R&D Investment and Capital Structure*

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Abstract

It is well known that innovative firms tend to issue equity for external finance, but no one has attempted to differentiate whether this is due to financial frictions from the supply side of capital or is voluntarily chosen by firms given that the policy implications are quite different. This paper tries to fill this gap. We first confirm that firms with high R&D investment issue more equity and less debt, have a lower leverage, and tend to become zero-leverage. We also use the introduction of state-level R&D tax credits in the US as an exogenous event to establish the causality. Then we examine corporate financing decisions after firms are granted patents. We find that firms with more favorable patent characteristics issue less debt and more equity, and have a lower leverage. Because patents can reduce information asymmetry associated with R&D investment and be used as collateral, firms' tendency to issue equity after credit constraints are partially relaxed shows that frictions from the supply side of capital are not the critical reason for innovative firms to issue equity. Innovative firms may find that equity is conducive to innovation so that they choose to issue equity.

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1. Introduction

The irrelevance theory proposed by the seminal paper of Modigliani and Miller (1958) implies that corporate investment and financing are completely separable decisions in perfect capital markets. Not surprisingly, subsequent papers document that corporate investment and financing activities are closely related after relaxing some of their assumptions. On one hand, high external financing cost will reduce corporate investment, which is the focus of the financial constraints literature[1], and each financing security has its pros and cons in terms of corporate investment. For instance, debt can mitigate the free cash flow problem pointed out by Jensen (1986) that managers tend to do empire building, but can also cause the overhang problem discussed in Myers (1977) that it is more difficult for firms with higher debt level to raise funds for new growth opportunities. On the other hand, corporate investment can also affect corporate financing decisions. Mauer and Triantis (1994) show that high production flexibility can enhance a firm’s debt capacity while the impact of financial flexibility on investment is negligible. Tsyplakov (2008) demonstrates that investment frictions can explain the observed leverages. Furthermore, the results of corporate investment, like corporate profitability, asset volatility and tangible assets ratio are important determinants of corporate leverage.

As one of the most important activities for a firm’s survival, R&D investment is commonly believed to associate with lower leverage after Bradley, Jarrell and Kim (1984) and Titman and Wessels (1988). There are mainly two strands of reasons given. First, because of debt overhang, firms themselves choose equity over debt when financing R&D investment.

[1] See Hubbard (1998) and Stein (2003) for a summary of the literature.

This is considered from the perspective of firms, i.e., the demand side of capital. The other is considered from the borrowers' point of view, i.e., the supply side of capital. R&D investment is very risky and cannot generate tangible assets that are commonly used as collaterals. As a result, firms with high R&D investment are unable to borrow even though they would if debt is available. These two strands of reasons can have quite different policy implications. If the demand side is true, policy maker should take measures to facilitate the development of equity market. Otherwise, more incentives should be given to borrowers to lend to the innovative firms. Nevertheless, no paper has attempted to disentangle these two sides so far, and this paper tries to fill this gap.

To lay out the foundation for analysis, we first examine the relationship between R&D investment and corporate capital structure. As for corporate capital structure, we analyze both the incremental financing choices and the cumulative leverage level. We employ the multinomial logistic regression to analyze firms' choice among internal funds, equity and debt, and logistic regression between equity and debt conditional on external issuance as in Hovakimian, Opler, and Titman (2001) and Chang, Dasgupta and Hilary (2006). Then we use the pooled OLS regression to analyze the determinants of corporate leverage. Specifically, we use lagged R&D investment to explain the incremental financing choice, and R&D capital, constructed using the perpetual inventory method similar to tangible assets, to explain firm leverage. Besides, we also use the logistic regression to link R&D capital to the probability of having zero leverage as an extreme case of leverage. Consistent with prior literature, the regression results show that firms with high R&D investment tend to issue equity, and firms with high R&D capital have a low leverage and a high probability of using zero debt. Since financial constraints are an important factor that can affect financing choice (Chang and Song, 2013), we also run the regression separately for financially constrained and unconstrained firms, and find that constrained firms do use more equity issues to finance R&D while unconstrained firms do not. But the negative relation between R&D capital and leverage is the same for both constrained and unconstrained firms, which means that financial constraints cannot explain the effects of R&D investment.

This paper also uses the introduction of state-level R&D tax credits as an exogenous shock to establish the causality from high R&D investment to low leverage. Wilson (2009) finds that state R&D tax credits are effective at increasing R&D within the state, and R&D tax credits are unlikely to correlate with other variables rather than R&D investment that may affect corporate financing decisions. Thus the introduction of state-level R&D tax credits satisfies the relevance and exclusiveness conditions of an exogenous shock. We find that after the introduction of state R&D tax credits, firms headquartered in that state tend to issue less debt and more equity, have lower leverage, and have a larger probability of becoming a zero-leverage firm.

To differentiate the supply side effect from the demand side effect, we analyze firms' financing decisions after being granted patents. Patents are outputs of R&D investment and are publicly announced after being granted so that they can alleviate the information asymmetry problem concerning R&D. Loumioti (2012) suggests that the proportion of secured syndicated loans that are collateralized by intangible assets (mostly patents) has been steadily increasing since the mid-1990s. If firms are forced to issue equity due to financial frictions from the supply side, we should expect they use more debt and have higher leverage after being granted patents, in particular firms with more patents, more influential patents, and higher innovation efficiency. First, we examine the relationship between patents and firms' incremental financing choices. After controlling for R&D investment in the regression, we find that firms with more patents and with higher innovation efficiency tend to use less debt in the next fiscal year, firms with higher citations tend to use more equity, while the results for firms with higher generality or originality scores are insignificant. Next, we examine the relationship between patents and firm leverage as the cumulative results. We find a consistently negative relationship for firms with more patents, with higher citations, with higher generality or originality scores, and with higher innovation efficiency. These empirical results indicate that even though the frictions from the supply side of capital may be mitigated, firms use more equity financing after being granted patents. It means that the negative relationship between R&D investment and leverage mainly derives from the demand side of capital, i.e., corporate preference, and it also indirectly confirms that equity financing is conducive to innovation.

We also conduct several alternative tests and show that our results are pretty robust. First, we use the Fama and French 49 industry classification rather than that based on the SIC code, and find that our results remain the same. Second, we include the interaction terms of year and industry dummies to account for the time-variant industry effects, and finds that our results are not affected. Besides, we also try to exclude the firms in the software industry whose accounting treatment of R&D may be different from other firms, and find that this does not change our results.

The contributions of this paper are at least threefold. First, corporate preference in using equity to finance R&D implies that policy maker should create favorable environment to develop different layers of equity markets to fund the R&D investment. Second, the rise in R&D investment can to some extent explain the increasing proportion of firms with zero leverage documented by Strebulaev and Yang (2013). We show after the introduction of state-level R&D tax credits, firms are more likely to have zero leverage. The industrial R&D investment increases from US $41.0 billion in 1975 to US $202.8 billion in 2007[2], and it is not a coincidence that the percentage of zero-leverage firms concurrently increases from 5.4 to 19.8. Third, this paper explicitly shows that the nature of corporate investment, whether it is R&D investment or fixed investment, can greatly affect corporate capital structure. Compared with using production flexibility or investment frictions to differentiate corporate investment, it may be more direct and relevant to classify investment into fixed and R&D investment when we discuss capital structure.

The findings in this paper are consistent with those of the papers that examine how finance affects innovation. Brown, Fazzari, and Petersen (2009) show that shifts in the supply of equity finance may have driven much of the 1990s R&D boom. Using cross-country evidence, Hsu, Tian, and Xu (2013) show that equity markets encourage while credit markets discourage innovation.

This paper is closely related to the literature that discusses credit supply and corporate innovation. Focusing on how credit supply affects corporate innovation, Chava, Oettl, Subramanian, and Subramanian (2013) find that intrastate banking deregulation has a negative effect while interstate banking deregulations has a positive effect on the innovation

[2] The numbers are from the US National Science Foundation's Survey of Industry Research and Development (SIRD), and are measured in constant 2000 dollars.

of young, private firms. Amore, Schneider, and Zaldokas (2013) also confirm the positive effect of interstate banking deregulation on the publicly listed manufacturing firms. On the other hand, Chava, Nanda, and Xiao (2013) and Hsu, Lee, Liu, and Zhang (2013) find that banks and bond investors recognize the value of corporate innovation by charging lower spread. Different from the perspective of credit suppliers, this paper analyzes firms' choice for external finance, and shows that even though credit market may value corporate innovation, equity market is more favorable for firms.

Meanwhile, a large empirical literature analyzes how the stock market reacts to innovation. Pakes (1985), Austin (1993), Lev and Sougiannis (1996) and Deng, Lev, and Narin (1999) all document a positive relationship between innovation and subsequent stock returns, whereas Chan, Martin, and Kensinger (1990) find that increases in R&D spending bring positive abnormal return mainly for high-tech firms, Chan, Lakonishok, and Sougiannis (2001) find that only firms with high R&D to equity market value (past losers) earn large excess returns, and Li (2009) find that only among financially constrained firms R&D predicts stock returns. Chambers, Jennings, and Thompson (2002) try to distinguish between the two explanations for the positive relationship, mispricing and risk, and find support for the risk explanation. Eberthart, Maxwell, and Siddique (2004), Cohen, Diether, and Malloy (2013) and Hirshleifer, Hsu, and Li (2013) find that the stock market is also slow to react to the unexpected R&D increase, firm-level R&D track records, and innovation efficiency. Overall, the stock market under-reacts to the information regarding innovation activities. The results of this paper show that despite the under-reaction of the stock market, equity is still preferred to debt by firms, which may be because it can better solve the agency and information asymmetry problems.

This paper is also related to papers that analyze the interactions of corporate financing and investment decisions. Besides Mauer and Triantis (1994) and Tsyplakov (2008) that focus on the direct interaction between corporate financing and investment decision, Childs, Mauer, and Ott (2005), and Morellec, and Schurhoff (2011) also discuss their interactions when there are agency conflicts or information asymmetry, respectively. Childs, Mauer, and Ott (2005) show when there are stockholder-bondholder conflicts, financial flexibility encourages the use of short-term debt, but firms' leverage level depends on the type of growth options faced. This paper shows that when the growth options are too risky, short-term debt may not solve the agency problem. Morellec, and Schurhoff (2011) show that firms may prefer equity as issuing equity permits them to invest early while issuing debt postpones investment in the presence of asymmetric information, which may offer one of the reasons why we find that firms prefer equity to fund R&D.

The paper is organized as follows. Section 2 describes the data and presents some descriptive statistics. Section 3 explains the methodology. Section 4 discusses our empirical results. Section 5 gives the conclusion.

2. Data

2.1 Sample

We use the Compustat North America fundamentals annual data to construct financial statement variables. Because the accounting treatment of R&D expenditure was not uniform until FASB issued SFAS No. 2 in 1974 which requires the full expending and disclosure of R&D investment, we begin with the year 1975. The sample period is from 1975 to 2011 except for the dependent variables in the regressions, which are one-year ahead from 1976 to 2012. We exclude financial companies (SIC 6000-6999), utilities (SIC 4900-4999), non-US companies (FIC not equal to USA), and non-publicly traded firms and subsidiaries (STKO equal to one or two). We also exclude observations with missing or less than $10 million in constant 2004 dollars total assets, a missing or non-positive sale, or a negative age. Here age is the number of years the firm has been on Compustat with a non-missing stock price. We also use the stock data from CRSP to construct several control variables.

To examine the effect of state R&D tax credits on corporate capital structure, we use R&D tax credits data from Daniel Wilson's webpage[3]. Since the U.S. federal R&D tax credit was adopted in 1981, and state-level R&D tax credit data is from 1982 to 2006, to rule out the effect of federal R&D tax credit, we restrict our analysis period to 1981-2006 for this exogenous event.

The US patent data is from the National Bureau of Economic Research (NBER) Patent Data Project[4], which contains detailed information on all the patents granted from 1976 to 2006 by US Patent and Trademark Office (USPTO). We use the number of patents granted, the citations made to the patents, and their generality and originality scores (Hall, Jaffe, and Trajtenberg, 2001) to generate the patent measures.

2.2 Main Variables

There are three sources of capital that firms can use to fund R&D investment, i.e., internal capital, equity issues and debt issues, and we use the variables *Issue* and *Equity* to classify them. Following Hovakimian, Opler, and Titman (2001), we define a firm issuing

[3] Thanks Daniel Wilson for generously providing the data online: http://www.frbsf.org/economic-research/economists/daniel-wilson/.

[4] Their website is https://sites.google.com/site/patentdataproject/Home.

equity (debt) is the net equity (debt) issued exceeds 5% of book value of assets, and we also exclude observations with both equity and debt issues. *Issue*, the dependent variable in the multinomial logistic regression, equals 1 for internal funds, 2 for equity issues, and 3 for debt issues, while *Equity*, the dependent variable in the logistic regression, equals 1 for equity issues, and 0 for debt issues.

To explain corporate leverage, we use the cumulative variable *R&D Capital Ratio*. Analogical to tangible capital, the concept of R&D capital treats R&D as an investment in intangible assets which will bring benefits in subsequent periods. We follow Hall, Thoma, and Torris (2007) and Falato, Kadryzhanova, and Sim (2013) and use the perpetual inventory method to calculate the R&D Capital as shown by Equation (1)[5]. Here $K_{i,t}^{R\&D}$ is the R&D capital of firm i at time t, $\delta_{R\&D}$ is the depreciation ratio of R&D capital, which is set at 15% as in prior literature, $R\&D_{i,t}$ is the R&D expenditure of firm i at time t, and CPI_t is the relative inflation rate at time t to year 2004. Assuming a growth rate of 5% as in Hall (1993), we equal the initial R&D capital for each firm to 5 times R&D expenditure in the initial year, and we linearly interpolate the missing values of R&D. For firms with R&D expenditure missing in all the financial years, we replace R&D expenditure with zero and set R&D capital to zero. R&D capital is then deflated by the total value of assets to obtain the variable *R&D Capital Ratio*.

$$K_{i,t}^{R\&D} = (1-\delta_{R\&D})K_{i,t-1}^{R\&D} + R\&D_{i,t} / CPI_{t,2004}. \quad (1)$$

As for the patent data, since they are not expected to have a linear relationship with

[5] Our treatment of R&D expenditure as investment on intangible assets can be justified as follows. First, according to learning by doing, firms that make large R&D investment can accumulate skills which will be beneficial in future R&D investments. Second, on July 31, 2013, US Commerce Department's Bureau of Economic Analysis released the overhauled GDP data by including investments in research and development and entertainment and the arts. This is equivalent to treating R&D as products compared to "intermediate" that previously R&D is considered.

corporate capital structure, we use several dummy variables to denote firms with favorable patent characteristics. For the incremental financing choice regressions, we use one-year data to construct the dummy variables, while for the leverage regressions, we use five-year data since we assume a deprecation rate of 20% as in Chava, Nanda, and Xiao (2013). First of all, we use *Patent Dummy* equal to one for firms that have been granted patents from 1976 to 2006, zero for the rest of firms whose industries may not value patents or which have no capability to generate patents. Next, we use *High Patent Dummy* to label firms with above median number of patents among firms with non-zero patents, and *High Patent Stock Dummy* to label firms with above median number of patent stock among firms with non-zero patent stock, where patent stock is computed as follows:

$$\text{Patent Stock}_{i,t} = \text{Patents Granted}_{i,t} + 0.8 \times \text{Patents Granted}_{i,t-1} + 0.6 \times \text{Patents Granted}_{i,t-2} + 0.4 \times \text{Patents Granted}_{i,t-3} + 0.2 \times \text{Patents Granted}_{i,t-4}. \quad (2)$$

where $\text{Patents Granted}_{i,t}$ is the number of patents granted to firm i in year t. Nevertheless, not all patents have the same importance, and we first capture the importance of patents using the number of citations. *High Citation Dummy* equals 1 for firms with above median number of citations per patent, and 0 otherwise, while *High Citation Stock Dummy* equals one for firms with above median number of citation stock over patent stock, and 0 otherwise, where the computation of citation stock is similar to Equation (2) except for using the variables Citations for Patents Granted to replace those of Patents Granted. Furthermore, we also use *High Generality Dummy* and *High Originality Dummy* to label firms with above median average generality and originality scores for all the patents granted in year t, while *High Generality Stock Dummy* and *High Originality Stock Dummy* to label firms with above median average generality and originality scores over five years. According to Hall, Jaffe, and Trajtenberg (2001), $\text{Generality}_i = 1 - \sum_{j}^{n_i} s_{i,j}^2$, where $s_{i,j}$ is the percentage of citations received by patent i that belong to patent class j out of n_i patent classes, and originality is defined in the same way except that it uses the citations of patent i made.

Besides patent characteristics, corporate innovation efficiency may also be valued by financial markets, and we examine the relationship between the two proxies for innovation efficiency (IE) used in Hirshleifer, Hsu, and Li (2013) and corporate capital structure. The first proxy is patents granted scaled by R&D capital (Patents/RDC) calculated according to Equation (3):

$$\text{Patents/RDC}=\text{Patents}_{i,t}/(\text{R\&D}_{i,t-2}+0.8\times\text{R\&D}_{i,t-3}+0.6\times\text{R\&D}_{i,t-4}+0.4\times\text{R\&D}_{i,t-5}+0.2\times\text{R\&D}_{i,t-6}). \quad (3)$$

The second proxy is adjusted patent citations scaled by R&D expenses (Citations/RD) computed as follows:

$$\frac{Citations}{RD}=\frac{\sum_{j=1}^{5}\sum_{K=1}^{N_{t-j}} C_{ik}^{t-j}}{(R\&D_{i,t-3}+R\&D_{i,t-4}+R\&D_{i,t-5}+R\&D_{i,t-6}+R\&D_{i,t-7})}. \quad (4)$$

Following Hirshleifer, Hsu, and Li (2013), we use the natural log of one plus IE measures in the regressions since they are highly skewed and mostly zero.

The other variables are commonly used, and their definitions can be found in the Appendix. To mitigate the effects of outliers, all the continuous variables are winsorized at the 1 and 99 percentiles except for the industry and IE variables, and for book leverage, values greater than 1 are replaced by 1.

2.3 Descriptive Statistics

[Insert Table 1 here]

Table 1 presents the summary statistics of the total sample. There are overall 148,456 firm-year observations, and as mentioned before, all the variables are from 1975 to 2011 except for *Debt*, *Equity*, *Market Leverage*, *Book Leverage*, and *Zero Leverage Dummy* which are one-year ahead. First, R&D investment is mainly concentrated in a specific portion of firms, and its measures are highly skewed. About 44 percent of firms do not make R&D investment, 51 percent of firms have no R&D capital, and the median of *R&D/Sale* and *R&D Capital Ratio* is 0. But for those who do make R&D investment, R&D expenditure is an important activity. On average, firms spend 12 percent of sales on R&D, and R&D capital is as high as 18 percent of total assets. Second, as for corporate capital structure, 17 percent of firms issue debt within the next fiscal year while 11 percent of firms issue equity, the average market (book) leverage is 0.21 (0.26), and about 11 percent of firms have zero leverage, which is consistent with Strebulaev and Yang (2013). Finally, the statistics of other variables are basically consistent with prior studies.

[Insert Table 2 here]

Table 2 provides the names of states that begin to offer state-level R&D tax credits between 1982 and 2006, the specific years and the levels of credit rate offered. There are in total 32 states with Minnesota in 1982 as the first and Nebraska in 2006 as the last, and the credit rate ranges between 2.5% and 20%.

[Insert Table 3 here]

Table 3 shows the patent variables used in the regressions. Since the period is shorter due to the availability of patent data, there are 127,753 firm-year observations. Among them, 62 percent have been granted patents from 1976 to 2006. The mean of dummy variables for high patent, citation, generality and originality are all around 10 percent, which confirms that patents vary enormously in their value and the distribution of their value is extremely skewed (Hall, Jaffe, and Trajtenberg, 2001). This skewness also manifests in the two measures of IE.

3. Methodology

We analyze corporate financing decisions on two different levels, first on the incremental financing choice level and second on the cumulative leverage level. In all the regressions, independent variables are lagged one year to make sure that information is publicly available when firms make decisions. First, we use both the multinomial logistic regression and logistic regression to examine firms' incremental financing activities. Because firms can obtain capital from three sources to fund an investment, retained earnings, equity issues, and debt issues, we first employ the multinomial logistic regression to analyze firms' choice among internal funds, equity and debt as shown in Equation (5):

$$P(Issue_{i,t} = 1, 2, 3) = Mlogit(\alpha + \beta X_{i,t-1} + \varepsilon_{i,t}). (5)$$

The independent variables are factors documented to relate to firms' financing choice (e.g., Hovakimian, Opler, and Titman, 2001; Chang, Dasgupta and Hilary, 2006), including *R&D/Sale*, *R&D Dummy*, *Firm Size*, *Ln (Age)*, *M/B Ratio*, *Tangibility*, *Profitability*, *Sales Growth Rate*, *Operating Loss Carry Forwards*, *Depreciation*, *Z Score*, *Dividend Payer*, *One-year Stock Return*, *Cash Flow Volatility*, *S&P Rating Dummy*, *Investment-grade Rating Dummy*, and industry and year dummies. As Petersen (2009) suggests, we correct the t-statistics by clustering at the firm level. Since firms with high R&D investment usually do not have much internal funds, we next run a logistic regression to examine firms' choice between equity and debt conditional on external financing. The independent variables are the same as in Equation (5) while the dependent variable is replaced by *Equity*. The t-statistics is corrected by double clustering at firm and year levels for the logistic regression.

Second, we run the pooled OLS regression for both market and book leverage.

Following Lemmon, Roberts, and Zender (2008), besides the four widely used factors since Rajan and Zingales (1995), i.e., *Firm Size*, *M/B Ratio*, *Tangibility*, and *Profitability*, we also include our interested R&D capital or patent variables, *Industry Median Leverage* to control for industry effects, *Cash Flow Volatility* to control for firm risk, *Dividend Payer* to incorporate the fact that firms paying dividends tend to have lower leverage (Frank and Goyal, 2009) and year fixed effects. We also correct the t-statistics by double clustering at firm and year levels.

Besides, we also consider the phenomenon of zero leverage as an extreme case of leverage and analyze the effect of corporate R&D capital ratio on the probability of becoming zero-leverage. We follow Strebulaev and Yang (2013) in using the logistic regression. The dependent variable is the *Zero Leverage Dummy*, and independent variables include *R&D Capital Ratio*, *R&D Capital Dummy*, and the main variables[6] in Strebulaev and Yang (2013) except for *R&D/Sale*. We correct the t-statistics by double clustering at firm and year levels.

4. Empirical Results

4.1 R&D Investment and Corporate Capital Structure

[Insert Table 4 here]

We first analyze the effects of R&D investment on corporate incremental financing choice, and the results are shown in Table 4. Confirming prior studies (like Hovakimian, Opler, and Titman, 2001, and Chang, Dasgupta and Hilary, 2006), both multinomial logistic and logistic regressions show that firms with higher R&D investment tend to use equity for

[6] Here we do not include the two variables used in Strebulaev and Yang (2013), Operating leases and Pension liabilities, because adding them will greatly reduce the sample with Operating leases reducing one-quarter and Pension liabilities reducing four-fifths, and Strebulaev and Yang (2013) also do not include them in some of their regressions.

fund raising. The estimated coefficients of *R&D/Sale* are significantly positive for equity issues in both regressions, while the coefficients of *R&D Dummy* (firms with no R&D investment) are negative for equity issues and positive for debt issues. The results of other control variables are basically consistent with prior studies. Larger and older firms issue less equity and older firms also issue less debt considering that mature firms have less growth opportunities and they tend to have access to the bond market. Firms with higher M/B ratio issue more equity since these firms are either with higher growth opportunities or with higher stock returns. Firms with more tangible assets tend to raise external funds and issue more debt given that tangible assets can be used as collaterals for debt financing. Profitable firms are more likely to issue debt and less likely to issue equity as profitable firms tend to be mature firms. Firms with higher sales growth rate tend to do external financing as higher sales growth rate implies more growth opportunities. Partially consistent with the tradeoff theory, firms with more operating loss carry forwards issue more equity and firms with more depreciation issue less debt but only relative to firms using internal funds. Firms with higher Z score do less external finance maybe because they are likely to be mature firms and tend to issue debt compared with equity. Dividend payers issue less equity as they also tend to be mature firms. Firms with higher stock return in the past year tend to do external finance and issue more equity than debt, which indicates that firms do time the stock market. Firms with higher cash flow volatility use less debt as they are more risky. Firms with S&P rating tend to do more external finance, but only firms with investment-grade tend to issue more debt.

[Insert Table 5 here]

Next, we examine the relationship between R&D capital and corporate leverage as the cumulative results, and not surprisingly, we also find a significantly negative relation as shown in Table 5. When we use only R&D capital ratio and dummy as explanatory variables, they can explain about 10 percent of the variance in market leverage. Adding other control variables reduces the coefficient of R&D capital ratio by nearly one half from -0.092 to -0.048 as R&D capital may be correlated with other firm characteristics like tangibility and M/B ratio, but it is still significantly negative, and the economic significance is also large. One standard deviation change (0.40) in positive R&D capital ratio is associated with a reduction of 1.92% in market leverage. If we compare a firm with no R&D capital with a firm with average R&D capital ratio (0.18), the difference in market leverage is much larger (2.76%) since the coefficient of R&D capital dummy is 0.019. In column (3), we also include contemporaneous market leverage to account for reverse causality, the coefficient decreases about two-thirds, suggesting that the leverage level affects how much to invest in R&D capital, but it is still significantly negative. The coefficients for other control variables are consistent with prior literature. Larger firms, firms with higher tangible assets, and firms in higher industry median leverage tend to have higher market leverage, whereas more profitable firms, firms with higher M/B ratio, higher cash flow volatility, and dividend payers tend to have lower market leverage. The results for book leverage are basically the same with these for market leverage.

[Insert Table 6 here]

As an extreme case of low leverage, the probability of being zero leverage is positively correlated with R&D capital as expected, and the results can be found in Table 6. The estimated coefficient of *R&D Capital Ratio* is significantly positive, while the coefficient of

R&D Capital Dummy is negative, though it becomes insignificant when other control variables are included. The results for other variables follow Strebulaev and Yang (2013). Bigger firms, firms with higher tangible assets, and firms whose anticipated investment is larger are less likely to have zero leverage, whereas firms with higher growth opportunities or M/B ratio, more profitable firms, firms in an industry with a higher proportion of zero leverage, firms paying more dividends, firms having zero leverage when entering the Compustat for the first time, and firms with higher capital expenditure and asset sales have a higher probability of becoming zero-leverage.

[Insert Table 7 here]

Financial constraints measure the difference in cost between internal capital and external capital, and are an important factor that can affect financing choice (Chang and Song, 2013), so we also run the regression separately for unconstrained versus constrained firms to see whether the relationship between R&D investment and capital structure is different across firms. We classify firms into unconstrained versus constrained firms based on two widely used financial constraints criteria, the WW index and the SA index, and the estimation results can be found in Table 7. Consistent with Brown, Fazzari, and Petersen (2009) that external equity finance is more important for young firms, we find that constrained firms issue equity more frequently to fund R&D investment relative to internal capital, while the result is mixed for unconstrained firms. Nevertheless, the cumulative result is similar. The R&D capital is negatively correlated with leverage both for unconstrained and constrained firms, and the economic significance is equivalent. Although the coefficient for unconstrained firms (around -0.08) is higher than that for constrained firm (around -0.03), the standard deviation of R&D

capital ratio is 19% for unconstrained firms, and 58% for constrained firms, and the change in market leverage caused by one standard deviation in R&D capital ratio is close. The results for other control variables are similar as before, and are omitted henceforth.

4.2 Introduction of state-level R&D Tax Credits and Corporate Capital Structure

Table 5 shows that there are reverse causality from leverage to R&D investment. To clearly establish the causality from R&D investment to capital structure, we use the introduction of state-level R&D tax credits as an exogenous event, which satisfies the relevance and exclusiveness conditions. First, state-level R&D tax credits can lower the R&D user cost and increase the R&D activities within the state (Wilson, 2009), which will surely benefits the firms headquartered in the state. Second, state-level R&D tax credits are unlikely to correlate with factors other than R&D investment that can affect corporate capital structure. Third, the state-level introduction makes it less likely for R&D tax credits to coincide with other corporate events.

[Insert Table 8 here]

Table 8 reports the regression results. The regressions for the incremental financing choice show that firms tend to issue debt less frequently after the introduction of state-level R&D tax credits. The estimated coefficient of R&D tax credit dummy is significantly negative, and the difference between equity and debt choices is positive. Accordingly, both market and book leverage decrease over 1% after the enactment of state R&D tax credit dummy. Firms are more likely to become zero-leverage after the tax credits. Before the state-level R&D tax credits, the average *R&D/Sale* ratio is less than 7 percent and over a half of firm-year observations do not make any R&D investment, whereas after the R&D tax credits, the average *R&D/Sale* ratio is over 22 percent and only 34 percent of firm-year observations make no R&D investment. We also control for the industry and year fixed effects in all the regressions except for the leverage regression where we control for the industry median leverage and year fixed effects, and either industry or year effects cannot explain the negative relations we find. Therefore, increase in R&D investment does cause firms to issue equity more frequently and have lower leverage.

4.3 Patents and Corporate Capital Structure

After confirming that firms with high R&D investment tend to issue equity and have low leverage, we further consider whether this is caused by financial frictions from the supply side of capital or is chosen voluntarily by firms. Admittedly, we can only observe the interaction results between the supply and demand sides of capital, and cannot observe each side directly. But we can observe how firm behaviors change when the R&D investment turns into granted patents which can partially relief financial frictions faced by firms. Different from the high riskiness of R&D investment, a patent is required to be novel, non-obvious and useful, and it acts as a good signal of corporate innovation capability. Meanwhile, granted patents are publicly released in a timely manner. Thus, as the output of R&D investment, patents can reveal significantly positive information about corporate innovation activities and greatly reduce the information asymmetry problem. According to Loumioti (2012), since the mid-1990s, US credit market such as secured syndicated loans has been increasingly using intangible assets as a form of collateral, among which are mostly patents. Therefore, it is reasonable to conclude that granted patents can partially alleviate corporate credit constraints.

In this section, we analyze how corporate financing decisions change after being granted patents. If firms are forced to issue equity to fund R&D investment due to its uncertainty, riskiness and intangibility, we should expect that firms have a higher probability of issuing debt after being granted patents which increase firms' debt capacity compared with before. Then we can conclude that the negative relationship between corporate innovation and leverage is due to the frictions from the supply side of capital. On the other hand, if firms choose to issue more equity after being granted patents, then we know the negative relationship is mainly a result of firms' own preference.

[Insert Table 9 here]

Table 9 presents the regression results of incremental financing choices on patent variables. After controlling for R&D investment and patent dummy, firms with favorable patent characteristics tend to issue less debt and more equity. Panel A presents the results for firms with more patents or highly cited patents. Firms with more patents issue debt less frequently, while conditional to external financing, the difference between issuing equity and debt is not significant. This suggests that firms value patents more than the credit market so that they choose not to issue debt when they have more patents. Meanwhile, equity market may neither value firms with more patents correctly so that firms tend to use internal capital to fund innovation. On the other hand, equity market seems to be able to price the importance of patents measured by the citations received so that firms with highly cited patents issue equity more frequently relative to both internal capital and debt. Panel B presents the results for firms with patents that are more general or original. It seems that both credit and equity markets cannot value these two characteristics of patents in the short run so that the results for high generality and high originality are not significant. Finally, for the IE measures, firms with high IE issue debt less frequently but they do not issue equity more. This may be due to the slow reaction by the stock market documented by Hirshleifer, Hsu, and Li (2013). As a weaker form of results, firms that have been ever granted patents marginally issue debt less frequently. Consistent with prior results, firms with higher R&D investment tend to issue equity more, and firms with no R&D investment tend to issue debt more, which means that the results we find for patent variables are not due to the R&D investment.

[Insert Table 10 here]

Next, we examine whether credit and stock markets can react differently to patent variables in the long run and how firms respond to the market reactions. In Table 10, we run the regressions of corporate leverage on patent dummy variables calculated over the past five years and IE variables. The results show that patent variables are all negatively correlated with corporate leverage, which indicates that stock market can value patents correctly and firms choose to use equity rather than debt. Firms with non-zero patents have over 1 percent lower leverage than those with no patent. Then firms with more patents and firms with patents that are highly cited, more general or original have around 1 percent lower leverage than firms with non-zero patents. Since we do not expect any kind of linear relationship between patents and leverage, the results for IE measures are a little lower but they are mostly significant. The results for R&D capital variables are the same with prior results, which further confirms that what we find for the patent variables cannot be contributed to the R&D investment.

Overall, after being granted patents, rather than issue more debt accompanied with the relaxation of credit constraints, firms choose to issue less debt and more equity. This contradicts the point that innovative firms are forced to issue equity due to the frictions from the supply side of capital, and supports that equity is better in valuing and financing innovation. As a result, in order to promote innovation, measures should be taken to encourage the development of the equity market.

4.4 Robustness Check

All the regression results do not change if we use the Fama and French 49 industry classification. In the regressions above, we control for the industry fixed effects based on the first two digits of SIC code and calculate the industry variables based on the first three digits of SIC code. One problem with the SIC code is that the number of observations across industries vary dramatically. Some industries may only have several observations while others have thousands of ones. Fama and French (1997) industry classification is created with the goal of having a manageable number of distinct industries, and the distribution of industries is indeed much better with each industry having at least over one hundred observations. We rerun our regressions using their 49 industry classification, and the results remain the same.

It is possible that R&D investment and patent variables capture the time-variant industry effects since innovation is highly concentrated in several industries, and to account for potential time-variant industry effect, we rerun the regression after controlling for the year-industry fixed effects. That is, we include the interaction terms of year and two-digit SIC dummies. The results are not affected, and some coefficients even become a little stronger.

Besides, we also rerun the regressions after excluding firms in the software industry (SIC code: 7370-7372), because their accounting treatment of R&D is different from other firms in that their development costs of software can be capitalized according to SFAS No. 86, and find that the results are barely affected.

5. Conclusion

In this paper, we conduct an in-depth analysis of the relationship between R&D investment and corporate capital structure. Prior literature suggests that high R&D investment is associated with low leverage, but no paper has tried to find out whether it is because of financial frictions from the supply side of capital or it is chosen voluntarily by firms. This paper tries to answer this question by comparing firms' behaviors before and after being granted patents. As output of R&D investment, patents are legally authorized monopoly rights to take advantage of useful inventions and are publicly available after grant, and credit market has been increasingly using patents as collateral, thus it is reasonable to say that patents can partially relax corporate credit constraints. Accordingly, analyzing the change in corporate financing decisions after being granted patents can reveal whether innovative firms are forced to issue more equity or not.

As a foundation of analysis, we first examine the relationship between R&D investment and corporate capital structure. The analysis is done on both the incremental and cumulative levels. We use the multinomial logistic and logistic regressions to study the relation between R&D investment and corporate incremental financing choice, and find that firms with high R&D investment tend to issue equity. Then we run the pooled OLS regression of corporate leverage on R&D capital constructed analogous to tangible assets using the perpetual inventory method, and a negative relationship is also documented. As an extreme case of leverage, zero leverage is becoming more prevalent, and we find that R&D investment is also positively correlated with the probability of having zero leverage. Since reverse causality also exists between R&D investment and leverage, we further establish the causality from R&D investment to capital structure using the introduction of state-level R&D tax credits as an exogenous event, and find that firms tend to issue less debt and have lower leverage after the tax credits, which confirms that increase in R&D investment does cause lower leverage.

Then we analyze how firms change their financing decisions after being granted patents. We consider several salient characteristics related to patent, including the number of patents, the number of citations received by patents, the generality and originality scores of patents, and IE measures used in Hirshleifer, Hsu, and Li (2013), and find that firms with favorable patent characteristics tend to issue less debt and more equity in the short run and have lower leverage in the long run. This means that firms choose to issue more equity after their credit constraints are to some extent relieved.

To summarize, the fact that innovative firms make more use of equity is not mainly because they are credit constrained and cannot issue debt, but because they prefer equity to debt for external financing. The policy implication is that in order to stimulate innovation through relaxing financial constraints faced by innovative firms, more focus should be placed on measures that can pave the way for the prosperity of equity market.

Appendix

Other Variable Definitions

- **Net equity issues**: sale of common and preferred stock (Item 108) minus purchase of common and preferred stock (Item 115) over total assets (Item 6).
- **Net debt issues**: long-term debt issuance (Item 111) minus long-term debt reduction (Item 114) over total assets.
- **Market value of assets**: liabilities (Item 181) minus balance sheet deferred taxes and investment tax credit (Item 35) plus value of preferred stock plus market value of equity (stock price (Item 199) times shares outstanding (Item 25)), where value of preferred stock equals liquidating value (Item 10) if available, else redemption value (Item 56) if available, else carrying value (Item 130).
- **Market leverage**: book value of short-term debt (Item 34) plus long-term debt (Item 9) over market value of assets.
- **Book leverage**: book value of short-term debt (Item 34) plus long-term debt (Item 9) over total assets.
- **R&D/Sale**: ratio of R&D expense (Item 46) to sales (Item 12).
- **R&D dummy**: equals 1 if R&D expense is 0 or missing, and 0 otherwise.
- **R&D capital dummy**: equals 1 if R&D capital is 0 or missing, and 0 otherwise.
- **Firm size**: natural log of total assets converted to 2004 dollars using CPI index.
- **Ln (Age)**: natural log of one plus the number of years the firm has been on Compustat with a non-missing stock price.
- **M/B ratio**: ratio of market value of assets to total assets.
- **Profitability**: ratio of earnings before interest and taxes (Item 13) to total assets.
- **Tangibility**: ratio of total property, plant and equipment (Item 8) to total assets.
- **Sales growth rate**: $(\text{Item } 12_t \,/\, \text{CPI}_t - \text{Item } 12_{t-1} \times \text{CPI}_{t-1}) / (\text{Item } 12_{t-1} \times \text{CPI}_{t-1})$.
- **Operating loss carry forwards**: tax loss carry forward (Item 52) over total assets.
- **Depreciation**: ratio of depreciation and amortization (Item 14) to total assets.
- **Z-score**:

  3.3 × [Income before extraordinary items (Item 18) + Interest expense (Item 15)

$+ \text{Total income taxes (Item 16)}\,] + \text{Sales} + 1.4 \times \text{Retained earnings (Item 36)}$

$+ 1.2 \times [\text{Current assets (Item 4)} - \text{Current liabilities (Item 5)}] / \text{Total assets},$

as unlevered Z-score introduced by MacKie-Mason (1990).

- **Dividend payer**: equals 1 if cash dividends (Item 127) are greater than 0, and 0 otherwise.
- **One-year stock return**: the cumulative stock return in the 12 months before the fiscal year end.
- **Cash flow volatility**: the standard deviation of profitability over the last ten years, requiring at least 3 years of data.
- **S&P rating dummy**: equals 1 if the firm has an S&P domestic long term issuer credit rating in Compustat, and 0 otherwise.
- **Investment-grade rating dummy**: equal 1 if the S&P domestic long term issuer credit rating of the firm is BBB- or higher, and 0 otherwise.
- **Industry median leverage**: the median leverage of the same 3-digit SIC industry.
- **The WW index**:

  $WW = -0.091CF - 0.062DIVPOS + 0.021TLTD - 0.044LNTA + 0.102ISG - 0.035SG,$

  where CF is computed as income before extraordinary items (Item 18) plus depreciation and amortization (Item 14) over total assets, $DIVPOS$ equals 1 if cash dividends (Item 127) is greater than 0 and 0 otherwise, $TLTD$ is Book leverage, $LNTA$ is Firm size, ISG is the real sales growth rate of the same 3-digit SIC industry, and SG is Sales growth rate. According to Whited and Wu (2006), all variables should be deflated by the replacement cost of total assets. For simplicity, here we deflate all variables by the inflation-adjusted total assets, and this adjustment does not affect the main results.
- **The SA index**: $SA = -0.737 \times Size + 0.043 \times Size^2 - 0.040 \times Age,$

  where $Size$ is Firm size, Age is the number of years the firm has been on Compustat with a non-missing stock price, and $Size$ and Age have a upper bond of ln ($4.5 billion) and 37 years, respectively.
- **Constrained dummy**: equals 1 if the WW (SA) index is in the top three deciles.
- **Unconstrained dummy**: equals 1 if the WW (SA) index is in the bottom three deciles.

- **R&D tax credit dummy**: equals 1 if the state where the firm is headquartered has introduced state-level R&D tax credits, and 0 otherwise.
- **Zero leverage dummy**: equals 1 if total value of debt is 0, and 0 otherwise.
- **Industry fraction of zero leverage**: the fraction of zero leverage (excluding the firm) in the same 3-digit SIC industry.
- **Dividend**: ratio of common dividends (Item 21) to total assets.
- **Initial zero leverage dummy**: equals 1 if initial total value of debt is 0, and 0 otherwise.
- **Capital expenditure**: ratio of capital expenditure (Item 128) to total assets.
- **Abnormal capital expenditure**: the ratio of capital expenditure in year t over the average capital expenditure from t-1 to t-3 minus 1. It is contemporaneous to the dependent variable to capture anticipated investment.
- **Asset sales**: sale of property (Item 107) plus sale of investments (Item 109) over total assets.

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Table 1

Summary statistics

This table presents the summary statistics of the total sample. We use the Compustat annual data from 1975 to 2011 to construct all the variables except for Debt, Equity, Market leverage, Book leverage, and Zero leverage dummy which are one-year ahead. Financial companies, utilities, non-US companies, non-publicly traded firms and subsidiaries, and observations with missing or less than $10 million in constant 2004 dollars total assets, missing or non-positive sales, or a negative age are all excluded. R&D capital is generated from R&D expenditure using the perpetual inventory method with a deprecation rate of 15%, and R&D capital ratio is R&D capital over total assets. Equity (Debt) equals 1 if the net equity (debt) issues exceed 5% of book value of assets and 0 otherwise. Definition of other variables can be found in the Appendix.

Variable	Observations	Mean	Median	Std. Dev.	Min	Max
R&D/Sale	148,456	0.12	0	0.56	0	4.73
R&D dummy	148,456	0.44	0	0.5	0	1
R&D capital ratio	148,456	0.18	0.00	0.4	0	2.44
R&D capital dummy	148,456	0.51	1	0.5	0	1
Debt	148,456	0.17	0	0.38	0	1
Equity	148,456	0.11	0	0.31	0	1
Market leverage	129,937	0.21	0.16	0.19	0	0.76
Book leverage	136,282	0.26	0.22	0.23	0	1
Zero leverage dummy	137,441	0.11	0	0.32	0	1
Firm size	148,456	5.24	5.03	1.81	2.37	10.21
Ln (Age)	143,222	2.17	2.30	0.97	0	3.78
M/B ratio	140,485	1.75	1.30	1.35	0.54	8.64
Profitability	147,998	0.09	0.12	0.17	-0.68	0.41
Tangibility	148,129	0.30	0.24	0.23	0.01	0.9
Sales growth rate	144,997	0.19	0.06	0.66	-0.65	4.81
Operating loss carry forwards	111,782	0.22	0	0.67	0	4.51
Depreciation	147,962	0.05	0.04	0.03	0	0.21
Z score	142,038	1.55	2.00	2.44	-10.32	5.94
Dividend payer	148,456	0.35	0	0.48	0	1
One-year stock return	119,617	0.16	0.14	0.56	-1.34	2
Cash flow volatility	138,653	0.1	0.06	0.13	0.01	0.93
Industry median leverage	148,426	0.16	0.15	0.12	0	0.98
S&P rating dummy	148456	0.16	0	0.37	0	1
Investment-grade rating dummy	148456	0.07	0	0.25	0	1
The WW index	144,233	-0.26	-0.25	0.1	-0.53	-0.04
The SA index	143,222	-3.02	-2.99	0.72	-4.64	-1.62
Industry fraction of zero leverage	148,456	0.11	0.08	0.11	0	0.75
Dividend	147,458	0.01	0	0.02	0	0.11
Initial zero leverage dummy	143,217	0.13	0	0.34	0	1
Capital expenditure	148,456	0.07	0.04	0.07	0	0.4
Abnormal capital expenditure	128,391	0.08	-0.11	0.88	-1	4.76
Asset sales	148,456	0.03	0.00	0.09	0	0.61

Table 2

Summary of state-level R&D tax credits as of 2006

This table reports the years that state-level R&D tax credits are enacted across states and the statutory credit rates. If a state adopts different credit rates for different levels of investment, highest-tier credit rate is reported. The data is from Daniel Wilson's webpage.

State	Year enacted	Statutory credit rate
Arizona	1994	11.00%
California	1987	15.00%
Connecticut	1993	6.00%
Delaware	2000	10.00%
Georgia	1998	10.00%
Hawaii	2000	20.00%
Idaho	2001	5.00%
Illinois	1990	6.50%
Indiana	1985	5.00%
Iowa	1985	6.50%
Kansas	1988	6.50%
Louisiana	2003	8.00%
Maine	1996	5.00%
Maryland	2000	10.00%
Massachusetts	1991	10.00%
Minnesota	1982	2.50%
Missouri	1994	6.50%
Montana	1999	5.00%
Nebraska	2006	3.00%
New Jersey	1994	10.00%
North Carolina	1996	5.00%
North Dakota	1988	4.00%
Ohio	2004	7.00%
Oregon	1989	5.00%
Pennsylvania	1997	10.00%
Rhode Island	1994	16.90%
South Carolina	2001	5.00%
Texas	2001	5.00%
Utah	1999	6.00%
Vermont	2003	10.00%
West Virginia	1986	10.00%
Wisconsin	1986	5.00%

Table 3

Patent measures

This table reports the statistics of dummy and innovation efficiency variables constructed using the US patent data from 1976 to 2006 collected by the National Bureau of Economic Research (NBER) Patent Data Project, and there are 127,753 firm-year observations. Patent dummy equals 1 if the firm has been granted at least one patent over the whole period and 0 otherwise. High patent dummy equals 1 if the firm has been granted above median number of patents among firms with non-zero patents and 0 otherwise, while High patent stock dummy is defined in the same way except for the five-year accumulative patent stock with a straight depreciation rate of 20%. High citation dummy equals 1 if the firm has above median number of citations per patent among firms with non-zero patents, while High citation stock dummy is defined for the ratio of citation stock to patent stock where citation stock is calculated in the same way with patent stock. High generality (originality) dummy equals 1 if the firm has above median average generality (originality) score among firms with non-zero patents, while High generality (originality) stock dummy is defined for the five-year mean of average generality (originality) score, where generality (originality) score is computed as 1 minus the sum of squared percentage of citations received (made) by one patent that belong to each of the defined patent classes. The last two variables are the innovation efficiency variables defined in Hirshleifer, Hsu, and Li (2013), where

Patents/RDC=Patents$_{i,t}$/(R&D$_{i,t-2}$+0.8×R&D$_{i,t-3}$+0.6×R&D$_{i,t-4}$+0.4×R&D$_{i,t-5}$+0.2×R&D$_{i,t-6}$) and

$$\frac{Citations}{RD}=\frac{\sum_{j=1}^{5}\sum_{K=1}^{N_{t-j}}C_{ik}^{t-j}}{(R\&D_{i,t-3}+R\&D_{i,t-4}+R\&D_{i,t-5}+R\&D_{i,t-6}+R\&D_{i,t-7})}.$$

Variable	Mean	Std. Dev.	Min	Max
Patent dummy	0.62	0.48	0	1
High patent dummy	0.11	0.32	0	1
High patent stock dummy	0.17	0.37	0	1
High citation dummy	0.11	0.31	0	1
High citation stock dummy	0.16	0.37	0	1
High generality dummy	0.10	0.30	0	1
High generality stock dummy	0.15	0.36	0	1
High originality dummy	0.09	0.29	0	1
High originality stock dummy	0.13	0.34	0	1
Ln (1+Patents/RDC)	0.71	1.77	0	13.05
Ln (1+Citations/RD)	1.61	3.16	0	15.48

Table 4

R&D investment and corporate incremental financing choice

This table shows both the multinomial logistic and logistic regression results between R&D investment and corporate incremental financing choice. Observations with both equity and debt issues are excluded in the regressions. For the multinomial logistic regression shown in the second and third columns, the dependent variable is *Issue*, which equals 1 for no issuance, 2 for equity issues and 3 for debt issues. Here observations with no issuance are treated as the base outcome. The last column shows the results of the logistic regression, and the dependent variable is *Equity*, which equals 1 for equity issues and 0 for debt issues. Robust t-statistics clustered at the firm level for the multinomial logistic regression and at both firm and year levels for the logistic regression are shown in parentheses. ***, ** and * denote a significant level of 1 percent, 5 percent, and 10 percent, respectively.

	Issue		
VARIABLES	Equity	Debt	Equity
R&D/Sale	0.170***	-0.053	0.215***
	(5.801)	(-1.030)	(4.328)
R&D dummy	-0.085*	0.132***	-0.239***
	(-1.898)	(4.527)	(-4.754)
Firm size	-0.105***	-0.002	-0.117***
	(-6.929)	(-0.238)	(-3.070)
Ln (age)	-0.268***	-0.152***	-0.148***
	(-12.108)	(-9.280)	(-6.670)
M/B ratio	0.224***	0.003	0.239***
	(18.635)	(0.231)	(8.014)
Tangibility	0.798***	1.226***	-0.712***
	(6.725)	(14.174)	(-4.549)
Profitability	-1.060***	0.817***	-1.181***
	(-7.090)	(5.626)	(-4.018)
Sales growth rate	0.239***	0.259***	0.062
	(10.560)	(12.553)	(1.476)
Operating loss carry forwards	0.096***	-0.033	0.062
	(2.932)	(-0.898)	(1.378)
Depreciation	-1.078*	-2.546***	0.859
	(-1.800)	(-5.037)	(0.961)
Z score	-0.126***	-0.068***	-0.139***
	(-9.034)	(-5.467)	(-5.971)
Dividend payer	-0.389***	0.000	-0.353***
	(-8.728)	(0.010)	(-5.756)
One-year stock return	0.575***	0.254***	0.398***
	(19.567)	(11.258)	(8.766)
Cash flow volatility	-0.115	-0.307**	0.319
	(-0.752)	(-1.981)	(1.310)
S&P rating dummy	0.251***	0.168***	0.123
	(3.596)	(3.602)	(1.183)
Investment-grade rating dummy	-0.628***	0.099*	-0.741***

	(-5.344)	(1.737)	(-4.650)
Constant	-2.464***	-2.419***	-0.277
	(-6.939)	(-12.160)	(-0.631)
Industry fixed effects	Yes		Yes
Year fixed effects	Yes		Yes
Observations	81,732		18,295
Pseudo R-squared	0.0952		0.2387

Table 5

R&D capital and corporate leverage

This table reports the results for the pooled OLS regression of corporate market and book leverage on R&D capital ratio. Column (1) to (3) report the results for market leverage, and column (4) to (6) report the results for book leverage. Column (1) and (4) only include R&D capital ratio and dummy as independent variables, column (2) and (5) include other control variables, while column (3) and (6) also include lagged leverage to rule out the effects of reverse causality. Robust t-statistics clustered at both firm and year levels are shown in parentheses. ***, ** and * denote a significant level of 1 percent, 5 percent, and 10 percent, respectively.

	Market leverage			Book leverage		
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Lagged leverage			0.843***			0.870***
			(108.721)			(178.489)
R&D capital ratio	-0.092***	-0.048***	-0.014***	-0.065***	-0.048***	-0.013***
	(-13.842)	(-7.525)	(-7.718)	(-9.564)	(-5.309)	(-5.972)
R&D capital dummy	0.071***	0.019***	0.007***	0.077***	0.020***	0.005***
	(14.497)	(5.764)	(6.936)	(15.140)	(5.081)	(5.325)
Firm size		0.008***	0.001**		0.013***	0.001***
		(8.690)	(2.120)		(9.562)	(2.921)
M/B ratio		-0.029***	0.000		-0.006***	0.000
		(-20.745)	(0.479)		(-3.537)	(0.765)
Tangibility		0.114***	0.016***		0.164***	0.018***
		(13.132)	(2.904)		(16.687)	(5.598)
Profitability		-0.184***	-0.023***		-0.241***	-0.058***
		(-9.307)	(-4.583)		(-12.137)	(-10.085)
Industry median leverage		0.521***	0.052***		0.518***	0.043***
		(31.396)	(6.447)		(22.341)	(6.640)
Cash flow volatility		-0.015**	0.004**		-0.001	0.010***
		(-2.090)	(2.557)		(-0.110)	(4.723)
Dividend		-0.052***	-0.003***		-0.058***	-0.001
		(-15.662)	(-2.846)		(-12.464)	(-1.414)
Constant	0.189***	0.124***	-0.001	0.235***	0.052***	0.006**
	(25.443)	(11.522)	(-0.216)	(42.515)	(3.386)	(1.979)
Year fixed effects	No	Yes	Yes	No	Yes	Yes
Observations	129,937	121,818	121,776	136,282	122,441	122,398
Adjusted R-squared	0.097	0.321	0.76	0.055	0.2	0.753

Table 6

R&D capital and zero leverage

This table shows the logistic regression results of zero leverage dummy on R&D capital variables and the main control variables in Strebulaev and Yang (2013) except for R&D/Sale. All the independent variables are lagged one year except that abnormal capital expenditure is contemporaneous to capital anticipated investment. Robust t-statistics clustered at both firm and year levels are shown in parentheses. ***, ** and * denote a significant level of 1 percent, 5 percent, and 10 percent, respectively.

VARIABLES		Zero leverage dummy	
R&D capital	0.865***	0.331***	0.311***
	(15.416)	(6.687)	(6.480)
R&D capital dummy	-0.349***	0.097	0.097
	(-5.077)	(1.602)	(1.562)
Firm size		-0.349***	-0.371***
		(-15.251)	(-16.781)
M/B ratio		0.136***	0.125***
		(10.308)	(8.839)
Tangibility		-2.528***	-2.794***
		(-15.014)	(-11.898)
Profitability		1.466***	1.565***
		(11.109)	(12.505)
Industry faction of zero leverage		3.196***	3.022***
		(14.738)	(13.987)
Cash flow volatility		-0.226*	-0.198
		(-1.787)	(-1.600)
Dividend payer dummy		-0.117	-0.035
		(-1.555)	(-0.461)
Dividend		17.579***	17.646***
		(9.495)	(9.137)
Initial zero leverage dummy		1.353***	1.344***
		(17.871)	(17.232)
Ln (Age)			-0.044
			(-1.553)
Capital expenditure			1.472***
			(2.787)
Abnormal capital expenditure			-0.012***
			(-2.583)
Asset sales			1.994***
			(14.457)
Constant	-2.140***	-1.445***	-1.339***
	(-22.131)	(-13.314)	(-11.965)
Year fixed effects	No	Yes	Yes
Observations	137,441	123,159	121,918
Pseudo R-squared	0.0401	0.2248	0.233

Table 7

Financial constraints, R&D investment and corporate capital structure

This table presents the regression results for financially unconstrained and constrained firms based on the WW index and the SA index, respectively. In Panel A and B, the two columns below Issue present the results of the multinomial logistic regression, while the column below Equity presents the results of the logistic regression. Robust t-statistics clustered at firm level for the multinomial logistic regression and at both firm and year levels for the logistic regression are shown in parentheses. ***, ** and * denote a significant level of 1 percent, 5 percent, and 10 percent, respectively.

Panel A R&D investment and incremental financing choices for unconstrained versus constrained firms based on the WW index

	Unconstrained firms (WW index)			Constrained firms (WW index)		
	Issue			Issue		
VARIABLES	Equity	Debt	Equity	Equity	Debt	Equity
R&D/Sale	0.175	-0.250	0.417**	0.153***	-0.043	0.207***
	(1.510)	(-1.353)	(1.988)	(4.383)	(-0.675)	(2.892)
R&D dummy	0.106	0.133***	-0.013	-0.106	0.172***	-0.272***
	(1.080)	(2.846)	(-0.148)	(-1.470)	(2.848)	(-2.921)
Control variables	Yes		Yes	Yes		Yes
Year fixed effects	Yes		Yes	Yes		Yes
Industry fixed effects	Yes		Yes	Yes		Yes
Observations	26,757		5,437	20,772		5,229
Pseudo R-squared	0.0659		0.1764	0.1358		0.2484

Panel B R&D investment and incremental financing choices for unconstrained versus constrained firms based on the SA index

	Unconstrained firms (SA index)			Constrained firms (SA index)		
	Issue			Issue		
VARIABLES	Equity	Debt	Equity	Equity	Debt	Equity
R&D/Sale	-0.533	0.331	-1.664***	0.164***	-0.114	0.269***
	(-1.622)	(1.295)	(-2.875)	(4.723)	(-1.623)	(3.481)
R&D dummy	-0.093	0.092**	-0.191**	-0.014	0.309***	-0.333***
	(-0.976)	(1.993)	(-2.107)	(-0.196)	(5.205)	(-3.833)
Control variables	Yes		Yes	Yes		Yes
Year fixed effects	Yes		Yes	Yes		Yes
Industry fixed effects	Yes		Yes	Yes		Yes
Observations	27,816		5,187	20,324		5,424
Pseudo R-squared	0.0506		0.1526	0.1381		0.2715

Panel C R&D capital and corporate leverage for unconstrained versus constrained firms

	Unconstrained (WW index)	Constrained (WW index)	Unconstrained (SA index)	Constrained (SA index)
R&D capital ratio	-0.084***	-0.026***	-0.076***	-0.028***
	(-7.663)	(-5.443)	(-6.217)	(-5.940)
R&D capital dummy	0.011**	0.029***	0.000	0.028***
	(2.253)	(5.241)	(0.079)	(5.462)
Control variables	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	38,989	34,044	39,803	32,868
Adjusted R-squared	0.356	0.297	0.338	0.286

Table 8

Introduction of state-level R&D tax credits and corporate capital structure

This table reports the regression results after adding the state-level R&D tax credit dummy. The second and third columns report the results for the multinomial logistic regression of Issue, the fourth column for the logistic regression of Equity, the fifth and sixth columns for the leverage regressions, and the final column for the logistic regression of Zero leverage dummy. Robust t-statistics clustered at firm level for the multinomial logistic regression and at both firm and year levels for the remaining regressions are shown in parentheses. ***, ** and * denote a significant level of 1 percent, 5 percent, and 10 percent, respectively.

	Issue					
VARIABLES	Equity	Debt	Equity	Market leverage	Book leverage	Zero leverage dummy
R&D tax credit dummy	0.048	-0.183***	0.237***	-0.010***	-0.016***	0.180***
	(1.18)	(-6.205)	(4.462)	(-3.212)	(-4.297)	(3.137)
R&D/Sale	0.158***	-0.056	0.191***	-0.047***	-0.051***	0.302***
	(5.46)	(-1.098)	(3.299)	(-6.699)	(-5.172)	(5.735)
R&D dummy	-0.017	0.184***	-0.212***	0.020***	0.020***	0.096
	(-0.379)	-6.256	(-3.542)	(5.563)	(4.814)	(1.397)
Control variables	Yes		Yes	Yes	Yes	Yes
Industry fixed effects	Yes		Yes	No	No	No
Year fixed effects	Yes		Yes	Yes	Yes	Yes
Observations	58,126		13,547	89,434	89,968	89,514
Pseudo/Adjusted R square	0.0964		0.2306	0.309	0.196	0.2213

Table 9

Patent variables and corporate incremental financing choice

This table presents the regression results of corporate incremental financing choice on patent variables. Panel A include the High patent dummy and High citation dummy in the regression, Panel B include High generality dummy and High originality dummy, and Panel C include the two measures of innovation efficiency (IE). Robust t-statistics clustered at firm level for the multinomial logistic regression and at both firm and year levels for the logistic regression are shown in parentheses. ***, ** and * denote a significant level of 1 percent, 5 percent, and 10 percent, respectively.

Panel A High patent, high citation and corporate incremental financing choice

	Issue			Issue		
VARIABLES	Equity	Debt	Equity	Equity	Debt	Equity
High patent dummy	0.076	-0.122***	0.119			
	(1.200)	(-2.699)	(1.520)			
High citation dummy				0.151***	-0.051	0.233***
				(2.815)	(-1.276)	(3.295)
Patent dummy	-0.032	-0.047	0.041	-0.044	-0.049	0.025
	(-0.699)	(-1.550)	(0.725)	(-0.957)	(-1.582)	(0.437)
R&D/Sale	0.166***	-0.067	0.201***	0.165***	-0.068	0.200***
	(5.305)	(-1.129)	(3.529)	(5.261)	(-1.133)	(3.492)
R&D dummy	-0.061	0.133***	-0.216***	-0.055	0.141***	-0.207***
	(-1.286)	(4.304)	(-4.103)	(-1.158)	(4.586)	(-3.919)
Control variables	Yes		Yes	Yes		Yes
Year fixed effects	Yes		Yes	Yes		Yes
Industry fixed effects	Yes		Yes	Yes		Yes
Observations	70,255		16,185	70,255		16,185
Pseudo R-squared	0.0915		0.2286	0.0915		0.2291

Panel B High generality, high originality and corporate incremental financing choice

	Issue			Issue		
VARIABLES	Equity	Debt	Equity	Equity	Debt	Equity
High generality dummy	-0.010	0.022	-0.041			
	(-0.177)	(0.567)	(-0.502)			
High originality dummy				0.035	0.003	0.026
				(0.634)	(0.067)	(0.306)
Patent dummy	-0.027	-0.054*	0.049	-0.031	-0.052*	0.044
	(-0.600)	(-1.753)	(0.913)	(-0.684)	(-1.700)	(0.810)
R&D/Sale	0.168***	-0.071	0.207***	0.166***	-0.070	0.205***
	(5.361)	(-1.176)	(3.550)	(5.329)	(-1.170)	(3.488)
R&D dummy	-0.065	0.145***	-0.226***	-0.063	0.144***	-0.222***
	(-1.385)	(4.704)	(-4.301)	(-1.347)	(4.678)	(-4.200)
Control variables	Yes		Yes	Yes		Yes
Year fixed effects	Yes		Yes	Yes		Yes
Industry fixed effects	Yes		Yes	Yes		Yes
Observations	70,255		16,185	70,255		16,185

Pseudo R-squared	0.0913	0.2285	0.0913	0.2285

Panel C Innovation efficiency (IE) and corporate incremental financing choice

	Issue			Issue		
VARIABLES	Equity	Debt	Equity	Equity	Debt	Equity
Ln (1+Patents/RDC)	-0.011	-0.025***	0.016			
	(-0.784)	(-3.031)	(1.082)			
Ln (1+Citations/RD)				0.003	-0.013***	0.013
				(0.346)	(-2.585)	(1.559)
Patent dummy	-0.024	-0.044	0.040	-0.031	-0.040	0.032
	(-0.530)	(-1.449)	(0.723)	(-0.676)	(-1.303)	(0.561)
R&D/Sale	0.165***	-0.079	0.209***	0.168***	-0.076	0.210***
	(5.280)	(-1.305)	(3.594)	(5.355)	(-1.266)	(3.588)
R&D dummy	-0.074	0.117***	-0.212***	-0.062	0.115***	-0.203***
	(-1.554)	(3.706)	(-4.011)	(-1.277)	(3.561)	(-3.719)
Control variables	Yes		Yes	Yes		Yes
Year fixed effects	Yes		Yes	Yes		Yes
Industry fixed effects	Yes		Yes	Yes		Yes
Observations	70,255		16,185	70,255		16,185
Pseudo R-squared	0.0915		0.2286	0.0914		0.2286

Table 10

Patent variables and corporate leverage

This table presents the regression results of corporate leverage on patent variables. Panel A include the High patent stock dummy and High citation stock dummy in the regression, Panel B include High generality stock dummy and High originality stock dummy, and Panel C include the two measures of innovation efficiency (IE). Robust t-statistics clustered at both firm and year levels are shown in parentheses. ***, ** and * denote a significant level of 1 percent, 5 percent, and 10 percent, respectively.

Panel A High patent, high citation and corporate leverage

VARIABLES	Market leverage	Book leverage	Market leverage	Book leverage
High patent stock dummy	-0.014***	-0.011**		
	(-4.095)	(-2.286)		
High citation stock dummy			-0.014***	-0.016***
			(-5.423)	(-4.314)
Patent dummy	-0.011***	-0.020***	-0.011***	-0.018***
	(-3.413)	(-4.692)	(-3.189)	(-4.367)
R&D capital ratio	-0.046***	-0.050***	-0.046***	-0.050***
	(-6.486)	(-5.149)	(-6.461)	(-4.986)
R&D capital dummy	0.013***	0.012***	0.014***	0.012***
	(3.412)	(2.629)	(3.769)	(2.743)
Year fixed effects	Yes	Yes	Yes	Yes
Observations	93,011	93,557	93,011	93,557
Adjusted R-squared	0.312	0.196	0.312	0.196

Panel B High generality, high originality and corporate leverage

VARIABLES	Market leverage	Book leverage	Market leverage	Book leverage
High generality stock dummy	-0.008***	-0.010***		
	(-2.903)	(-3.087)		
High originality stock dummy			-0.007**	-0.007**
			(-2.219)	(-1.962)
Patent dummy	-0.012***	-0.019***	-0.012***	-0.020***
	(-3.529)	(-4.609)	(-3.653)	(-4.748)
R&D capital ratio	-0.048***	-0.051***	-0.047***	-0.051***
	(-6.628)	(-5.175)	(-6.641)	(-5.193)
R&D capital dummy	0.015***	0.013***	0.015***	0.013***
	(3.964)	(2.911)	(4.002)	(3.002)
Year fixed effects	Yes	Yes	Yes	Yes
Observations	93,011	93,557	93,011	93,557
Adjusted R-squared	0.311	0.196	0.311	0.196

Panel C Innovation efficiency (IE) and corporate leverage

VARIABLES	Market leverage	Book leverage	Market leverage	Book leverage
Ln (1+Patents/RDC)	-0.003***	-0.002		
	(-3.105)	(-1.542)		
Ln (1+Citations/RD)			-0.002***	-0.001*
			(-3.081)	(-1.647)
Patent dummy	-0.012***	-0.020***	-0.011***	-0.019***
	(-3.552)	(-4.701)	(-3.278)	(-4.454)
R&D capital ratio	-0.046***	-0.050***	-0.046***	-0.050***
	(-6.538)	(-5.077)	(-6.489)	(-5.056)
R&D capital dummy	0.013***	0.012**	0.012***	0.011**
	(3.195)	(2.534)	(2.798)	(2.232)
Year fixed effects	Yes	Yes	Yes	Yes
Observations	90,150	90,690	90,150	90,690
Adjusted R-squared	0.310	0.196	0.310	0.196