# Less is More: Financial Constraints and Innovative Efficiency

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## Abstract

We show that financial constraints may benefit innovation by improving the efficiency of innovative activities. We measure firm-level innovative efficiency by patents (or patent citations) scaled by R&D (research and development) investment or the number of employees, and find that financial constraints are positively associated with innovative efficiency. Tests using the 1989 junk bond crisis as an exogenous shock to financial constraints suggest a causal interpretation for the link. Consistent with agency problems, the positive effect of financial constraints on innovative efficiency is stronger among firms with high excess cash holdings and low investment opportunities, and among firms in less competitive industries. Financial constraints appear to mitigate free cash flow problems that induce firms to make unproductive R&D investment in fields out of their direct expertise. Our findings point to a bright side of the role of financial constraints for corporate investment in intangible assets.

*JEL Classification:* G32, G34, O32

*Keywords:* Financial constraints, innovation, patents, R&D investment, free cash flow, agency problems.

## 1. Introduction

How does financial slack affect innovative efficiency? Conventional wisdom suggests that financial constraints hurt innovation by reducing firms' R&D spending and thus lowering the probability of winning patent races in the long term. However, anecdotal evidence suggests that more financial resources do not necessarily lead to more and better innovation.

For example, some question whether U.S. firms' R&D investment generated commensurate inventions (*Economist* 1990; Jensen 1993; Jaffe 2000; Lanjouw and Schankerman 2004; Skinner 2008).[1] Furthermore, a recent report shows that small biotechnology companies spend on aggregate around $28 billion annually on R&D, which is much lower than the $50 billion R&D spending for large pharmaceutical companies.[2] However, the dominance of large pharmaceutical companies in R&D spending did not make them the winner in discovering new drugs. Munos (2009) shows that the share of approved new drugs from large pharmaceutical companies has gradually declined from roughly 75% since the early 1980s to nearly 35% in 2008. At the same time, the share attributable to small biotechnology and pharmaceutical companies has jumped from 23% to nearly 65% during the same period. In other words, small firms collectively produce more for less.[3] These findings suggest that when it comes to innovative *efficiency* in converting innovative input into valuable output, less can be more.

Existing studies mainly focus on the link between financial constraints and innovative

[1] Jensen (1993) shows that U.S. real R&D expenditures grow at an average annual rate of 5.8% from 1975 to 1990 without generating appropriate economic and financial gains. Skinner (2008) reports that, over the period from 1980 to 2005, U.S. public firms' R&D expenditures increase by about 250%, while their capital expenditures increase by less than 50%. The *Economist* (1990) notes that "American industry went on an R&D spending spree, with few big successes to show for it." Jaffe (2000) and Lanjouw and Schankerman (2004) also observe that the escalating R&D investment does not generate commensurate patents since the 1980s.
[2] Life sciences: a 20/20 vision to 2020. http://www.burrillandco.com/content/BT08_execSum.pdf
[3] See also Kortum and Lerner (1998).

input or output, and leave the effect of financial constraints on innovative *efficiency* unexplained.[4] Since innovative efficiency is value-relevant and increases future profitability (Hirshleifer, Hsu, and Li 2013; Cohen, Diether, and Malloy 2013), the link between financial constraints and firms' innovative efficiency is an important issue that calls for investigation.

This paper shows that tighter financial constraints improve firms' innovative efficiency. Firms that are more likely to be constrained generate more patents and citations per unit of R&D investment and per employee.[5] This relation between financial constraints (FC) and innovative efficiency (IE) has a causal interpretation, and is stronger among firms with excess cash holdings and low investment opportunities, and among firms in less competitive industries. We also find evidence that suggests that the marginal value of R&D investment is negative for financially unconstrained firms with large cash holdings, while always positive for financially constrained firms. Furthermore, the FC-IE relation appears to be due to the fact that firms with large free cash flow invest in less productive R&D projects that are out of their areas of expertise and thus less valuable to shareholders. Tighter constraints (*less* slack) thus lead to *more* productive and value-enhancing innovation.

The "less is more" effect can be a consequence of Jensen's (1986) free cash flow argument. Firms with large free cash flow are more likely to invest in unproductive projects

[4] Schumpeter (1942) suggests that firms with financial slack and stable internally generated funds can secure risky R&D projects and generate more technological inventions (see also Cohen, Levin, and Mowery 1987). Henderson and Cockburn (1996) find that research programs located within larger firms are more productive due to within-firm spillovers, while Cohen and Klepper (1996) report a negative relation between firm size and R&D productivity in the 1970s because larger firms tend to undertake more marginal R&D projects. Aghion, Angeletos, Banerjee, and Manova (2010) argue that constrained firms are less likely to engage in long-term innovative investments because they are subject to long-run macroeconomic shocks. Ciftci and Cready (2011) find that larger firms' R&D investment is associated with substantially higher future profitability. Li (2011) show that financial constraints increase the risk of R&D-intensive firms. Brown, Martinsson, and Petersen (2012) find that financial constraints effectively limit R&D activities.

[5] These are the same measures of innovative efficiency used in recent literature (see Lanjouw and Schankerman (2004), Acharya, Baghai, and Subramanian (2012a and 2012b), Hirshleifer, Hsu, and Li (2013), and Cohen, Diether, and Malloy (2013)).

due to agency problems. Financial constraints can force firms to make optimal investment decisions and to be creative in improving capital efficiency (e.g., the lean startup approach developed in Ries (2011) and endorsed by industry leaders such as Jeffery Immelt, CEO of General Electric, and Marc Andreessen, cofounder of Netscape.).

This disciplinary benefit of financial constraints can be particularly important for innovative investment which is more subject to agency problems due to its unique features such as high uncertainty, long horizon to resolve the uncertainty, intangibility, and severe information asymmetry (e.g., Kumar and Langberg 2009; Hall and Lerner 2010). These features may make it easier for managers to seek private benefits and disguise their suboptimal investment decisions when investing in innovation.[6]

Alternatively, a simple neoclassical model with decreasing returns to R&D investment may also predict higher innovative efficiency for more constrained firms. Financial constraints raise the firm's cost of capital and lower its resources available for innovative investment. As a result, the firm only invests in its most promising projects achieving higher *average* innovative efficiency.

We empirically test whether financial constraints (FC) lead to higher IE, and whether such a relation can be attributed to free cash flow problems or decreasing returns to scale. We start the analysis by relating our measures of IE to standard proxies for FC including the SA index (Hadlock and Pierce 2010), the WW index (Whited and Wu 2006), and size (market capitalization, see Livdan, Sapriza, and Zhang 2009). We find that more constrained firms

[6] Private benefits from wasteful R&D investment come in many ways. For example, managers may gain insider profits from their R&D investment. Aboody and Lev (2000) find that R&D investment is positively associated with information asymmetry and leads to significant insider gains. Moreover, having a large R&D budget represents power, which can help enhance managers' self-esteem. Conducting topical, high-profile R&D projects (e.g., developing drugs targeting currently untreatable diseases such as cancer, AIDS, Alzheimer) can also enhance CEOs' ego or social image.

generate significantly more patents and citations per unit of R&D investment and per employee. This relation is economically significant, and is robust to controlling for variables that have been used to explain innovation in prior studies.[7] For example, a one standard deviation increase in the SA index enhances one-year ahead IE measures by 29.16% to 46.02% from sample averages.

Although size is often used as a proxy of financial constraints in the literature, it may reflect other dimensions in addition to financial constraints such as firms' life cycle or organizational structure (Seru 2010). To ensure our results are not driven *only* by size, we also conduct similar tests using the residual financial constraints indices measured by the residuals from panel regressions of the SA or WW index on size and squared size and explicitly control for size and age (a proxy of life cycle). We find a robust positive FC-IE relation. Furthermore, we find the FC-IE effect is also robust to excluding conglomerates from the sample in unreported results. The results are also robust to controlling for contemporaneous R&D and using the logarithmic form of IE as the dependent variable.

Standard tests that relate outcome variables to proxies for financial constraints are subject to endogeneity concerns. For example, since most of the variation in constraints proxies is cross-sectional, we cannot include firm fixed effects in the model and thus cannot rule out the possibility that our results are explained by unobserved heterogeneity at the firm level. To address such issues, we conduct difference-in-differences tests using the collapse of the junk bond market in 1989 as an exogenous shock to financial constraints (Lemmon and Roberts 2010). This collapse is largely unexpected and significantly tightens up financial constraints for junk-bond issuing firms. It is also unlikely to directly affect innovation activities through

[7] See Bhagat and Welch (1995); Lev and Sougiannis (1996); Aghion, Bond, Klemm, and Marinescu (2004); Atanassov, Nanda, and Seru (2007); Aghion, Van Reenen, and Zingales (2013); Hirshleifer, Hsu, and Li (2013); and Cohen, Diether, and Malloy (2013).

channels other than financial constraints. We find that the increase in IE following the shock for junk bond issuers (treatment group) is significantly higher than that for unrated firms (control group). For example, compared to the control group, the treatment group's patent citations per unit of R&D investment increase by 97.46% to 122.31% from sample averages after the shock.

Furthermore, to address the possibility that the results are confounded by the 1990-1991 recession, we conduct a placebo test using the 1996-2003 period that encompasses the 2000-2001 recession (1996-1999 as the pre-crisis period and 2000-2003 as the post-crisis period). We do not find similar changes in IE across junk-issuing and control firms, suggesting that our results are not explained by a demand channel. These tests suggest a causal interpretation for the link between FC and IE.

To examine whether the positive FC-IE relation is due to agency problems and/or a neoclassical argument of decreasing returns to scale, we conduct further tests. First, we examine how the effect of FC on IE varies with firms' *excess* cash holdings and investment opportunities measured by the market-to-book asset ratio (MTB). We find that the FC-IE relation is substantially stronger among firms that are more prone to agency problems (i.e., firms with excess cash holdings above the 70$^{th}$ percentile and MTB below the 30$^{th}$ percentile). This evidence supports the agency explanation since the decreasing-returns-to-scale alternative does not predict a stronger effect of constraints on innovation among this group of firms.

Second, we investigate how the marginal value of R&D investment to shareholders varies with cash holdings across financial constraints subsamples using the methodology of Faulkender and Wang (2006). We find that the marginal value of R&D is always above one for constrained firms, but below one for unconstrained firms with large cash holdings. While the high marginal value of R&D for constrained firms is consistent with decreasing returns to scale, the low marginal value of R&D for unconstrained firms suggests that these firms spend the marginal R&D dollar on negative NPV projects. These findings further suggest that FC increase IE by reducing investment in negative NPV projects as predicted by the free cash flow argument.

Third, we examine the interaction of product market competition with the FC-IE relation. Competition can be a proxy of external governance and substitute for financial constraints in alleviating agency problems. Thus, a stronger FC-IE relation in less competitive industries is consistent with the free cash flow explanation. In contrast, the neoclassical argument does not have a clear prediction for competition. Consistent with the free cash flow explanation, we find that the FC-IE link is in general stronger in less competitive industries (i.e., weaker external governance).

Fourth, we examine how financial constraints affect a firm's innovative strategies that may serve as a channel through which financial constraints influence innovative efficiency. Following the management literature, we classify firms' innovative strategies into "exploratory" and "exploitative" using patent data. Firms focusing on their existing expertise fields and current competitive advantages are expected to produce more exploitative patents, while firms exploring new areas and reaching out for new competitive advantages are expected to produce more exploratory patents (e.g., Sorensen and Stuart 2000; Benner and Tushman 2002; Katila and Ahuja 2002; Phelps 2010). Our analysis shows that the exogenous shock to financial constraints during the junk bond crisis is associated with a lower percentage of exploratory patents (both absolute and relative to exploitative patents). We also find that the percentage of exploratory patents is negatively associated with innovative efficiency. These results suggest that tighter financial constraints force firms to focus on fields of innovation closer to their direct expertise, thereby increasing innovative efficiency.

This paper contributes to the literature in several ways. First, it challenges conventional wisdom that suggests that financial constraints hurt innovation by reducing firms' R&D spending and the probability of winning patent races. Second, it shows that free cash flow problems may adversely affect the productivity of firms' innovative investment, which is more susceptible to agency problems due to high uncertainty, intangibility, and severe information asymmetry. Third, based on the detailed information contained in patent data, we propose and empirically test a new and explicit channel (i.e., exploratory or exploitative innovative strategies) that connects firms' financial status to managers' investment behaviors.

A related study by Seru (2010) shows that conglomerates conduct less novel R&D and that conglomerates with more novel R&D tend to operate with decentralized R&D budgets. Since financial constraints are negatively correlated with firm size, these results are related to ours as they imply that innovation is better conducted outside the boundaries of large firms. Nevertheless, we show that the FC-IE relation is robust to controlling for size and excluding conglomerates from the sample. Thus, our results are unlikely to be driven by the same mechanism that explains the results in Seru (2010).[8]

This paper continues as follows. Section 2 discusses the data and the construction of the

[8] Previous studies have also shown that firm-level innovation performance is related to shareholder composition and risk preferences (Tian and Wang 2011; Ederer and Manso 2012; Aghion, Van Reenen, and Zingales 2013), private ownership (Lerner, Sorensen, and Stromberg 2011; Ferreira, Manso, and Silva 2012; Bernstein 2012), law environments (Acharya and Subramanian 2009; Acharya, Baghai, and Subramanian 2012a, 2012b; Atanassov 2012), conglomerate form (Seru 2010), CEO overconfidence and characteristics (Hirshleifer, Low, and Teoh 2012), CEO contract and compensation (Manso 2011; Lerner and Wulf 2007; Francis, Hasan, and Sharma 2011; Baranchuk, Kieschnick, and Moussawi 2011; Bereskin and Hsu 2012), corporate governance and anti-takeover provision (Chemmanur and Tian 2012; Sapra, Subramanian, and Subramanian 2013), investment cycles in financial markets (Nanda and Rhodes-Kropf 2011, 2012), and product market competition (Aghion, Bloom, Blundell, Griffith, and Howitt 2005).

IE and FC measures. Section 3 examines the relation between financial constraints and innovative efficiency. Section 4 studies whether agency problems or decreasing returns to scale explain the FC-IE relation. Section 5 examines how an exogenous shock to financial constraints affects firms' innovative strategies and how these strategies are related to innovative efficiency. Section 6 concludes.

## 2. The data and the measures of innovative efficiency and financial constraints

Our sample consists of firms in the intersection of three databases: the NBER patent database (2006 edition, Hall, Jaffe, and Trajtenberg 2001) for public firms' patenting records, the CRSP (Center for Research in Security Prices) database for stock price and return data, and the Compustat database for accounting data. All domestic common shares trading on NYSE, AMEX, and NASDAQ with accounting and price data and patent data available are included except financial and utilities firms (with standard industrial classification (SIC) codes between 6000 and 6999 or equal to 4900). Following Fama and French (1993), we also exclude closed-end funds, trusts, American Depository Receipts, Real Estate Investment Trusts, units of beneficial interest, and firms with negative book value of equity. In addition, we require firms to be listed on Compustat for two years before including them in the sample to mitigate backfilling bias. Institutional ownership data are from the Thomson Reuters Institutional (13f) Holdings dataset.

The NBER patent database contains detailed information on all U.S. patents granted by the U.S. Patent and Trademark Office (USPTO) between January 1976 and December 2006.[9]

[9] The NBER patent database is available at https://sites.google.com/site/patentdataproject/Home/downloads and contains patent assignee names and Compustat-matched identifiers (if available), the number of citations received by each patent, technological class, application years, and other details.

For each patent, the database records both the application year and the grant year. Following the corporate finance literature on innovation, we use the application year as the effective year for each patent.

We use patent data from 1980 to 2004. Our sample begins in 1980 because U.S. firms started to actively patent their inventions since the early 1980s (Hall and Ziedonis 2001; Hall 2005). Our sample ends in 2004 because patent counts toward the end of the NBER patent database are subject to truncation bias as it takes on average two years for a patent application to be approved (Hall, Jaffe, and Trajtenberg 2001).

Previous studies suggest that R&D has a strong effect on *contemporaneous* patent applications and a weak effect on subsequent patent applications (Hausman, Hall, and Griliches 1984; Hall, Griliches, and Hausman 1986; Lerner and Wulf 2007). Therefore, we use R&D or employees in the same year as the patent application year to construct four IE measures: Patents/R&D, Patents/Employees, Citations/R&D, and Citations/Employees.[10] Patents/R&D (Patents/Employees) is the total number of *adjusted* patents applied in year *t* scaled by *adjusted* R&D expense (number of employees) in year *t*. Citations/R&D (Citations/Employees) is the total number of *adjusted* citations received from the grant year till 2006 by a firm's patents applied in year *t* scaled by *adjusted* R&D expense (number of employees) in year *t*. Since it takes time for a patent to be cited, we adjust citations using the weighting factor developed by Hall, Jaffe, and Trajtenberg (2001) to control for this truncation bias.

[10] We also consider IE measures based on lagged R&D and employees and obtain similar test results (unreported). Patent citations are usually regarded as a better proxy for innovation output than patent counts because they may better reflect the economic and technical impact of firms' inventions (e.g., Trajtenberg 1990; Aghion, Van Reenen, and Zingales 2013; Lerner, Sorensen, and Stromberg 2011; Bernstein 2012). The employee-based IE measures reflect a firm's innovative efficiency from the perspective of human capital (e.g., Acharya, Baghai, and Subramanian 2012a, 2012b). The unit of R&D expenses (employees) is millions (thousands).

The method of adjusting patents and citations follows the literature (e.g., Seru 2010; Bena and Garlappi 2012) and helps control for the patenting and citing propensities associated with application year and technological class. Specifically, to compute the adjusted patents, we scale the number of patents in each technological class by the cross-sectional average number of patents applied in the same year and assigned to the same technological class by the USPTO. To compute the adjusted citations, we scale the number of citations received by each patent by the average number of citations received by patents applied in the same year and assigned to the same technological class.[11] Similarly, we also adjust innovative input (the denominator of the IE measures) by scaling R&D (Employees) by the corresponding industry average R&D expense (number of employees) in the same year based on Fama-French (1997) 48 industry classifications to remove the industrial component in R&D expenditures and employees.

As a robustness check, we also construct IE measures based on *unadjusted* patents, citations, R&D expenses, and employees, and report similar results in Section 3.1.

We use three primary measures of financial constraints (FC): the SA index (Hadlock and Pierce 2010), the WW index (Whited and Wu 2006), and firm size (yearend market capitalization).[12] By construction, financially more constrained firms have higher SA index, higher WW index, or smaller size.

The SA index is a combination of asset size and firm age and is calculated as ($-0.737 * Assets + 0.043 * Assets^2 - 0.040 * Age$), where *Assets* is the natural log of inflation-adjusted

[11] Alternatively, we adjust the total number of patents (citations) for each firm-year observation by its corresponding industry average patents (citations) in the same application year based on the Fama-French (1997) 48 industry classifications. The results are similar (unreported).

[12] In addition, we use payout ratio, asset size, and sales as alternative measures of financial constraints. The results (unreported) are qualitatively similar. We also experiment with the Kaplan and Zingales (1997) index, but the index is weakly correlated with the other measures of financial constraints as shown in other literature (e.g., Almeida, Campello, and Weisbach 2004; Whited and Wu 2006; Hennessy and Whited 2007; and Hadlock and Pierce 2010).

book assets and is capped at (the natural log of) \$4.5 billion, and *Age* is the number of years a firm is listed with a non-missing stock price on Compustat and is capped at 37 years. The WW index is a linear combination of the following variables with signs in parentheses: cash flow to total assets (–), sales growth (–), long-term debt to total assets (+), log of total assets (–), dividend policy indicator (–), and the firm's three-digit SIC industry sales growth (+).[13] By construction, both indexes are higher for firms that are financially more constrained. Market capitalization (size) is a popular measure of financial constraints (e.g., Livdan, Sapriza, and Zhang 2009). Since our IE measures span from 1980 to 2004, we construct each firm's FC measures from 1979 to 2003.

In examining the effect of FC on IE, we control for different sets of variables including leverage (DE), institutional ownership (IO), the natural logarithm of the assets-to-employees ratio (ln(K/L)), market-to-book asset ratio (MTB), and R&D-to-sales ratio (RDS). DE is the ratio of long-term debt to market value of equity, and it is included because a firm's capital structure can potentially affect a firm's R&D and patenting activities (e.g., Bhagat and Welch 1995; Aghion, Bond, Klemm, and Marinescu 2004; Atanassov, Nanda, and Seru 2007). IO is institutional ownership defined as the percentage of shares outstanding owned by institutional investors (Aghion, Van Reenen, and Zingales 2013).[14] ln(K/L) is the natural log of the ratio of total assets to the number of employees. MTB is defined as the market value of assets divided

[13] Following Whited and Wu (2006), we compute the WW index using Compustat quarterly data according to the following formula: $WW = -0.091*CF - 0.062*DIVPOS + 0.021*TLTD - 0.044*LNTA + 0.102*ISG - 0.035*SG$, where *CF* is the ratio of cash flow to total assets; *DIVPOS* is an indicator that takes the value of one if the firm pays cash dividends; *TLTD* is the ratio of the long-term debt to total assets; *LNTA* is the natural log of total assets; *ISG* is the firm's three-digit SIC industry sales growth; and *SG* is the firm's sales growth. All variables are deflated by the replacement cost of total assets as the sum of the replacement value of the capital stock plus the rest of the total assets. Whited (1992) details the computation of the replacement value of the capital stock. We use WW index in the last quarter of each year in the regressions.

[14] It is worth noting that the IO data used in this paper contain 157,865 firm-year observations with non-missing IO, while the data of Aghion, Van Reenen, and Zingales (2013) only cover 6,208 observations with non-missing IO. This reflects the difference in the IO databases used.

by book value of assets, where market value of assets is measured by total assets minus book equity plus market value of equity. MTB reflects growth opportunities perceived by the stock market. RDS is R&D expenses divided by sales, which reflects the R&D input and investment intensity and is positively associated with future operating performance (Lev and Sougiannis 1996).

Panel A of Table 1 reports summary statistics of the IE and FC measures and these control variables. All variables and measures are winsorized at the 5% and 95% levels to mitigate the influence of outliers. The means of Patents/R&D, Citations/R&D, Patents/Employees, and Citations/Employees are 11.02, 37.24, 9.55, and 37.75, respectively. It is worth mentioning that patents and citations are adjusted for technology classes and R&D and employees are adjusted by industries. We also report the summary statistics of unadjusted IE measures, which suggest that an average sample firm produce 1.63 patents with 22.46 citations by investing one million dollars in R&D activities per year. In addition, a sample firm with one thousand employees produces 9.58 patents with 136.58 citations per year. In addition, the IE measures are highly skewed. For example, the average Patents/R&D is 11.02, whereas the median and maximum Patents/R&D are 3.13 and 71.15, respectively. For robustness, we also use the logarithmic form of IE measures in regressions to address their high skewness in Section 3.1. The statistics for the other variables are largely consistent with those reported in prior studies.

Panel B of Table 1 reports the Pearson and Spearman rank correlations and associated *p*-values among these variables. The IE measures are one year ahead of all the other variables. The four IE measures are highly correlated with correlations ranging from 0.27 to 0.82 and significant at the 1% level. The three FC measures are also highly correlated with statistical significance. For example, the Pearson correlation between log of size and the SA (WW) index is –0.70 (–0.83).

## 3. The effect of financial constraints on innovative efficiency

In this section, we employ regression analyses to examine the effect of financial constraints on innovative efficiency and show that more constrained firms generate more patents and citations per unit of R&D expenses or employees. We also use the collapse of the junk bond market in the late 1980s as an exogenous shock to financial constraints and conduct placebo crisis tests. The results point to a positive causal effect of financial constraints on innovative efficiency.

### 3.1. Financial constraints and innovative efficiency

We first conduct the following panel regressions following the set-up of Aghion, Van Reenen, and Zingales (2013):

$$IE_{i,t} = \alpha_0 + \alpha_1 FC_{i,t-1} + \alpha_2 DE_{i,t-1} + \alpha_3\, IO_{i,t-1} + \alpha_4 \ln(K/L)_{i,t-1} + \alpha_5 MTB_{i,t-1} + \alpha_6\, RDS_{i,t-1} + \sum_{j=1}^{48} \gamma_j Industry_j + \sum_{t=1}^{25} \rho_t Year_t, \qquad (1)$$

where $IE_{i,t}$ is one of the four innovative efficiency measures for firm *i* in year *t*, $FC_{i,t-1}$ is one of the three financial constraints measures for firm *i* in year *t* – 1, and $Industry_j$ is a dummy variable that equals 1 for the industry that firm *i* belongs to and 0 otherwise based on the Fama and French (1997) 48 industry classifications. $Year_t$ reflects the year fixed effect. The detailed definitions of all the other variables are provided in Section 2. To reduce the influence of outliers, we winsorize all variables (except dummy variables) at the top and bottom 5% levels.

We control for leverage because the use of debt affects a firm's R&D and patenting activities (see Bhagat and Welch 1995; Aghion, Bond, Klemm, and Marinescu 2004; Atanassov, Nanda, and Seru 2007). We also control for institutional ownership as Aghion, Van Reenen, and Zingales (2013) show that institutional ownership is associated with more innovation *output* measured by patent citations. Including ln(K/L) in the regression helps control for a potential link between capital-intensity and firms' innovation performance (Aghion, Van Reenen, and Zingales 2013). MTB is included to control for differences in investment opportunities. The inclusion of RDS helps control for R&D intensity. In unreported tables, we find that excluding R&D intensity generates very similar results. We control for industry dummies because previous studies report heterogeneous patenting intensity across industries (e.g., Hirshleifer, Hsu, and Li 2013). However, in unreported results, we find that regressions without controlling for industry fixed effects generate very similar results. Lastly, we also include year dummies in the regression to control for aggregate innovation opportunities, macroeconomic factors, and business cycles.

We propose that financially constrained firms (i.e., firms with higher SA index, higher WW index, or smaller market capitalization) are more efficient in innovation due to the disciplinary benefit of constraints. Therefore, if our hypothesis is supported, the slopes on the SA index and the WW index should be significantly positive, and the slopes on ln(Size) should be significantly negative. We use the natural log of size (ln(Size)) since size is highly skewed.

Table 2A reports the slopes and their *t*-statistics based on standard errors clustered at the firm level. The results show that more constrained firms have significantly higher IE and that the relation is robust to alternative FC and IE measures. Specifically, the slopes on the SA index are 6.18 ($t$ = 9.29), 16.21 ($t$ = 6.53), 6.56 ($t$ = 17.35), and 21.15 ($t$ = 11.48) for Patents/R&D, Citations/R&D, Patents/Employees, and Citations/Employees, respectively. Furthermore, the effect of the SA index on IE is also *economically* significant. Based on the standard deviation of the SA index and the mean of IE measures reported in Table 1, these slopes imply that a one standard deviation increase in the SA index enhances average IE by 37.57%, 29.16%, 46.02%, and 37.54% for Patents/R&D, Citations/R&D, Patents/Employees, and Citations/Employees, respectively. Similar results are found for the WW index and size. For example, a one standard deviation increase in the WW index enhances average IE by 3.87% to 21.50%.

In Table 2B, we find similar results using IE measures based on *unadjusted* patents, citations, R&D, and employees and controlling for industry, year, and industry-year fixed effects. The inclusion of industry-year fixed effects helps eliminate any time-varying industry component, and such a set-up is necessary when we use unadjusted IE measures for analysis because they vary across industries to a great extent. We find that the slopes on the SA index are 0.73 ($t$ = 9.48), 10.78 ($t$ = 9.32), 5.92 ($t$ = 16.53), and 93.70 ($t$ = 12.80) for Patents/R&D, Citations/R&D, Patents/Employees, and Citations/Employees, respectively. Based on the standard deviation of the SA index and the mean of unadjusted IE measures reported in Table 1, these slopes imply that a one standard deviation increase in the SA index enhances average IE by 30.01%, 32.16%, 41.40%, and 45.97% for Patents/R&D, Citations/R&D,

Patents/Employees, and Citations/Employees, respectively. Similar results are found for the WW index and size.

In an unreported table, we construct IE measures based on lagged R&D or employees and obtain qualitatively similar results. These additional tests suggest that the positive effect of financial constraints on subsequent innovative efficiency is robust to estimation methods and how we construct IE measures.

Since the SA and WW indices are highly correlated with size, which could capture dimensions other than financial constraints (such as life cycle of a firm), we use the residual SA and WW indices, measured by the residuals from panel regressions of the SA and WW indices on ln(Size) and squared ln(Size), as additional proxies of financial constraints.[15] In addition, we augment Equation (1) by controlling for ln(Size), age, and current R&D to address the concern that the FC-IE relation may be driven by life cycle or the denominator (i.e., R&D level) effect. Furthermore, we use the logarithmic form of the IE measures to address their high skewness.

The results in Table 2C show that the positive FC-IE effect is robust to the form of IE measures used and to controlling for size, age, and current R&D. The effect remains economically and statistically significant. Thus, the findings reported in Table 2A cannot be simply attributed to life cycles, size-specific effects, denominator effects, or skewness. In untabulated results, we conduct the same tests in the sample that excludes conglomerates and find qualitatively similar results.[16]

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[15] We include the squared ln(Size) in computing the residual financial constraints to address a potential nonlinear relation between size and the constraints indices. Recognizing potential error-in-estimation biases from using residual financial constraints in predicting IE, we check the correlation between residual financial constraints and the residuals from regressions of IE on residual financial constraints and find them statistically uncorrelated.

[16] Following Seru (2010), we define conglomerates as multi-segment firms.

### 3.2. The collapse of the junk bond market and innovative efficiency

We recognize that the proposed FC-IE effect could be subject to various endogeneity issues such as an omitted variable problem. There may exist aggregate, industry, and firm-level omitted variables that influence *both* financial constraints and subsequent IE, leading to a seemingly significant FC-IE relation. Economy cycles, industry-specific business cycles, and innovation waves are all potential aggregate- and industry-level factors that could affect the availability of extra financing and innovation opportunities. Our empirical design used in Tables 2A to 2C addresses this problem by controlling for industry and year fixed effects. Moreover, we also remove any time-varying industry component from the IE measures by adjusting patents, citations, R&D, and employees by their industrial/technological class averages. Therefore, our findings are less likely subject to economy/industry effects.

Firm-level omitted variables, on the other hand, could be more challenging. Although we have considered several control variables at the firm level in the regressions, we cannot fully rule out the possibility that there is an omitted firm-level variable influencing the results. To further address this issue and to improve the identification of the FC-IE relation, we conduct the following tests using the junk bond market crisis as an exogenous shock to financial constraints. For robustness, we also conduct placebo crisis tests using the 1996-2003 period.

Lemmon and Roberts (2010) report that a series of bond market developments in 1989 effectively made junk-bond issuing firms lose access to liquidity provided by the corporate bond market.[17] The tightening in financial constraints affects most firms that rely on junk

[17] In 1989, financial institutions such as savings and loans are precluded to acquire junk bonds due to the introduction of new regulatory standards. Later in that same year, a major operator in the junk bond market, Drexel-Burnham-Lambert (DBL), collapsed due to the investigation from Securities and Exchange Commission and eventually filed for bankruptcy in February 1990. Almeida, Campello, and Hackbarth (2011) also use this event as a proxy of exogenous shocks to financial constraints.

bonds for their financing prior to the crisis. If there is a causal link between financial constraints and innovative efficiency, we would expect IE to increase more following the collapse for junk bond-reliant firms (treatment group) relative to firms that do not rely on bond markets for financing (control group).

The key identification assumption behind this difference-in-differences (Dif-in-Dif) test is that the junk bond collapse does not affect the innovative efficiency of junk bond issuing firms (relative to the control group) for reasons other than financing constraints. We believe this assumption is likely satisfied. In addition, there are no notable contemporary shocks in the late 1980s (such as major technological breakthroughs) that may generate similar implications to the junk bond market collapse. Furthermore, Lemmon and Roberts (2010) provide a detailed analysis of the crisis and argue that the events contributing to the supply shock are likely exogenous to investment opportunities.

Following Lemmon and Roberts (2010), we focus on an event window that spans from 1986 to 1993 and assign the 1986-1989 and 1990-1993 periods as the pre- and post-event periods, respectively. Similarly, we use S&P's long-term domestic issuer credit rating to classify firms. According to S&P, firms rated BBB– or higher are investment-grade; firms rated BB+ or lower are junk bond issuers; and firms without an S&P rating are unrated. The sample for the Dif-in-Dif test only includes junk bond issuers and unrated firms during the period 1986-1993 and satisfying three additional criteria: first, unrated firms are always unrated throughout the entire 1986-1993 period; second, junk bond issuers retain their status and do not change to or from investment grade during the period; and third, each firm needs to have at least one observation in both pre- and post-event periods.

We use panel regressions to estimate the following model for the Dif-in-Dif test:

$$IE_{i,t} = \alpha_0 + \alpha_1 Post_t * Junk_i + \alpha_2 Junk_i + \alpha_3 Post_t + \alpha_4\, CF_{i,t-1} + \alpha_5 DE_{i,t-1} + \alpha_6\, IEG_{i,t-1} + \alpha_7\, IO_{i,t-1} + \alpha_8\, Age_{i,t-1} + \alpha_9 \ln(K/L)_{i,t-1} + \alpha_{10} \ln(Sales)_{i,t-1} + \alpha_{11}\, MTB_{i,t-1} + \alpha_{12}\, NYSE_i + \alpha_{13}\, RDS_{i,t-1} + \alpha_{14}\, SP500_i + \alpha_{15} Zscore_{\,i,t-1} + \sum_{j=1}^{48} \gamma_j Industry_j + \sum_{t=1}^{8} \rho_t Year_t, \quad (2)$$

where $Post_t$ is one for observations occurring in 1990-1993 and zero otherwise, and $Junk_i$ is one if firm *i* is junk bond issuer and zero otherwise.

Following Lemmon and Roberts (2010), we control for variables that explain firms' financing choices and whether they issue junk bonds. Specifically, $SP500_i$ is a dummy variable that equals one if firm *i* is included in the S&P 500 index during 1986–1993 and zero otherwise, and $NYSE_i$ is a dummy variable that equals one if a firm is listed in New York Stock Exchange and zero otherwise. $Age_{i,t-1}$ is the natural log of one plus the number of years firm *i* exists in Compustat with nonmissing pricing data in year $t$ – 1. $CF_{i,t-1}$ is defined as firm *i*'s income before extraordinary items minus accrual, scaled by lagged total assets in year $t$ – 1. Altman's Z-score (Altman, 1968) is a proxy of the likelihood of financial distress and is computed following Lemmon and Roberts (2010).[18]

Moreover, we control for $IEG_{i,t-1}$, the annual growth rate in IE from year $t$ – 2 to year $t$ – 1, to help ensure that the parallel trend assumption (i.e., sample firms are expected to have the same growth trend in IE before the event) is satisfied. Since $IEG_{i,t-1}$ also captures growth in IE post the event, we estimate Equation (2) with and without this variable. $Year_t$ is the year dummy, and all the other variables are defined in Section 3.1. To reduce the impact of

[18] Altman's Z-score is computed as (3.3*pre-tax income + sales + 1.4*retained earnings + 1.2*(current assets – current liabilities))/book assets.

outliers, all variables except the dummy variables are winsorized at the 5% and 95% levels. In addition, we cluster the standard errors at the firm level.

The focus is the slopes on the interaction term, $Post_t * Junk_i$, which capture the average change in IE from pre-1989 to post-1989 for junk bond issuers minus the change in IE from pre-1989 to post-1989 for unrated firms. A significantly positive slope on this interaction term would support our hypothesis that financial constraints increase innovative efficiency.

Table 3A reports the results from estimating Equation (2) without and with growth in IE in Models 1 and 2, respectively. Both models support our hypothesis. For example, for Model 2, the slopes of $Post_t * Junk_i$ are 4.54 ($t$ = 1.80), 23.05 and ($t$ = 2.73), 1.81 ($t$ = 1.79), and 9.19 ($t$ = 2.10) in Panels A, B, C, and D for Patents/R&D, Citations/R&D, Patents/Employees, and Citations/Employees, respectively. These slopes imply that the effect of tightening financial constraints due to the collapse of the junk bond market on IE is significantly higher for junk bond issuers than for unrated firms. In terms of economic significance, these slopes imply that, compared to unrated firms, a junk bond issuing firm's IE increases by 69.15%, 110.92%, 50.14%, and 68.85% for Patents/R&D, Citations/R&D, Patents/Employees, and Citations/Employees, respectively, from their averages in this sample after the crisis.

This difference-in-differences analysis suggests that junk bond issuing firms, whose financing should be adversely affected by the junk bond collapse, significantly improve their innovative efficiency after the collapse. Our interpretation is consistent with Lemmon and Roberts (2010). They find that the operating performance of junk bond issuers increased after the crisis relative to unrated firms. They interpret this evidence as consistent with overinvestment by junk bond issuers prior to the crisis, which is likely due to the low cost of debt.

The recession in the late 1980s and early 1990s can create a demand shock on junk bond issuers and confound the effects of the supply shock from the junk bond crisis. In order to rule out the demand shock channel, we conduct a placebo crisis test using the 1996-2003 period, which includes the 2000-2001 recession. Therefore, the placebo test based on this period can help address the concern that our previous results are driven by the demand shock due to the recession. We use the same methodology for the placebo test as in the previous Dif-in-Dif regressions. Specifically, we define 1996-1999 as the pre-crisis period and 2000-2003 as the post-crisis period. Table 3B reports the results. Consistent with our hypothesis, we do not find a significant difference in the effect of the placebo crisis on firms' IE between junk bond issuers and unrated firms.

In unreported results, we also conduct placebo tests using other periods outside the junk bond crisis, such as 1995-2002 and 1980-1987. We find similar evidence. These tests address the concern that our results are driven by firm-level omitted variables and suggest a causal effect of financial constraints on innovative efficiency.

## 4. Why do financial constraints increase innovative efficiency?

The evidence above shows that financial constraints increase innovative efficiency. What is the driving force for this relation? One possible explanation has to do with decreasing returns to scale in innovation. A firm with many R&D investment opportunities should select projects following a pecking order, from the one with the highest value to the one with the lowest value. When this firm is under stricter financial constraints, its cost of capital increases and resources available for R&D investment drop. As a result, it only invests in more efficient innovation projects, resulting in higher IE on average. On the other hand, the positive FC-IE relation can also be a manifestation of free cash flow problems. Specifically, a firm with financial slack may overinvest in innovation, especially in the fields that are beyond its expertise, and thereby destroy shareholders' value. An increase in financial constraints forces the firm to cut down on wasteful innovation activities.

To understand to what extent the abovementioned stories explain our findings, we further implement three sets of empirical tests. First, we examine whether the effect of financial constraints on innovative efficiency depends on firms' excess cash holdings and investment opportunities (proxied by MTB). The free cash flow story would suggest that the FC-IE link should be stronger among firms with high excess cash and low investment opportunities because FC refrain these firms from wasteful innovative investment. In contrast, the decreasing returns to scale hypothesis would suggest that the FC-IE link may be mitigated for firms with high excess cash, as these firms can use cash to avoid losing profitable innovation opportunities. Second, we investigate how the marginal value of R&D investment to shareholders varies with financial constraints and cash holdings. The free cash flow story predicts that the marginal value of R&D dollar for unconstrained firms with high cash holdings could be less than one dollar. In other words, the marginal R&D is spent on negative NPV projects for these firms. Third, if free cash flow problems exist, the effect of financial constraints on innovative efficiency should be stronger in uncompetitive industries because product market competition can also restrain managers from potential wasteful investment.

We find evidence that is consistent with the free cash flow story. The positive effect of financial constraints on innovative efficiency is more pronounced in firms with high excess cash holdings and low MTB. We also find that the marginal value of R&D to shareholders is lower than one dollar for unconstrained firms with high cash holdings. In contrast, the marginal value of R&D is always greater than one dollar for financially constrained firms. Moreover, we observe a stronger FC-IE relation in uncompetitive industries that are of lower external governance. These findings support the argument that financial constraints mitigate agency problems associated with intangible investment.

### 4.1. Interaction of the FC-IE relation with excess cash holdings and investment opportunities

If the relation between financial constraints and innovative efficiency is driven by agency problems, we would expect it to be stronger among firms with high excess cash holdings and low MTB. These firms both have financial slack, and lack growth opportunities according to the market's view. Specifically, we conduct the following panel regressions that augment Equation (1) with a dummy as follows:

$$IE_{i,t} = \alpha_0 + \alpha_1 FC_{i,t-1} * Agency_{i,t-1} + \alpha_2 Agency_{i,t-1} + \alpha_3 FC_{i,t-1} + \alpha_4 DE_{i,t-1} + \alpha_5\, IO_{i,t-1} + \alpha_6 \ln(K/L)_{i,t-1} + \alpha_7 MTB_{i,t-1} + \alpha_8\, RDS_{i,t-1} + \sum_{j=1}^{48} \gamma_j Industry_j + \sum_{t=1}^{25} \rho_t Year_t, \qquad (3)$$

where $Agency_{i,t-1}$ is one for firms with excess cash holdings above the 70$^{th}$ percentile and the market-to-book assets (MTB) below the 30$^{th}$ percentile of all sample firms in year $t-1$. We define excess cash holdings as the cash-to-assets ratio minus estimated normal cash-to-assets ratio following DeAngelo, DeAngelo, and Stulz (2010).[19] All the other variables are defined in Section 3.1.

If financial constraints improve innovative efficiency by mitigating free cash flow problems, we would expect the slope on the interaction term, $FC * Agency$, to be significantly positive for the WW and SA indices and significantly negative for ln(Size).

Table 4 shows that the slopes on the interaction term, $SA * Agency$, are 2.42 ($t$ = 2.19), 8.55 ($t$ = 2.29), 1.23 ($t$ = 1.90), and 5.58 ($t$ = 1.81) for Patents/R&D, Citations/R&D, Patents/Employees, and Citations/Employees, respectively. In terms of economic significance, these slopes imply that a one standard deviation increase in the SA index enhances IE of a potentially wasteful firm by 14.7%, 15.4%, 8.6%, and 9.9% for Patents/R&D, Citations/R&D, Patents/Employees, and Citations/Employees, respectively, in comparison with an average firm.

We find similar results using the WW index and ln(Size) as financial constraints measures. A one standard deviation increase in the WW index enhances a potentially wasteful firm's IE from 7.6% to 15.5% in comparison with an average firm. A one standard deviation decrease in ln(Size) increases a potentially wasteful firm's IE from 5.6% to 23.6% in comparison with an average firm.

Overall, our results are consistent with a free cash flow explanation for the FC-IE link.

## 4.2. Financial constraints, cash holdings, and the marginal value of R&D

[19] Normal cash-to-assets ratio is calculated by sorting all sample firms in a given year into three equal size groups based on total book assets and three equal size groups based on the market-to-book assets. Each firm is then allocated to one of the nine groups based on its total book assets and market-to-book assets. Within each of the nine groups, a normal cash-to-assets ratio is calculated for each two-digit SIC industry as the median ratio among all firms in that industry for that year.

If financial slack causes firms to overinvest in innovation, we should observe a low, and possibly even negative marginal value of R&D for firms with high financial slack. More specifically, if unconstrained firms with high cash holdings invest in negative NPV projects due to agency problems, their marginal value of R&D should be less than one. To examine this hypothesis, we use the methodology of Faulkender and Wang (2006) to estimate the value that the stock market places on an extra dollar of R&D investment made by firms with different levels of financial constraints and cash holdings. We first form constrained and unconstrained subsamples based on the 30$^{th}$ and 70$^{th}$ percentiles of the FC measures in year *t* – 1.[20] We then run the following panel regression within each subsample:

$$
\begin{aligned}
ExcessReturn_{i,t} = {} & \alpha_0 + \alpha_1 \Delta RD_{i,t} * C_{i,t-1} + \alpha_2 \Delta RD_{i,t} + \alpha_3 C_{i,t-1} + \alpha_4 \Delta C_{i,t} + \alpha_5 \Delta D_{i,t} \\
& + \alpha_6 \Delta E_{i,t} + \alpha_7 \Delta I_{i,t} + \alpha_8 \Delta NA_{i,t} + \alpha_9 \Delta C_{i,t} * C_{i,t-1} + \alpha_{10} L_{i,t} + \alpha_{11} \Delta C_{i,t} \\
& * L_{i,t} + \alpha_{12} NF_{i,t} + \sum_{j=1}^{48} \gamma_j Industry_j + \sum_{t=1}^{T} \rho_t Year_t, \qquad (4)
\end{aligned}
$$

where *i* indexes firm and *t* indexes year. $ExcessReturn_{i,t}$ is a proxy for shareholders' value, defined as the annualized difference between firm *i*'s monthly stock return and the value-weighted monthly return of one of the Fama and French 25 (5 by 5) size and book-to-market (BTM) portfolios to which the stock belongs.[21] $RD_{i,t}$ is R&D expense. $C_{i,t}$ is cash plus marketable securities, and $D_{i,t}$ is total dividends measured as common dividends paid. $E_{i,t}$ is earnings before extraordinary items plus interest, deferred tax credits, and investment tax credits. $I_{i,t}$ is interest expense. $NA_{i,t}$ is total assets minus cash holdings. $L_{i,t}$ is market

[20] For the SA and WW indices, the constrained (unconstrained) subsample includes firms in the top (bottom) 30% in year *t* – 1. For Size, the constrained (unconstrained) subsample includes firms in the bottom (top) 30% in year *t* – 1.

[21] We form the size and book-to-market portfolios at the end of June of year *t* based on size at the end of June of year *t* and BTM in fiscal year ending in calendar year *t* – 1. The breakpoints for size and BTM are based on NYSE firms. For each firm, we compute the monthly excess return first and then compute the cumulative excess returns over the 12 months prior to its fiscal year end.

leverage, and $NF_{i,t}$ is total equity issuance minus repurchases plus debt issuance minus debt redemption. All independent variables except $L_{i,t}$ are deflated by the market value of equity in year $t$ – 1. $\Delta X_{i,t}$ is compact notation for the 1-year change, $X_{i,t} - X_{i,t-1}$. All variables are defined following Faulkender and Wang (2006). $Year_t$ is the year dummy for year $t$ and $Industry_j$ is the industry dummy for industry $j$.

Table 5A shows that the marginal value of R&D decreases with the level of cash holdings for both unconstrained and constrained firms, but at a much faster speed for unconstrained firms.[22] Specifically, the slopes on $\Delta RD_{i,t} * C_{i,t-1}$ are –2.52 ($t$ = –2.03) and –1.15 ($t$ = –1.65) for the low and high SA index groups, respectively. The slopes on $\Delta RD_{i,t} * C_{i,t-1}$ are –4.12 ($t$ = –2.70) and –1.73 ($t$ = –2.19) for the low and high WW index groups, respectively. In addition, the slopes on $\Delta RD_{i,t} * C_{i,t-1}$ are –3.90 ($t$ = –2.26) and –1.40 ($t$ = –2.16) for the big and small groups, respectively.

To better illustrate these results, we plot the marginal value of R&D at different levels of cash holdings for the constrained and unconstrained groups in Figure 1. The slopes on $\Delta RD_{i,t}$ reported in Table 5A reflect the marginal value of R&D when cash holdings are zero. We can also calculate the marginal value of R&D for different levels of cash holdings, by adding the slopes on $\Delta RD_{i,t}$ to the slopes on the interaction term $\Delta RD_{i,t} * C_{i,t-1}$ over the relevant range of cash holdings (0.00 to 0.64 for both subsamples). We find that the marginal value of R&D for constrained firms always exceeds 1, suggesting that marginal R&D of these firms is spent on positive NPV R&D projects. However, the marginal value of R&D for unconstrained firms based on the SA index, the WW index, and Size falls below one dollar

[22] Our implicit assumption is that, without agency problems, the marginal value of R&D of constrained firms should be the same as that of unconstrained firms, given the existence of extensive control variables. However, we cannot entirely rule out the possibility that the marginal value of R&D may be a function of financial constraints and such an effect is not captured by our control variables.

when their cash holdings exceeds 0.17, 0.10, and 0.16, respectively.[23] This finding suggests that unconstrained firms' marginal R&D investment is value-destroying when their cash holdings are high, consistent with the free cash flow argument.

To check whether the marginal value of R&D for constrained firms is significantly higher than that for unconstrained firms, we run regressions similar to Equation (4) in the combined sample of constrained and unconstrained firms with $\Delta RD_{i,t}$ and the other control variables interacting with a dummy, $UC_{i,t}$, that equals one for unconstrained firms and zero for constrained firms.[24] Table 5B shows that the slopes on the interaction term, $UC_{i,t} * \Delta RD_{i,t}$, are significantly negative, indicating that the marginal value of R&D is significantly lower for unconstrained firms. Specifically, the slopes on $UC_{i,t} * \Delta RD_{i,t}$ are –0.90 ($t$ = –3.19), –1.37 ($t$ = –4.25), and –0.74 ($t$ = –2.42) for the dummy defined on the SA index, the WW index, and Size, respectively. Table 5B also confirms that the marginal value of R&D for constrained firms defined on the SA index, the WW index, and Size is always above 1 since the slopes on $\Delta RD_{i,t}$ are 1.78 ($t$ = 10.66), 1.79 ($t$ = 10.15), and 1.57 ($t$ = 10.07), respectively. Furthermore, the sum of these two sets of slopes, which reflects the marginal value of R&D for unconstrained firms, is below 1 for all the three constraints measures.

Overall, these findings suggest that the marginal R&D dollar of constrained (unconstrained) firms is spent on positive (negative) NPV R&D projects, consistent with the free cash flow argument.

[23] As a benchmark, the average cash holdings (and corresponding marginal values of R&D) in the unconstrained groups based on the SA index, the WW index, and Size are 0.14, 0.12, and 0.11 (1.06, 0.89, and 1.16), respectively.
[24] We interact the other control variables with the dummy variable to allow the slopes on these control variables to vary across the constraints groups.

## 4.3. Interaction of product market competition with the financial constraints effect

Product market competition can serve as external governance and a substitute of financial constraints in restraining managers from inefficient investment because stronger competition lowers future cash flows and puts managers in contests. Firms in uncompetitive industries should be subject to free cash flow problems to a greater extent because they do not have much outside competition and shareholders have difficulty in assessing managers' capabilities. We thus hypothesize a stronger effect of financial constraints on innovative efficiency in uncompetitive industries than that in competitive industries. On the other hand, the decreasing returns to scale explanation does not necessarily predict a stronger FC-IE link in uncompetitive industries.

To test our proposition, we first calculate a competition index for each of Fama-French 48 industries every year, defined as one minus the Herfindahl index based on annual sales of all firms in the same industry. In year *t*, we assign firms into the competitive and uncompetitive groups based on the 30$^{th}$ and 70$^{th}$ percentiles of the competition index of their industries in year $t - 1$: the bottom 30% forms the uncompetitive group, and the top 30% forms the competitive group. Within each group for the period 1980-2004, we conduct the same panel regression as specified in Equation (1).

Consistent with our hypothesis, Table 6 suggests a stronger positive effect of financial constraints on innovative efficiency in the uncompetitive group with higher (lower) slopes of the SA and WW indices (ln(Size)). In the first column for the uncompetitive group, we find statistically significant slopes on FC in most cases. In addition, the FC slopes and associated *t*-statistics in the competitive group (second column) are in general less significant and lower in magnitude than their counterparts in the uncompetitive group. These results support the proposition that financial constraints improve firms' innovative efficiency to a greater extent in a less competitive environment.

To gauge the statistical significance of the cross-subsample difference in the FC effect, we pool the uncompetitive and competitive groups together and augment Equation (1) with an interaction term, *Dummy(Uncompetitive)*FC*, in which *Dummy(Uncompetitive)* equals one if the sample firm belongs to the uncompetitive group and zero otherwise. As shown in the third column of Table 6, the slopes on *Dummy(Uncompetitive)*FC* are always positive (negative) for the SA and WW indices (ln(Size)), consistent with the argument of a stronger FC-IE relation in an uncompetitive environment. Moreover, most of these slopes are statistically significant.

Overall, Table 6 supports our proposition that product market competition substitutes financial constraints in restraining managers from wasteful innovative investment, and further confirms that financial constraints help firms innovate more efficiently by mitigating free cash flow problems.

## 5. Financial constraints shocks, innovative strategies, and innovative efficiency

If financial constraints improve innovative efficiency by lowering agency costs, they are expected to affect firms' project choices and innovative strategies. We hypothesize that financial constraints force managers to stay away from overly risky, exploratory projects and focus on better established, safer projects that can be implemented more easily. To test such a channel, we first examine whether exogenous shocks to financial constraints affect firms' choices of innovative activities, and then test whether these choices explain firms' innovative efficiency.

We classify firms' innovative strategies into "exploratory" and "exploitative" using patent data. Following the management literature, we define patents built on a firm's existing knowledge and aimed to deepen the firm's expertise in current territories as "exploitative patents", and patents tangential or even irrelevant to the firm's existing knowledge and serving as pilot trials into new fields as "exploratory patents" (e.g., Sorensen and Stuart, 2000; Benner and Tushman, 2002; Katila and Ahuja, 2002; Phelps, 2010).

We classify a firm's innovative strategy based on the percentage of exploratory or exploitative patents relative to the total number of patents filed in the same year. Firms focusing on their existing expertise fields and concentrating on current competitive advantages are expected to produce a higher percentage of exploitative patents, while firms exploring new areas and reaching out for new competitive advantages are expected to produce a higher percentage of exploratory patents.

We propose that tightened financial constraints motivate firm managers to adopt more exploitative innovative strategies, which can contribute to higher IE. On the other hand, exploratory strategies involve distant search of new knowledge and shifting technological trajectory, and are usually more costly and associated with higher uncertainty. Tightened financial constraints can force managers to stay focused and continue investing in fields in which they have the greatest competitive advantages. When firms are doing what they are already good at, they perform more efficiently in general. Therefore, tightened financial constraints could lead to higher innovative efficiency by encouraging firms to stay focused in innovative activities and to curtail ambitious yet potentially inefficient divergence.

To test this hypothesis, we first determine if a firm's newly granted patents are exploratory or exploitative based on the extent to which a patent is built on new knowledge or the firm's existing knowledge. A patent is categorized as "exploratory" if at least 60% of the patents it cites are from the firm's "new knowledge" (i.e., patents not in the firm's existing knowledge). On the other hand, a patent is categorized as "exploitative" if at least 60% of the patents it cites are from the firm's "existing knowledge".[25]

We then construct two proxies of a firm's innovative strategies. The first is the percentage of exploratory patents, defined as the number of exploratory patents filed by firm $i$ in year $t$ divided by the number of all patents filed by the firm in the same year. A lower percentage of exploratory patents suggests a more focused innovative strategy. The second is the difference between the percentage of exploratory patents and the percentage of exploitative patents, when the latter is defined as the number of exploitative patents filed by firm $i$ in year $t$ divided by the number of all patents filed by the firm in the same year. A lower difference also suggests a more focused innovative strategy.

We empirically examine the relation between the junk bond crisis, as an exogenous shock to financial constraints, and innovative strategies. We conduct Dif-in-Dif test similar to Equation (2) using the proposed proxies for innovative strategies as the dependent variables. The results reported in Table 7A show that junk bond issuers become significantly more focused in innovation than unrated firms after the junk bond market collapse, as the slopes associated with $Post * Junk$ are significantly negative, suggesting that junk bond issuers

[25] As defined in Benner and Tushman (2002), a firm's "existing knowledge" consists of two sources: its own previously filed patents over the past five years, and other companies' patents cited by the firm's patents filed over the past five years. A patent can be neither exploratory nor exploitative. For example, if 50% of the patents cited by a patent are from a firm's "existing knowledge", this patent is neither exploitative nor exploratory under the 60% threshold. Therefore, the sum of the percentages of exploratory patents and exploitative patents is not necessarily equal to 1. Moreover, we also use the 80% threshold in tests and obtain qualitatively similar results.

curtail their exploratory innovations more than other firms after 1989. This effect is robust to different proxies of innovative strategies and different sets of control variables. We then conduct placebo tests for the period 1996-2003 and find that the slopes associated with $Post * Junk$ are in general statistically insignificant as shown in Table 7B, suggesting that junk bond issuers do not curtail their exploratory innovations more than other firms since 2000. Tables 7A and 7B thus collectively support a causal effect of financial constraints on innovative strategies.

Lastly, to establish the channel based on innovative strategies, we examine the relation between innovative strategies and innovative efficiency by estimating the following model using panel regressions:

$$IE_{i,t} = \alpha_0 + \alpha_1 Explore_{i,t} + \alpha_2 DE_{i,t-1} + \alpha_3\, IO_{i,t-1} + \alpha_4 \ln(K/L)_{i,t-1} + \alpha_5 MTB_{i,t-1} + \alpha_6\, RDS_{i,t-1} + \sum_{j=1}^{48} \gamma_j Industry_j + \sum_{t=1}^{25} \rho_t Year_t, \quad (5)$$

where $Explore_{i,t}$ is the percentage of exploratory patents or the difference between the percentage of exploratory patents and the percentage of exploitative patents for firm $i$ in year $t$. A significantly positive slope of $Explore_{i,t}$ would support our proposition that exploratory innovations lead to inefficiency.

Table 8 reports our estimation of Equation (5) and provides strong evidence for the impact of innovative strategies on innovative efficiency. Firms adopt more exploratory strategies tend to generate fewer patents per R&D dollar or employee. Panel A shows significantly negative slopes on the percentage of exploratory patents. In terms of economic significance, when a firm decreases its exploratory innovations by 10%, its Patents/R&D, Citations/R&D, Patents/Employees, and Citations/Employees increases by 35.0%, 204.4%, 47.7%, and

271.5%, respectively. Similar results are reported in Panel B, when we use the difference between the percentage of exploratory patents and the percentage of exploitative patents as another proxy of exploratory innovations.

Overall, Tables 7A and 7B suggest that financial constraints lead to more concentrated innovative activities, and Table 8 suggests that more concentrated innovative activities improve firms' efficiency in innovations. We interpret these results as confirming our proposition that managers may spend free cash in exploratory innovation that they know little about, while focusing on areas of expertise as financial constraints tighten.

## 6. Conclusion

This paper shows that financial constraints improve innovation performance. We find that financial constraints increase innovative efficiency by generating more patents or citations per dollar of R&D expenses or per employee. Tests using the 1989 junk bond crisis as an exogenous shock to financial constraints suggest a causal interpretation for our findings.

Further analyses suggest that such a relation may be largely attributed to agency problems. We find that the positive effect of financial constraints on innovative efficiency is stronger among firms with high excess cash holdings and low investment opportunities, and among firms in less competitive industries. Moreover, the marginal R&D dollar of unconstrained firms is likely spent on negative NPV projects, while the marginal R&D dollar of constrained firms is always spent on positive NPV projects. Finally, financial constraints seem to mitigate free cash flow problems that induce firms to make unproductive R&D investment in fields out of their direct expertise.

Overall, this paper contributes to the literature that studies the drivers of corporate innovation. In particular, we show that agency problems may adversely affect the productivity of firms' innovative investment due to their unique features such as high uncertainty, severe information asymmetry, and intangibility. Our empirical evidence suggests the possibility of using financial constraints as a tool to improve efficiency of firms' innovation activities. While financial constraints contain important exogenous determinants that are difficult to change (such as transaction costs and asset type), they can also be shaped by policy variables such as cash, payout and debt maturity. In addition, firms can also reap the benefit of constraints by outsourcing R&D to and/or collaborating with leaner and more efficient firms.

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**Table 1. Summary statistics and correlations**

Panel A reports the summary statistics of measures of innovative efficiency (IE) from 1980 to 2004, measures of financial constraints, and other characteristics from 1979 to 2003. The IE measures are: Patents/R&D, Citations/R&D, Patents/Employees, and Citations/Employees. Patents/R&D (Patents/Employees) is the number of adjusted patents applied in year *t* scaled by adjusted R&D expense (number of employees) in year *t*. Citations/R&D (Citations/Employees) is the number of adjusted citations received by a firm's patents applied in year *t* from the year granted till 2006 scaled by adjusted R&D expense (number of employees) in year *t*. We scale Patents (Citations) by the average patents (citations) in the same application year and the same technological class assigned by the USPTO. We scale R&D (Employees) by the average R&D expense (number of employees) in the same year and same industry based on the Fama-French 48 industry classifications. We also report the summary statistics of unadjusted IE measures: Patents/R&D (unadjusted) is the number of patents applied in year *t* scaled by R&D expense in year *t*; Citations/R&D (unadjusted) is the number of citations received by a firm's patents applied in year *t* from the year granted till 2006 scaled by R&D expense in year *t*; Patents/Employees (unadjusted) is the number of patents applied in year *t* scaled by the number of employees in year *t*; and Citations/Employees (unadjusted) is the number of citations received by a firm's patents applied in year *t* from the year granted till 2006 scaled by the number of employees in year *t*. The SA index and the WW index are financial constraints indices as in Hadlock and Pierce (2010) and Whited and Wu (2006), respectively. ln(Size) is the natural log of a firm's market capitalization at year end. DE is the ratio of long-term debt to market value of equity. IO is institutional ownership defined as the percentage of shares outstanding owned by institutional investors. ln(K/L) is the natural log of the ratio of total assets to the number of employees. Market-to-book assets (MTB) is market value of assets divided by book value of assets, where market value of assets is measured by total assets minus book equity plus market value of equity. RDS is R&D expense divided by sales. We winsorize all variables at the 5% and 95% levels. Panel B reports the Pearson (Spearman rank) correlations and associated *p*-values in parentheses between the IE measures and these characteristics below (above) the diagonal.

Panel A. Summary statistics

| | Mean | StdDev | Min | 25% | Median | 75% | Max |
|---|---|---|---|---|---|---|---|
| Patents/R&D | 11.02 | 18.26 | 0.11 | 0.83 | 3.13 | 11.06 | 71.15 |
| Citations/R&D | 37.24 | 63.70 | 0.00 | 1.87 | 9.60 | 37.28 | 248.08 |
| Patents/Employees | 9.55 | 13.78 | 0.24 | 1.27 | 3.76 | 10.75 | 53.64 |
| Citations/Employees | 37.75 | 64.85 | 0.00 | 2.03 | 9.69 | 36.82 | 252.08 |
| Patents/R&D (unadjusted) | 1.63 | 2.45 | 0.02 | 0.19 | 0.58 | 1.80 | 11.63 |
| Citations/R&D (unadjusted) | 22.46 | 39.56 | 0.00 | 1.43 | 6.39 | 22.55 | 216.89 |
| Patents/Employees (unadjusted) | 9.58 | 17.85 | 0.09 | 0.81 | 2.56 | 9.01 | 111.11 |
| Citations/Employees (unadjusted) | 136.58 | 293.75 | 0.00 | 4.66 | 23.62 | 107.23 | 2095.09 |
| SA index | -3.25 | 0.67 | -4.37 | -3.76 | -3.27 | -2.78 | -1.95 |
| WW index | -0.27 | 0.11 | -0.47 | -0.36 | -0.27 | -0.19 | -0.10 |
| ln(Size) | 5.61 | 1.92 | 2.43 | 4.11 | 5.47 | 7.01 | 9.28 |
| DE | 0.24 | 0.34 | 0.00 | 0.01 | 0.10 | 0.33 | 1.23 |
| IO | 0.40 | 0.24 | 0.03 | 0.19 | 0.40 | 0.60 | 0.82 |
| ln(K/L) | 4.73 | 1.08 | 2.92 | 3.90 | 4.70 | 5.55 | 6.70 |
| MTB | 1.92 | 1.26 | 0.77 | 1.05 | 1.45 | 2.27 | 5.52 |
| RDS | 0.11 | 0.21 | 0.00 | 0.00 | 0.03 | 0.10 | 0.86 |

Panel B. Correlations

| | Patents /R&D | Citations /R&D | Patents /Employees | Citations /Employees | SA index | WW index | ln(Size) | DE | IO | ln(K/L) | MTB | RDS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Patents/R&D | 1.00 | 0.79 | 0.55 | 0.38 | 0.01 | -0.07 | -0.09 | 0.10 | -0.04 | -0.45 | -0.10 | -0.27 |
| | | (0.00) | (0.00) | (0.00) | (0.09) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| Citations/R&D | 0.82 | 1.00 | 0.49 | 0.71 | 0.00 | -0.06 | -0.02 | 0.03 | -0.01 | -0.31 | -0.03 | -0.12 |
| | (0.00) | | (0.00) | (0.00) | (0.85) | (0.00) | (0.04) | (0.00) | (0.15) | (0.00) | (0.00) | (0.00) |
| Patents/Employees | 0.44 | 0.43 | 1.00 | 0.74 | 0.36 | 0.25 | -0.19 | -0.23 | -0.16 | 0.13 | 0.18 | 0.29 |
| | (0.00) | (0.00) | | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| Citations/Employees | 0.27 | 0.48 | 0.77 | 1.00 | 0.24 | 0.17 | -0.07 | -0.22 | -0.08 | 0.12 | 0.19 | 0.31 |
| | (0.00) | (0.00) | (0.00) | | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| SA index | 0.06 | 0.06 | 0.36 | 0.32 | 1.00 | 0.84 | -0.70 | -0.37 | -0.51 | 0.28 | 0.24 | 0.40 |
| | (0.00) | (0.00) | (0.00) | (0.00) | | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| WW index | -0.03 | -0.03 | 0.23 | 0.21 | 0.84 | 1.00 | -0.82 | -0.32 | -0.57 | 0.27 | 0.18 | 0.41 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| ln(Size) | -0.07 | -0.01 | -0.16 | -0.09 | -0.70 | -0.83 | 1.00 | 0.08 | 0.67 | 0.00 | 0.08 | -0.09 |
| | (0.00) | (0.35) | (0.00) | (0.00) | (0.00) | (0.00) | | (0.00) | (0.00) | (0.83) | (0.00) | (0.00) |
| DE | 0.06 | 0.01 | -0.15 | -0.18 | -0.23 | -0.18 | -0.02 | 1.00 | 0.07 | -0.29 | -0.43 | -0.43 |
| | (0.00) | (0.31) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | | (0.00) | (0.00) | (0.00) | (0.00) |
| IO | -0.02 | 0.01 | -0.15 | -0.10 | -0.51 | -0.56 | 0.65 | 0.00 | 1.00 | -0.05 | -0.04 | -0.13 |
| | (0.02) | (0.16) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.76) | | (0.00) | (0.00) | (0.00) |
| ln(K/L) | -0.35 | -0.25 | 0.14 | 0.21 | 0.26 | 0.26 | 0.00 | -0.19 | -0.05 | 1.00 | 0.27 | 0.48 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.97) | (0.00) | (0.00) | | (0.00) | (0.00) |
| MTB | -0.04 | 0.03 | 0.22 | 0.25 | 0.30 | 0.22 | 0.03 | -0.58 | 0.01 | 0.31 | 1.00 | 0.40 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.03) | (0.00) | | (0.00) |
| RDS | -0.16 | -0.08 | 0.28 | 0.33 | 0.40 | 0.35 | -0.12 | -0.24 | -0.08 | 0.44 | 0.41 | 1.00 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | |

**Table 2A. Financial constraints and innovative efficiency**

This table reports the slopes and their *t*-statistics from panel regressions of firms' innovative efficiency (IE) in year *t* from 1980-2004 on their financial constraints measures (FC), debt-to-equity ratio (DE), institutional ownership (IO), log of capital-to-labor ratio (ln(K/L)), market-to-book assets (MTB), and R&D-to-sales ratio (RDS) in year $t-1$. All regressions control for industry fixed effects based on the Fama-French 48 industry classifications and year fixed effects. All variables are winsorized at the 5% and 95% levels except the dummy variables. We compute *t*-statistics based on standard errors clustered at the firm level. We use four IE measures: Patents/R&D, Citations/R&D, Patents/Employees, and Citations/Employees. We measure FC by the SA index (Hadlock and Pierce 2010), the WW index (Whited and Wu 2006), and ln(Size). All variables are defined in Table 1.

| | **Panel A. IE = Patents/R&D** | | | | | | **Panel B. IE = Citations/R&D** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SA Index | | WW Index | | ln(Size) | | SA Index | | WW Index | | ln(Size) | |
| Variable | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value |
| FC | 6.18 | (9.29) | 13.28 | (3.31) | -0.83 | (-3.84) | 16.21 | (6.53) | 13.10 | (0.86) | -0.09 | (-0.11) |
| DE | 1.30 | (1.37) | 0.67 | (0.67) | 0.25 | (0.25) | 3.23 | (0.95) | 1.30 | (0.37) | 0.51 | (0.15) |
| IO | 2.51 | (2.02) | -2.08 | (-1.67) | -1.39 | (-1.05) | 10.27 | (2.15) | -5.72 | (-1.21) | -9.95 | (-1.99) |
| ln(K/L) | -7.44 | (-22.90) | -7.23 | (-21.80) | -7.22 | (-21.82) | -23.80 | (-20.07) | -23.19 | (-19.14) | -23.37 | (-19.51) |
| MTB | 0.49 | (2.69) | 0.70 | (3.60) | 0.79 | (4.14) | 3.74 | (5.20) | 4.34 | (5.60) | 4.32 | (5.75) |
| RDS | -7.35 | (-8.70) | -6.26 | (-6.83) | -5.46 | (-6.89) | -20.50 | (-6.14) | -16.31 | (-4.32) | -14.45 | (-4.53) |
| Intercept | 58.67 | (13.90) | 43.51 | (10.31) | 44.96 | (11.14) | 157.04 | (11.37) | 111.09 | (8.32) | 110.86 | (8.34) |
| R-square | 0.25 | | 0.23 | | 0.23 | | 0.19 | | 0.18 | | 0.18 | |
| No. of Obs. | 15985 | | 14900 | | 15985 | | 15985 | | 14900 | | 15985 | |

| | **Panel C. IE = Patents/Employees** | | | | | | **Panel D. IE = Citations/Employees** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SA Index | | WW Index | | ln(Size) | | SA Index | | WW Index | | ln(Size) | |
| Variable | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value |
| FC | 6.56 | (17.35) | 18.67 | (8.34) | -0.76 | (-6.25) | 21.15 | (11.48) | 53.51 | (4.90) | -0.76 | (-1.30) |
| DE | -2.28 | (-5.84) | -2.61 | (-6.30) | -3.08 | (-7.38) | -10.13 | (-5.66) | -11.67 | (-6.24) | -12.51 | (-6.66) |
| IO | -0.10 | (-0.12) | -3.70 | (-4.78) | -4.66 | (-5.79) | 2.59 | (0.65) | -10.16 | (-2.59) | -20.21 | (-5.07) |
| ln(K/L) | 0.13 | (0.80) | 0.20 | (1.17) | 0.45 | (2.69) | 3.30 | (3.90) | 3.44 | (3.96) | 4.27 | (5.11) |
| MTB | 1.07 | (7.22) | 1.21 | (7.65) | 1.35 | (8.87) | 5.33 | (6.92) | 5.62 | (6.93) | 5.99 | (7.72) |
| RDS | 10.95 | (10.00) | 15.32 | (11.95) | 13.68 | (13.16) | 66.89 | (11.74) | 88.73 | (13.27) | 76.26 | (14.00) |
| Intercept | 26.91 | (11.67) | 11.35 | (4.89) | 9.59 | (4.32) | 51.75 | (4.09) | 1.70 | (0.14) | -11.70 | (-0.99) |
| R-square | 0.25 | | 0.21 | | 0.20 | | 0.22 | | 0.20 | | 0.20 | |
| No. of Obs. | 19569 | | 18302 | | 19569 | | 19569 | | 18302 | | 19569 | |

**Table 2B. Financial constraints and innovative efficiency — unadjusted IE measures**

This table reports the slopes and their *t*-statistics from panel regressions of firms' unadjusted innovative efficiency (IE) in year *t* from 1980-2004 on their financial constraints measures (FC), debt-to-equity ratio (DE), institutional ownership (IO), log of capital-to-labor ratio (ln(K/L)), market-to-book assets (MTB), and R&D-to-sales ratio (RDS) in year *t* – 1. All regressions control for industry fixed effects based on the Fama-French 48 industry classifications, year fixed effects, and industry-year fixed effects. All variables are winsorized at the 5% and 95% levels except the dummy variables. We compute *t*-statistics based on standard errors clustered by industry-year. We use four unadjusted IE measures: Patents/R&D, Citations/R&D, Patents/Employees, and Citations/Employees. We measure FC by the SA index (Hadlock and Pierce 2010), the WW index (Whited and Wu 2006), and ln(Size). All variables are defined in Table 1.

| | **Panel A. IE = Patents/R&D** | | | | | | **Panel B. IE = Citations/R&D** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SA Index | | WW Index | | ln(Size) | | SA Index | | WW Index | | ln(Size) | |
| Variable | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value |
| FC | 0.73 | (9.48) | 1.24 | (2.70) | -0.05 | (-2.30) | 10.78 | (9.32) | 17.20 | (2.48) | -0.44 | (-1.24) |
| DE | 0.06 | (0.82) | -0.01 | (-0.14) | -0.05 | (-0.69) | 1.36 | (1.18) | 0.02 | (0.02) | -0.37 | (-0.32) |
| IO | 0.25 | (2.51) | -0.40 | (-3.96) | -0.46 | (-4.53) | 6.29 | (3.58) | -3.18 | (-1.91) | -5.82 | (-3.57) |
| ln(K/L) | -1.01 | (-33.79) | -0.99 | (-33.55) | -0.97 | (-33.09) | -12.29 | (-17.11) | -12.11 | (-16.53) | -11.77 | (-16.52) |
| MTB | 0.06 | (2.78) | 0.09 | (4.25) | 0.09 | (4.27) | 1.82 | (4.94) | 2.31 | (6.08) | 2.28 | (5.95) |
| RDS | -0.32 | (-4.18) | -0.19 | (-3.10) | -0.20 | (-3.34) | -2.62 | (-2.36) | -0.52 | (-0.67) | -0.77 | (-0.92) |
| Intercept | 8.41 | (13.37) | 6.56 | (12.00) | 6.37 | (11.85) | 130.58 | (9.77) | 102.42 | (8.67) | 99.02 | (8.50) |
| R-square | 0.18 | | 0.16 | | 0.16 | | 0.12 | | 0.10 | | 0.10 | |
| No. of Obs. | 15894 | | 14830 | | 15894 | | 15894 | | 14830 | | 15894 | |

| | **Panel C. IE = Patents/Employees** | | | | | | **Panel D. IE = Citations/Employees** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SA Index | | WW Index | | ln(Size) | | SA Index | | WW Index | | ln(Size) | |
| Variable | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value |
| FC | 5.92 | (16.53) | 10.78 | (5.55) | -0.12 | (-1.07) | 93.70 | (12.80) | 214.52 | (5.52) | -0.21 | (-0.10) |
| DE | -1.58 | (-4.89) | -2.10 | (-5.72) | -2.34 | (-6.86) | -25.30 | (-4.13) | -34.56 | (-5.15) | -37.16 | (-5.87) |
| IO | 0.34 | (0.38) | -4.58 | (-5.33) | -6.92 | (-7.41) | 32.92 | (2.32) | -35.62 | (-2.63) | -90.01 | (-7.25) |
| ln(K/L) | 0.77 | (5.24) | 0.98 | (5.90) | 1.14 | (7.20) | 16.80 | (5.90) | 19.96 | (6.20) | 22.77 | (7.65) |
| MTB | 1.70 | (12.14) | 1.96 | (12.52) | 1.95 | (13.37) | 32.23 | (9.09) | 35.49 | (9.83) | 35.96 | (9.59) |
| RDS | 12.12 | (9.24) | 13.15 | (8.49) | 13.16 | (9.12) | 85.90 | (4.42) | 99.33 | (4.50) | 102.93 | (4.67) |
| Intercept | 27.79 | (7.13) | 8.19 | (1.17) | 6.96 | (1.77) | 409.44 | (6.43) | 160.25 | (1.13) | 68.56 | (1.14) |
| R-square | 0.20 | | 0.17 | | 0.17 | | 0.11 | | 0.09 | | 0.09 | |
| No. of Obs. | 19464 | | 18209 | | 19464 | | 19464 | | 18209 | | 19464 | |

**Table 2C. Financial constraints indices and innovative efficiency — robustness check**

This table reports the slopes and their corresponding *t*-statistics from panel regressions of firms' innovative efficiency (IE) in year *t* from 1980-2004 on their financial constraints measures (FC), Age, debt-to-equity ratio (DE), institutional ownership (IO), log of capital-to-labor ratio (ln(K/L)), log of one plus R&D-to-sales ratio (RDS), ln(Size), and market-to-book assets (MTB) in year $t-1$, as well as log of one plus RDS in year *t* (current RDS). We use four IE measures: Patents/R&D, Citations/R&D, Patents/Employees, and Citations/Employees. The IE measures are in logarithmic form. We measure FC by the residual SA index or the residual WW index from panel regressions of the SA index (Hadlock and Pierce 2010) or the WW index (Whited and Wu 2006) on ln(Size) and squared ln(Size). All variables are defined in Table 1. All regressions control for year fixed effects and industry fixed effects based on the Fama-French 48 industry classifications. All variables are winsorized at the 5% and 95% levels except the dummy variables. We compute *t*-statistics based on standard errors clustered at the firm level.

| | **Panel A. IE = ln(1+Patents/R&D)** | | | | **Panel B. IE = ln(1+Citations/R&D)** | | | |
|---|---|---|---|---|---|---|---|---|
| | Residual SA Index | | Residual WW Index | | Residual SA Index | | Residual WW Index | |
| Variable | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value |
| FC | 1.29 | (27.55) | 1.40 | (3.64) | 1.30 | (19.55) | 2.44 | (4.72) |
| Age | 0.07 | (24.84) | 0.03 | (10.63) | 0.07 | (17.09) | 0.03 | (7.43) |
| DE | 0.14 | (2.70) | 0.00 | (0.02) | 0.05 | (0.67) | -0.09 | (-1.22) |
| IO | -0.09 | (-1.20) | -0.31 | (-3.73) | -0.15 | (-1.46) | -0.32 | (-2.95) |
| ln(1+current RDS) | -0.92 | (-7.62) | -0.72 | (-5.34) | -0.97 | (-5.70) | -0.80 | (-4.31) |
| ln(K/L) | -0.17 | (-7.27) | -0.39 | (-16.53) | -0.20 | (-6.38) | -0.42 | (-13.95) |
| ln(1+RDS) | -0.36 | (-2.68) | -0.11 | (-0.71) | 0.09 | (0.49) | 0.39 | (1.91) |
| ln(Size) | -0.22 | (-18.49) | -0.11 | (-8.43) | -0.13 | (-7.87) | -0.02 | (-1.04) |
| MTB | 0.01 | (0.63) | 0.05 | (4.49) | 0.02 | (1.40) | 0.06 | (3.58) |
| Intercept | 1.64 | (9.41) | 2.84 | (10.62) | 0.23 | (1.03) | 1.42 | (5.16) |
| R-square | 0.45 | | 0.38 | | 0.33 | | 0.30 | |
| Number of Obs. | 15924 | | 14863 | | 15924 | | 14863 | |

| | **Panel C. IE = ln(1+Patents/Employees)** | | | | **Panel D. IE = ln(1+Citations/Employees)** | | | |
|---|---|---|---|---|---|---|---|---|
| | Residual SA Index | | Residual WW Index | | Residual SA Index | | Residual WW Index | |
| Variable | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value |
| FC | 1.49 | (38.09) | 3.17 | (9.60) | 1.55 | (25.27) | 5.16 | (10.36) |
| Age | 0.06 | (27.23) | 0.02 | (7.01) | 0.06 | (16.74) | 0.02 | (4.85) |
| DE | -0.20 | (-5.70) | -0.30 | (-7.58) | -0.31 | (-5.82) | -0.40 | (-7.09) |
| IO | -0.12 | (-1.85) | -0.32 | (-4.45) | -0.14 | (-1.45) | -0.29 | (-2.84) |
| ln(1+current RDS) | 0.68 | (5.15) | 1.03 | (7.23) | 0.33 | (1.47) | 0.60 | (2.52) |
| ln(K/L) | 0.32 | (17.13) | 0.08 | (4.31) | 0.36 | (12.64) | 0.12 | (4.25) |
| ln(1+RDS) | 0.38 | (2.60) | 0.83 | (4.92) | 1.11 | (4.54) | 1.68 | (6.22) |
| ln(Size) | -0.23 | (-22.11) | -0.11 | (-9.76) | -0.14 | (-9.16) | -0.02 | (-1.53) |
| MTB | 0.04 | (3.63) | 0.08 | (6.57) | 0.06 | (3.50) | 0.08 | (4.61) |
| Intercept | 0.21 | (0.80) | 1.38 | (4.42) | -1.92 | (-5.11) | -0.66 | (-1.54) |
| R-square | 0.40 | | 0.28 | | 0.28 | | 0.24 | |
| Number of Obs. | 19501 | | 18260 | | 19501 | | 18260 | |

**Table 3A. Effect of the junk bond market collapse on innovative efficiency — difference-in-differences tests**

This table reports the results from the difference-in-differences tests for the effect of the junk bond market collapse on firms' innovative efficiency (IE). The sample only includes below-investment-grade (BB+ or lower) and unrated firms in the annual Compustat database (excluding financial firms) during the period 1986-1993 and satisfying three additional criteria: i) unrated firms are always unrated throughout the entire 1986–1993 period, ii) below-investment-grade firms do not change status to or from investment grade during the period, and iii) each firm contains at least one observation both before and after 1989. We regress firms' IE in year *t* on a junk bond issuer dummy (Junk) that equals one if a firm is a junk bond issuer and zero otherwise, a post-collapse dummy (Post) that equals one if year *t* is in the period 1990-1993, an interaction term, Junk*Post, and other control variables in year $t - 1$. SP500 is a dummy variable that equals one if a firm is included in the S&P 500 index during 1986–1993 and zero otherwise. NYSE is a dummy variable that equals one if a firm is listed in NYSE and zero otherwise. Age is the natural log of one plus the number of years a firm is in Compustat with nonmissing pricing data. Cash flow (CF) is defined as income before extraordinary items minus accrual scaled by lagged total assets. IEG is the annual growth rate in IE. Altman's Z-score is a proxy of the likelihood of financial distress (Altman, 1968). The computation is detailed in Section 3.2. All models control for industry fixed effects and year fixed effects, where industry is based on the Fama-French 48 industry classifications. The other variables are defined in Table 1. All variables except the dummy variables are winsorized at the 5% and 95% levels. The *t*-statistics in parentheses are based on standard errors clustered at the firm level. # Obs is the total number of observations.

**Panel A. IE = Patents/R&D**

| Model | Post*Junk | Junk | Post | CF | DE | IEG | IO | Age | ln(K/L) | ln(Sales) | MTB | NYSE | RDS | SP500 | Z-Score | Intercept | $R^2$ | # Obs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.32 | -1.50 | 0.13 | -0.38 | 2.47 | | -2.00 | 2.41 | -0.91 | -3.01 | 0.51 | 2.99 | -21.27 | -2.49 | 0.40 | 17.68 | 0.29 | 2063 |
| | (1.96) | (-0.89) | (0.11) | (-0.13) | (1.70) | | (-0.94) | (3.91) | (-1.45) | (-10.16) | (1.53) | (2.15) | (-5.96) | (-1.45) | (1.17) | (4.45) | | |
| 2 | 4.54 | -1.02 | -0.03 | 0.45 | 2.89 | 0.13 | -2.42 | 2.37 | -0.66 | -3.17 | 0.60 | 3.17 | -23.27 | -2.27 | 0.38 | 17.51 | 0.30 | 1849 |
| | (1.80) | (-0.54) | (-0.02) | (0.13) | (1.82) | (1.41) | (-1.07) | (3.45) | (-0.95) | (-10.12) | (1.66) | (2.11) | (-5.67) | (-1.26) | (0.97) | (3.98) | | |

**Panel B. IE = Citations/R&D**

| Model | Post*Junk | Junk | Post | CF | DE | IEG | IO | Age | ln(K/L) | ln(Sales) | MTB | NYSE | RDS | SP500 | Z-Score | Intercept | $R^2$ | # Obs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 20.25 | -7.69 | -1.02 | 1.41 | 5.21 | | -3.37 | 7.04 | -3.23 | -8.60 | 3.06 | 8.33 | -64.00 | -5.03 | -0.61 | 52.98 | 0.24 | 2063 |
| | (2.71) | (-1.77) | (-0.26) | (0.13) | (1.22) | | (-0.49) | (3.76) | (-1.58) | (-9.30) | (3.07) | (2.04) | (-5.09) | (-0.86) | (-0.48) | (4.06) | | |
| 2 | 23.05 | -8.11 | -2.64 | 3.63 | 6.83 | 0.33 | -2.38 | 6.62 | -2.86 | -8.95 | 2.76 | 8.58 | -66.03 | -4.90 | -0.84 | 55.39 | 0.25 | 1841 |
| | (2.73) | (-1.76) | (-0.61) | (0.30) | (1.43) | (1.70) | (-0.33) | (3.25) | (-1.27) | (-9.35) | (2.59) | (1.94) | (-4.61) | (-0.80) | (-0.59) | (3.84) | | |

**Panel C. IE = Patents/Employees**

| Model | Post*Junk | Junk | Post | CF | DE | IEG | IO | Age | ln(K/L) | ln(Sales) | MTB | NYSE | RDS | SP500 | Z-Score | Intercept | $R^2$ | # Obs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.62 | 0.24 | -1.05 | -0.37 | -0.89 | | 0.68 | 0.18 | 1.31 | -1.86 | 0.49 | -0.05 | 0.15 | 1.02 | -0.04 | 11.79 | 0.41 | 2393 |
| | (1.72) | (0.47) | (-2.99) | (-0.24) | (-2.11) | | (0.88) | (0.89) | (6.12) | (-15.47) | (3.74) | (-0.14) | (0.08) | (1.99) | (-0.29) | (5.37) | | |
| 2 | 1.81 | 0.15 | -1.10 | -0.82 | -0.91 | 0.13 | 0.73 | 0.17 | 1.36 | -1.84 | 0.48 | -0.05 | 0.07 | 0.87 | -0.02 | 12.66 | 0.40 | 2182 |
| | (1.79) | (0.30) | (-2.71) | (-0.50) | (-2.07) | (2.02) | (0.89) | (0.75) | (5.87) | (-14.48) | (3.56) | (-0.14) | (0.03) | (1.67) | (-0.13) | (6.56) | | |

**Panel D. IE = Citations/Employees**

| Model | Post*Junk | Junk | Post | CF | DE | IEG | IO | Age | ln(K/L) | ln(Sales) | MTB | NYSE | RDS | SP500 | Z-Score | Intercept | $R^2$ | # Obs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8.11 | -1.83 | -5.19 | 1.39 | -2.03 | | 5.74 | 0.80 | 4.32 | -5.75 | 2.88 | -0.05 | 16.54 | 2.99 | -1.49 | 26.95 | 0.40 | 2393 |
| | (1.98) | (-0.81) | (-3.48) | (0.21) | (-1.26) | | (1.79) | (0.88) | (4.95) | (-11.43) | (5.32) | (-0.04) | (1.88) | (1.42) | (-2.19) | (4.43) | | |
| 2 | 9.19 | -2.68 | -5.38 | 1.07 | -2.07 | 0.07 | 6.92 | 0.58 | 4.75 | -5.82 | 2.47 | 0.24 | 20.17 | 2.71 | -1.42 | 26.80 | 0.39 | 2170 |
| | (2.10) | (-1.13) | (-3.22) | (0.15) | (-1.20) | (0.53) | (2.02) | (0.59) | (4.96) | (-10.73) | (4.47) | (0.18) | (2.01) | (1.25) | (-1.99) | (3.94) | | |

**Table 3B. Effect of the placebo crisis on innovative efficiency — difference-in-differences tests**

This table reports the results from the difference-in-differences tests for the effect of the placebo crisis on firms' innovative efficiency (IE). The sample only includes below-investment-grade (BB+ or lower) and unrated firms in the annual Compustat database (excluding financial firms) during the period 1996-2003 and satisfying three additional criteria: i) unrated firms are always unrated throughout the entire 1996-2003 period, ii) below-investment-grade firms do not change status to or from investment grade during the period, and iii) each firm contains at least one observation both before and after 1999. We regress firms' IE in year *t* on a junk bond issuer dummy (Junk) that equals one if a firm is a junk bond issuer and zero otherwise, a post placebo crisis dummy (Post) that equals one if year *t* is in the period 2000-2003, an interaction term, Junk*Post, and other control variables in year $t-1$. SP500 is a dummy variable that equals one if a firm is included in the S&P 500 index during 1996–2003 and zero otherwise. NYSE is a dummy variable that equals one if a firm is listed in NYSE and zero otherwise. Age is the natural log of one plus the number of years a firm is in Compustat with nonmissing pricing data. Cash flow (CF) is defined as income before extraordinary items minus accrual scaled by lagged total assets. IEG is the annual growth rate in IE. Altman's Z-score is a proxy of the likelihood of financial distress (Altman, 1968). The computation is detailed in Section 3.2. All models control for industry fixed effects and year fixed effects, where industry is based on the Fama-French 48 industry classifications. The other variables are defined in Table 1. All variables except the dummy variables are winsorized at the 5% and 95% levels. The *t*-statistics in parentheses are based on standard errors clustered at the firm level. # Obs is the total number of observations.

**Panel A. IE = Patents/R&D**

| Model | Post*Junk | Junk | Post | CF | DE | IEG | IO | Age | ln(K/L) | ln(Sales) | MTB | NYSE | RDS | SP500 | Z-Score | Intercept | $R^2$ | # Obs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -2.49 | 3.44 | -0.07 | 1.96 | 2.98 | | 1.06 | 1.23 | -1.62 | -1.71 | 0.01 | 1.34 | -1.00 | -0.23 | 0.24 | 16.89 | 0.34 | 3538 |
| | (-1.34) | (1.65) | (-0.12) | (3.02) | (2.89) | | (1.69) | (3.90) | (-6.65) | (-11.62) | (0.09) | (2.25) | (-5.67) | (-0.20) | (3.51) | (7.92) | | |
| 2 | -2.24 | 3.21 | 0.10 | 1.96 | 2.53 | 0.15 | 0.88 | 1.22 | -1.62 | -1.73 | 0.03 | 1.42 | -1.05 | -0.16 | 0.22 | 16.88 | 0.34 | 3210 |
| | (-1.11) | (1.40) | (0.15) | (2.74) | (2.33) | (2.75) | (1.32) | (3.49) | (-6.16) | (-11.10) | (0.31) | (2.27) | (-5.46) | (-0.13) | (2.99) | (7.37) | | |

**Panel B. IE = Citations/R&D**

| Model | Post*Junk | Junk | Post | CF | DE | IEG | IO | Age | ln(K/L) | ln(Sales) | MTB | NYSE | RDS | SP500 | Z-Score | Intercept | $R^2$ | # Obs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -11.41 | 17.11 | -3.08 | 9.42 | 6.76 | | 6.12 | 5.92 | -5.40 | -7.53 | 0.38 | 6.08 | -4.77 | 2.67 | 0.54 | 61.48 | 0.24 | 3538 |
| | (-0.97) | (1.38) | (-1.01) | (2.23) | (1.31) | | (1.77) | (3.38) | (-4.30) | (-9.32) | (0.97) | (1.94) | (-5.43) | (0.31) | (1.33) | (5.80) | | |
| 2 | -6.57 | 15.96 | -4.22 | 6.61 | 5.21 | 0.70 | 4.29 | 6.13 | -5.10 | -7.76 | 0.40 | 7.09 | -5.41 | 2.87 | 0.57 | 63.48 | 0.25 | 3007 |
| | (-0.50) | (1.15) | (-1.20) | (1.38) | (0.92) | (2.98) | (1.11) | (3.00) | (-3.55) | (-8.60) | (0.89) | (2.09) | (-5.36) | (0.33) | (1.21) | (5.23) | | |

**Panel C. IE = Patents/Employees**

| Model | Post*Junk | Junk | Post | CF | DE | IEG | IO | Age | ln(K/L) | ln(Sales) | MTB | NYSE | RDS | SP500 | Z-Score | Intercept | $R^2$ | # Obs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -0.71 | 0.71 | -1.41 | 1.83 | -0.66 | | 0.32 | 0.12 | 1.39 | -1.67 | 0.24 | -0.03 | -0.32 | 1.68 | -0.12 | 13.15 | 0.30 | 3860 |
| | (-0.95) | (0.63) | (-4.04) | (2.58) | (-1.23) | | (0.61) | (0.49) | (8.01) | (-14.40) | (3.52) | (-0.09) | (-1.79) | (1.70) | (-1.84) | (4.03) | | |
| 2 | -1.18 | 1.09 | -1.55 | 2.08 | -0.51 | 0.05 | 0.23 | -0.06 | 1.33 | -1.70 | 0.23 | -0.03 | -0.37 | 1.59 | -0.13 | 18.21 | 0.30 | 3506 |
| | (-1.55) | (0.91) | (-4.37) | (2.75) | (-0.88) | (1.07) | (0.41) | (-0.22) | (7.07) | (-13.94) | (3.23) | (-0.10) | (-1.92) | (1.61) | (-1.87) | (10.61) | | |

**Panel D. IE = Citations/Employees**

| Model | Post*Junk | Junk | Post | CF | DE | IEG | IO | Age | ln(K/L) | ln(Sales) | MTB | NYSE | RDS | SP500 | Z-Score | Intercept | $R^2$ | # Obs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -0.23 | 3.77 | -5.43 | 7.99 | -6.20 | | 3.80 | 0.60 | 8.34 | -7.93 | 1.56 | -0.70 | -0.99 | 8.68 | -0.71 | 59.85 | 0.19 | 3860 |
| | (-0.05) | (0.54) | (-1.95) | (1.34) | (-1.65) | | (1.03) | (0.34) | (7.22) | (-10.38) | (3.26) | (-0.31) | (-0.71) | (1.00) | (-1.22) | (2.62) | | |
| 2 | -2.03 | 6.65 | -8.95 | 9.81 | -7.21 | 0.63 | 2.27 | 0.26 | 8.55 | -8.20 | 1.28 | -0.28 | -0.94 | 8.16 | -0.83 | 95.03 | 0.20 | 3289 |
| | (-0.40) | (0.88) | (-3.06) | (1.48) | (-1.80) | (2.50) | (0.56) | (0.13) | (6.74) | (-9.88) | (2.42) | (-0.11) | (-0.62) | (0.97) | (-1.29) | (8.16) | | |

**Table 4. Interaction of the relation between financial constraints and innovative efficiency with excess cash holdings and investment opportunities**

This table reports the slopes and their corresponding *t*-statistics from panel regressions of firms' innovative efficiency (IE) in year *t* from 1980-2004 on their financial constraints proxy (FC), a dummy variable for agency problems (Agency, defined later), an interaction term (FC*Agency), debt-to-equity ratio (DE), institutional ownership (IO), log of capital-to-labor ratio (ln(K/L)), market-to-book assets (MTB), and R&D-to-sales ratio (RDS) in year $t-1$. We use four IE measures: Citations/R&D, Patents/R&D, Citations/Employee, and Patents/Employee. We use three FC proxies: the SA index (Hadlock and Pierce 2010), the WW index (Whited and Wu 2006), and ln(Size). The agency dummy variable is equal to one for firms with excess cash holdings above the $70^{th}$ percentile and MTB below the $30^{th}$ percentile of all sample firms in year $t-1$. Excess cash holdings is defined as the cash-to-assets ratio minus estimated normal cash-to-assets ratio following DeAngelo, DeAngelo, and Stulz (2010). Normal cash-to-assets ratio is calculated by sorting all sample firms in a given year into three equal size groups based on total book assets and three equal size groups based on the market-to-book assets. Each firm is then allocated to one of the nine groups based on its total book assets and market-to-book assets. Within each of the nine groups, a normal cash-to-assets ratio is calculated for each two-digit SIC industry as the median ratio among all firms in that industry for that year. All the other variables are defined in Table 1. All models control for year fixed effects and industry fixed effects based on the Fama-French 48 industries. All variables are winsorized at the 5% and 95% levels except the industry dummy variables. The *t*-statistics are based on standard errors clustered at the firm level.

| | Panel A. IE = Patents/R&D | | | | | | Panel B. IE = Citations/R&D | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SA Index | | WW Index | | ln(Size) | | SA Index | | WW Index | | ln(Size) | |
| Variable | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value |
| FC*Agency | 2.42 | (2.19) | 15.51 | (2.22) | -1.32 | (-3.30) | 8.55 | (2.29) | 52.43 | (2.25) | -4.57 | (-3.38) |
| Agency | 7.32 | (2.06) | 3.65 | (2.02) | 7.03 | (3.04) | 24.88 | (2.03) | 11.12 | (1.81) | 23.28 | (2.99) |
| FC | 6.01 | (8.92) | 12.46 | (3.09) | -0.75 | (-3.44) | 15.64 | (6.19) | 10.46 | (0.68) | 0.19 | (0.23) |
| DE | 1.35 | (1.43) | 0.70 | (0.70) | 0.31 | (0.32) | 3.35 | (0.99) | 1.30 | (0.37) | 0.65 | (0.19) |
| IO | 2.49 | (2.00) | -2.07 | (-1.66) | -1.39 | (-1.05) | 10.16 | (2.13) | -5.71 | (-1.21) | -9.97 | (-2.00) |
| ln(K/L) | -7.45 | (-22.93) | -7.24 | (-21.81) | -7.22 | (-21.89) | -23.81 | (-20.04) | -23.20 | (-19.09) | -23.35 | (-19.51) |
| MTB | 0.52 | (2.70) | 0.72 | (3.51) | 0.80 | (4.02) | 3.78 | (5.03) | 4.33 | (5.33) | 4.30 | (5.50) |
| RDS | -7.35 | (-8.69) | -6.24 | (-6.77) | -5.39 | (-6.77) | -20.42 | (-6.10) | -16.10 | (-4.25) | -14.11 | (-4.40) |
| Intercept | 58.10 | (13.69) | 43.25 | (10.22) | 44.29 | (10.90) | 155.11 | (11.16) | 110.26 | (8.26) | 108.59 | (8.12) |
| R-square | 0.25 | | 0.23 | | 0.23 | | 0.19 | | 0.18 | | 0.18 | |
| No. of Obs. | 15985 | | 14900 | | 15985 | | 15985 | | 14900 | | 15985 | |

| | Panel C. IE = Patents/Employees | | | | | | Panel D. IE = Citations/Employees | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SA Index | | WW Index | | ln(Size) | | SA Index | | WW Index | | ln(Size) | |
| Variable | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value |
| FC*Agency | 1.23 | (1.90) | 6.61 | (1.70) | -0.28 | (-1.33) | 5.58 | (1.81) | 33.45 | (1.83) | -1.55 | (-1.51) |
| Agency | 3.32 | (1.46) | 1.19 | (1.01) | 1.19 | (0.96) | 17.34 | (1.58) | 8.41 | (1.45) | 8.78 | (1.48) |
| FC | 6.48 | (16.92) | 18.34 | (8.14) | -0.74 | (-6.05) | 20.75 | (11.08) | 51.67 | (4.66) | -0.65 | (-1.11) |
| DE | -2.27 | (-5.83) | -2.60 | (-6.29) | -3.08 | (-7.39) | -9.96 | (-5.61) | -11.52 | (-6.19) | -12.39 | (-6.64) |
| IO | -0.13 | (-0.17) | -3.71 | (-4.80) | -4.67 | (-5.81) | 2.49 | (0.62) | -10.15 | (-2.59) | -20.22 | (-5.08) |
| ln(K/L) | 0.13 | (0.80) | 0.20 | (1.16) | 0.45 | (2.71) | 3.28 | (3.87) | 3.41 | (3.93) | 4.27 | (5.11) |
| MTB | 1.05 | (6.91) | 1.19 | (7.29) | 1.33 | (8.55) | 5.41 | (6.91) | 5.68 | (6.88) | 6.04 | (7.68) |
| RDS | 11.00 | (10.01) | 15.39 | (11.96) | 13.74 | (13.17) | 66.88 | (11.70) | 88.77 | (13.23) | 76.32 | (13.96) |
| Intercept | 26.68 | (11.51) | 11.29 | (4.85) | 9.50 | (4.28) | 50.24 | (3.94) | 1.03 | (0.09) | -12.51 | (-1.06) |
| R-square | 0.25 | | 0.21 | | 0.20 | | 0.22 | | 0.20 | | 0.20 | |
| No. of Obs. | 19569 | | 18302 | | 19569 | | 19569 | | 18302 | | 19569 | |

**Table 5A. Financial constraints and the marginal value of R&D investment — subsample regressions**

This table reports results from regressing firms' excess stock return in fiscal year $t$ on changes in firm characteristics over the fiscal year within the unconstrained and constrained subsamples, following Faulkender and Wang (2006). A stock's excess return in fiscal year $t$ is computed based on the difference between the stock's monthly return and the value-weighted monthly return of one of the 25 (5 by 5) size and book-to-market portfolios to which the stock belongs at the end of June of year $t-1$. All variables except $L_t$ and excess stock return are deflated by the lagged market value of equity. R&D ($RD_t$) is R&D expense. $C_t$ is cash plus marketable securities, $E_t$ is earnings before extraordinary items plus interest, deferred tax credits, and investment tax credits, and $NA_t$ is total assets minus cash holdings. $I_t$ is interest expense, total dividends ($D_t$) are measured as common dividends paid, $L_t$ is market leverage, and $NF_t$ is the total equity issuance minus repurchases plus debt issuance minus debt redemption. $\Delta X_t$ is compact notation for the 1-year change, $X_t - X_{t-1}$. The subscript $t-1$ means the value of the variable is at the end of fiscal year $t-1$. We use the SA index (Hadlock and Pierce 2010), the WW index (Whited and Wu 2006), and Size (market capitalization) in year $t-1$ to form the constrained and unconstrained subsamples. For the SA and WW indices, the constrained (unconstrained) subsample includes firms in the top (bottom) 30% in year $t-1$. For Size, the constrained (unconstrained) subsample includes firms in the bottom (top) 30% in year $t-1$. The $t$-statistics in parentheses are computed based on standard errors clustered at the firm level. The sample is from 1980-2008 for the SA index and Size, and from 1980 to 2006 for the WW index. All regressions control for year fixed effects and industry fixed effects based on the Fama-French 48 industry classifications. All independent variables are winsorized at the 5% and 95% levels. All variables are converted to real values in 2008 dollars using the consumer price index (CPI).

| | FC proxy | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SA index | | | | WW index | | | | ln(Size) | | | |
| | Unconstrained | | Constrained | | Unconstrained | | Constrained | | Unconstrained | | Constrained | |
| | Slope | *t*-stat | Slope | *t*-stat | Slope | *t*-stat | Slope | *t*-stat | Slope | *t*-stat | Slope | *t*-stat |
| $\Delta RD_t * C_{t-1}$ | -2.52 | (-2.03) | -1.15 | (-1.65) | -4.12 | (-2.70) | -1.73 | (-2.19) | -3.90 | (-2.26) | -1.40 | (-2.16) |
| $\Delta RD_t$ | 1.41 | (4.29) | 2.03 | (8.35) | 1.38 | (3.51) | 2.15 | (8.28) | 1.59 | (4.00) | 1.94 | (8.40) |
| $C_{t-1}$ | 0.28 | (12.70) | 0.46 | (20.42) | 0.28 | (10.24) | 0.42 | (16.83) | 0.34 | (12.24) | 0.31 | (15.52) |
| $\Delta C_t$ | 1.31 | (16.88) | 1.77 | (26.57) | 1.50 | (17.21) | 1.82 | (25.73) | 2.12 | (23.84) | 1.66 | (25.80) |
| $\Delta D_t$ | 6.70 | (6.42) | 17.98 | (6.83) | 6.92 | (6.14) | 13.54 | (4.77) | 5.01 | (4.50) | 18.32 | (8.70) |
| $\Delta E_t$ | 0.74 | (23.97) | 0.76 | (25.41) | 0.75 | (21.34) | 0.77 | (25.82) | 0.82 | (21.41) | 0.70 | (29.52) |
| $\Delta I_t$ | 0.11 | (3.59) | 0.26 | (6.45) | 0.12 | (3.50) | 0.13 | (3.31) | 0.13 | (3.20) | 0.10 | (3.52) |
| $\Delta NA_t$ | 0.15 | (7.99) | 0.28 | (12.86) | 0.19 | (8.84) | 0.31 | (14.15) | 0.23 | (9.34) | 0.26 | (16.20) |
| $\Delta C_t * C_{t-1}$ | -0.53 | (-2.85) | -1.25 | (-7.98) | -0.47 | (-1.97) | -1.27 | (-7.63) | -1.16 | (-4.72) | -1.18 | (-8.46) |
| $L_t$ | -0.41 | (-25.12) | -0.60 | (-31.16) | -0.39 | (-21.98) | -0.49 | (-23.69) | -0.42 | (-21.98) | -0.45 | (-27.09) |
| $\Delta C_t * L_t$ | -1.30 | (-8.16) | -1.26 | (-8.32) | -1.75 | (-9.12) | -1.34 | (-8.52) | -2.81 | (-14.40) | -1.09 | (-9.70) |
| $NF_t$ | -0.09 | (-3.07) | 0.19 | (6.08) | -0.15 | (-4.56) | 0.13 | (3.93) | -0.18 | (-4.77) | 0.03 | (0.97) |
| Intercept | 0.08 | (4.13) | -0.15 | (-5.58) | -0.16 | (-1.28) | -0.86 | (-23.38) | 0.08 | (4.22) | -0.10 | (-4.10) |
| $R^2$ | 0.20 | | 0.25 | | 0.20 | | 0.25 | | 0.19 | | 0.24 | |
| # Obs | 20577 | | 19570 | | 17354 | | 16804 | | 20589 | | 19580 | |

**Table 5B. Financial constraints and the marginal value of R&D investment**

This table reports results from regressing firms' excess stock return in fiscal year *t* on changes in firm characteristics over the fiscal year, following Faulkender and Wang (2006). A stock's excess return in fiscal year *t* is computed based on the difference between the stock's monthly return and the value-weighted monthly return of one of the 25 (5 by 5) size and book-to-market portfolios to which the stock belongs at the end of June of year $t - 1$. We use the SA index (Hadlock and Pierce 2010), the WW index (Whited and Wu 2006), and Size (market capitalization) in year $t - 1$ to define the dummy ($UC_t$) that equals 1 for unconstrained firms, and 0 for constrained firms. For the SA and WW indices, constrained (unconstrained) firms are in the top (bottom) 30% in year $t - 1$. Firms in the middle group are excluded from the regressions. For Size, constrained (unconstrained) firms are in the bottom (top) 30% in year $t - 1$. $L_t$, $RD_t$, $C_t$, $E_t$, $NA_t$, $I_t$, and $D_t$ have been defined in Table 5A. $\Delta X_t$ is compact notation for the 1-year change, $X_t - X_{t-1}$. The subscript $t - 1$ means the value of the variable is at the end of fiscal year $t - 1$. The *t*-statistics in parentheses are computed based on standard errors clustered at the firm level. The sample is from 1980-2008 for the SA index and Size, and from 1980 to 2006 for the WW index. All regressions control for year effect and industry effect based on the Fama-French 48 industry classifications. All independent variables are winsorized at the 5% and 95% levels. All variables are converted to real values in 2008 dollars using the consumer price index (CPI).

| | FC proxy | | | | | |
|---|---|---|---|---|---|---|
| | SA index | | WW index | | ln(Size) | |
| Variable | Slope | *t*-stat | Slope | *t*-stat | Slope | *t*-stat |
| $UC_t * \Delta RD_t$ | -0.90 | (-3.19) | -1.37 | (-4.25) | -0.74 | (-2.42) |
| $UC_t$ | 0.13 | (17.37) | 0.11 | (13.02) | 0.00 | (-0.20) |
| $\Delta RD_t$ | 1.78 | (10.66) | 1.79 | (10.15) | 1.57 | (10.07) |
| $C_{t-1}$ | 0.49 | (22.87) | 0.46 | (19.44) | 0.34 | (17.87) |
| $\Delta C_t$ | 1.25 | (32.00) | 1.24 | (29.78) | 1.04 | (30.14) |
| $\Delta D_t$ | 20.51 | (7.91) | 15.69 | (5.54) | 19.20 | (8.98) |
| $\Delta E_t$ | 0.77 | (25.68) | 0.78 | (26.12) | 0.72 | (30.23) |
| $\Delta I_t$ | 0.24 | (5.96) | 0.11 | (2.75) | 0.09 | (3.12) |
| $\Delta NA_t$ | 0.29 | (13.31) | 0.32 | (14.41) | 0.26 | (16.01) |
| $L_t$ | -0.55 | (-29.97) | -0.44 | (-23.38) | -0.43 | (-27.73) |
| $NF_t$ | 0.22 | (7.10) | 0.16 | (5.00) | 0.05 | (1.77) |
| $UC_t * C_{t-1}$ | -0.21 | (-6.99) | -0.18 | (-4.96) | -0.03 | (-0.90) |
| $UC_t * \Delta C_t$ | -0.53 | (-9.44) | -0.41 | (-6.32) | 0.11 | (1.75) |
| $UC_t * \Delta D_t$ | -14.75 | (-5.30) | -9.16 | (-3.02) | -15.15 | (-6.30) |
| $UC_t * \Delta E_t$ | -0.02 | (-0.46) | -0.02 | (-0.49) | 0.08 | (1.86) |
| $UC_t * \Delta I_t$ | -0.12 | (-2.37) | 0.03 | (0.61) | 0.02 | (0.39) |
| $UC_t * \Delta NA_t$ | -0.15 | (-5.38) | -0.14 | (-4.48) | -0.02 | (-0.81) |
| $UC_t * L_t$ | 0.11 | (4.66) | 0.02 | (0.84) | 0.00 | (-0.06) |
| $UC_t * NF_t$ | -0.30 | (-6.94) | -0.28 | (-6.08) | -0.19 | (-4.22) |
| Intercept | -0.10 | (-5.54) | -0.48 | (-2.40) | -0.02 | (-1.33) |
| $R^2$ | 0.22 | | 0.22 | | 0.21 | |
| # Obs | 40147 | | 34158 | | 40169 | |

**Table 6. Effect of financial constraints on innovative efficiency conditional on product market competition**

This table reports the slopes and their corresponding *t*-statistics from panel regressions of firms' innovative efficiency (IE) in year *t* from 1980-2004 on their financial constraints proxy (FC), debt-to-equity ratio (DE), institutional ownership (IO), log of capital-to-labor ratio (ln(K/L)), market-to-book assets (MTB), and R&D-to-sales ratio (RDS) in year $t-1$. We use four IE measures: Citations/R&D, Patents/R&D, Citations/Employee, and Patents/Employee. We use three FC proxies: the SA index (Hadlock and Pierce 2010), the WW index (Whited and Wu 2006), and ln(Size). The uncompetitive (competitive) subsample includes all firm-years that are in industries of bottom (top) 30% of one minus Herfindahl index of sales in year $t-1$. The pooled sample includes both uncompetitive and competitive subsamples. In pooled sample regressions, the main explanatory variable is Dummy(Uncompetitive)*FC, in which Dummy(Uncompetitive) equals one if the sample firm belongs to the uncompetitive subsample and zero otherwise. Dummy(Uncompetitive) is also included in pooled sample regressions. All the other variables are defined in Table 1. All models control for year fixed effects and industry fixed effects based on the Fama-French 48 industry classifications. All variables are winsorized at the 5% and 95% levels except the industry dummy variables.

| **Panel A. IE = Patents/R&D** | | | |
|---|---|---|---|
| | Uncompetitive subsample | Competitive subsample | Pooled sample |
| FC proxy | FC | FC | Dummy(Uncompetitive)*FC |
| SA index | 5.99 | 6.27 | 0.51 |
| | (4.97) | (6.98) | (0.44) |
| WW index | 25.48 | 18.27 | 10.40 |
| | (3.31) | (3.03) | (1.40) |
| ln(Size) | -1.27 | -0.78 | -0.67 |
| | (-3.28) | (-2.27) | (-1.69) |
| **Panel B. IE = Citations/R&D** | | | |
| | Uncompetitive subsample | Competitive subsample | Pooled sample |
| FC proxy | FC | FC | Dummy(Uncompetitive)*FC |
| SA index | 13.34 | 12.33 | 3.34 |
| | (3.00) | (3.37) | (0.76) |
| WW index | 46.10 | -7.54 | 50.25 |
| | (1.61) | (-0.32) | (1.75) |
| ln(Size) | -0.92 | 1.75 | -2.87 |
| | (-0.63) | (1.28) | (-1.91) |
| **Panel C. IE = Patents/Employees** | | | |
| | Uncompetitive subsample | Competitive subsample | Pooled sample |
| FC proxy | FC | FC | Dummy(Uncompetitive)*FC |
| SA index | 7.45 | 6.98 | 1.42 |
| | (11.16) | (12.36) | (2.00) |
| WW index | 30.42 | 20.46 | 12.71 |
| | (7.68) | (4.67) | (2.70) |
| ln(Size) | -1.26 | -0.48 | -0.82 |
| | (-6.18) | (-1.96) | (-3.29) |
| **Panel D. IE = Citations/Employees** | | | |
| | Uncompetitive subsample | Competitive subsample | Pooled sample |
| FC proxy | FC | FC | Dummy(Uncompetitive)*FC |
| SA index | 24.73 | 24.98 | 7.06 |
| | (6.99) | (7.95) | (1.91) |
| WW index | 101.52 | 52.79 | 74.10 |
| | (4.89) | (2.22) | (3.00) |
| ln(Size) | -2.61 | 1.18 | -4.39 |
| | (-2.54) | (0.83) | (-3.31) |

**Table 7A. Effect of the junk bond market collapse on innovative strategies — difference-in-differences tests**

This table reports the results from the difference-in-differences tests for the effect of the junk bond market collapse on firms' innovative strategies. We use two proxies of innovative strategies: the percentage of exploratory patents and the difference between the percentage of exploratory patents and the percentage of exploitative patents defined in Section 5. The sample only includes below-investment-grade (BB+ or lower) and unrated firms in the annual Compustat database (excluding financial firms) during the period 1986-1993 and satisfying three additional criteria: i) unrated firms are always unrated throughout the entire 1986–1993 period, ii) below-investment-grade firms do not change status to or from investment grade during the period, and iii) each firm contains at least one observation both before and after 1989. We regress firms' innovative strategies proxies in year *t* on a junk bond issuer dummy (Junk) that equals one if a firm is a junk bond issuer and zero otherwise, a post-collapse dummy (Post) that equals one if year *t* is in the period 1990-1993, an interaction term, Junk*Post, and other control variables in year $t-1$. SP500 is a dummy variable that equals one if a firm is included in the S&P 500 index during 1986–1993 and zero otherwise. NYSE is a dummy variable that equals one if a firm is listed in NYSE and zero otherwise. Age is the natural log of one plus the number of years a firm is in Compustat with nonmissing pricing data. Cash flow (CF) is defined as income before extraordinary items minus accrual scaled by lagged total assets. Dep. Growth is the growth in the dependent variable. All models control for industry fixed effects and year fixed effects, where industry is based on the Fama-French 48 industry classifications. Altman's Z-score is a proxy of the likelihood of financial distress (Altman, 1968). The computation is detailed in Section 3.2. The other variables are defined in Table 1. All variables except the dummy variables are winsorized at the 5% and 95% levels. The *t*-statistics in parentheses are based on standard errors clustered at the firm level. # Obs is the total number of observations.

**Panel A. Dependent variable = Percentage of exploratory patents**

| Model | Post*Junk | Post | Junk | CF | DE | Dep. Growth | IO | Age | ln(K/L) | ln(Sales) | MTB | NYSE | RDS | SP500 | Z-Score | Intercept | $R^2$ | # Obs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -0.08 | 0.15 | 0.10 | -0.13 | 0.03 | | -0.06 | 0.00 | 0.01 | 0.02 | -0.03 | 0.01 | 0.12 | 0.04 | 0.03 | 0.42 | 0.09 | 2278 |
| | (-1.97) | (4.30) | (2.94) | (-1.13) | (0.73) | | (-1.14) | (-0.22) | (0.75) | (1.85) | (-2.98) | (0.53) | (0.73) | (0.87) | (2.70) | (2.44) | | |
| 2 | -0.10 | 0.15 | 0.09 | -0.13 | 0.04 | 0.01 | -0.07 | 0.01 | 0.01 | 0.01 | -0.04 | 0.01 | 0.24 | 0.03 | 0.05 | 0.60 | 0.10 | 1542 |
| | (-2.19) | (3.15) | (2.32) | (-1.05) | (0.89) | (0.47) | (-1.11) | (0.29) | (0.74) | (1.42) | (-3.11) | (0.29) | (1.26) | (0.72) | (3.23) | (4.13) | | |

**Panel B. Dependent variable = Percentage of exploratory patents - Percentage of exploitative patents**

| Model | Post*Junk | Post | Junk | CF | DE | Dep. Growth | IO | Age | ln(K/L) | ln(Sales) | MTB | NYSE | RDS | SP500 | Z-Score | Intercept | $R^2$ | # Obs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | -0.14 | 0.27 | 0.16 | -0.27 | 0.08 | | -0.15 | 0.00 | 0.03 | 0.03 | -0.04 | 0.03 | 0.27 | 0.06 | 0.07 | -0.13 | 0.09 | 2278 |
| | (-1.74) | (4.48) | (2.62) | (-1.23) | (1.15) | | (-1.53) | (0.15) | (0.99) | (2.12) | (-2.44) | (0.66) | (0.90) | (0.78) | (2.78) | (-0.38) | | |
| 4 | -0.12 | 0.25 | 0.12 | -0.26 | 0.11 | 0.06 | -0.18 | 0.01 | 0.03 | 0.04 | -0.04 | 0.02 | 0.16 | 0.04 | 0.08 | 0.22 | 0.12 | 1549 |
| | (-1.44) | (3.00) | (1.55) | (-1.07) | (1.38) | (2.98) | (-1.54) | (0.29) | (0.79) | (2.32) | (-2.01) | (0.49) | (0.44) | (0.42) | (2.79) | (0.83) | | |

**Table 7B. Effect of the placebo crisis on innovative strategies — difference-in-differences tests**

This table reports the results from the difference-in-differences tests for the effect of the placebo crisis on firms' innovative strategies. We use two proxies of innovative strategies: the percentage of exploratory patents and the difference between the percentage of exploratory patents and the percentage of exploitative patents defined in Section 5. The sample only includes below-investment-grade (BB+ or lower) and unrated firms in the annual Compustat database (excluding financial firms) during the period 1996-2003 and satisfying three additional criteria: i) unrated firms are always unrated throughout the entire 1996–2003 period, ii) below-investment-grade firms do not change status to or from investment grade during the period, and iii) each firm contains at least one observation both before and after 1999. We regress firms' innovative strategies proxies in year *t* on a junk bond issuer dummy (Junk) that equals one if a firm is a junk bond issuer and zero otherwise, a post placebo crisis dummy (Post) that equals one if year *t* is in the period 2000-2003, an interaction term, Junk*Post, and other control variables in year $t-1$. SP500 is a dummy variable that equals one if a firm is included in the S&P 500 index during 1996–2003 and zero otherwise. NYSE is a dummy variable that equals one if a firm is listed in NYSE and zero otherwise. Age is the natural log of one plus the number of years a firm is in Compustat with nonmissing pricing data. Cash flow (CF) is defined as income before extraordinary items minus accrual scaled by lagged total assets. Dep. Growth is the growth in the dependent variable. All models control for industry fixed effects and year fixed effects, where industry is based on the Fama-French 48 industry classifications. Altman's Z-score is a proxy of the likelihood of financial distress (Altman, 1968). The computation is detailed in Section 3.2. The other variables are defined in Table 1. All variables except the dummy variables are winsorized at the 5% and 95% levels. The *t*-statistics in parentheses are based on standard errors clustered at the firm level. # Obs is the total number of observations.

**Panel A. Dependent variable = Percentage of exploratory patents**

| Model | Post*Junk | Post | Junk | CF | DE | Dep. Growth | IO | Age | ln(K/L) | ln(Sales) | MTB | NYSE | RDS | SP500 | Z-Score | Intercept | $R^2$ | # Obs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.04 | 0.11 | -0.09 | 0.06 | 0.05 | | -0.07 | 0.04 | -0.01 | 0.03 | -0.01 | -0.05 | -0.03 | -0.02 | 0.00 | 0.26 | 0.12 | 3389 |
| | (0.55) | (2.88) | (-1.49) | (1.14) | (1.17) | | (-1.87) | (2.23) | (-0.80) | (3.35) | (-1.61) | (-2.02) | (-2.13) | (-0.46) | (-0.21) | (1.70) | | |
| 2 | 0.00 | 0.14 | -0.04 | 0.07 | 0.09 | 0.06 | -0.04 | 0.04 | -0.01 | 0.02 | 0.00 | -0.06 | -0.03 | -0.04 | 0.00 | 0.13 | 0.15 | 2209 |
| | (-0.02) | (2.76) | (-0.66) | (1.06) | (1.83) | (3.97) | (-0.92) | (2.25) | (-0.74) | (2.60) | (-0.62) | (-1.81) | (-1.57) | (-0.75) | (-0.61) | (0.96) | | |

**Panel B. Dependent variable = Percentage of exploratory patents - Percentage of exploitative patents**

| Model | Post*Junk | Post | Junk | CF | DE | Dep. Growth | IO | Age | ln(K/L) | ln(Sales) | MTB | NYSE | RDS | SP500 | Z-Score | Intercept | $R^2$ | # Obs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.04 | 0.19 | -0.11 | 0.14 | 0.07 | | -0.14 | 0.07 | -0.03 | 0.06 | -0.02 | -0.09 | -0.05 | -0.05 | 0.00 | -0.45 | 0.13 | 3389 |
| | (0.28) | (2.68) | (-1.11) | (1.33) | (0.91) | | (-1.96) | (2.19) | (-1.21) | (3.80) | (-1.59) | (-1.98) | (-1.90) | (-0.56) | (-0.23) | (-1.55) | | |
| 2 | -0.22 | 0.23 | 0.16 | 0.19 | 0.10 | 0.05 | -0.15 | 0.09 | -0.04 | 0.06 | -0.01 | -0.12 | -0.05 | -0.11 | 0.00 | -0.60 | 0.17 | 2324 |
| | (-1.73) | (2.37) | (1.59) | (1.60) | (1.08) | (3.16) | (-1.87) | (2.38) | (-1.50) | (3.48) | (-1.13) | (-2.06) | (-1.45) | (-1.13) | (-0.46) | (-2.38) | | |

**Table 8. Innovative strategies and innovative efficiency**

This table reports the results from testing the effect of firms' innovative strategies on their innovative efficiency. We conduct panel regressions by regressing firms' innovative efficiency (IE) in year *t* from 1980-2004 on innovative strategies (Explore) in year *t*, debt-to-equity ratio (DE), institutional ownership (IO), log of capital-to-labor ratio (ln(K/L)), market-to-book assets (MTB), R&D-to-sales ratio (RDS) in year $t-1$, year fixed effects, and industry fixed effects, where industry is based on the Fama-French 48 industry classifications. We use four IE measures: Patents/R&D, Citations/R&D, Patents/Employees, and Citations/Employees, defined in Table 1. Innovative strategies are measured with the percentage of exploratory patents and the difference between the percentage of exploratory patents and the percentage of exploitative patents defined in Section 5. The other variables are defined in Table 1. All variables except the dummy variables are winsorized at the 5% and 95% levels. The *t*-statistics in parentheses are based on standard errors clustered at the firm level.

**Panel A. Explore = Percentage of exploratory patents**

| | Patents/R&D | | Citations/R&D | | Patents/Employees | | Citations/Employees | |
|---|---|---|---|---|---|---|---|---|
| Variable | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value |
| Explore | -3.50 | (-5.49) | -20.44 | (-8.44) | -4.77 | (-10.15) | -27.15 | (-10.38) |
| DE | 0.82 | (0.85) | -0.16 | (-0.05) | -2.95 | (-6.58) | -13.05 | (-6.20) |
| IO | -5.73 | (-4.80) | -9.36 | (-2.16) | -9.29 | (-11.76) | -31.03 | (-7.22) |
| ln(K/L) | -6.92 | (-21.64) | -22.07 | (-19.06) | 0.83 | (4.49) | 6.50 | (6.32) |
| MTB | 0.45 | (2.44) | 3.20 | (4.40) | 1.27 | (7.93) | 6.29 | (6.83) |
| RDS | -2.74 | (-5.85) | -11.05 | (-5.98) | 4.94 | (8.65) | 27.60 | (6.97) |
| Intercept | 52.43 | (19.89) | 143.27 | (17.49) | 12.59 | (1.70) | 3.39 | (0.15) |
| R-square | 0.23 | | 0.19 | | 0.19 | | 0.18 | |
| No. of Obs. | 14653 | | 14653 | | 17874 | | 17874 | |

**Panel B. Explore = Percentage of exploratory patents - Percentage of exploitative patents**

| | Patents/R&D | | Citations/R&D | | Patents/Employees | | Citations/Employees | |
|---|---|---|---|---|---|---|---|---|
| Variable | Estimate | t-value | Estimate | t-value | Estimate | t-value | Estimate | t-value |
| Explore | -1.91 | (-5.58) | -11.02 | (-8.41) | -2.62 | (-10.02) | -14.74 | (-9.98) |
| DE | 0.81 | (0.84) | -0.22 | (-0.07) | -2.97 | (-6.62) | -13.14 | (-6.24) |
| IO | -5.72 | (-4.79) | -9.30 | (-2.15) | -9.30 | (-11.76) | -31.02 | (-7.22) |
| ln(K/L) | -6.92 | (-21.64) | -22.08 | (-19.05) | 0.83 | (4.47) | 6.48 | (6.29) |
| MTB | 0.45 | (2.43) | 3.19 | (4.39) | 1.27 | (7.93) | 6.28 | (6.81) |
| RDS | -2.77 | (-5.91) | -11.20 | (-6.05) | 4.89 | (8.59) | 27.37 | (6.92) |
| Intercept | 50.91 | (20.00) | 134.19 | (17.12) | 10.32 | (1.40) | -9.60 | (-0.41) |
| R-square | 0.23 | | 0.19 | | 0.19 | | 0.18 | |
| No. of Obs. | 14653 | | 14653 | | 17874 | | 17874 | |

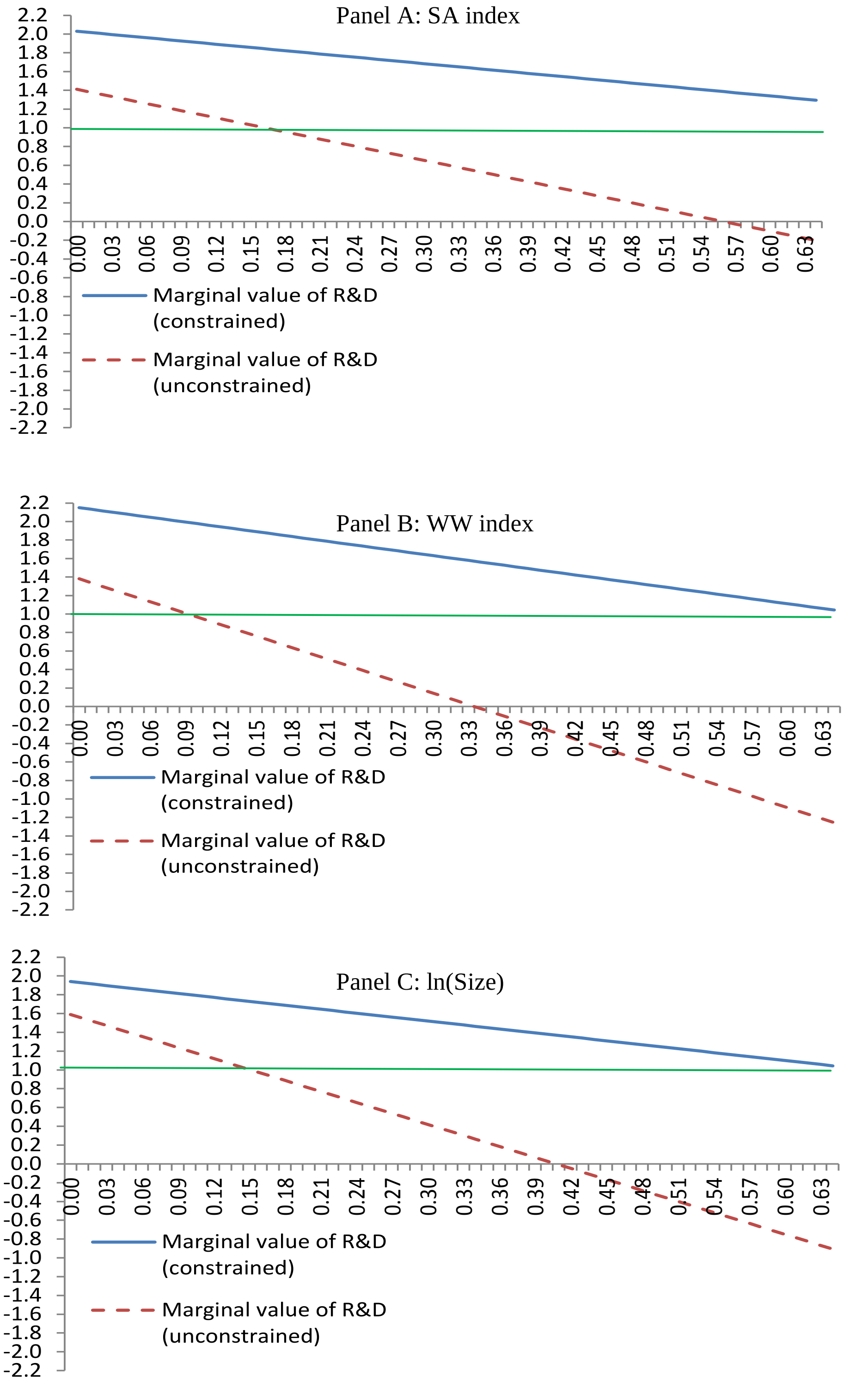


**Figure 1. Variation of the marginal value of R&D investment with cash holdings**

The vertical axis denotes the marginal value of an R&D dollar, defined as the slope of $\Delta RD_t$ plus the slope of $\Delta RD_t * C_{t-1}$ times the value of $C_{t-1}$, while the horizontal axis denotes the cash holdings scaled by market value, ranging from 0.00 (minimum) to 0.64 (maximum). Panels A, B, and C are based on the SA index, the WW index, and ln(Size), respectively.