80)	(0.65)	(0.51)	(0.82)
Debt/assets		-1.77	-1.73		46.3	49.3
		(-1.55)	(-1.49)		(0.63)	(0.65)
Cash/sales		0.001	0.001		0.04	0.04
		(0.74)	(0.53)		(1.29)	(1.08)
R&D/sales		0.27	0.19		5.26	1.74
		(1.39)	(0.92)		(0.77)	(0.23)
Patent grants/R&D		0.32	0.29		6.81	6.07
		(1.28)	(1.23)		(1.42)	(1.14)
Underpricing			-0.48			-17.1
			(-1.39)			(-1.32)
Log(1+firm age at IPO)			-0.21			-23.5
			(-0.73)			(-1.32)
Underwriter reputation			0.18**			6.82**
			(2.37)			(2.22)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.097	0.103	0.111	0.068	0.076	0.081

Appendix for "Patents, Innovation, and Performance of Venture Capital-backed IPOs"

Table A1: List of successful patent filings for some VC-backed IPOs in NBER patent database and patent information in the IPO prospectus

Panel A: Number of patent filed and granted in NBER patent database and IPO prospectus

			Event year of pre-IPO successful patent filings in NBER database						IPO prospectus
Firm name	IPO Date		-5	-4	-3	-2	-1	0	
Google	20040819	Filed	0	10	6	1	10	2	No details
		Granted	0	0	0	0	4	3	No details
Marvell Technology	20000626	Filed	1	1	5	4	0	0	9
		Granted	0	1	1	3	2	3	9
Priceline.com	19990329	Filed	0	0	0	10	2	2	25
		Granted	0	0	0	0	0	1	2
Sandisk	19951107	Filed	0	1	0	3	7	19	20
		Granted	0	0	0	0	0	0	58
Silicon Image	19991005	Filed	0	1	5	4	7	9	17
		Granted	0	0	0	0	3	5	4

Panel B: Descriptions on patents filed and granted before the IPO in IPO prospectus

Firm name	Patent descriptions in IPO prospectus
Google	The first version of the PageRank technology was created while Larry and Sergey attended Stanford University, which owns a patent to PageRank. The PageRank patent expires in 2017. We hold a perpetual license to this patent. In October 2003, we extended our exclusivity period to this patent through 2011, at which point our license is non-exclusive.
Marvell Technology	As of February 29, 2000, we had been granted nine United States patents on various aspects of our technology, with expiration dates ranging from 2015 to 2018, and we had filed nine additional United States patent applications. However, there can be no assurance that patents will ever be issued for these applications.
Priceline.com	We currently hold one issued United States patent directed to a unique Internet-based buyer-driven commerce method and system underlying our business model. We also hold one issued United States patent directed to a method and system for pricing and selling airline ticket options and one issued United States patent directed to methods and systems for generating airline-specified time tickets. In addition, we have pending 25 United States and four international patent applications directed to different aspects of our technology and business processes.

Sandisk	The Company currently owns or has exclusive rights to fifty-eight United States and fourteen foreign issued patents, six patent applications allowed and over twenty patent applications pending in the United States, as well as seventeen pending in foreign patent offices.
Silicon Image	Our success and future revenue growth will depend, in part, on our ability to protect our intellectual property. We rely on a combination of patent, copyright, trademark and trade secret laws, as well as nondisclosure agreements and other methods to protect our proprietary technologies. We have been issued four United States patents. We have filed 17 additional United States patent applications. Three of these 17 applications have been allowed by the U.S. Patent and Trademark Office.

Table A2: Average raw and abnormal percentage returns for VC-backed IPOs with and without patents based on patent applications before the IPO

The sample consists of 2,254 VC-backed IPOs between January 1981 and December 2006. Panels A and B report the average raw and abnormal returns of 1,628 VC-backed IPOs without patents and 626 VC-backed IPOs with patents, respectively, based on at least one successful patent filings in event year -3 or earlier prior to the IPO. For example, an IPO in 1998 would be classified as having a patent if it has at least one subsequently successful filing occurring in 1995 or earlier. In Table 4, the classification of VC-backed IPOs with and without patents is based on patent grants before the IPO, irrespective of when the filing occurred. The buy-and hold returns and monthly returns are computed on the basis of monthly stock returns ending 24, 36, 48, and 60 calendar months after the IPO and starting from the closing market price on the last trading day of the IPO month. The buy-and-hold market-adjusted returns and monthly market-adjusted returns are adjusted by the value-weighted (VW) NYSE/Amex/Nasdaq market index. FF3 alphas are the intercepts estimated by running firm-specific time-series regressions of monthly firm excess returns on the Fama-French three factors for 24, 36, 48, and 60 months after the IPO. FF5 alphas are the intercepts estimated using Fama-French five factors as independent variables. If the sample firm gets delisted, the IPO returns and corresponding benchmark returns are calculated using data up to the delisting date. When available, we include the firm's delisting return.

Holding periods after the IPO (month)	Buy-and-hold raw return (%)	Buy-and-hold market-adjusted return (%)	Monthly raw return (%)	Monthly market-adjusted return (%)	Monthly FF3 alpha (%)	Monthly FF5 alpha (%)
Panel A: 1,628 VC-backed IPOs without successful patent filings from event year -3 or earlier						
24	10.5	-12.9	-0.18	-1.07	-0.48	-0.09
36	10.8	-25.5	0.01	-0.85	-0.27	0.14
48	26.3	-25.4	0.35	-0.57	-0.17	0.22
60	30.5	-31.4	0.32	-0.58	-0.18	0.24
Panel B: 626 VC-backed IPOs with successful patent filings from event year -3 or earlier						
24	27.9	5.5	0.96	0.02	0.35	0.68
36	30.3	-4.6	1.13	0.32	0.64	1.04
48	46.8	-3.0	1.45	0.59	0.73	1.09
60	64.3	5.4	1.42	0.58	0.68	1.05

Table A3: Means of financials for VC-backed IPOs with and without patents sorted on size and book-to-market ratio

The sample consists of 2,254 VC-backed IPOs between January 1981 and December 2006. Among them, 2,195 have financial information in COMPUSTAT for the fiscal year during which the IPO occurred. Panels A and B report the means for VC-backed IPOs without and with patents, respectively, based on at least one patent grant prior to the IPO. For each cohort of IPOs issued in a given calendar year, firms are sorted into three size groups ("Small", "Medium", and "Large") and three book-to-market ratio groups ("Growth", "Medium", and "Value") based on the market value at the first closing price listed by CRSP and the book value of equity for the fiscal year in which the IPO occurred. For IPOs with dual-class shares, we use post-issue shares outstanding reported by SDC. Both size breakpoints and book-to-market ratio breakpoints are the same for the VC-backed IPOs with and without patents in each year. The firm characteristics are equity market capitalization ($2006), total assets ($2006), the ratio of book value to the market value of firm's equity, the ratio of operating income to assets, the ratio of net income to assets (ROA), the capital expenditures (CAPEX)-to-assets ratio, the debt-to-assets ratio, the long-term debt-to-assets ratio, the R&D-to-assets ratio, and the R&D-to-sales ratio. All of the variables except market values are measured at the end of the fiscal year during which the IPO occurred using data from COMPUSTAT.

	Size Terciles			Book-to-Market Terciles		
	Small	Medium	Large	Growth	Medium	Value
Panel A: VC-backed IPOs without patents						
Market value (millions of dollars)	158	492	1602	915	704	635
Assets (millions of dollars)	47	92	223	95	104	145
Book-to-market ratio	0.42	0.36	0.32	0.26	0.36	0.49
Operating income/assets	-9.2%	-3.4%	-1.9%	-10.9%	-6.2%	2.9%
Net income/assets (ROA)	-16.1%	-9.6%	-8.4%	-18.7%	-11.4%	-3.5%
CAPEX/assets	6.7%	7.0%	7.3%	7.4%	6.5%	7.0%
Total debt/assets	9.3%	8.2%	8.5%	9.0%	5.8%	11.1%
Long-term debt/assets	5.9%	6.3%	7.0%	6.6%	4.0%	8.5%
R&D/assets	12.0%	9.9%	8.5%	12.5%	10.5%	7.2%
R&D/sales	0.72	0.58	0.43	0.61	0.67	0.45
Number of observations	532	530	542	527	535	542
Panel B: VC-backed IPOs with patents						
Market value (millions of dollars)	147	250	999	781	231	256
Assets (millions of dollars)	42	71	220	105	58	137
Book-to-market ratio	0.36	0.35	0.26	0.31	0.32	0.43
Operating income/assets	-10.2%	-6.6%	0.6%	-17.7%	-7.5%	3.0%
Net income/assets (ROA)	-14.2%	-10.5%	-5.1%	-22.3%	-10.9%	-1.1%
CAPEX/assets	4.4%	4.6%	6.6%	3.9%	4.9%	5.3%
Total debt/assets	5.8%	4.9%	5.3%	7.0%	4.1%	4.6%
Long-term debt/assets	3.8%	3.1%	4.0%	3.7%	2.7%	3.4%
R&D/assets	15.7%	15.0%	11.3%	18.7%	14.2%	11.6%
R&D/sales	0.96	0.81	0.66	0.88	0.89	0.71
Number of observations	208	215	199	251	237	230

Table A4: Fama-French-adjusted performance for calendar-time portfolios of VC-backed IPOs with patents sorted on citations

The sample consists of 594 VC-backed IPOs with at least one patent grant prior to the IPO from January 1981 through December 2006. Among them, 432 firms have citation data. We form the monthly calendar-time high and low citation portfolios according to citation information up to the event year -1 before the IPO year by including all VC-backed IPOs with patents that were undertaken in the three years previous to the month of the observation. We divide the VC-backed IPOs with patents into a low citation portfolio with below median number of citation counts and another high citation portfolio with above median number of citation counts; and the portfolios are rebalanced monthly and firms are allowed to switch portfolios every half year. Both equally and value-weighted calendar-time portfolios are constructed and the value weights are based on previous month's market values of the firms. RMRF is the value weighted market return on all NYSE/Amex/Nasdaq firms (RM) minus the risk free rate (RF) which is the one-month Treasury bill rate. SMB is the difference each month between the return on small firms and big firms. HML is the difference each month between the return on a portfolio of high book-to-market stocks and the return on a portfolio of low book-to-market stocks. The analysis extends between January 1981 and December 2009. White (1980) robust *t*-statistics are reported in parentheses.

	Equally-weighted		Value-weighted	
	Low citation	High citation	Low citation	High citation
Alpha	0.99% (3.42)	0.43% (1.07)	1.09% (3.03)	-0.05% (-0.12)
RMRF	1.11 (13.74)	1.22 (10.81)	1.21 (13.76)	1.24 (11.24)
SMB	1.45 (9.17)	1.50 (9.86)	1.17 (7.36)	1.43 (6.96)
HML	1.02 (-6.97)	-1.10 (-7.83)	-1.34 (-8.23)	-1.35 (-7.61)
R^2	0.75	0.68	0.60	0.66

Table A5: 3-factor time-series regressions for portfolios of VC-backed IPOs with and without patents sorted on size and book-to-market ratio

The sample consists of 2,254 VC-backed IPOs between January 1981 and December 2006, including 1,660 VC-backed IPOs without patents and 594 VC-backed IPOs wit patents based on at least one patent grant before the IPO. In Panels A and B, we form the monthly size calendar-time portfolios of VC-backed IPOs without and with patents by including all issues that were undertaken in the three years previous to the month of the observation. Following Brav and Gompers (1997), we allocate equal number of firms into three size portfolios ("Small", "Medium", and "Large") every six months based on the previous month's size distribution using all VC-backed IPOs. In Panels C and D, we form the monthly book-to-market portfolios of VC-backed IPOs without and with patents by including all issues that were undertaken in the three years previous to the month of the observation. Every six months we divide the sample into three book-to-market portfolios ("Growth", "Medium", and "Value") based on the previous month's book-to-market ratio distribution using all VC-backed IPOs. The portfolios are rebalanced monthly and VC-backed IPOs are allowed to switch portfolios every six months. Both equally and value-weighted size and book-to-market calendar-time portfolios are constructed and the value weights are based on previous month's market values of the firms. RMRF is the value weighted market return on all NYSE/Amex/Nasdaq firms (RM) minus the risk free rate (RF) which is the one-month Treasury bill rate. SMB is the difference each month between the return on small firms and big firms. HML is the difference each month between the return on a portfolio of high book-to-market stocks and the return on a portfolio of low book-to-market stocks. The analysis extends for the 347 months between February 1981 and December 2009. White (1980) robust *t*-statistics are reported in parentheses.

	Equally weighted size terciles			Value-weighted size terciles		
	Small	Medium	Large	Small	Medium	Large
Panel A: VC-backed IPOs without patents						
Alpha	-0.24%	-0.11%	0.21%	-0.47%	-0.16%	0.39%
	(-0.55)	(-0.38)	(0.70)	(-1.23)	(-0.57)	(1.10)
RMRF	1.41	1.43	1.53	1.44	1.39	1.56
	(11.62)	(18.10)	(16.36)	(12.98)	(17.63)	(14.81)
SMB	1.44	1.21	0.96	1.35	1.19	0.76
	(5.79)	(6.54)	(7.29)	(5.77)	(6.75)	(5.19)
HML	-0.29	-0.73	-1.11	-0.36	-0.80	-1.28
	(-1.60)	(-5.79)	(-7.96)	(-2.17)	(-6.45)	(-8.00)
R^2	0.61	0.80	0.77	0.66	0.79	0.74
Panel B: VC-backed IPOs with patents						
Alpha	0.47%	0.46%	0.68%	-0.45%	0.29%	0.96%
	(0.98)	(1.20)	(2.19)	(-1.01)	(0.57)	(2.34)
RMRF	0.95	1.30	1.24	0.97	1.31	1.15
	(7.41)	(12.06)	(13.26)	(7.37)	(12.43)	(10.32)
SMB	1.55	1.48	1.42	1.39	1.41	1.21
	(7.95)	(12.40)	(8.57)	(7.65)	(11.78)	(4.49)
HML	-0.69	-0.72	-1.24	-0.62	-0.73	-1.44
	(-3.26)	(-4.20)	(-9.21)	(-3.31)	(-4.56)	(-8.49)
R^2	0.53	0.78	0.74	0.58	0.77	0.64

	Equal-weighted book-to-market terciles			Value-weighted book-to-market terciles		
	Growth	Medium	Value	Growth	Medium	Value
Panel C: VC-backed IPOs without patents						
Alpha	-1.67% (-4.82)	-0.19% (-0.69)	1.87% (4.15)	-1.05% (-2.88)	0.12% (0.37)	1.96% (4.75)
RMRF	1.58 (15.09)	1.43 (17.29)	1.34 (15.22)	1.63 (13.76)	1.43 (14.13)	1.53 (14.96)
SMB	1.05 (5.92)	1.15 (6.53)	1.40 (8.40)	0.88 (5.32)	0.94 (5.89)	1.31 (9.04)
HML	-0.87 (-5.55)	-0.79 (-6.25)	-0.62 (-4.76)	-1.12 (-6.89)	-1.15 (-7.58)	-0.75 (-4.52)
R^2	0.76	0.77	0.69	0.75	0.76	0.70
Panel D: VC-backed IPOs with patents						
Alpha	-1.21% (-3.43)	0.47% (1.34)	2.06% (6.07)	-0.79% (-2.01)	0.69% (1.81)	2.13% (4.38)
RMRF	1.12 (11.78)	1.33 (12.85)	1.22 (10.07)	1.07 (9.98)	1.32 (11.97)	1.44 (11.41)
SMB	1.17 (8.91)	1.62 (11.43)	1.63 (8.82)	1.08 (5.94)	1.72 (8.06)	1.44 (6.39)
HML	-0.98 (-7.69)	-0.75 (-5.56)	-0.71 (-3.79)	-1.27 (-7.54)	-1.06 (-6.55)	-0.84 (-3.84)
R^2	0.68	0.77	0.60	0.63	0.78	0.59