Financial Constraints, R&D Investment, and Stock Returns: Theory and Evidence

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Abstract

This paper uses R&D data to examine the link between asset prices and financing constraints. Through a real-options model I show that there is a strong positive relation between financing constraints and stock returns but only for high-R&D firms. Conversely, the model also predicts a strong positive relation between R&D and returns for highly constrained firms. Empirical data confirms these predictions. These findings not only explain the puzzling flat relation between financial constraints and stock returns documented in the literature, but also shed light on the economic source of the predictability of R&D investments on stock returns.

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1 Introduction

This paper uses data on research and development (R&D) expenditures by firms to examine the impact of firms' financing constraints on stock returns. As is well known, the presence of information asymmetries or agency problems may create frictions preventing firms from making all desired investments. Moreover, since these financing constraints are often tighter when macroeconomic conditions are adverse, it is likely that the output and the value of financially constrained firms will covary more closely with the macroeconomic environment. Intuitively then we would expect more constrained firms to be more risky and to exhibit higher expected returns. However, existing empirical studies have failed to produce consistent evidence to this effect.[1]

Using R&D data allows me to shed new light on this question. This is because financing frictions play an important role in R&D investment decisions, especially for young and small firms. The technical complexity and the high uncertainty of R&D investments significantly raises the cost of external funds.[2] Moreover these firms often lack positive cash flows and usually require large amounts of funds to finance R&D projects which usually take many years to complete.[3]

To understand the impact of financing constraints on R&D and asset returns I develop a real-options model along the lines of Berk, Green, and Naik (2004). This approach is important because irreversibility and the possibility of delay are very important characteristics of R&D investments that typically involve separate stages of development. Therefore an R&D project can be viewed as a series of compound options on the underlying cash flows, where the strike price is the expected future investment required to complete the project. Another

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[1] For example, Lamont, Polk, and Saá-Requejo (2001), Campello and Chen (2005), Gomes, Yaron, and Zhang (2006), and Whited and Wu (2006).

[2] See, e.g., Hall (1992, 2002), Carpenter et al. (2002), Himmelberg and Petersen (1994), and Metrick (2006).

[3] For example, according to DiMasi (2003), it costs over $800 million and takes 10 to 15 years (on average) to bring a new drug to the market. In addition, the required R&D investment is mainly determined by scientific reasons, hence very inflexible. R&D firms either invest the required amount or have to suspend the project if they cannot finance it.

essential feature of R&D investments is the extreme uncertainty in outcomes, which makes the options approach even more important. In this context, whether a firm can raise enough funds to continue the R&D project is also critical for resolving the uncertainty, which affects the probability of a successful and timely completion, and hence the value and the risk of the option on the underlying cash flows. As a result the model predicts a strong positive relation between financing constraints and stock returns among high-R&D firms, but a rather flat relation for low-R&D firms. Conversely, it also predicts a strong positive relation between R&D investments and returns for financially constrained firms.

The empirical results confirm these predictions. Using the KZ index derived from Kaplan and Zingales (1997) as a measure of financial constraints and three different measures of R&D intensity, I find that among high-R&D firms, the difference in equal-weighted excess returns between most constrained firms and least constrained firms can be as high as 62 basis points per month. When the WW index derived from Whited and Wu (2006) is used to measure financial constraints, the monthly difference in excess returns is as high as 117 basis points among R&D-intensive firms. These large differences are present even after I control for the standard risk factors in the literature. Financial constraints seem unrelated to stock returns among low-R&D firms, a finding that is consistent with the model as well as other existing literature.

Similarly, the strength of the relation between R&D and returns increases with financial constraints. In fact, there is no significant relation between R&D and stock returns among less-constrained firms measured by the WW index for two of the three R&D measures. However, within the most constrained segment, the difference in monthly excess returns between high- and low-R&D firms is as large as 70 basis points. For the third measure, the difference increases from 39 basis points for least-constrained firms to 153 basis points for most-constrained firms. Standard risk adjustments cannot explain these differences. When the KZ index is used, the positive R&D-return relation only exists in constrained firms for one R&D measure. For the other two measures, this relation is also much stronger among most-constrained firms. For example, the monthly return spread between high- and low-R&D firms can increase from 54 basis points among the least-constrained firms to 99 basis points among the most-constrained firms.

This paper contributes to two strands of literature in finance. First, it helps explain the existing puzzling evidence on the asset pricing implication of financial constraints. Several authors have found that either financing constraints do not explain cross-sectional variation in expected returns or the risk premium of the constraints factor is insignificant. The findings in this paper suggest that those studies fail to find the intuitive result because the relation among financing constraints, investment, and stock returns for non-R&D firms is not as strong as in R&D ventures. By establishing the importance of financing constraints for R&D ventures' investment decision and their value and risk, this paper provides a strong connection between real activities and financial variables, in other words, linking corporate finance and asset pricing.[4]

Second, the findings suggest that the economic source for the predictability of R&D investment on stock returns is related to financing constraints. Several studies document a positive relation between R&D intensity and subsequent stock returns.[5] However the underlying force driving this predictability is not clear. This paper shows that the positive R&D-returns relation is much stronger among financially constrained firms, and in many cases, only exists in the most-constrained firms. Therefore, a large portion of the predictability of R&D investment can be attributed to financing constraints.

The results are also related to the macroeconomic effect of financing constraints. Both theoretical and empirical work in macroeconomics show that the real activities of financially constrained firms are more sensitive to macroeconomic shocks, suggesting that financing constraints matter for stock returns.[6] This paper provides supporting evidence at the firm

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[4] Papers in this general effort include, among others, Cochrane (1991, 1996), Berk (1995), Berk et al. (1999), Gomes, Kogan, and Zhang (2003), Carlson, Fisher, and Giammarino (2004, 2006), Kogan (2004), Pastor and Veronesi (2005), Zhang (2005), Cooper (2006), and Gala (2006), and Livdan et al. (2006).

[5] For example, Chan et al. (1990), Lev and Sougiannis (1996, 1999), Chan, Lakonishok, and Sougiannis (2001), Eberhart, Maxwell, and Siddique (2004), and Chambers, Jennings, and Thompson (2002).

[6] For example, Bernanke and Gertler (1989), Gertler and Gilchrist (1994), Bernanke, Gertler, and Gilchrist

level.

The paper proceeds as follows. Section 2 describes the model and its predictions. Section 3 discusses the empirical testing results. Section 4 concludes.

2 The Model

2.1 Overview

A firm working in continuous time consists of a single multistage R&D project, which generates a stream of stochastic cash flows y_t after the firm successfully completes N discrete stages. We assume the manager can observe the future cash flows were the project completed today. Accordingly, he makes optimal investment decisions by maximizing the firm's value subject to financial constraints. Therefore the systematic risk associated with future cash flows is transferred to the investment decisions. Note that the firm's decision in this model is a binary variable, i.e., whether to continue or suspend the project. The level of investment is not a choice variable as the investment requirement is very inflexible due to the scientific nature of R&D.

At time t, let $n(t)$ be the number of stages the firm has successfully completed. The firm needs to decide whether to continue investing by comparing the investment cost, $x(n(t))$, over the next instant with the potential benefit, which depends on the exogenous success intensity $\pi(n(t))$ and on the jump in the firm value if it successfully completes the next stage. For simplicity, we write $\pi(n(t))$ as $\pi(n)$, and $x(n(t))$ as $x(n)$ hereafter. $x(n)$ are assumed to be positively correlated with $x(n+1)$.

In addition, since the firm does not have cash flows before the project is completed, the investment decision also depends on its external financing constraints. If it cannot raise enough funds to finance R&D investment, $x(n)$, it has to suspend the project even if the benefit of investing exceeds the cost.

(1996), and Bernanke et al. (1999).

To model the effect of financing frictions caused by either hidden information, as in Myers and Majluf (1984) and Greenwald, Stiglitz, and Weiss (1984), or agency problems, as in Jensen and Meckling (1976), Grossman and Hart (1982), and Hart and Moore (1995), I assume only a fraction of the expected change in firm value conditional on investing can be pledged as the "collateral" for external financing purpose. This is a parsimonious way to model costly external finance as the focus here is not to identify the source of capital market imperfections, but rather to understand the effect of financing constraints on R&D investment and on firms' value and risk.

As discussed before, the technical complexity, high uncertainty, and long horizon associated with R&D and firms' reluctancy to fully reveal inside information due to strategic reasons may aggravate the information asymmetry problem for R&D-intensive firms. Therefore only a fraction of the expected change in firm value can be used for raising external funds. Ceteris paribus, the fraction is lower for firms with more complex and risky technology. On the other hand, the amount of funds a firm can raise also depends on the expected change in firm value. The product of these two jointly determines the upper bound of the external funds a firm can raise.

2.2 Valuation

The firm value, at any time t, is the result of the manager's optimal investment decision based on the financial constraints, the number of completed stages n, and the observed future cash flow $y(t)$, which follows a geometric Brownian motion

$$dy(t) = \widehat{\mu} y(t)dt + \sigma y(t)d\widehat{w}(t).$$

The pricing kernel in this economy is taken as exogenous and given by the process

$$dm(t) = -rm(t)dt + \theta m(t)d\widehat{z}(t),$$

where r is the constant risk free rate. The systematic risk of the cash flows results from the correlation ρ between the two Brownian motion processes $\widehat{w}(t)$ and $\widehat{z}(t)$. Accordingly, the market price of risk for future cash flow $y(t)$ is computed as the covariance between the innovation of future cash flow and the innovation of the pricing kernel:

$$\lambda = \sigma\theta\rho.$$

Hence, under the risk neutral measure, the drift term of $y(t)$ is adjusted by the market price of risk, and the cash flow process is given by

$$dy(t) = \mu y(t)dt + \sigma y(t)dw(t),$$

where $\mu = \widehat{\mu} - \lambda$, and $w(t)$ is a Brownian motion under the risk-neutral measure. We assume $\mu < r$ to ensure a finite firm value.

After successfully completing N stages, the firm completes the R&D project and does not need to make investment decisions anymore. It receives a random stream of cash flows, therefore, its value is trivially given by the continuous-time version of the Gordon-Williams growth model with a discount rate reflecting the risk of obsolescence and a risk-adjusted growth rate:[7]

$$V(y(t), N(t)) = \frac{y(t)}{r - \mu}.$$

For simplicity, we write $V(y, n(t))$ as $V(y, n)$ hereafter.

Under the risk neutral measure, at any t before the project is completed, such that $y(t) = y$, the firm's value is the maximum of the following Bellman equation subject to the

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[7] To reflect the risk of obsolescence, r can be set to a number higher than the risk free rate.

financing constraint:

$$rV(y,n) = \max_{v\in\{0,1\}} -vx(n) + \frac{1}{dt}E_t[dV] \tag{1}$$

$$s.t.\ p(n)\frac{1}{dt}E_t[dV] \geq x(n), \tag{2}$$

where v is the control variable, which equals 1 if the firm continues investing over the next instant, and 0 otherwise. If the firm continues investing, it incurs an instantaneous cost $x(n)$. Equation (2) indicates that the firm can invest only if it can raise enough funds to finance the required investment $x(n)$.

The amount of external funds the firm can raise is modeled as the product of the firm's financing ability, $p(n)$, and the expected change in firm value, $\frac{1}{dt}E_t[dV]$. p can be interpreted as the amount of funds a firm can raise per dollar change in firm value. Assuming no irrationality of the investors, p cannot exceed 1. It is trivial when p equals 1 since from the Bellman equation at $v = 1$, we have $\frac{1}{dt}E_t[dV] = rV + x$. Therefore the financial constraints are always satisfied. If p equals 0, then the firm is never able to finance the R&D externally. In that case, there is no market for R&D projects at all. This is the most extreme version of the lemons model as in Akerlof (1970). As a result I assume p lies between 0 and 1. Many factors can affect a firm's financing ability, p, such as information asymmetry, market liquidity, or even investors' tastes. I assume $p(n)$ is positively correlated with $p(n-1)$.[8]

From equation (1) we can see that the expected change in firm value is equal to $rV(y,n)+vx(n)$, which increases with future cash flow y. Therefore the external funds a firm can raise is positively related to its financing ability, p, and its future cash flow, y.

Applying Ito's lemma to the value function V in equation (1) and taking expectations

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[8] In the numerical examples, for simplicity, p is assumed to be constant over different stages for the same firm.

provides us with the Hamilton-Jacobi-Bellman (HJB) equation:

$$rV(y,n) = \frac{1}{2}\sigma^2 y^2 \frac{\partial^2}{\partial y^2} V(y,n) + \mu y \frac{\partial}{\partial y} V(y,n) + \max_{v\in\{0,1\}} v\{\pi(n)[V(y,n+1) - V(y,n)] - x(n)\}.$$

The intuition of the HJB equation is that the required return per unit of time for holding the firm, $rV(y,n)$, should equal the sum of the expected rate of capital gain (the first two terms on the right-hand side plus the expected jump in the firm's value, $v\pi(n)[V(y,n+1)-V(y,n)]$) and the immediate payoff, $-vx(n)$, which is the negative investment cost over the next instant.

The term in the curly brackets captures the cost-benefit analysis or fundamentals regarding new R&D investment. With probability $\pi(n)$ over the next instant, the firm will complete the current stage, and its value will jump to $V(y,n+1)$. Therefore the benefit of investing is the expected jump in firm value due to the investment.

In a perfect capital market, the firm only needs to conduct the cost-benefit analysis to determine whether to invest or not. However, due to financial frictions, the firm may not be able to raise enough funds to finance all desired investments. Therefore in this model the firm invests only if the cost benefit analysis warrants the investment *and* the financing constraints are satisfied.

2.3 Solution

The firm value needs to satisfy $V(0,n) = 0$ and $\lim_{y\to\infty} \frac{V(y,n)}{y} < \infty$. The first condition derives from the assumption that future cash flow $y(t)$ follows a geometric Brownian motion. Since $y(t)$ stays at zero forever if it ever reaches zero, the firm value at $y(t) = 0$ has to be 0. The second condition ensures the firm value increases in proportion to future cash flow to prevent bubbles.

For $n < N$, under certain technical conditions, there exists a threshold, $y^*(n)$, such that the firm continues investing if future cash flow, $y(t)$, exceeds it and suspends the project otherwise.[9] I refer to the former as the continuation region and the latter as the mothball region. The firm values in the two regions are denoted by $V^c(y,n)$ and $V^m(y,n)$, respectively.

In the mothball region ($v = 0$), the HJB equation reduces to a homogenous ordinary differential equation (ODE) with a standard solution given by

$$V^m(y,n) = D(n)y^{\beta} \qquad y < y^*(n), \tag{3}$$

where β satisfies

$$\beta = \frac{(\sigma^2 - 2\mu) + \sqrt{8\sigma^2 r + (2\mu - \sigma^2)^2}}{2\sigma^2} > 1, \tag{4}$$

and the constant $D(n)$ is determined by the boundary conditions below.

The firm in the mothball region holds an option to invest, where the strike price of the option is the expected investment cost to complete the project and the underlying asset is the value of future cash flow. Therefore the firm value increases nonlinearly as future cash flow increases. This provides the intuition for the positive root of β in the firm value, $V^m(y,n)$.

In the continuation region ($v = 1$), the firm value can be solved backwards starting from $n = N-1$ and takes the form

$$V^c(y,n) = \sum_{i=n}^{N-1} C(i,n)y^{\gamma(i)} + B(n)y + A(n) \qquad y \geq y^*(n), \tag{5}$$

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[9] According to Dixit and Pindyck (1994), two conditions need to be satisfied for this property. First, the difference between the benefit from continuing and the profit flow from suspension, which is zero in this case, increases with future cash flow. This is satisfied since the benefit from continuing is the expected value of future cash flow minus the expected investment cost. Second, this advantage from continuing will not reverse in the near term. Since future cash flow is a brownian motion and exhibits positive serial correlation, this condition is satisfied in this model.

where,

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\begin{aligned}
C(i,n) &= \begin{cases} 0 & i = N \\ \frac{\pi(n)C(i,n+1)}{\pi(n)-\pi(i)} & n < i < N \end{cases} \\
\gamma(n) &= \frac{(\sigma^2 - 2\mu) - \sqrt{8\sigma^2(r+\pi(n)) + (2\mu - \sigma^2)^2}}{2\sigma^2} < 0 \\
B(n) &= \frac{\pi(n)B(n+1)}{r+\pi(n)-\mu} > 0 \text{ with } B(N) = \frac{1}{r-\mu} \\
A(n) &= \frac{\pi(n)A(n+1) - x(n)}{r+\pi(n)} < 0 \text{ with } A(N) = 0.
\end{aligned}
$$

The nonlinear terms in the firm value, $V^c(y,n)$, reflect the combined effects of financial constraints and the option to suspend. Because R&D investment typically involves multiple stages, the manager makes investment decision sequentially and can choose to suspend the project in unfavorable situations. This option to suspend is very valuable to the firm due to the high uncertainty of R&D. However, as future cash flow increases, it becomes less likely that the firm needs to suspend the project. Therefore the value of the option to suspend decreases. In addition, the negative effect of financing constraints also decreases since the financing capacity increases with future cash flow. This explains why $\gamma_i < 0$ in the value function, $V^c(y,n)$.

The linear terms in the firm value, $B(n)y + A(n)$, reflects the discounted value of future cash flow ($B(n)y$) and the effect of the investment cost ($A(n)$). They increase with future cash flow y and decrease with the investment cost x.

To determine the threshold $y^*(n)$, the constants $D(n)$ and $C(n,n)$, and the firm value, we need the following boundary conditions:

$$V^c(y^*(n), n) = V^m(y^*(n), n) \tag{6}$$

$$\frac{\partial}{\partial y} V^c(y^*(n), n) = \frac{\partial}{\partial y} V^m(y^*(n), n) \tag{7}$$

$$\pi(n)[V(y^*_{CB}(n), n+1) - V(y^*_{CB}(n), n)] = x(n) \tag{8}$$

$$p(n)\frac{1}{dt} E_t[dV(y^*_{FC}(n), n)] = x(n). \tag{9}$$

Equation (6) is the familiar value matching (VM) condition by continuity of the value function, and equation (7) is the smooth pasting (SP) condition to ensure that the slopes of the two value functions match at the threshold $y^*(n)$. Equation (8) is the cost-benefit (CB) condition, where the threshold, $y^*_{CB}(n)$, is derived from the first three boundary conditions. The financial constraints (FC) condition is stated in equation (9), where the threshold, $y^*_{FC}(n)$, is derived from equations (6), (7), and (9).

Without financing constraints, the threshold, $y^*(n)$, is derived from the first three conditions, therefore, equal to $y^*_{CB}(n)$. The firm will invest as long as the benefit exceeds the cost of investment. However, in an imperfect capital market, the firm also needs to ensure that its financing capacity exceeds the required investment. Hence the threshold $y^*(n) = \max(y^*_{CB}(n), y^*_{FC}(n))$.

For firms with low financing ability, p, it is more likely that $y^*_{FC}(n) > y^*_{CB}(n)$. These firms' investment decisions are mainly determined by their financing constraints. For firms with high financing ability, the fundamentals play a more important role in determining investment decisions. We discuss the solutions for the two scenarios next.

2.3.1 Valuation of Highly Constrained Firms

I refer to firms with $y^*_{FC}(n) > y^*_{CB}(n)$ as highly constrained firms because they tend to have more external financing difficulties (low $p(n)$), given the level of future cash flow, y, and the investment requirement, $x(n)$. From the Bellman equation at $v = 1$, we have

$\frac{1}{dt}E_t[dV] = rV + x$. Combining this with equation (9) gives us $\frac{p(n)r}{1-p(n)}V(y^*_{FC}) = x(n)$. Therefore the threshold, y^*_{FC}, decreases with $p(n)$ since the firm value V increases with cash flow. For these firms, financial constraints play a more important role than the fundamentals since the latter is automatically satisfied if the financial constraint is met. The following proposition characterizes the threshold and the constants needed to compute the value of these firms.

Proposition 1 *For $n < N$, if $y^*_{FC}(n) > y^*_{CB}(n)$, then $y^*(n) = \max(y^*_{FC}(n), y^*_{CB}(n)) = y^*_{FC}(n)$ and solves the following equation*

$$\begin{aligned}
&\left[\sum_{i=n+1}^{N-1} C(i,n)(\gamma(i)-\gamma(n))(y^*(n))^{\gamma(i)}\right] + B(n)y^*(n)(1-\gamma(n)) - A(n)\gamma(n) \\
&= (\beta - \gamma(n))\frac{x(n)}{k(n)}, \\
\textit{where} \quad & k(n) \equiv \frac{p(n)r}{1-p(n)}.
\end{aligned}$$

The constants $D(n)$ and $C(n,n)$ in equations (3) and (5) are given by

$$\begin{aligned}
C(n,n) &= (\gamma(n)-\beta)^{-1}(y^*(n))^{-\gamma(n)}[\sum_{i=n+1}^{N-1} C(i,n)(\beta-\gamma(i))(y^*(n))^{\gamma(i)} \\
&\quad + B(n)y^*(n)(\beta-1) + \beta A(n)] \\
D(n) &= \frac{x(n)}{k(n)}(y^*(n))^{-\beta}.
\end{aligned}$$

In the continuation region, the nonlinear term, $C(n,n)y^{\gamma(n)}$, reflects the negative effect of current financial constraints on the firm value.

2.3.2 Valuation of Less Constrained Firms

I refer to firms with $y^*_{FC}(n) < y^*_{CB}(n)$ as less constrained firms because they tend to have high financing ability, $p(n)$. These firms typically have no trouble financing the desired investments. The following proposition states the solutions for these firms.

Proposition 2 *For $n < N$, if $y^*_{FC}(n) < y^*_{CB}(n)$, the threshold $y^*(n) = y^*_{CB}(n)$ and satisfies* *the following equation*

$$\sum_{i=n+1}^{N-1}[\gamma(i)\pi(n)-\gamma(n)\pi(i)+\beta(\pi(i)-\pi(n))]C(i,n)(y^*(n))^{\gamma(i)} = \\ B(n)y^*(n)\left[(r-\mu)(\beta-\gamma(n))+(\beta-1)\pi(n)\right]+A(n)\left(\beta\pi_n+r(\beta-\gamma(n))\right),$$

The constants $D(n)$ and $C(n,n)$ in equations (3) and (5) are given by

$$C(n,n)=\frac{(y^*(n))^{-\gamma(n)}}{\pi(n)}\left[(r-\mu)B(n)y^*(n)+rA(n)-\sum_{i=n+1}^{N-1}\pi(i)C(i,n)(y^*(n))^{\gamma(i)}\right]$$

$$D(n)=\frac{(y^*(n))^{-\beta}}{\beta\pi(n)}\{(\pi(n)+(r-\mu)\gamma(n))B(n)y^*(n)+r\gamma(n)A(n) \\ +\sum_{i=n+1}^{N-1}(\gamma(i)\pi(n)-\gamma(n)\pi(i))C(i,n)(y^*(n))^{\gamma(i)}\}.$$

For these firms, the threshold $y^*(n)$ is determined by the fundamentals. Therefore the nonlinear term, $C(n,n)y^{\gamma(n)}$, only reflects the value of the option to suspend. However, although the financial constraint is not important in the current stage, it can still affect the firm's value in the future as its financing capacity, required investment, and the future cash flow change over time. Therefore the other $N-n-1$ nonlinear terms reflect the potential effects of financial constraints and the option to suspend in the future stages.

Note that the same firm can switch between the two scenarios over its life. For example, a young biotech firm may find it difficult to fund early stage R&D. Therefore its investment decisions will be mainly determined by its financing constraints. After it successfully completes several stages, its financing capacity may increase and the investment decisions could be determined by the cost-benefit analysis only.

In sum, this model shows that in addition to the real-options feature, it is very important to consider the effect of financial constraints in evaluating R&D ventures since their financial constraints tend to dominate their investment decisions, especially in early stages.

2.4 Risk Premium

We are now ready to understand how a R&D firm's risk premium varies with its financing ability $p(n)$ and investment level $x(n)$. By standard arguments, the firm's risk premium (instantaneous expected rate of return in excess of the risk free rate) at any stage is given by

$$\frac{V_y(y,n)y}{V(y,n)}\lambda. \tag{10}$$

Applying the firm value to equation (10) gives us the risk premium. Upon completion, the risk premium simply equals λ, which is the market price of risk for the cash flow stream. The intuition is after completion, the firm is equivalent to the underlying cash flow since no further investment decision is needed, therefore they have the same risk premium.

In the mothball region, the risk premium becomes $\beta\lambda$, which is higher than λ since $\beta > 1$ as stated in equation (4). This is because in the mothball region, the firm value purely consists of an option to invest, where the strike price is the expected cost to complete the project and the underlying asset is the future cash flow. Since an option is riskier than the underlying asset due to the implicit leverage, the risk premium of a mothballed R&D project is higher than the completed project.

In the continuation region, the firm value is composed of the value of the option to suspend, the discounted value of future cash flow, as well as the expected investment cost. Therefore the risk premium lies in between the risk premium for a completed project, λ, and that for a mothballed project, $\beta\lambda$. Specifically, the risk premium, $R(p,x)$, is given by

$$R(p,x,y,n) = \frac{V_y(y,n)y}{V(y,n)}\lambda = \frac{\sum_{i=n}^{N-1}\gamma(i)C(i,n)y^{\gamma(i)} + B(n)y}{\sum_{i=n}^{N-1}C(i,n)y^{\gamma(i)} + B(n)y + A(n)}\lambda. \tag{11}$$

We discuss the implications on the relation among financing ability, R&D, and risk premiums in the continuation region next.

2.4.1 Financial Constraints and Risk Premium

There exists a negative relation between firms' financing ability, $p(n)$, and risk premium, $R(n)$, among highly constrained firms. This relation is stronger for firms with higher investment requirement. For unconstrained firms, the relation is flat. The following proposition formalizes this prediction for $n = N - 1$. The relation for the other stages are illustrated by numerical examples.

Proposition 3 *When* $n = N - 1$ *and the threshold* $y^*_{FC}(n) > y^*_{CB}(n)$*,*

$$\begin{aligned} \frac{\partial R(n)}{\partial p(n)} &< 0 \\ \frac{\partial^2 R(n)}{\partial p(n) \partial x(n)} &< 0 \end{aligned}$$

in the continuation region. If $y^*_{FC}(n) < y^*_{CB}(n)$*, then* $\frac{\partial R(n)}{\partial p(n)} = 0$.

Intuitively, for firms with low financing abilities, the financing constraints require a higher threshold than the fundamentals before the firm can continue the project. Moreover, whether they can raise the required funds to continue the project mainly depends on the future cash flows, which must exceed the minimum threshold, $y^*_{FC}(n)$. Hence even a small drop in future cash flows can result in the firm mothballing the project. Therefore low financing ability increases the sensitivity of a firm's value to cash flow risk and its expected returns. On the other hand, if $p(n)$ is relatively high, the firm's investment decision and value are less sensitive to fluctuations in future cash flow. Therefore expected returns will also be lower.

Furthermore, as can be seen from equation (9), both an increase in the required investment, $x(n)$, and a decrease in the financing ability, $p(n)$, tend to increase the threshold, $y^*_{FC}(n)$. Hence, holding fixed the firm's financing ability, higher investment requirements make the firm value even more sensitive to future cash flow, and the firm more risky. Therefore the model predicts a stronger negative relation between the financing ability and risk premium among high-R&D firms.

The above negative relation only holds for highly constrained firms. If the firm has little financing difficulty, its investment decision, and hence its risk premium, are determined by fundamentals. Therefore as the financing ability $p(n)$ exceeds an upper bound, $p^u(n)$, the firm's risk premium will be flat with respect to $p(n)$.[10]

To illustrate these effects for different stages, I use numerical examples, in which time is measured in years, and it takes 5 stages to complete the project. Given the level of required investments, firms differ in the level of the financing ability, p. The drift (μ) and diffusion (σ) terms of the cash flow process are 3% and 40% per year, respectively. The risk free rate incorporating the obsolescence risk is 17.54% per year, and the market price of risk for the cash flow process, λ, is 8% per year. After the firm completes the first stage, the success intensity $\pi(1)$ is 1, and it increases by .1 with each completed stage.[11] Therefore after the firm completes the fourth stage, $\pi(4)$ becomes 1.3. The financing ability, $p(n)$, ranges from .35 to .8 cross-sectionally. For simplicity, I make $p(n)$ constant for each firm. The required R&D investment increases by 3 with each completed stage and starts from 1 for low-R&D firms, and 10 for high-R&D firms.

Figure 1 plots firms' risk premiums against their financing abilities p, for different levels of R&D investment and for different stages. In this example, future cash flow is so high that firms never need to mothball the project. For both the high and low investment levels, the risk premium is negatively related to the financing ability, p, when it is relatively low. As p increases beyond the level above which financing constraints do not affect the firm's investment decision, this relation becomes flat.

The figure also shows that this negative relation is stronger and lasts over a larger range of financing ability, p, for high-R&D firms. In addition, the difference between the strengths of this relation becomes smaller as the firms complete more stages. This is reasonable since the risk premium converges to the market price of risk for the cash flow, λ, as the firm gets

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[10] The upper bound, $p^u(n)$, is the financing ability above which the firm's investment decision is determined by fundamentals, i.e. $y^*_{FC}(n) < y^*_{CB}(n)$.

[11] The assumption, $\pi(1) = 1$, corresponds to a 63.2% probability of completing at least one stage in a year. The results are robust to how the success intensity varies with each additional completed stage.

closer to the completion of the project. The negative relation between the financing ability and the risk premium also weakens as firms mature. This is due to the increase in firm value, which relaxes the financing constraints and reduces the possibility of suspension.

2.4.2 R&D Investment and Risk Premium

Similarly, there exists a positive relation between R&D investment and risk premium in the continuation region for firms with $y^*_{FC}(n) > y^*_{CB}(n)$. This relation is stronger among firms with low financing abilities. The next proposition characterizes these patterns for $n = N-1$. For the other stages, numerical examples are used to illustrate the effects.

Proposition 4 *When* $n = N-1$ *and the threshold* $y^*_{FC}(n) > y^*_{CB}(n)$*,*

$$\begin{aligned} \frac{\partial R(n)}{\partial x(n)} &> 0 \\ \frac{\partial^2 R(n)}{\partial x(n)\partial p(n)} &< 0 \end{aligned}$$

in the continuation region.

The intuition for firms with $y^*_{FC}(n) > y^*_{CB}(n)$ is similar to the one used before because the required investment x is, to a certain degree, the mirror image of the financing ability p. A high x has a similar effect on a firm's investment decision as a low p. Ceteris paribus, a firm with a higher required investment is more likely to mothball the project due to insufficient funds in the event of an adverse shock to future cash flow. Therefore its investment decisions and value are more sensitive to the systematic risk carried by the cash flow. Similarly, this relation is stronger for firms with lower financing ability, p, since a decrease in p intensifies the sensitivity to future cash flow. However, the theory does not necessarily predict a monotonic relation between R&D and returns for firms with $y^*_{FC}(n) < y^*_{CB}(n)$.

I also use numerical examples to illustrate these effects for firms with different financing ability over different stages. Figure 2 illustrates these relations by plotting firms' risk premiums against their investment requirements, x, for different levels of financing ability, p, and for different stages.[12] The horizontal parts correspond to the mothball regions. It is easy to see that R&D is positively related to risk premiums in the continuation regions. Furthermore, this relation is stronger for more constrained firms. Similarly, as firms get closer to completion, this positive relation weakens because the threat of suspension due to insufficient funds decreases resulting from the increase in firm value.

Finally Figure 3 also examines the relation between the investment intensity, x/V, and the risk premium. Since an increase in the required investment reduces a firm's value, x/V is positively related to x. Therefore the investment intensity is also positively related to risk premiums as shown in the figure. This relation is also stronger among firms with lower financing abilities. As before, the relation also weakens as firms age.

These findings are robust to the use of many different values for the key parameters. Figures 4, 5, and 6 illustrate the same negative financing ability-returns relation and the positive R&D investment-returns relation with the cash flow volatility $\sigma = .2$ instead of .4 used in the previous examples. In Figure 7, I let the success intensity, π, start from 2 instead of 1. The patterns are the same as before. Figure 8 and Figure 9 have π starting from 3 instead of 2 and show the same relation.

In sum, this model provides a solid theoretic foundation for the asset pricing implication of financial constraints among R&D ventures. It predicts a significant impact of financing constraints on stock returns among R&D-intensive firms. Moreover, it suggests that the economic source driving the positive relation between R&D investment and expected stock returns documented in existing literature is financial constraints. I now turn to the empirical data to test these predictions next.

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[12] The required investment x ranges from 7 to 25 cross-sectionally. The financing ability p is constant over the stages. The low p equals .53 and the high p equals .85. The success intensity, π, starts from 2 and increases by .1 with each completed stage. All the other parameters are the same as before.

3 Empirical Results

3.1 Importance and Characteristics of R&D Firms

R&D activities drive innovation and economic growth. According to National Science Foundation, U.S. R&D spending now reaches \$300 billion a year and represents approximately 2.7% of GDP. Table 1 provides a summary of public R&D firms by fiscal years and by selected high-tech industries. R&D *expenditure* is expressed relative to sales, earnings (net income), capital expenditure, and book value of common equity. The estimated R&D *capital* is compared to book value of equity and total assets. In each of these ratios, the items in the numerator and denominator are aggregated separately to reduce the effect of outliers.

Under current U.S. accounting policies, unlike capital expenditures, R&D expenditures are immediately expensed and do not accumulate toward capital on the balance sheet. There is no consensus on estimates for the useful life of R&D expenditure and the amortization rate in existing literature.[13] Following Chan, Lakonishok, and Sougiannis (2001), R&D capital, RDC_{it}, for firm i in year t is estimated as the weighted sum of the R&D expenditure (RD_{it}) over the past five years assuming an annual amortization rate of 20%:

$$RDC_{it} = RD_{it} + .8 * RD_{it-1} + .6 * RD_{it-2} + .4 * RD_{it-3} + .2 * RD_{it-4.}$$

Panel A in Table 1 shows that the importance of R&D firms has grown sharply. The market capitalization of all firms doing R&D exceeds 7 trillion in fiscal 2005, representing about 70% of the U.S. equity market. The total amount of R&D spending has grown from 14.7 billion in 1975 to 188.7 billion by 2005, a more than ten-fold increase. As a percentage of sales, R&D spending has increased from 1.7% in 1975 to 4.1% in 2005. The percentage of R&D spending relative to capital expenditure has been increasing steadily as well, from 20.4% in 1975 to 83.6% in 2005, reflecting a persistent shift from the traditional economy

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[13] See, for example, Lev et al. (1996) and Kothari et al. (2002).

toward the knowledge-based new economy. Since R&D expenditure is expensed immediately, firms' balance sheets currently do not reflect the important intangible asset represented by R&D capital. For example, it accounts for 25.4% of book equity in 2005.

R&D firms mainly concentrate in technology and science-oriented industries, such as biotechnology, pharmaceuticals, computer software, electronics, etc. Panel B of Table 1 shows the characteristics of several high-tech industries (defined by two-digit or three-digit SIC codes) as of fiscal 2005. These industries are ranked according to the ratio of R&D spending to industry sales. Over 70% of the total R&D spendings are from these selected industries. The market capitalization of these high-tech industries accounts for about 40% of U.S. equity market. In 2005, the drug and pharmaceutical industry (SIC codes beginning with 283) spends the most in R&D, which represents 18.2% of sales, 137.9% of earnings, and 301.5% of capital expenditure. The market capitalization of this industry alone exceeds one trillion.

3.2 Data and Portfolio Characteristics

The data comes from COMPUSTAT and the Center for Research in Security Prices (CRSP). Before 1975, firms had more discretion in determining what accounts for R&D expenditure. Therefore, the sample period covers from January 1975 till December 2004, the period for which the accounting treatment of R&D expense reporting is standardized (Financial Accounting Standards Board Statement No. 2). All domestic common shares trading on NYSE, AMEX, and NASDAQ with accounting data and returns data available are included except utility and financial firms.

Several measures are used to identify R&D-intensive firms. Two popular measures in the literature are the R&D *expenditure* to market equity ratio and the R&D *capital* to total assets ratio. In this paper, I also use the ratio of R&D expenditure to capital expenditure because R&D is the main type of investment for these firms.

One concern is whether the *required* R&D investment of firms with high R&D intensity is indeed large since the requirement is unobservable in the data. To answer this question, I examine the high-tech industry distribution of the three R&D groups sorted on the ratio of R&D capital to total assets as of June 2004. Table 2 shows that over 94% of the high-R&D firms are from high-tech industries, such as drugs and pharmaceuticals, computer software, computer equipment, and electronics, etc. However, only 25% of the low-R&D firms belong to these high-tech industries. The R&D groups sorted on the other two measures of R&D intensity show a very similar pattern. Therefore the high-R&D groups identified by these measures indeed have high *required* R&D investment and provide an appropriate framework to test the model predictions.

R&D intensity measures are typically high for R&D ventures, which are young and small. However, established high-tech firms, such as big pharmaceutical companies, also have high R&D intensity. Since the model predictions mainly apply to R&D ventures, equal-weighted portfolio returns are computed to reduce the confounding effect of large firms.

To measure firms' external financing abilities, p, I choose the widely used KZ index and the most recently developed WW index. Kaplan and Zingales (1997) classify a group of low-dividend paying firms into discrete categories of financial constraints based on their financial reports and managers' letters to shareholders. They then use an ordered logit regression to associate firms' categories with different accounting variables. Following Lamont, Polk, and Saá-Requejo (2001, henceforth LPS), I construct the KZ index using the regression coefficients reported in Kaplan and Zingales (1997). The KZ index is a linear combination of the following five variables with the signs in the parenthesis: debt to total capital (+), dividends to capital (-), cash holdings to capital (-), cash flow to capital (-), and Tobin's Q (+). The KZ index is higher for more constrained firms (lower financing ability, p).

The WW index is constructed by Whited and Wu (2006) based on a standard intertemporal investment model augmented to account for financial frictions. It represents the shadow value of scarce external funds and is a linear combination of cash flow to total assets (-), sales growth (-), long term debt to total assets (+), log of total assets (-), dividend policy indicator (-), and the firm's 3-digit industry sales growth (+).[14] By construction, more constrained firms have higher WW index. The Appendix provides more information on how to construct these two indices.

Table 3 shows the time-averaged equal-weighted characteristics of portfolios formed on different measures of R&D intensity and financial constraints. As shown in Panels A, B, and C, R&D-intensive firms are typically small, young, and growth firms with low debt and high cash holdings. Since a large portion of high-tech firms' assets are knowledge-based and intangible, these firms have low debt capacity, especially for R&D ventures. In addition, due to costly external financing caused by information asymmetry, high-R&D firms tend to hold more cash as a precaution. However, the cash holding is insufficient to finance the required investment as shown in the high ratio of R&D spending to lagged cash holding.

Unlike capital investment, R&D projects have to be sustained at a certain level to keep them alive. Therefore firms tend to smooth R&D spending as much as they can (Hall(1992)). Nevertheless, the volatility of R&D spending (standard deviation of R&D spending over the past five years with missing R&D replaced by zero) increases with the R&D intensity, reflecting the effect of financing constraints on R&D spending.

Panel D of Table 3 reports the characteristics of portfolios formed on the KZ index. By construction, firms with high KZ index have high leverage, low dividends, low cash holdings, and low cash flows. They are also small and young. These are the typical characteristics of constrained firms. Similarly, in Panel E, constrained firms measured by the high WW index are also small, young, and have low dividends, and negative cash flows. The gap between the R&D spending and the lagged cash holdings, as measured by the R&D-to-cash ratio, increases with both indices.

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[14] Whited and Wu (2006) use the replacement cost of total assets to scale the relevant variables in the index. The method of computing the replacement cost of total assets is detailed in Whited (1992).

3.3 Univariate Analysis

In this section, I examine the simple relation between R&D investment and subsequent returns and that between financial constraints and stock returns. In addition, following LPS and Whited and Wu (2006), I also construct the financial constraints factors based on the KZ index and the WW index, respectively. The results confirm the documented positive R&D-returns relation and the puzzling flat relation between financial constraint indices and stock returns.

Table 4 reports the returns on the portfolios formed on the three measures of R&D intensity. Specifically, I first separate firms into the R&D group and the non-R&D group according to whether the reported R&D (data item 46) is available or not. Within the R&D group, three equal-numbered portfolios are formed in June of year t based on the rank of R&D intensity, using the accounting variables reported in the fiscal year ending in calendar year $t-1$. The monthly portfolio returns in excess of the one-month T-bill rate for the next twelve months are computed, and the portfolios are reformed in June of year $t+1$.[15]

To correct for the delisting bias in CRSP returns data, I follow Shumway and Warther (1999) and Shumway (1997) by setting missing performance-related delisting returns to -55% for NASDAQ firms, and -30% for NYSE and AMEX firms. Performance-related delistings include bankruptcy, failure to meet capital requirements, etc. The CRSP delisting codes used for this adjustment are either 500 or between 520 and 584.

Risk-adjusted returns are computed by the matching portfolio method and the risk factor model method. Using matching portfolios to adjust risk may capture unknown risks associated with certain portfolio characteristics and reduce idiosyncratic risks. Specifically, for each stock, I first find its matching portfolio based on its size and book-to-market ranks. There are a total of 25 matching portfolios, corresponding to five size portfolios and five

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[15] Although some firms with zero R&D, such as McDonald, are not in high-tech industries, excluding these firms from the low-R&D group by setting zero R&D to missing R&D does not change the results. Conversely, the non-R&D group may have some R&D firms with missing reported R&D. However, it is rare for active high-tech firms to report missing R&D. For example, over 85% of the firms in the drug and pharmaceutical industry report consecutively positive R&D spending.

book-to-market portfolios. The breakpoints for size and book-to-market are based on NYSE stocks only. The matching portfolio adjusted returns for the R&D portfolios are computed based on the individual stock's adjusted returns, which is the difference between its return and the matching portfolio's value-weighted return.

Alternatively, I adjust the portfolio returns by standard risk factor models, such as the Fama-French three-factor model including the market, size, and book-to-market factors, the four-factor model with momentum as the fourth factor, and the five-factor model with the liquidity factor as the fifth factor. Specifically, the five-factor model adjustment is conducted by estimating time series regressions of the form

$$R_{pt} - R_{ft} = \alpha_p + m_p[R_{mt} - R_{ft}] + s_p SMB_t + h_p HML_t + u_p UMD_t + l_p LIQ_t + \varepsilon_{pt}.$$

The dependent variable, $R_{pt} - R_{ft}$, is the post-ranking monthly excess return of portfolio p in month t. $R_{mt} - R_{ft}$ is the excess return on the value-weighted market portfolio, and SMB_t, HML_t are the returns of factor-mimicking portfolios for size and book-to-market as detailed in Fama and French (1993), respectively.

UMD_t is the momentum factor, representing the effect of short-term continuation in returns. To construct this factor, six value-weighted portfolios are formed each month as the intersections of two size portfolios and three portfolios formed on prior (2-12) return. UMD_t is the average return on the two high prior return portfolios minus the average return on the two low prior return portfolios. The one-month lag in forming the prior return portfolios helps reduce the bid-ask bounce effect documented in Blume and Stambaugh (1983). The liquidity factor, LIQ_t, is constructed by Pastor and Stambaugh (2003). It captures the effect of marketwide liquidity and is the difference between the returns on a portfolio of firms with high sensitivity to the innovation of market liquidity and on a portfolio of firms with low sensitivity.

As the results are robust to the risk factor models used, I only report the regression estimates from the Fama-French three-factor model in Table 4. For each portfolio, the first line reports the mean returns and regression estimates from the three-factor model; the second line reports the heteroscedasticity-robust t statistics. The excess return, matching portfolio adjusted return, and the alphas from the three-factor model all indicate a significantly positive relation between R&D and subsequent returns. For example, Panel A shows that the monthly excess return on the portfolio with the highest ratio of R&D spending to capital expenditure is 1.5%, compared to .88% for the low-R&D portfolio. The three-factor model fully explains the excess return on the low-R&D portfolio. However, the monthly alpha for the high-R&D portfolio is .68% with a t-value of 3.29. This indicates that existing risk factors cannot explain the return on high-R&D firms well.

The simple relation between financial constraints indices and subsequent returns are reported in Table 5. Three financial constraints portfolios are formed in each June based on the lagged indices, and their monthly excess returns over the next 12 months are computed. The results in Panel A indicate that there is no significant relation between the KZ index and stock returns. Panel B shows that the WW index is positively related to stock returns when the portfolios are formed on the index alone. However, when the portfolios are formed as the intersection of the three size portfolios based on the market capitalization in each June and the three WW portfolios based on the lagged WW index as in Table 6, there is no positive relation between the WW index and stock returns within each size portfolio. In fact, the WW index is negatively related to the returns within the mid- and large-cap firms. Another observation is that the high-WW group is dominated by small firms, while the low-WW group mainly consists of large firms. These suggest that the positive relation in Panel B of Table 5 may be due to the size effect.

Following Whited and Wu (2006), in Table 6, I construct the financial constraints factor as the difference between the average returns on the three high-WW portfolios and that on the three low-WW portfolios. Consistent with their findings, the risk premium of this factor is insignificant whether equal- or value-weighted returns are used. Similar to Lamont et al.

(2001), the results for the KZ index, as reported in Table 7, show an insignificant relation between the KZ index and stock returns.

3.4 Financial Constraints and Stock Returns

Now let's study the relation between financial constraints and expected returns within the R&D framework. The model predicts that among high-R&D firms, more constrained firms have higher risk premiums. This relation is rather flat among low-R&D firms.

To test these predictions, I form nine portfolios among firms with nonmissing R&D by a two-way conditional sort based on the R&D intensity first and then on the KZ index. Specifically, in each June of year t, I form three portfolios based on the R&D rank, using accounting data from the fiscal year ending in calendar year $t-1$. Within each R&D portfolio, I further sort firms into three portfolios based on the KZ index.

In order to check the significance of this relation, I form three zero-investment portfolios within each R&D group by going long the most constrained portfolio (high KZ) and short the least constrained portfolio (low KZ). I then calculate the subsequent monthly portfolio returns from July of year t to June of year $t+1$ and reform the portfolios in June of year $t+1$.

Realized excess returns are used as the proxy for the risk premiums. To the extent that the systematic risk of R&D firms may not be fully captured by standard risk factors in the literature, the model predictions also apply to the risk adjusted returns. If there exists a risk factor associated with financial constraints as argued in LPS (2001) and Whited and Wu (2006), we would expect the same pattern in the risk adjusted returns as in the excess returns. As before, I adjust the returns by both matching portfolios and risk factor models.

Table 8 reports the results when the R&D intensity is measured by the ratio of R&D capital to total assets. For each portfolio, the first line shows the mean returns and regression estimates from the Fama-French three-factor model, and the second line reports heteroscedasticity robust t statistics. All portfolio returns are adjusted for delisting bias as before.

The returns of the zero-investment portfolios indicate a significantly positive relation between the KZ index and the expected stock returns among high-R&D firms. However, this relation is flat in low-R&D firms. The monthly excess returns of the zero-investment portfolio formed in the high-R&D group (33-31 portfolio) is .60% and significant at the 1% level. However, the monthly excess returns of the zero-investment portfolio formed in the low-R&D group (13-11 portfolio) is merely .02% and insignificant. Moreover, within the high-R&D group, the excess returns increase monotonically with the KZ index: 1.20%, 1.58%, and 1.80% for the low-, middle-, and high-KZ portfolios, respectively.

These findings are consistent with the model predictions. Among high-tech ventures, financial constraints bind more often due to the high and inflexible R&D requirement and the lack of positive cash flows. Their investment decisions are more sensitive to marketwide liquidity. Therefore the output and the value of these firms comove with macroeconomic shocks more closely. Consequently, they are more risky and demand higher risk premiums. However, for low-R&D firms, the required R&D investment is low and financial constraints do not bind as often. Firms' investment behavior mainly depends on the fundamentals. Therefore the relation between returns and the financial constraints measure is flat.

The sharp difference between the high- and low-R&D groups is also evident in the returns adjusted by either matching portfolios or risk factor models. For example, the monthly alpha from the Fama-French three-factor model is .32% for the 33-31 portfolio and significant, while only $-.15\%$ for the 13-11 portfolio and insignificant. This suggests a potential risk factor associated with financial constraints. In addition, the loadings on the market, size, and book-to-market factors for the high-KZ portfolio are generally higher than those for the low-KZ portfolio, consistent with the model prediction that more constrained firms are more risky.

Table 9 reports the regression results from the five-factor model including the Fama-French three factors, the momentum factor, and the liquidity factor. The pattern is exactly the same. The monthly alpha is a significant .38% for the 33-31 portfolio, and an insignificant

−.14% for the 13-11 portfolio. In addition, the alphas also increase monotonically with the KZ index within the high-R&D group.

The results for the other two R&D intensity measures are shown in Tables 10 and 11. Consistent with the model predictions, they both indicate a significantly positive relation between stock returns and the KZ index among the high-R&D group. The same relation is flat among the low-R&D group.

Additionally, I also sort firms with missing R&D but nonmissing KZ into three KZ portfolios. Similar to LPS, the untabulated results show no significant relation between the KZ and the returns among these firms.

To examine the robustness of these findings, I conduct the same analysis using the WW index to measure financial constraints. The findings are qualitatively similar to the results with the KZ index for all the three measures of R&D intensity. To save space, I only report the results for the ratio of R&D expenditure to market value of equity in Table 12. The mean excess returns and the t statistics (in parenthesis) for the zero-investment portfolios formed within the low-, middle-, and high-R&D groups are .18% (.74), 0.28% (0.94), and 1.17% (3.59), respectively. The risk adjusted returns show a similar pattern.

These robust findings provide strong evidence that financial constraints matter for stock returns of high-R&D ventures. They also help explain the puzzling flat relation between financial constraints and returns documented in existing literature. As the model shows, financial constraint only matter when it affects firms' investment behavior. Furthermore, the effect of financing constraints on firms' investment has to affect their risk as well. For young R&D-intensive firms, the external financing ability is very important in determining their investment decisions because they typically do not have positive cash flows. In addition, whether they could raise enough funds to continue R&D projects in a timely fashion determines the resolution of firms' uncertainty and systematic risk. Therefore R&D ventures provide an ideal framework to study the impact of financing constraints on stock returns.

3.5 R&D Intensity and Stock Returns

Similarly, the model predicts a stronger positive relation between R&D investments and returns among more constrained firms.

To test this prediction, I form nine equal-numbered portfolios by a two-way conditional sort on the KZ index first and then on the R&D intensity. Specifically, in each June of year t, I form three equal-numbered portfolios based on the rank of KZ, using accounting data from the firm's fiscal year ending in calendar year $t-1$. Within each KZ group, I further sort firms into three equal-numbered portfolios based on the R&D intensity rank. To study the significance of the relation, I also create three zero-investment portfolios within each KZ group by going long the high-R&D portfolio and short the low-R&D portfolio. I then compute the subsequent equal-weighted excess returns on these portfolios from July of year t to June of year $t+1$ and reform the portfolios in June of year $t+1$.

Table 13 reports the results for the R&D capital to total assets measure. As predicted by the model, both the level and significance of the positive R&D-returns relation increase monotonically with the KZ index. For example, the monthly excess returns on the zero-investment portfolios formed within the low-, middle-, and high-KZ groups are .54%, .60%, and .99%, and the t statistics are 1.91, 2.33, and 3, respectively. The monthly alphas from the three-factor model for the three self-financing portfolios follow the same pattern, increasing from .63% for the low-KZ group to .96% for the high-KZ group. Similarly, as reported in Table 14, the alphas from the five-factor model also increase monotonically with the KZ index from .63% to 1.12% and are significant. These findings suggest that existing risk factors cannot fully explain the risks associated with R&D firms.

The results for the other two measures of R&D intensity also confirm the model predictions and are reported in Tables 15 and 16. For both measures, the strength of the positive R&D-returns relation increases with the KZ index. In fact, when the R&D expenditure to capital expenditure ratio is used, the positive relation between R&D and excess returns is statistically insignificant in the unconstrained group.

The findings with the WW index are qualitatively similar and support the model predictions for all the three R&D measures. To save space, I only report the results for the measure of R&D expenditure to market value of equity in Table 17. The average monthly excess returns and the t statistics (in parenthesis) of the three zero-investment portfolios formed within the low-, middle-, and high-WW groups are .39% (2.78), .86% (3.96), and 1.53% (5.71), respectively. When the other two R&D measures are used, R&D is only significantly positively related to excess returns in the most constrained group.

These robust findings not only confirm the model predictions, but also help discover the economic source of the positive R&D-returns relation. It shows that a large portion of the excess returns to R&D-intensive firms can be attributed to financial constraints since this relation is much stronger in more constrained firms and only exists in highly constrained firms for several measures of R&D intensity.

4 Conclusion

Two puzzling findings in the existing literature have attracted a fair amount of attention: the flat relation between financing constraints and stock returns; and the predictability of R&D on stock returns. Through a real-options valuation model of R&D ventures with financing constraints and the firm-level R&D spending data, this paper helps explain both puzzles.

The model shows that financing constraints affect stock returns only if firms' investment decisions are determined by their financing capacity and the consequence of insufficient funds has a significant effect on their value and risk. R&D investment is very sensitive to financing constraints, especially for young and small firms, due to its unique features. Moreover, the R&D investment experience has a significant impact on these firms' risk. Therefore they provide an ideal framework to study the asset pricing implication of financing constraints. Conversely, high R&D increases firms' risk premium because it exacerbates the impact of financing constraints on firms' risk. Consequently a large portion of the predictability of R&D

on stock returns can be attributed to the effect of financial constraints on stock returns.

Consistent with the model, empirical analysis produces a significantly positive return spread between constrained and unconstrained firms for R&D-intensive firms and a much stronger positive relation between R&D and subsequent stock returns within highly constrained firms.

Appendix A: Proofs

Proof of Proposition 1. Given $y^*_{FC}(n) > y^*_{CB}(n)$, the threshold, $y^*(n)$, and the constants, $C(n,n)$ and $D(n)$, are derived from the boundary conditions stated in equations (6), (7), and (9). Utilizing equation (1) at the optimum ($v = 1$), we can simplify equation (9) as the following:

$$p(n)\frac{1}{dt}E_t[dV] = p(n)[rV(y,n) + x(n)] = x(n),$$

which is equivalent to

$$k(n)V(n) = x(n),$$

where $k(n) = \frac{p(n)r}{1-p(n)}$.

Since we have three unknowns and three equations, it is easy to verify that the solutions given in Proposition 1 satisfy these boundary conditions. ■

Proof of Proposition 2. When $y^*_{FC}(n) < y^*_{CB}(n)$, the threshold, $y^*(n)$, and the constants, $C(n,n)$ and $D(n)$, are derived from the boundary conditions stated in equations (6), (7), and (8). It is easy to verify that the solutions given in Proposition 2 satisfy these boundary conditions. ■

Proof of Proposition 3. When $n = N - 1$, from Propositions 1 and 2, we have

$$\begin{aligned} y^*_{FC}(n) &= \frac{(\beta - \gamma(n))x(n) + A(n)\gamma(n)k(n)}{B(n)k(n)(1-\gamma(n))} \\ y^*_{CB}(n) &= \frac{[r(\gamma(n) - \beta) - \pi(n)\beta]A(n)}{B(n)[\pi(n)(\beta - 1) + (r-\mu)(\beta - \gamma(n))]}, \end{aligned}$$

where $A(n) = \frac{-x(n)}{r+\pi(n)}$ and $k(n) = \frac{p(n)r}{1-p(n)}$.

After simplification, we can show that $y^*_{FC}(n) > y^*_{CB}(n)$ is equivalent to

$$k(n) < \frac{\pi(n)(r + \pi(n))(\beta - 1) + (r + \pi(n))(r - \mu)(\beta - \gamma)}{r + \pi(n) - \mu\gamma(n)}. \tag{12}$$

In addition, we know that β and $\gamma(n)$ satisfy the following quadratic equations:

$$\frac{1}{2}\sigma^2\beta(\beta-1)+\mu\beta-r=0$$
$$\frac{1}{2}\sigma^2\gamma(n)(\gamma(n)-1)+\mu\gamma(n)-(r+\pi(n))=0.$$

Hence
$$\frac{\gamma(n)(\gamma(n)-1)}{\beta(\beta-1)}=\frac{r+\pi(n)-\mu\gamma(n)}{r-\mu\beta}.$$

Using this relation, we can show that inequality (12) is equivalent to

$$k(n)<\frac{-(\beta-\gamma(n))(\beta-1)(r+\pi(n))}{\gamma(n)}.$$

Therefore $y^*_{FC}(n)>y^*_{CB}(n)$ implies $(\beta-\gamma(n))(\beta-1)(r+\pi(n))+k(n)\gamma(n)>0$.

In this case, the value and the risk premium ($R(n)$) in the continuation region become

$$V(y,n)=C(n,n)y^{\gamma(n)}+B(n)y+A(n)\qquad y\geq y^*(n)$$
$$R(n)=\frac{V_y(y,n)y}{V(y,n)}\lambda=\frac{\gamma(n)C(n,n)y^{\gamma(n)}+B(n)y}{C(n,n)y^{\gamma(n)}+B(n)y+A(n)}\lambda,$$

where,

$$C(n,n)=(\gamma(n)-\beta)^{-1}(y^*(n))^{-\gamma(n)}[B(n)y^*(n)(\beta-1)+\beta A(n)]$$
$$B(n)=\frac{\pi(n)}{(r+\pi(n)-\mu)(r-\mu)}.$$

For simplicity, we subsume the number of completed stages, n, henceforth.

Since k increases with p, $sign(\frac{\partial R}{\partial p})=sign(\frac{\partial R}{\partial k})$ and $sign(\frac{\partial^2 R}{\partial p\partial x})=sign(\frac{\partial^2 R}{\partial k\partial x})$. Taking derivative of R with respect to k gives us

$$\frac{\partial R}{\partial k}=\frac{\frac{\partial C(n,n)}{\partial k}y^{\gamma}[\gamma V-V_y y]}{V^2}\lambda.$$

Since $\gamma<0$ and $V_y>0$, $sign(\frac{\partial R}{\partial k})=-sign(\frac{\partial C(n,n)}{\partial k})$. After simplifying, we obtain

$$\frac{\partial C(n,n)}{\partial k}=\frac{x(y^*)^{-\gamma}}{k^2[(\beta-\gamma)(r+\pi)-k\gamma]}[(\beta-\gamma)(\beta-1)(r+\pi)+k\gamma].$$

As $\beta>0$, $\gamma<0$, and $(\beta-\gamma)(\beta-1)(r+\pi)+k\gamma>0$, we know $\frac{\partial C(n,n)}{\partial k}>0$. Therefore $\frac{\partial R}{\partial k}<0$ and $\frac{\partial R}{\partial p}<0$. In addition, it is obvious that $\frac{\partial^2 C(n,n)}{\partial k\partial x}>0$.

To find the sign of $\frac{\partial^2 R}{\partial p\partial x}$, we utilize the relations $sign(\frac{\partial^2 R}{\partial p\partial x})=sign(\frac{\partial^2 R}{\partial k\partial x})$ and $\frac{\partial^2 R}{\partial k\partial x}=\frac{\partial^2 R}{\partial x\partial k}$.

Since

$$\frac{\partial R}{\partial x} = \frac{\frac{\partial C(n,n)}{\partial x} y^{\gamma}\gamma - \frac{V_y y}{V}\frac{\partial V}{\partial x}}{V}\lambda = \frac{\frac{\partial C(n,n)}{\partial x} y^{\gamma}\gamma - \frac{R}{\lambda}\frac{\partial V}{\partial x}}{V}\lambda,$$

we know

$$\frac{\partial^2 R}{\partial x \partial k} = \frac{[\frac{\partial^2 C(n,n)}{\partial x \partial k} y^{\gamma}\gamma - \frac{1}{\lambda}\frac{\partial R}{\partial k}\frac{\partial V}{\partial x} - \frac{R}{\lambda}\frac{\partial^2 V}{\partial x \partial k}]V - (\frac{\partial C(n,n)}{\partial x} y^{\gamma}\gamma - \frac{R}{\lambda}\frac{\partial V}{\partial x})\frac{\partial V}{\partial k}}{V^2}\lambda.$$

In addition,

$$\frac{\partial C(n,n)}{\partial x} = \frac{-(y^*)^{-\gamma}}{k[(\beta-\gamma)(r+\pi) - k\gamma]}[(\beta-\gamma)(\beta-1)(r+\pi) + k\gamma] < 0,$$

therefore

$$\begin{aligned} \frac{\partial V}{\partial x} &= \frac{\partial C(n,n)}{\partial x} y^{\gamma} - \frac{1}{r+\pi} < 0 \\ \frac{\partial^2 V}{\partial x \partial k} &= \frac{\partial^2 C(n,n)}{\partial x \partial k} y^{\gamma} = \frac{\partial^2 C(n,n)}{\partial k \partial x} y^{\gamma} > 0. \end{aligned}$$

We also have $\frac{\partial V}{\partial k} = \frac{\partial C(n,n)}{\partial k} y^{\gamma} > 0$. Therefore $\frac{\partial^2 R}{\partial x \partial k} < 0$ and $\frac{\partial^2 R}{\partial x \partial p} < 0$. Hence $\frac{\partial^2 R}{\partial p \partial x} < 0$.

If $y^*_{FC}(n) < y^*_{CB}(n)$, the value and the risk premium in the continuation region are independent of $p(n)$. Therefore $\frac{\partial R}{\partial p} = 0$. ■

Proof of Proposition 4. As shown in the proof of Proposition 3, when $n = N-1$ and $y^*_{FC}(n) < y^*_{CB}(n)$, in the continuation region,

$$\frac{\partial R}{\partial x} = \frac{\frac{\partial C(n,n)}{\partial x} y^{\gamma}\gamma - \frac{R}{\lambda}\frac{\partial V}{\partial x}}{V}\lambda.$$

Therefore $\frac{\partial R}{\partial x} > 0$ since $\frac{\partial C(n,n)}{\partial x} < 0$, $\gamma < 0$, and $\frac{\partial V}{\partial x} < 0$. In addition, $\frac{\partial^2 R}{\partial x \partial p} < 0$ has been proved in the previous proof as well. ■

Appendix B: Financial Constraints Indices

Lamont et al. (2001) use the regression coefficients from Kaplan and Zingales (1997) to compute the KZ index as the following:

$$-1.001909 CashFlow/K + .2826389 Tobin's\,Q + 3.139193 Debt/TotalCapital$$

$$-39.3678 Dividends/K - 1.314759 Cash/K,$$

where $CashFlow/K$ is computed as (Item 18 + Item14)/Item 8, $Tobin's\,Q$ as (Item 6 + CRSP December Market Equity - Item 60 - Item 74)/Item 6, $Debt/TotalCapital$ as (Item 9 + Item 34)/(Item 9 + Item 34 +Item 216), $Dividends/K$ as (Item 21 + Item 19)/Item 8, and $Cash/K$ as (Item 1/Item 8). Item numbers refer to COMPUSTAT annual data items as in the following: 1 (cash and short-term investments), 6 (liabilities and stockholders' equity–total), 8 (property, plant, and equipment), 9 (long-term debt–total), 14 (depreciation and amortization), 18 (income before extraordinary items), 19 (dividends–preferred), 21 (dividends–common), 34 (debt in current liabilities), 60 (common equity–total), 74 (deferred taxes), and 216 (stockholders' equity–total). Data item 8 is lagged. A firm needs to have valid information on all the above annual items to be able to have a KZ index.

Following Whited and Wu (2006), the WW index is computed using COMPUSTAT quarterly data according to the following formula:

$$-.091CF - .062DIVPOS + .021TLTD - .044LNTA + .102ISG - .035SG,$$

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 industry sales growth; and SG is firm 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. The computation of the replacement value of the capital stock is detailed in Whited (1992).

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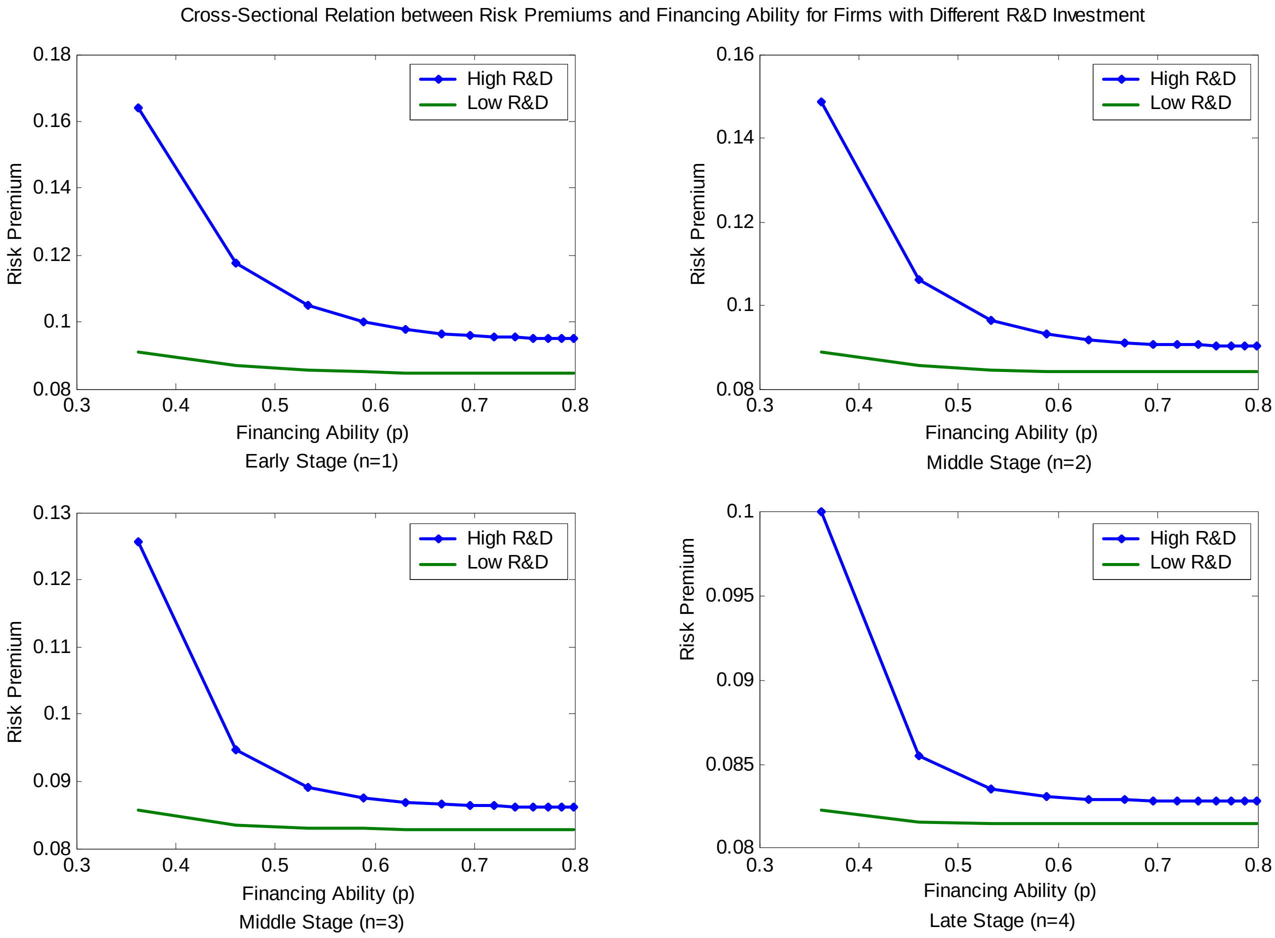


Figure 1: The risk premiums (per annum) of projects that require 5 stages to complete are plotted as a function of their financing abilities (p) for different levels of R&D investment and over different stages. For example, the top left plot is for projects that have completed the first stage ($n = 1$), the top right for projects having completed two stages ($n = 2$), and so forth. The risk premium is the instantaneous expected return minus the risk-free rate. The two lines correspond to different levels of R&D investment. The volatility of future cash flow $\sigma = .4$ and the success intensity begins with $\pi(1) = 1$ and increases by .1 with each additional completed stage.

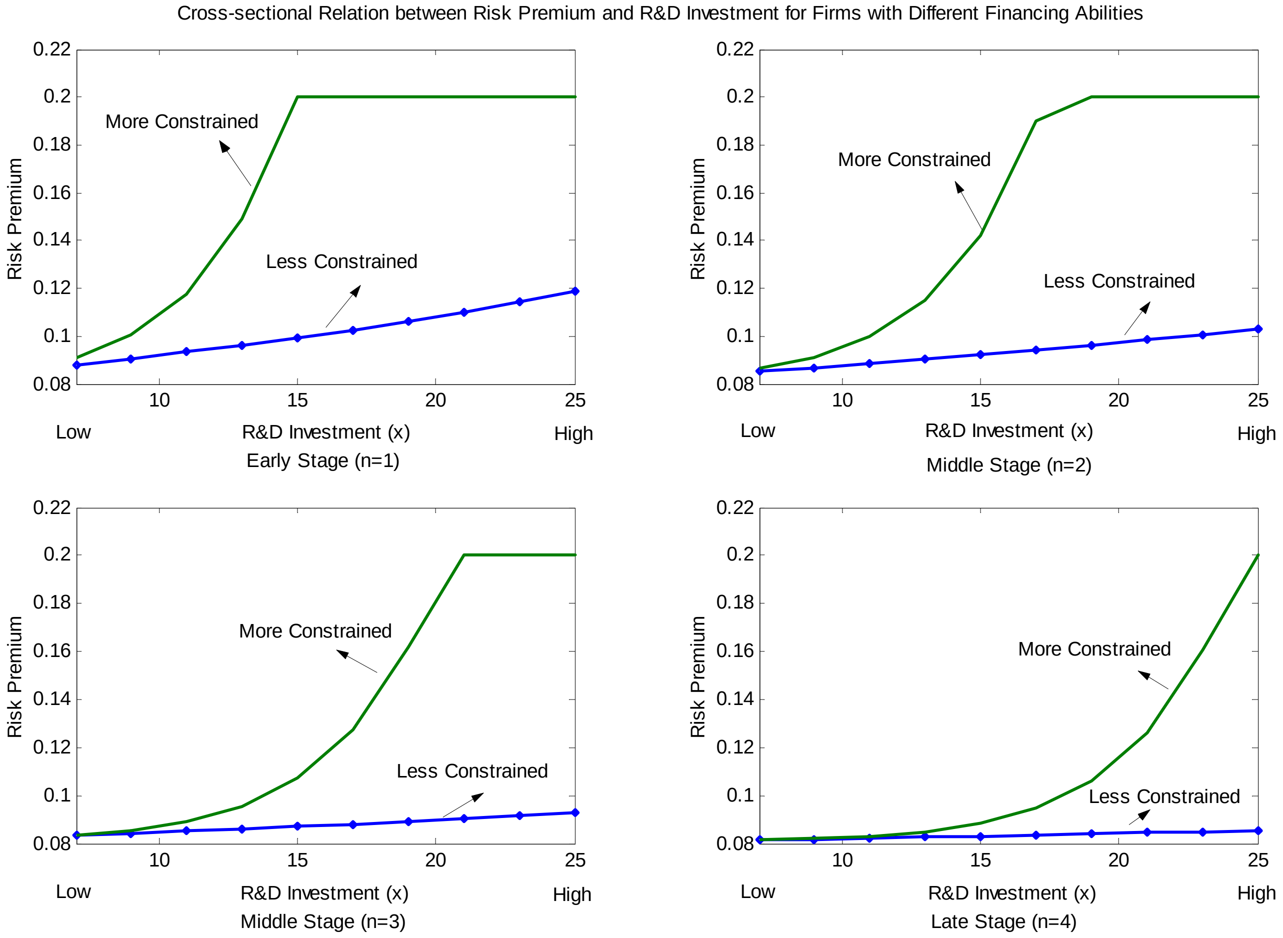


Figure 2: The risk premiums (per annum) of projects that require 5 stages to complete are plotted as a function of their investment requirement (x) for different financing abilities (p) and over different stages. For example, the top left plot is for projects that have completed the first stage ($n = 1$), the top right for projects having completed two stages ($n = 2$), and so forth. The risk premium is the instantaneous expected return minus the risk-free rate. The two lines correspond to different external financing abilities (p). The figure has $\sigma = .4$ and $\pi(1) = 1$.

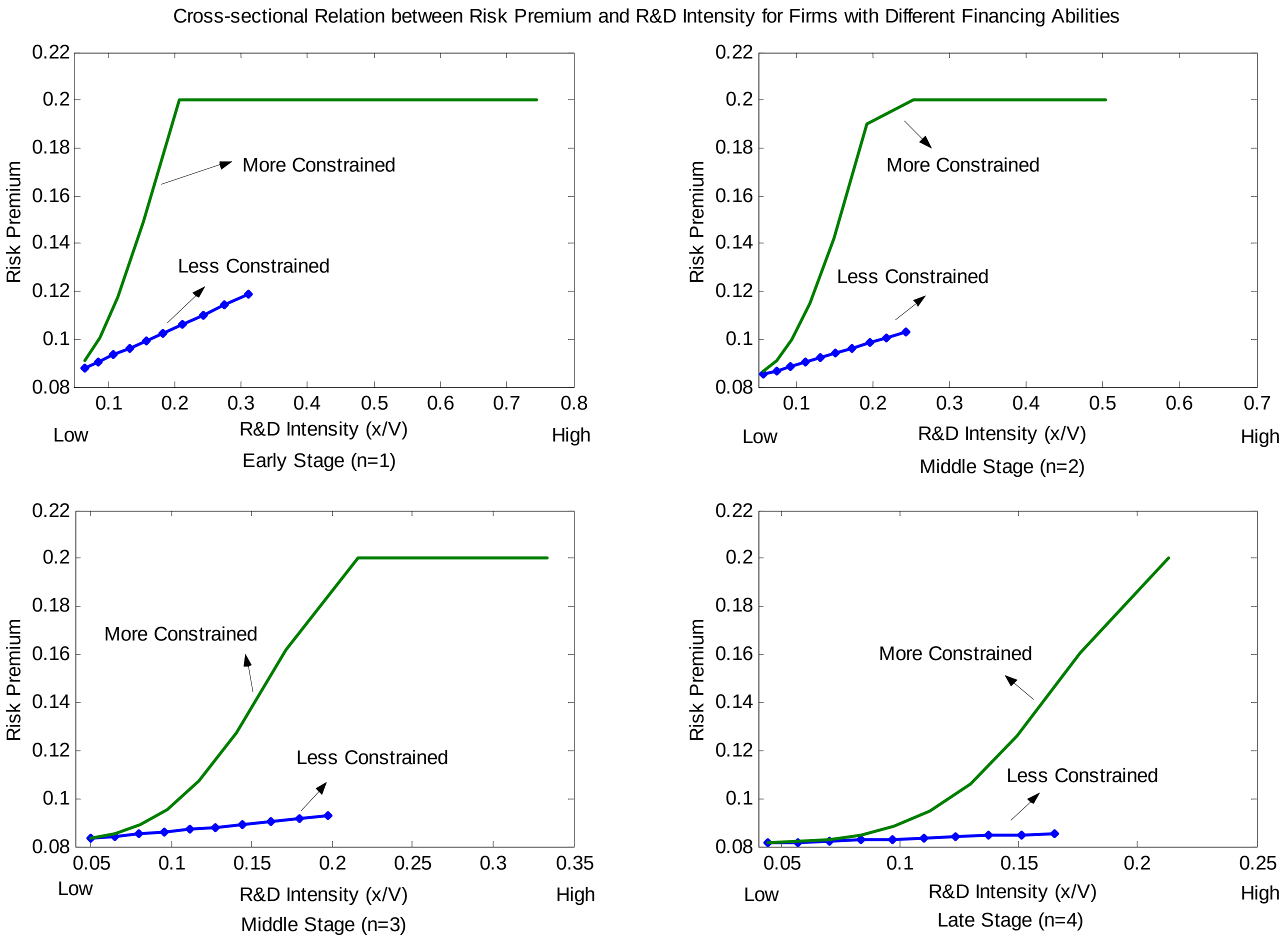


Figure 3: The risk premiums (per annum) of projects that require 5 stages to complete are plotted as a function of their investment intensity (x/V) for different financing abilities (p) and over different stages. For example, the top left plot is for projects that have completed the first stage $(n = 1)$, the top right for projects having completed two stages $(n = 2)$, and so forth. The risk premium is the instantaneous expected return minus the risk-free rate. The two lines correspond to different external financing abilities (p). The plots have $\sigma = .4$ and $\pi(1) = 1$.

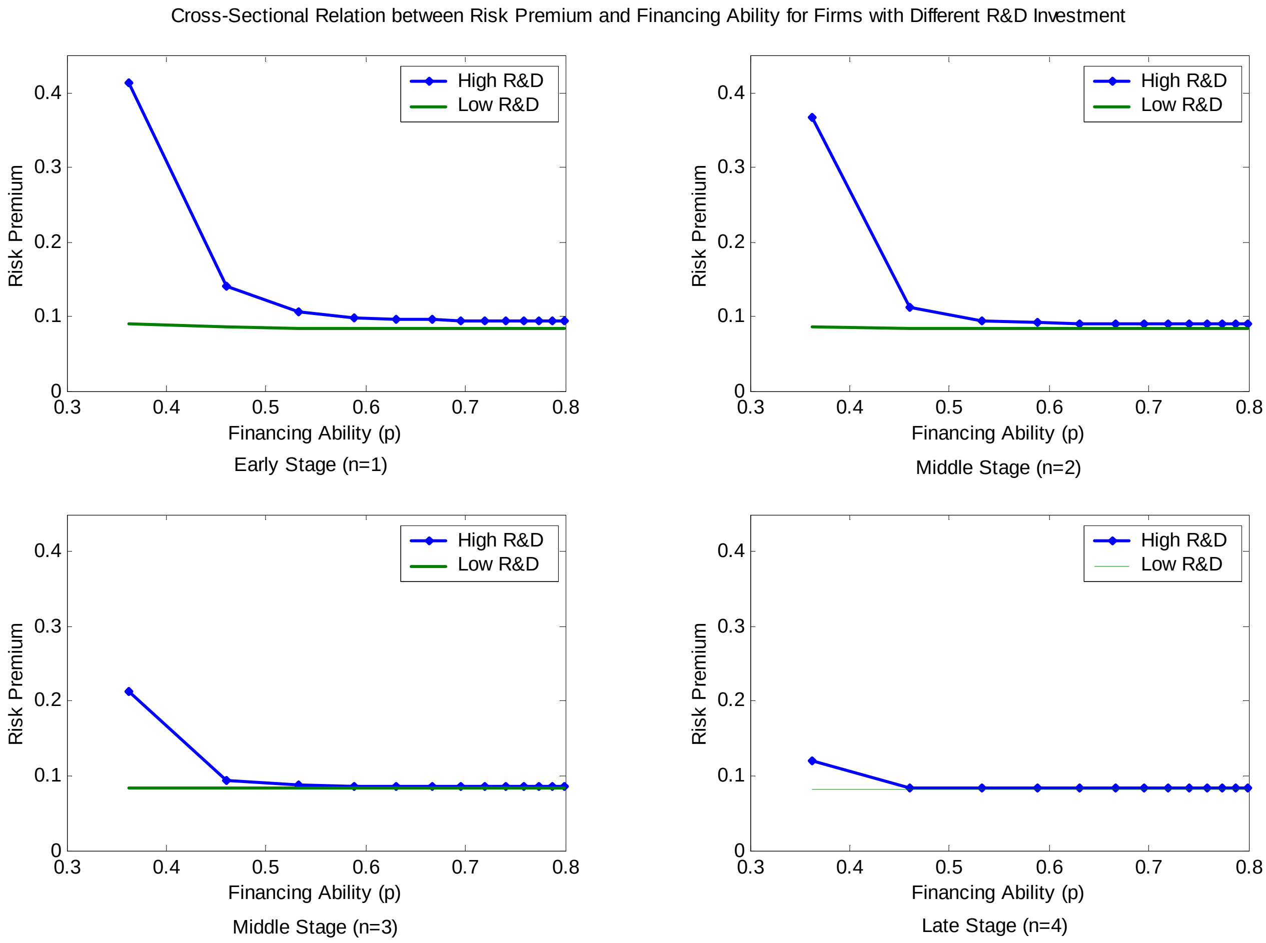


Figure 4: The risk premiums (per annum) of projects that require 5 stages to complete are plotted as a function of their financing abilities (p) for different levels of R&D investment and over different stages. For example, the top left plot is for projects that have completed the first stage ($n = 1$), the top right for projects having completed two stages ($n = 2$), and so forth. The risk premium is the instantaneous expected return minus the risk-free rate. The two lines correspond to different levels of R&D investment. In this figure, $\sigma = .2$ and $\pi(1) = 1$.

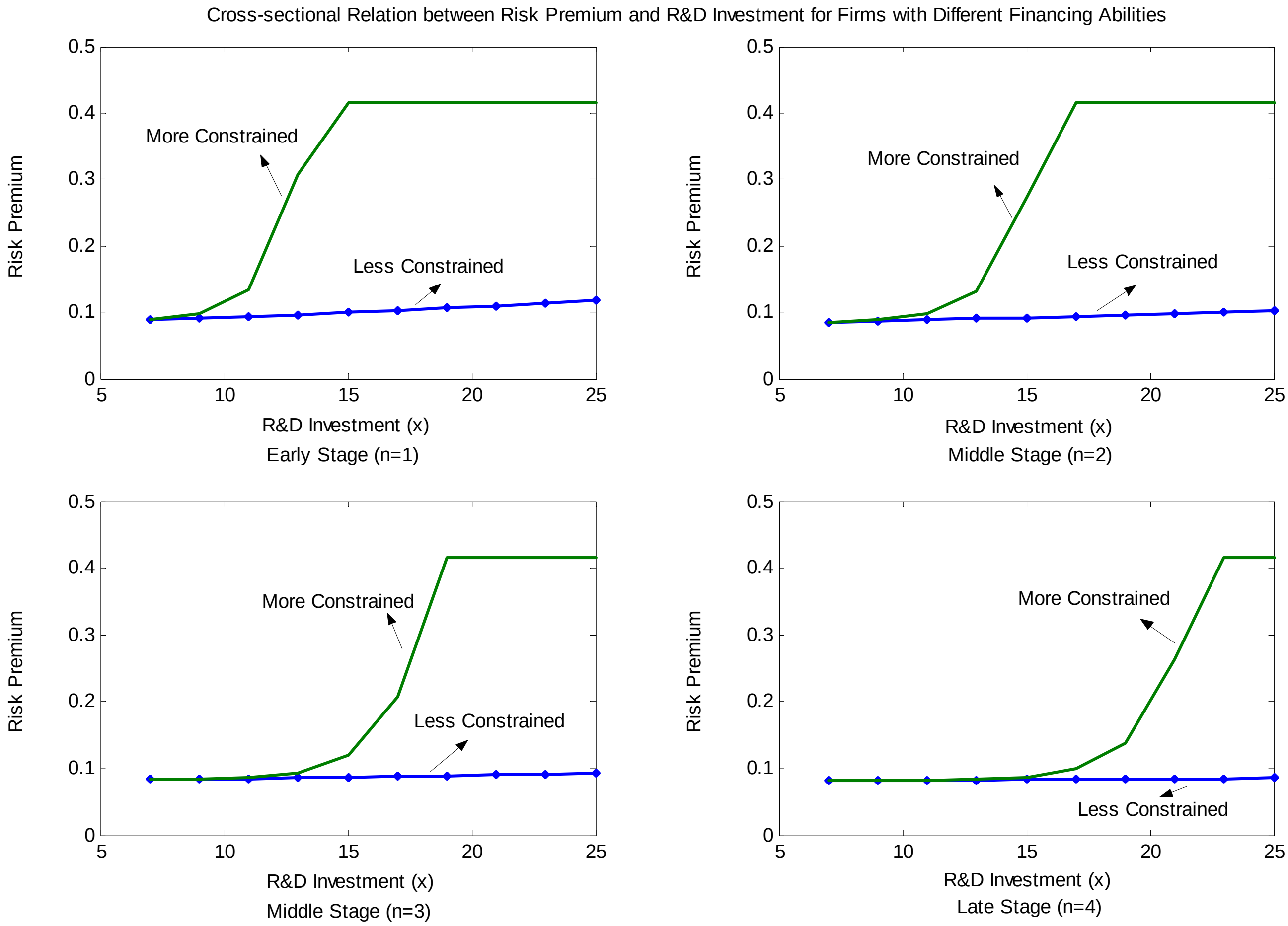


Figure 5: The risk premiums (per annum) of projects that require 5 stages to complete are plotted as a function of their investment requirement (x) for different financing abilities (p) and over different stages. For example, the top left plot is for projects that have completed the first stage ($n = 1$), the top right for projects having completed two stages ($n = 2$), and so forth. The risk premium is the instantaneous expected return minus the risk-free rate. The two lines correspond to different external financing abilities (p). In this figure, $\sigma = .2$ and $\pi(1) = 1$.

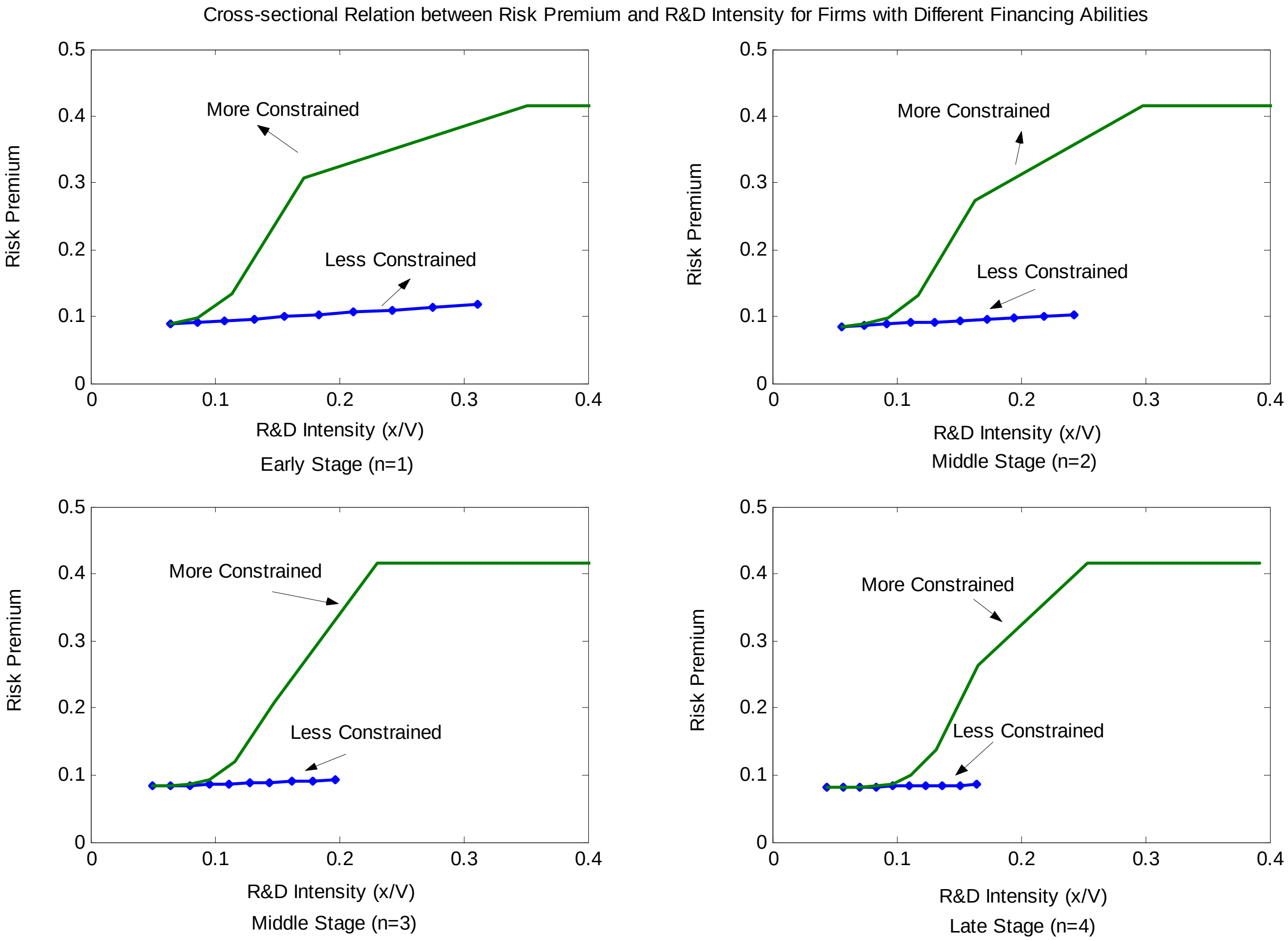
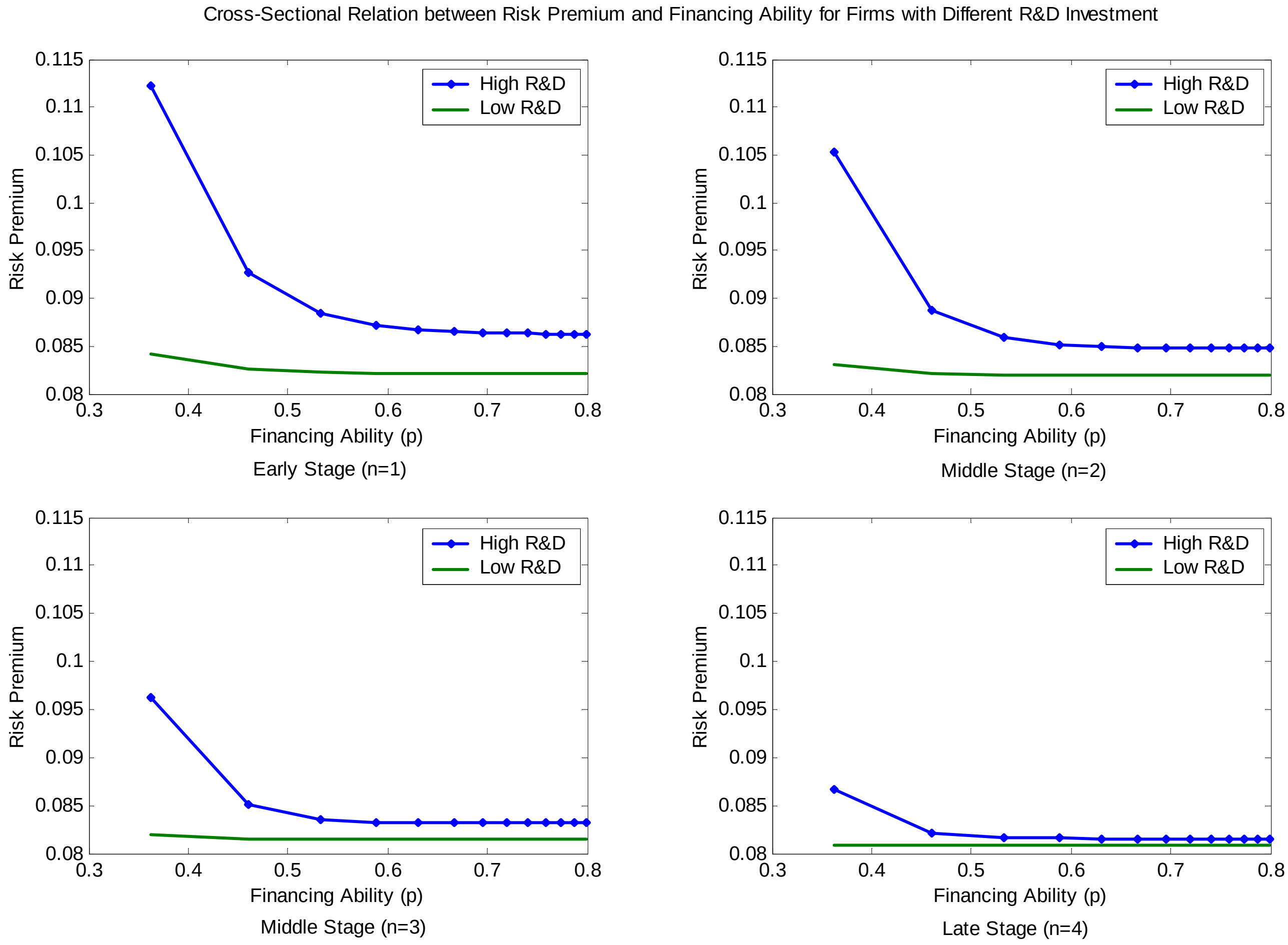


Figure 6: The risk premiums (per annum) of projects that require 5 stages to complete are plotted as a function of their investment intensity (x/V) for different financing abilities (p) and over different stages. For example, the top left plot is for projects that have completed the first stage $(n = 1)$, the top right for projects having completed two stages $(n = 2)$, and so forth. The risk premium is the instantaneous expected return minus the risk-free rate. The two lines correspond to different external financing abilities (p). In this figure, $\sigma = .2$ and $\pi(1) = 1$.


Cross-Sectional Relation between Risk Premium and Financing Ability for Firms with Different R&D Investment

Early Stage (n=1)

Middle Stage (n=2)

Middle Stage (n=3)

Late Stage (n=4)

Figure 7: The risk premiums (per annum) of projects that require 5 stages to complete are plotted as a function of their financing abilities (p) for different levels of R&D investment and over different stages. For example, the top left plot is for projects that have completed the first stage ($n = 1$), the top right for projects having completed two stages ($n = 2$), and so forth. The risk premium is the instantaneous expected return minus the risk-free rate. The two lines correspond to different levels of R&D investment. In this figure, $\sigma = .4$ and $\pi(1) = 2$.

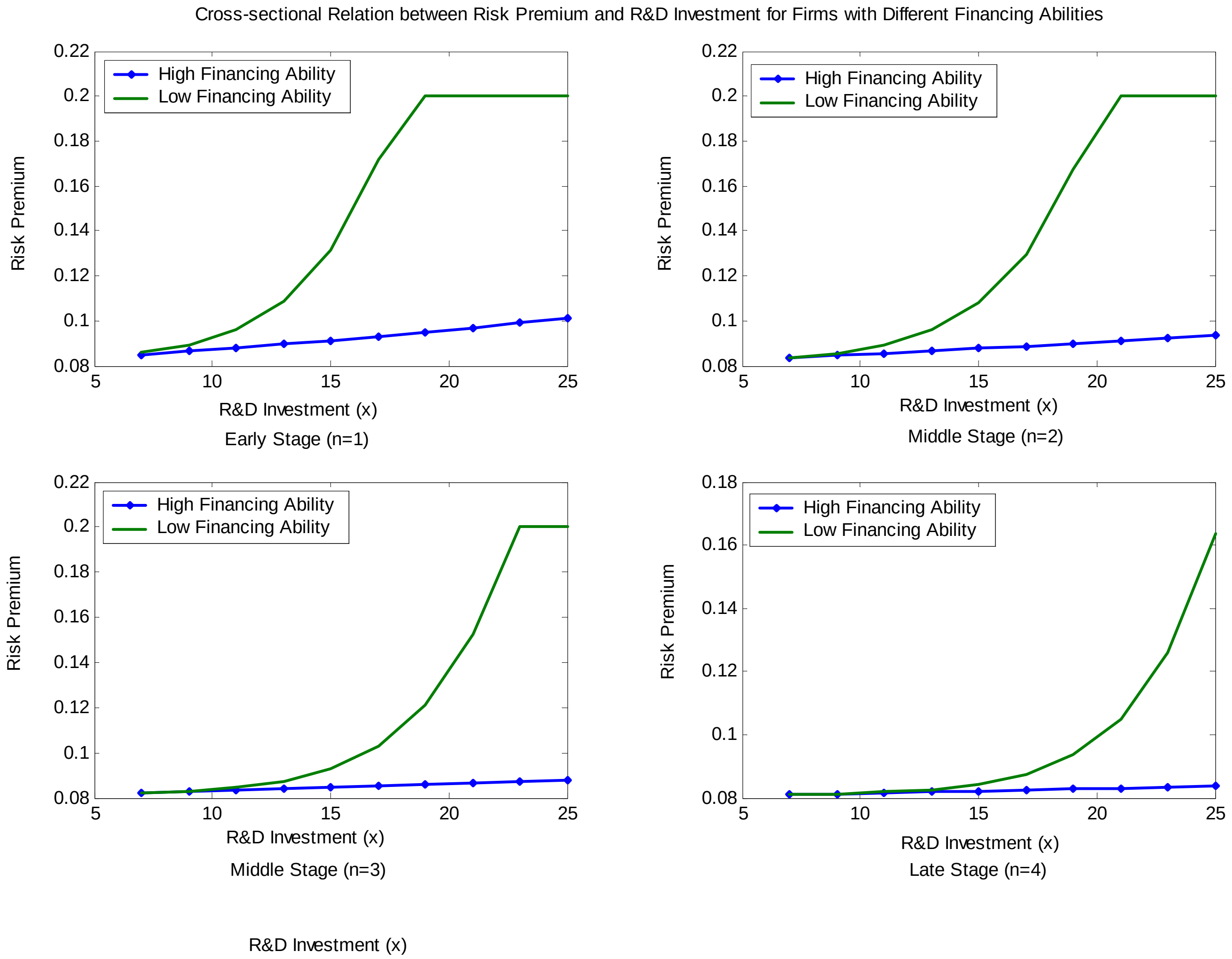


Figure 8: The risk premiums (per annum) of projects that require 5 stages to complete are plotted as a function of their investment requirement (x) for different financing abilities (p) and over different stages. For example, the top left plot is for projects that have completed the first stage $(n = 1)$, the top right for projects having completed two stages $(n = 2)$, and so forth. The risk premium is the instantaneous expected return minus the risk-free rate. The two lines correspond to different external financing abilities (p). In this figure, $\sigma = .4$ and $\pi(1) = 3$.

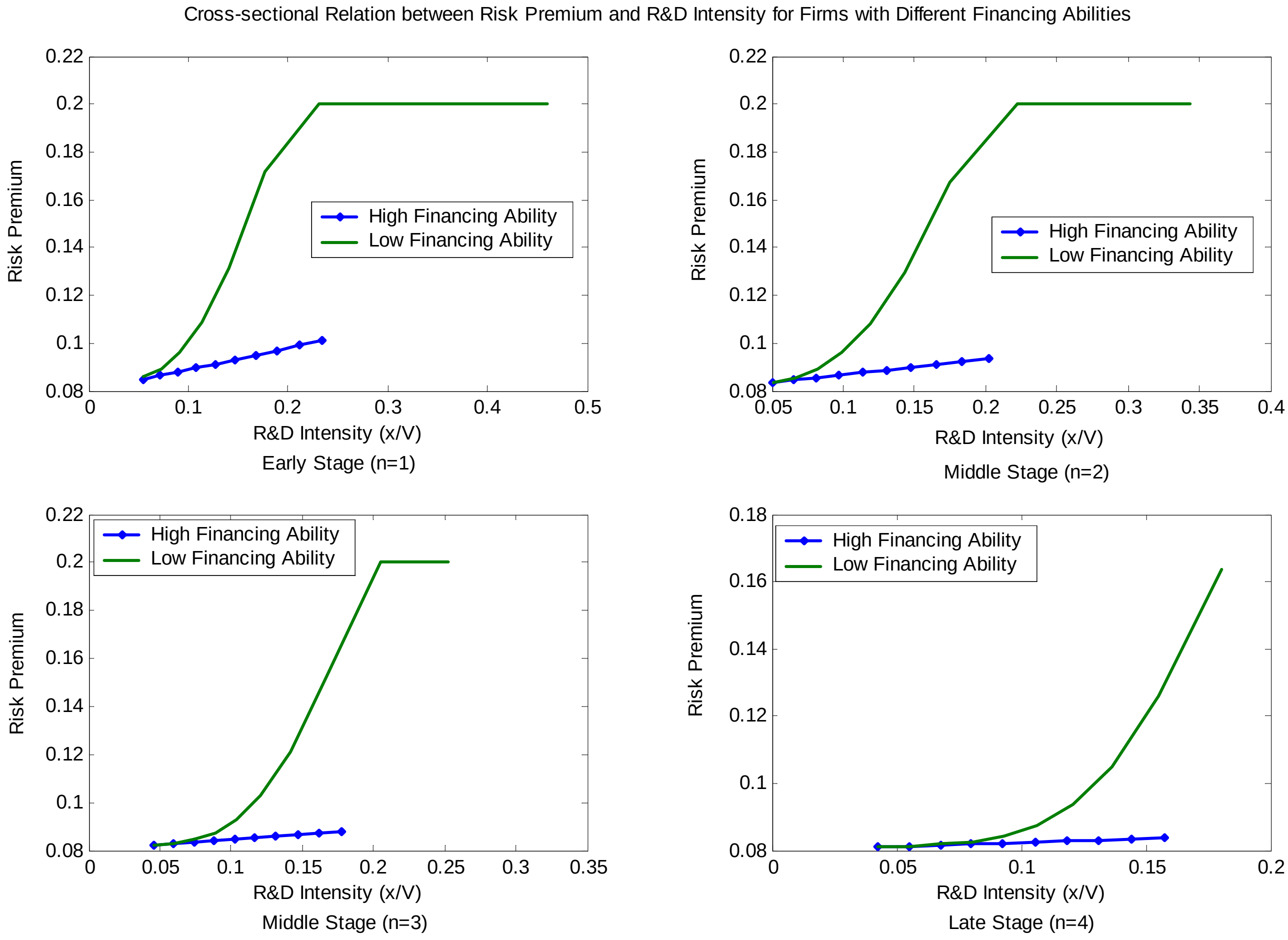


Figure 9: The risk premiums (per annum) of projects that require 5 stages to complete are plotted as a function of their investment intensity (x/V) for different financing abilities (p) and over different stages. For example, the top left plot is for projects that have completed the first stage $(n = 1)$, the top right for projects having completed two stages $(n = 2)$, and so forth. The risk premium is the instantaneous expected return minus the risk-free rate. The two lines correspond to different external financing abilities (p). In this figure, $\sigma = .4$ and $\pi(1) = 3$.

Summary of R&D Firms

Panel A: All Firms doing R&D

Fiscal Year	Number of Firms	R&D Expenditure ($Billions)	Market Capitalization ($Billions)	R&D Expenditure relative to				R&D Capital relative to	
				Sales	Earnings	Capital Expenditure	Book Equity	Book Equity	Total Assets
1975	1825	14.7	466.0	1.7%	35.5%	20.4%	4.1%	11.2%	5.2%
1980	1654	28.6	796.7	1.7%	34.3%	20.0%	5.0%	12.4%	5.5%
1985	2062	49.5	1027.9	2.9%	83.7%	38.1%	8.0%	20.8%	8.8%
1990	2001	70.9	1450.5	3.3%	77.5%	44.6%	9.6%	25.6%	8.0%
1995	2618	106.4	3201.2	3.9%	75.8%	54.0%	11.5%	29.6%	8.8%
2000	2876	172.9	8511.5	4.8%	114.0%	69.8%	10.4%	26.0%	9.4%
2005	2238	188.7	7066.8	4.1%	60.2%	83.6%	8.9%	25.4%	9.1%

Panel B: Selected Industries (Fiscal 2005)

Industry (SIC Code)	Number of Firms	R&D Expenditure ($Billions)	Market Capitalization ($Billions)	R&D Expenditure relative to				R&D Capital relative to	
				Sales	Earnings	Capital Expenditure	Book Equity	Book Equity	Total Assets
Drugs & pharmaceuticals (283)	344	50.4	1156.7	18.2%	137.9%	301.5%	19.0%	51.2%	27.1%
Computer programming, software, & services (737)	365	25.6	926.4	10.3%	81.7%	265.7%	13.1%	39.3%	19.8%
Electrical equipment excluding computers (36)	354	29.0	725.5	9.0%	103.9%	140.1%	13.5%	38.1%	22.2%
Measuring Instruments (38)	323	12.0	378.8	6.6%	111.0%	176.9%	9.9%	28.6%	15.2%
Computers & office equipment (357)	118	15.3	452.2	5.7%	86.4%	232.6%	12.1%	36.6%	18.0%
Total	1504	132.2	3639.6						

Table 1: For selected fiscal years from 1975 to 2005, Panel A reports the descriptive statistics for all firms with either positive R&D expenditure or positive R&D capital, which is computed as a weighted sum of the R&D expenditure over the past 5 years assuming a 20 percent amortization rate. All firms with Compustat data available are included except the utility and financial industries. Panel B reports the summary statistics of firms in selected high-tech industries for fiscal 2005.

High-tech Industry Distribution of R&D Capital / Total Assets Groups (June 2004; Percentage)

SIC	Industry	Low R&D	Middle R&D	High R&D
28	Drugs and pharmaceuticals	4.2	12.4	21.9
35	Computer equipment	5.1	12.6	9.2
36	Electrical equipment excluding computers	5.2	18.3	21.3
38	Measuring instruments; medical goods	3.8	16.7	12.0
73	Computer programming, software, & services	5.5	16.4	23.9
87	Research, development, and testing services	1.6	2.5	6.0
Total		25.4	78.8	94.3

Table 2: In June 2004, three R&D portfolios are formed based on the rank of the ratio of R&D capital to total assets. This table shows how the firms are distributed within the selected high-tech industries. All domestic firms trading on NYSE, AMEX, and NASDAQ with COMPUSTAT data available are included.

Portfolio Characteristics, 1975-2004

Panel A. Characteristics of Portfolios Classified by R&D Expenditure Relative to Capital Expenditure (R&D / CapExp)

Portfolio	Number of Firms	Age (Months)	Market Cap (MM)	Book-to-Market	Cash Flow/PPE	Debt / Total Capital	Cash / PPE	R&D/ Cash	R&D/ CapExp	Volatility of R&D/CapExp
1 (Low)	415	128	907	1.09	0.22	0.36	1.36	0.03	0.00	0.13
2	394	231	1795	0.89	0.21	0.33	1.98	1.39	0.21	0.31
3	398	205	2073	0.76	0.10	0.29	2.00	2.45	0.77	1.01
4	398	160	1310	0.74	-0.28	0.23	3.69	3.24	2.03	2.11
5 (High)	398	95	224	0.70	-5.56	0.15	11.73	4.34	16.55	13.94

Panel B. Characteristics of Portfolios Classified by R&D Capital Relative to Total Assets (R&D / TA)

Portfolio	Number of Firms	Age (Months)	Market Cap (MM)	Book-to-Market	Cash Flow/PPE	Debt / Total Capital	Cash / PPE	R&D/ Cash	R&D/ TA	Volatility of R&D/TA
1 (Low)	450	125	773	1.10	4.45	0.37	2.33	0.01	0.00	0.00
2	429	214	1620	0.95	-0.26	0.34	3.55	1.11	0.02	0.01
3	432	209	1418	0.82	-0.26	0.28	3.55	2.45	0.08	0.03
4	432	161	1887	0.71	-0.64	0.22	5.81	2.96	0.18	0.06
5 (High)	432	101	381	0.64	-5.10	0.16	7.50	4.48	0.59	0.22

Panel C. Characteristics of Portfolios Classified by R&D Expenditure Relative to Market Value of Equity (R&D / ME)

Portfolio	Number of Firms	Age (Months)	Market Cap (MM)	Book-to-Market	Cash Flow/PPE	Debt / Total Capital	Cash / PPE	R&D/ Cash	R&D/ ME	Volatility of R&D / ME
1 (Low)	421	122	850	1.05	4.73	0.35	2.73	0.03	0.00	0.00
2	400	194	2647	0.61	0.00	0.25	5.16	1.21	0.01	0.01
3	404	184	1630	0.64	-0.54	0.26	4.07	2.23	0.03	0.02
4	404	181	829	0.76	-2.78	0.25	5.76	3.06	0.07	0.04
5 (High)	404	137	317	1.14	-2.50	0.24	4.06	4.91	0.25	0.12

Panel D. Characteristics of Portfolios Classified by KZ Index

Portfolio	Number of Firms	Age (Months)	Market Cap (MM)	Book-to-Market	Cash Flow/PPE	Debt / Total Capital	Cash / PPE	R&D/ Cash	Sales Growth	Dividend/ PPE
1 (Least Constrained)	675	152	1303.60	0.70	2.97	0.07	15.60	1.00	1.11	1.00
2	676	200	1560.81	0.80	0.33	0.21	1.31	1.21	0.21	0.05
3	676	176	1051.29	0.99	0.23	0.27	0.54	2.24	0.18	0.02
4	676	149	566.36	1.17	0.10	0.38	0.28	3.04	0.36	0.01
5 (Most Constrained)	675	114	264.09	1.09	-4.98	0.64	1.44	5.05	0.85	0.00

Panel E. Characteristics of Portfolios Classified by WW Index

Portfolio	Number of Firms	Age (Months)	Market Cap (MM)	Book-to-Market	Cash Flow/PPE	Debt / Total Capital	Cash / PPE	R&D/ Cash	Sales Growth	Dividend/ PPE
1 (Least Constrained)	618	344	4764.79	0.81	0.79	0.37	1.83	1.33	0.22	0.13
2	598	193	478.78	0.91	0.44	0.33	1.65	1.18	0.17	0.09
3	619	130	169.06	0.97	0.41	0.31	2.59	1.95	0.29	0.08
4	598	113	72.21	1.02	-0.06	0.30	3.88	2.91	0.80	0.10
5 (Most Constrained)	619	100	23.45	0.89	-1.87	0.25	4.60	3.69	0.63	0.07

Table 3: Summary statistics, from 1975 to 2004, for portfolios formed by ranking in each June of year t all NYSE-AMEX-NASDAQ firms excluding utility and financial firms. We compute the cross-sectional average of the characteristics for each year and then take a simple mean of the 30 annual values.

Monthly Stock Returns and R&D Intensity

Panel A. Portfolios Based on R&D Expenditure / Capital Expenditure

Portfolio	Number of Firms	Monthly Excess Return	Portfolio Adjusted Monthly Return	alpha	rm-rf	smb	hml	Adjusted R-square
Missing	2159	1.09%	0.16%	-0.03%	1.04	0.93	0.23	89%
		3.33	1.47	-0.30	31.72	12.01	3.74	
Low	638	0.88%	0.03%	-0.10%	0.98	0.88	0.45	67%
		2.69	0.27	-0.49	16.45	6.79	3.90	
Middle	645	1.01%	0.27%	0.21%	1.05	0.80	-0.12	87%
		2.95	3.33	1.75	23.05	10.89	-1.47	
High	638	1.50%	0.73%	0.68%	1.02	1.42	-0.44	81%
		3.20	4.09	3.29	16.70	12.79	-4.26	

Panel B. Portfolios Based on R&D Capital / Total Assets

Portfolio	Number of Firms	Monthly Excess Return	Portfolio Adjusted Monthly Return	alpha	rm-rf	smb	hml	Adjusted R-square
Missing	2017	1.06%	0.14%	-0.06%	1.04	0.92	0.23	89%
		3.26	1.24	-0.52	32.00	12.00	3.74	
Low	685	0.88%	0.02%	-0.10%	0.97	0.91	0.44	67%
		2.65	0.14	-0.49	15.95	6.77	3.71	
Middle	693	0.96%	0.22%	0.14%	1.02	0.81	-0.06	86%
		2.87	2.64	1.22	22.35	10.33	-0.73	
High	688	1.59%	0.82%	0.76%	1.04	1.38	-0.43	81%
		3.42	4.62	3.82	17.07	12.01	-4.25	

Panel C. Portfolios Based on R&D Expenditure / MVE

Portfolio	Number of Firms	Monthly Excess Return	Portfolio Adjusted Monthly Return	alpha	rm-rf	smb	hml	Adjusted R-square
Missing	2129	1.08%	0.15%	-0.04%	1.04	0.92	0.23	89%
		3.30	1.36	-0.38	31.68	11.99	3.74	
Low	649	0.71%	-0.02%	-0.20%	0.99	0.88	0.27	68%
		2.07	-0.16	-0.98	16.33	6.45	2.18	
Middle	656	0.84%	0.20%	0.06%	1.04	0.83	-0.16	88%
		2.42	2.59	0.49	23.72	11.13	-2.12	
High	646	1.87%	0.89%	0.96%	1.01	1.40	-0.20	79%
		4.25	5.04	4.78	16.26	12.72	-1.94	

Table 4: This table shows how stock returns vary with the R&D intensities. Each June of year t from 1975 to 2004, we rank firms based on RD intensities into three equal-numbered portfolios based on the accounting data in fiscal year ending in calendar year $t-1$. We compute the subsequent monthly returns from July of year t to June of year $t+1$ and reform the portfolios in June of year $t+1$. The excess return is the difference between portfolio return and one-month T-bill rate. The portfolio adjusted return is based on the difference between each individual stock's return and the return of its matching portfolio by its size and book-to-market ranks. For each portfolio, the first line reports the mean returns and regression coefficients from the Fama-French three-factor model including the market factor (rm-rf), the size factor (smb), and the book-to-market factor (hml); the second line reports the heteroscedasticity robust t statistics. Portfolio returns are adjusted for delisting bias.

Monthly Stock Returns and Financial Constraints Indices

Panel A. Portfolios Based on KZ Index

Portfolio	Number of Firms	Monthly Excess Return	Portfolio Adjusted Monthly Return	alpha	rm-rf	smb	hml	Adjusted R-square
Missing	1101	1.04%	0.25%	-0.04%	1.11	1.12	-0.12	85%
		2.59	1.62	-0.23	25.09	11.85	-1.48	
Low	1009	1.03%	0.23%	0.23%	0.95	0.93	-0.08	87%
		3.09	2.92	1.84	26.55	15.09	-1.56	
Middle	1006	1.10%	0.25%	0.21%	0.97	0.82	0.19	88%
		3.70	4.18	2.06	22.99	12.60	2.66	
High	981	1.15%	0.32%	0.14%	1.02	0.97	0.28	79%
		3.39	2.73	0.93	20.36	9.70	3.04	

Panel B. Portfolios Based on WW Index

Portfolio	Number of Firms	Monthly Excess Return	Portfolio Adjusted Monthly Return	alpha	rm-rf	smb	hml	Adjusted R-square
Missing	1257	1.17%	0.27%	0.10%	1.05	1.16	-0.09	86%
		2.97	1.78	0.67	26.60	14.55	-1.21	
Low	994	0.72%	0.04%	-0.19%	1.11	0.42	0.32	92%
		2.57	0.57	-2.09	40.62	6.67	6.22	
Middle	947	0.85%	0.03%	-0.04%	1.04	0.90	0.04	87%
		2.50	0.40	-0.37	22.56	10.88	0.45	
High	929	1.37%	0.59%	0.48%	0.92	1.26	-0.05	75%
		3.43	4.30	2.43	16.05	12.28	-0.51	

Table 5: This table shows how stock returns vary with financial constraints indices. Each June of year t from 1975 to 2004, we rank firms based on the lagged financial constraint index into three equal-numbered groups. We compute the subsequent returns from July of year t to June of year $t+1$ and reform the portfolios in June of year $t+1$. The excess return is the difference between portfolio return and one-month T-bill rate. The portfolio adjusted return is based on the difference between each individual stock's return and the return of its matching portfolio by its size and book-to-market ranks. For each portfolio, the first line reports the mean returns and regression coefficients from the Fama-French three-factor model including the market factor (rm-rf), the size factor (smb), and the book-to-market factor (hml); the second line reports the heteroscedasticity robust t statistics. Portfolio returns are adjusted for delisting bias.

Financial Constraints Factor Constructed from the WW Index

Portfolio	Label	Number of Firms	Equal-Weighted Monthly Excess Return	Value-Weighted Monthly Excess Return
Small-cap Firms				
Low WW	11	19	1.74%	1.31%
Middle WW	12	190	1.24%	1.14%
High WW	13	667	1.77%	0.97%
Mid-cap Firms				
Low WW	21	169	0.86%	0.84%
Middle WW	22	538	0.83%	0.77%
High WW	23	270	0.58%	0.51%
Large-cap Firms				
Low WW	31	810	0.69%	0.55%
Middle WW	32	243	0.59%	0.63%
High WW	33	23	0.12%	0.10%
Financial Constraints Factor (High WW - Low WW)	(13+23+33)/3- (11+21+31)/3		-0.38% (-1.18)	-0.55% (-1.56)

Table 6: This table shows how stock returns vary with the WW index within each size group. Each June of year t, we form portfolios based on independent sorts of the top third, middle third, and bottom third of size (market capitalization in June of year t) and of lagged WW. We then compute the portfolio returns in excess of the one-month T-bill rate for the subsequent twelve months. The bottom two rows report the mean excess returns and the t statistic for the financial constraints factor created from the WW index. All returns are adjusted for delisting bias following Shumway and Warther (1999) and Shumway (1997). The sample period is from January 1975 to December 2004.

Financial Constraints Factor Constructed from the KZ Index

Portfolio	Label	Number of Firms	Equal-Weighted Monthly Excess Return	Value-Weighted Monthly Excess Return
Small-cap Firms				
Low KZ	11	239	1.65%	1.15%
Middle KZ	12	294	1.70%	1.27%
High KZ	13	446	1.79%	0.98%
Mid-cap Firms				
Low KZ	21	358	0.88%	0.80%
Middle KZ	22	333	1.05%	1.02%
High KZ	23	319	0.66%	0.60%
Large-cap Firms				
Low KZ	31	424	0.71%	0.60%
Middle KZ	32	385	0.71%	0.54%
High KZ	33	223	0.64%	0.47%
Financial Constraints Factor (High KZ - Low KZ)	(13+23+33)/3- (11+21+31)/3		-0.05% (-0.39)	-0.16% (-1.45)

Table 7: This table shows how stock returns vary with the KZ index within each size group. Each June of year t, we form portfolios based on independent sorts of the top third, middle third, and bottom third of size (market capitalization in June of year t) and of KZ using accounting variables reported in the fiscal year ending in calendar year $t-1$. We then compute the portfolio returns in excess of the one-month T-bill rate for the subsequent twelve months. The bottom two rows report the mean excess returns and the t statistic for the financial constraints factor created from the KZ index. All returns are adjusted for delisting bias following Shumway and Warther (1999) and Shumway (1997). The sample period is from January 1975 to December 2004.

Financial Constraints (KZ) and Stock Returns within R&D Capital / Total Assets Groups

Portfolio	Label	Number of Firms	Monthly Excess Return	Matching Portfolio Adjusted Return	alpha	m	s	h	Adjusted R-Square
Low R&D Capital / Total Assets									
Low KZ	11	208	0.82%	-0.01%	-0.06%	0.98	0.70	0.26	86%
			2.86	-0.05	-0.57	27.01	8.57	4.00	
Middle KZ	12	201	1.05%	0.15%	0.04%	0.99	0.86	0.55	64%
			3.24	1.12	0.19	16.20	6.56	4.79	
High KZ	13	202	0.84%	-0.01%	-0.21%	1.02	0.90	0.48	74%
			2.57	-0.06	-1.24	21.89	8.09	5.00	
High - Low	13 -11		0.02%	0.00%	-0.15%	0.04	0.21	0.22	6%
			0.14	-0.03	-1.00	1.25	3.43	3.10	
Middle R&D Capital / Total Assets									
Low KZ	21	207	0.83%	0.10%	0.05%	0.99	0.83	-0.14	86%
			2.39	0.87	0.36	26.06	13.02	-2.11	
Middle KZ	22	201	1.02%	0.22%	0.20%	0.99	0.63	0.12	85%
			3.50	2.99	1.80	24.31	10.01	1.75	
High KZ	23	197	1.23%	0.42%	0.27%	1.01	0.97	0.19	78%
			3.55	3.69	1.77	16.50	9.32	1.67	
High - Low	23 - 21		0.41%	0.34%	0.13%	0.07	0.23	0.45	17%
			2.65	2.66	0.91	1.76	3.07	6.52	
High R&D Capital / Total Assets									
Low KZ	31	222	1.20%	0.56%	0.42%	1.04	1.23	-0.50	83%
			2.61	3.42	2.17	15.85	10.92	-5.21	
Middle KZ	32	219	1.58%	0.80%	0.83%	1.01	1.29	-0.40	80%
			3.50	5.12	3.82	17.49	12.84	-4.73	
High KZ	33	216	1.80%	1.19%	0.75%	1.17	1.60	-0.26	75%
			3.36	5.13	2.96	15.80	9.81	-1.84	
High - Low	33 - 31		0.60%	0.63%	0.32%	0.13	0.37	0.24	12%
			3.24	4.00	1.94	3.01	3.69	2.49	

Table 8: This table shows the relation between postranking stock returns and financial constraints measured by the KZ index for different R&D intensity groups. The portfolios are formed in each June on a conditional two-way sorts on the lagged R&D intensity first and then on the lagged KZ index. Monthly portfolio returns are then computed over the next 12 months. The excess return is the difference between the raw portfolio return and the one-month T-bill rate. The matching portfolio adjusted return is based on the difference between the individual stock return and the return of its matching portfolio by size and book-to-market ranks. The alphas are estimated as intercepts from the regressions of excess portfolio postranking returns on the Fama-French factor returns. m is the coefficient of the market factor; s is the coefficient of the size factor; h is the coefficient of the book-to-market factor. For each portfolio, the first line reports the mean returns and the regression estimates, and the second line reports heteroscedasticity-robust t statistics. All portfolio returns are adjusted for delisting bias. The sample period is from January 1975 to December 2004.

Financial Constraints (KZ) and Stock Returns within R&D Capital / Total Assets Groups

Portfolio	Label	alpha	m	s	h	u	l	Adjusted R-square
Low R&D Capital / Total Assets								
Low KZ	11	0.15%	0.94	0.71	0.18	-0.13	-0.09	88%
		1.23	28.25	10.99	2.95	-2.66	-2.02	
Middle KZ	12	0.30%	0.92	0.86	0.43	-0.13	-0.16	67%
		1.45	16.34	7.59	4.40	-2.13	-2.47	
High KZ	13	0.01%	0.95	0.89	0.36	-0.05	-0.19	76%
		0.05	22.69	9.72	4.09	-0.79	-2.48	
High - Low	13 -11	-0.14%	0.01	0.19	0.18	0.08	-0.10	7%
		-0.94	0.41	3.24	2.59	1.83	-1.98	
Middle R&D Capital / Total Assets								
Low KZ	21	0.36%	0.97	0.88	-0.20	-0.33	0.01	91%
		2.86	31.05	15.81	-3.20	-7.07	0.30	
Middle KZ	22	0.40%	0.95	0.64	0.06	-0.15	-0.07	87%
		3.78	23.38	11.57	0.84	-4.41	-2.06	
High KZ	23	0.56%	0.95	0.98	0.07	-0.16	-0.16	81%
		3.54	15.78	10.95	0.66	-2.97	-2.71	
High - Low	23 - 21	0.12%	0.02	0.18	0.38	0.19	-0.20	25%
		0.84	0.49	2.78	5.89	4.37	-3.76	
High R&D Capital / Total Assets								
Low KZ	31	0.71%	1.04	1.30	-0.52	-0.38	0.09	86%
		3.85	20.43	11.07	-6.53	-5.26	1.18	
Middle KZ	32	1.03%	1.00	1.32	-0.44	-0.22	0.01	81%
		4.60	17.88	12.12	-5.12	-3.47	0.10	
High KZ	33	1.10%	1.11	1.63	-0.38	-0.27	-0.10	77%
		3.91	16.23	9.83	-3.11	-2.50	-0.86	
High - Low	33 - 31	0.38%	0.07	0.33	0.15	0.12	-0.19	16%
		2.11	1.60	3.70	1.85	1.67	-2.48	

Table 9: This table shows the relation between postranking stock returns and financial constraints measured by the KZ index for different R&D intensity groups. The portfolios are formed in each June on a conditional two-way sorts on the lagged R&D intensity first and then on the lagged KZ index. Monthly portfolio returns are then computed over the next 12 months. The alphas are estimated as intercepts from the regressions of excess portfolio postranking returns on the Fama-French factor returns, the momentum factor returns, and the liquidity factor returns. m is the loading on the market factor; s is the loading on the size factor; h is the loading on the book-to-market factor; u is the loading on the momentum factor; l is the loading on the liquidity factor. For each portfolio, the first line reports the regression estimates, and the second line reports heteroscedasticity-robust t statistics. The sample period is from January 1975 to December 2004. All portfolio returns are adjusted for delisting bias.

Financial Constraints (KZ) and Stock Returns within R&D/MVE Groups

Portfolio	Label	Number of Firms	Monthly Excess Return	Matching Portfolio Adjusted Return	alpha	m	s	h	Adjusted R-Square
Low R&D Expenditure / MVE									
Low KZ	11	195	0.68%	0.01%	-0.12%	1.01	0.65	0.04	88%
			2.24	0.13	-1.08	31.98	9.44	0.74	
Middle KZ	12	189	0.91%	0.10%	-0.04%	0.99	0.82	0.41	65%
			2.77	0.74	-0.18	16.22	6.14	3.47	
High KZ	13	190	0.77%	0.03%	-0.27%	1.02	0.92	0.43	71%
			2.26	0.18	-1.52	21.25	6.94	3.85	
High - Low	13 -11		0.09%	0.02%	-0.15%	0.01	0.27	0.39	12%
			0.48	0.10	-0.91	0.37	2.83	4.07	
Middle R&D Expenditure / MVE									
Low KZ	21	199	0.73%	0.11%	0.01%	1.00	0.89	-0.33	87%
			1.96	0.99	0.09	24.71	13.64	-5.03	
Middle KZ	22	192	0.99%	0.29%	0.21%	1.01	0.64	-0.03	87%
			3.19	4.09	1.91	24.96	9.34	-0.40	
High KZ	23	190	0.88%	0.22%	-0.05%	1.06	0.97	0.06	82%
			2.44	2.02	-0.36	18.76	10.06	0.54	
High - Low	23 - 21		0.14%	0.11%	-0.17%	0.11	0.17	0.51	19%
			0.88	0.89	-1.16	2.65	2.04	6.50	
High R&D Expenditure / MVE									
Low KZ	31	206	1.57%	0.71%	0.70%	1.03	1.37	-0.35	79%
			3.35	3.69	3.20	14.78	10.70	-3.15	
Middle KZ	32	202	1.74%	0.76%	0.86%	1.00	1.34	-0.09	77%
			4.06	4.91	3.93	17.03	12.86	-1.11	
High KZ	33	200	2.11%	1.27%	1.00%	1.12	1.51	0.02	75%
			4.39	6.26	4.28	16.33	11.77	0.16	
High - Low	33 - 31		0.54%	0.56%	0.30%	0.09	0.14	0.36	8%
			3.25	3.84	1.85	2.15	1.78	5.03	

Table 10: This table shows the relation between postranking stock returns and financial constraints measured by the KZ index for different R&D intensity groups. The R&D intensity is measured by the ratio of R&D expenditure to year-end market value of equity. The portfolios are formed in each June on a conditional two-way sorts on the lagged R&D intensity first and then on the lagged KZ index. Monthly portfolio returns are then computed over the next 12 months. The excess return is the difference between the raw portfolio return and the one-month T-bill rate. The matching portfolio adjusted return is based on the difference between the individual stock return and the return of its matching portfolio by size and book-to-market ranks. The alphas are estimated as intercepts from the regressions of excess portfolio postranking returns on the Fama-French factor returns. m is the coefficient of the market factor; s is the coefficient of the size factor; h is the coefficient of the book-to-market factor. For each portfolio, the first line reports the mean returns and the regression estimates, and the second line reports heteroscedasticity-robust t statistics. All portfolio returns are adjusted for delisting bias. The sample period is from January 1975 to December 2004.

Financial Constraints (KZ) and Stock Returns within R&D Expenditure / Capital Expenditure Groups

Portfolio	Label	Number of Firms	Monthly Excess Return	Matching Portfolio Adjusted Return	alpha	m	s	h	Adjusted R-Square
Low R&D Expenditure / Capital Expenditure									
Low KZ	11	197	0.87%	0.05%	-0.02%	0.98	0.65	0.30	87%
			3.14	0.48	-0.17	30.29	9.04	4.91	
Middle KZ	12	190	1.01%	0.12%	0.01%	1.00	0.82	0.53	65%
			3.14	0.96	0.04	16.38	6.21	4.65	
High KZ	13	191	0.82%	-0.01%	-0.23%	1.03	0.90	0.47	75%
			2.50	-0.08	-1.41	23.29	8.70	5.22	
High - Low	13 -11		-0.05%	-0.07%	-0.22%	0.05	0.25	0.17	7%
			-0.33	-0.51	-1.47	1.53	4.65	2.55	
Middle R&D Expenditure / Capital Expenditure									
Low KZ	21	200	0.81%	0.08%	0.05%	1.02	0.77	-0.18	87%
			2.34	0.80	0.38	26.83	11.60	-2.69	
Middle KZ	22	193	1.10%	0.34%	0.30%	1.02	0.66	0.01	86%
			3.54	4.61	2.67	24.43	11.11	0.09	
High KZ	23	190	1.26%	0.49%	0.33%	1.07	0.99	0.03	81%
			3.42	4.36	2.16	17.79	10.57	0.29	
High - Low	23 - 21		0.47%	0.42%	0.18%	0.10	0.32	0.33	16%
			3.18	3.57	1.30	2.66	4.73	5.19	
High R&D Expenditure / Capital Expenditure									
Low KZ	31	195	1.14%	0.51%	0.34%	1.03	1.29	-0.47	82%
			2.47	3.11	1.74	15.73	11.72	-4.97	
Middle KZ	32	191	1.52%	0.73%	0.76%	0.99	1.37	-0.42	78%
			3.25	4.22	3.32	16.16	12.99	-4.48	
High KZ	33	189	1.76%	1.11%	0.72%	1.11	1.59	-0.20	74%
			3.40	5.07	2.79	15.05	10.82	-1.47	
High - Low	33 - 31		0.62%	0.60%	0.37%	0.09	0.30	0.27	9%
			3.52	4.00	2.18	1.93	3.70	3.27	

Table 11: This table shows the relation between postranking stock returns and financial constraints measured by the KZ index for different R&D intensity groups. The portfolios are formed in each June on a conditional two-way sorts on the lagged R&D intensity first and then on the lagged KZ index. Monthly portfolio returns are then computed over the next 12 months. The excess return is the difference between the raw portfolio return and the one-month T-bill rate. The matching portfolio adjusted return is based on the difference between the individual stock return and the return of its matching portfolio by size and book-to-market ranks. The alphas are estimated as intercepts from the regressions of excess portfolio postranking returns on the Fama-French factor returns. m is the coefficient of the market factor; s is the coefficient of the size factor; h is the coefficient of the book-to-market factor. For each portfolio, the first line reports the mean returns and the regression estimates, and the second line reports heteroscedasticity-robust t statistics. All portfolio returns are adjusted for delisting bias. The sample period is from January 1975 to December 2004.

Financial Constraints (WW) and Stock Returns within R&D Expenditure / MVE Groups

Portfolio	Label	Number of Firms	Monthly Excess Return	Matching Portfolio Adjusted Return	alpha	m	s	h	Adjusted R-Square
Low R&D Expenditure / MVE									
Low WW	11	189	0.61%	0.01%	-0.22%	1.09	0.31	0.23	87%
			2.19	0.15	-1.93	32.48	3.98	3.94	
Middle WW	12	187	0.52%	-0.20%	-0.43%	1.08	0.84	0.16	84%
			1.52	-1.54	-2.97	25.40	8.25	2.01	
High WW	13	182	0.79%	0.09%	-0.17%	0.96	1.05	0.21	70%
			2.15	0.55	-0.82	18.99	10.04	2.14	
High - Low	13 -11		0.18%	0.08%	0.05%	-0.13	0.74	-0.02	27%
			0.74	0.54	0.22	-2.61	10.02	-0.19	
Middle R&D Expenditure / MVE									
Low WW	21	196	0.62%	0.01%	-0.18%	1.09	0.28	0.20	88%
			2.23	0.13	-1.71	35.31	4.83	3.57	
Middle WW	22	187	0.78%	0.13%	0.02%	1.06	0.90	-0.30	87%
			2.07	1.42	0.17	23.57	12.63	-4.37	
High WW	23	192	0.91%	0.34%	0.00%	1.02	1.34	-0.22	80%
			2.04	2.37	-0.01	18.61	12.64	-2.06	
High - Low	23 - 21		0.28%	0.33%	0.18%	-0.07	1.05	-0.41	50%
			0.94	2.27	0.84	-1.13	10.64	-3.68	
High R&D Expenditure / MVE									
Low WW	31	189	1.13%	0.36%	0.13%	1.19	0.89	0.08	83%
			2.95	2.60	0.80	23.07	13.07	1.10	
Middle WW	32	188	1.70%	0.78%	0.74%	1.07	1.45	-0.26	81%
			3.58	4.25	3.43	17.06	12.65	-2.45	
High WW	33	183	2.31%	1.46%	1.33%	0.97	1.77	-0.27	69%
			4.24	5.52	4.28	10.92	9.70	-1.73	
High - Low	33 - 31		1.17%	1.10%	1.19%	-0.23	0.87	-0.35	27%
			3.59	4.68	4.07	-2.75	5.65	-2.52	

Table 12: This table shows the relation between postranking stock returns and financial constraints measured by the WW index for different R&D intensity groups. The R&D intensity is measured by the ratio of R&D expenditure to year-end market value of equity. The portfolios are formed in each June on a conditional two-way sorts on the lagged R&D intensity first and then on the lagged WW index. Monthly portfolio returns are then computed over the next 12 months. The excess return is the difference between the raw portfolio return and the one-month T-bill rate. The matching portfolio adjusted return is based on the difference between the individual stock return and the return of its matching portfolio by size and book-to-market ranks. The alphas are estimated as intercepts from the regressions of excess portfolio postranking returns on the Fama-French factor returns. m is the coefficient of the market factor; s is the coefficient of the size factor; h is the coefficient of the book-to-market factor. For each portfolio, the first line reports the mean returns and the regression estimates; and the second line reports heteroscedasticity-robust t statistics. All portfolio returns are adjusted for delisting bias. The sample period is from January 1975 to December 2004.

R&D Intensity and Stock Returns within Financial Constraints (KZ) Groups

Portfolio	Label	Number of Firms	Monthly Excess Return	Matching Portfolio Adjusted Return	alpha	m	s	h	Adjusted R-Square
Low KZ									
Low R&D Capital / Total Assets	11	235	0.80%	0.00%	-0.05%	0.99	0.67	0.18	88%
			2.74	-0.02	-0.50	29.14	9.18	2.98	
Middle R&D Capital / Total Assets	12	230	1.02%	0.27%	0.27%	0.96	1.09	-0.19	74%
			2.59	2.14	1.30	15.51	9.41	-1.65	
High R&D Capital / Total Assets	13	227	1.33%	0.66%	0.66%	0.99	1.24	-0.64	79%
			2.84	3.75	3.00	14.55	9.32	-5.76	
High - Low	13 -11		0.54%	0.69%	0.63%	0.03	0.64	-0.75	50%
			1.91	3.07	2.86	0.41	4.13	-6.57	
Middle KZ									
Low R&D Capital / Total Assets	21	216	0.96%	0.09%	-0.04%	1.02	0.75	0.44	83%
			3.26	0.82	-0.29	28.07	8.72	6.43	
Middle R&D Capital / Total Assets	22	211	0.98%	0.16%	0.12%	1.00	0.65	0.20	86%
			3.41	2.12	1.13	20.50	9.55	2.32	
High R&D Capital / Total Assets	23	213	1.61%	0.82%	0.80%	1.05	1.25	-0.29	78%
			3.62	5.26	3.69	17.56	11.25	-3.35	
High - Low	23 - 21		0.60%	0.74%	0.71%	0.07	0.48	-0.73	49%
			2.33	3.43	3.61	1.21	3.57	-7.57	
High KZ									
Low R&D Capital / Total Assets	31	179	0.81%	-0.05%	-0.23%	1.00	0.86	0.50	71%
			2.49	-0.31	-1.31	20.54	7.70	5.23	
Middle R&D Capital / Total Assets	32	181	1.25%	0.46%	0.15%	1.08	1.01	0.42	77%
			3.51	3.30	0.88	23.53	8.97	4.50	
High R&D Capital / Total Assets	33	179	1.80%	1.19%	0.72%	1.16	1.62	-0.21	73%
			3.34	5.06	2.82	15.31	9.88	-1.39	
High - Low	33 - 31		0.99%	1.24%	0.96%	0.16	0.76	-0.71	47%
			3.00	4.71	4.08	2.26	5.26	-5.71	

Table 13: This table shows the relation between postranking stock returns and R&D intensity for different level of KZ groups. The portfolios are formed in each June on a conditional two-way sorts on the lagged KZ index first and then on the lagged R&D intensity. Monthly portfolio returns are then computed over the next 12 months. The excess return is the difference between the raw portfolio return and the one-month T-bill rate. The matching portfolio adjusted return is based on the difference between the individual stock return and the return of its matching portfolio by size and book-to-market ranks. The alphas are estimated as intercepts from the regressions of excess portfolio postranking returns on the Fama-French factor returns. m is the coefficient of the market factor; s is the coefficient of the size factor; h is the coefficient of the book-to-market factor. For each portfolio, the first line reports the mean returns and the regression estimates, and the second line reports heteroscedasticity-robust t statistics. All portfolio returns are adjusted for delisting bias. The sample period is from January 1975 to December 2004.

R&D Intensity and Stock Returns within Financial Constraints (KZ) Groups

Portfolio	Label	alpha	m	s	h	u	l	Adjusted R-square
Low KZ								
Low R&D Capital / Total Assets	11	0.21%	0.94	0.69	0.09	-0.19	-0.09	91%
		2.08	30.27	13.31	1.74	-4.95	-2.39	
Middle R&D Capital / Total Assets	12	0.50%	0.95	1.14	-0.22	-0.31	0.06	77%
		2.47	17.68	10.15	-2.13	-5.96	1.05	
High R&D Capital / Total Assets	13	0.90%	1.02	1.32	-0.62	-0.40	0.15	82%
		4.04	18.42	9.51	-6.37	-4.55	1.60	
High - Low	13 -11	0.63%	0.09	0.68	-0.66	-0.20	0.21	53%
		2.96	1.49	4.59	-7.22	-2.66	2.11	
Middle KZ								
Low R&D Capital / Total Assets	21	0.20%	0.96	0.76	0.34	-0.14	-0.12	86%
		1.43	27.85	10.86	4.93	-2.26	-2.50	
Middle R&D Capital / Total Assets	22	0.31%	0.95	0.66	0.12	-0.10	-0.11	88%
		2.96	20.04	11.26	1.44	-3.08	-3.44	
High R&D Capital / Total Assets	23	1.04%	1.02	1.28	-0.35	-0.21	-0.03	80%
		4.80	18.10	10.56	-4.48	-3.90	-0.46	
High - Low	23 - 21	0.69%	0.10	0.49	-0.69	-0.07	0.09	49%
		3.75	2.10	3.69	-8.59	-1.38	1.08	
High KZ								
Low R&D Capital / Total Assets	31	-0.02%	0.92	0.84	0.37	-0.03	-0.21	73%
		-0.11	21.01	9.23	4.21	-0.39	-2.84	
Middle R&D Capital / Total Assets	32	0.49%	0.99	1.01	0.26	-0.14	-0.23	81%
		2.90	22.07	12.35	3.52	-2.14	-3.03	
High R&D Capital / Total Assets	33	1.10%	1.09	1.65	-0.34	-0.27	-0.13	75%
		3.72	15.09	10.46	-2.71	-2.28	-1.09	
High - Low	33 - 31	1.12%	0.16	0.81	-0.71	-0.24	0.08	49%
		4.37	2.71	5.39	-6.78	-2.66	0.82	

Table 14: This table shows the relation between postranking stock returns and R&D intensity for different level of KZ groups. The portfolios are formed in each June on a conditional two-way sorts on the lagged KZ index first and then on the lagged R&D intensity. The alphas are estimated as intercepts from the regressions of excess portfolio postranking returns on the Fama-French factor returns, the momentum factor returns, and the liquidity factor returns. m is the loading on the market factor; s is the loading on the size factor; h is the loading on the book-to-market factor; u is the loading on the momentum factor; l is the loading on the liquidity factor. For each portfolio, the first line reports the regression estimates; and the second line reports heteroscedasticity-robust t statistics. All portfolio returns are adjusted for delisting bias. The sample period is from January 1975 to December 2004.

R&D Intensity and Stock Returns within Financial Constraints (KZ) Groups

Portfolio	Label	Number of Firms	Monthly Excess Return	Matching Portfolio Adjusted Return	alpha	m	s	h	Adjusted R-Square
Low KZ									
Low R&D Expenditure / MVE	11	224	0.67%	0.03%	-0.10%	1.00	0.65	-0.03	89%
			2.17	0.29	-0.89	34.12	10.31	-0.56	
Middle R&D Expenditure / MVE	12	219	0.86%	0.16%	0.12%	0.96	1.04	-0.22	75%
			2.18	1.36	0.59	15.77	9.03	-1.88	
High R&D Expenditure / MVE	13	215	1.62%	0.76%	0.86%	0.97	1.32	-0.45	77%
			3.55	4.00	3.87	13.87	9.58	-3.79	
High - Low	13 -11		0.96%	0.75%	0.87%	0.01	0.74	-0.32	37%
			3.76	3.31	4.03	0.08	5.02	-2.83	
Middle KZ									
Low R&D Expenditure / MVE	21	204	0.84%	0.07%	-0.12%	1.04	0.69	0.36	84%
			2.84	0.60	-0.95	29.00	8.17	5.39	
Middle R&D Expenditure / MVE	22	200	0.92%	0.21%	0.09%	1.04	0.66	0.04	87%
			2.96	2.67	0.87	21.24	8.49	0.50	
High R&D Expenditure / MVE	23	200	1.76%	0.78%	0.88%	1.00	1.31	-0.08	76%
			4.16	5.09	4.05	16.84	12.04	-0.94	
High - Low	23 - 21		0.87%	0.72%	0.88%	-0.01	0.59	-0.45	38%
			3.65	3.31	4.34	-0.16	4.33	-4.50	
High KZ									
Low R&D Expenditure / MVE	31	166	0.83%	0.04%	-0.24%	1.01	0.92	0.51	68%
			2.43	0.24	-1.28	19.50	6.50	4.35	
Middle R&D Expenditure / MVE	32	167	0.94%	0.33%	-0.13%	1.13	1.12	0.18	80%
			2.38	2.41	-0.77	25.17	10.50	1.88	
High R&D Expenditure / MVE	33	165	2.13%	1.28%	1.03%	1.12	1.50	0.00	73%
			4.36	5.97	4.15	15.52	11.57	0.01	
High - Low	33 - 31		1.30%	1.24%	1.27%	0.11	0.58	-0.51	35%
			4.62	4.98	5.51	1.70	4.58	-4.94	

Table 15: This table shows the relation between postranking stock returns and R&D intensity for different level of KZ groups. The R&D intensity is measured as the ratio of R&D expenditure to year-end market value of equity. The portfolios are formed in each June on a conditional two-way sorts on the lagged KZ index first and then on the lagged R&D intensity. Monthly portfolio returns are then computed over the next 12 months. The excess return is the difference between the raw portfolio return and the one-month T-bill rate. The matching portfolio adjusted return is based on the difference between the individual stock return and the return of its matching portfolio by size and book-to-market ranks. The alphas are estimated as intercepts from the regressions of excess portfolio postranking returns on the Fama-French factor returns. m is the coefficient of the market factor; s is the coefficient of the size factor; h is the coefficient of the book-to-market factor. For each portfolio, the first line reports the mean returns and the regression estimates, and the second line reports heteroscedasticity-robust t statistics. All portfolio returns are adjusted for delisting bias. The sample period is from January 1975 to December 2004.

R&D Intensity and Stock Returns within Financial Constraints (KZ) Groups

Portfolio	Label	Number of Firms	Monthly Excess Return	Matching Portfolio Adjusted Return	alpha	m	s	h	Adjusted R-Square
Low KZ									
Low R&D Expenditure / Capital Expenditure	11	221	0.82%	0.03%	-0.02%	0.99	0.66	0.18	89%
			2.87	0.32	-0.24	34.88	11.66	3.23	
Middle R&D Expenditure / Capital Expenditure	12	215	1.06%	0.31%	0.32%	1.00	1.06	-0.27	74%
			2.60	2.43	1.51	15.39	8.76	-2.23	
High R&D Expenditure / Capital Expenditure	13	213	1.26%	0.58%	0.57%	0.97	1.30	-0.60	79%
			2.70	3.30	2.63	14.44	10.43	-5.49	
High - Low	13 -11		0.44%	0.57%	0.50%	0.01	0.71	-0.70	51%
			1.56	2.63	2.41	0.10	5.61	-6.69	
Middle KZ									
Low R&D Expenditure / Capital Expenditure	21	201	0.94%	0.10%	-0.05%	1.03	0.70	0.45	84%
			3.27	0.91	-0.41	28.58	8.32	6.81	
Middle R&D Expenditure / Capital Expenditure	22	197	0.97%	0.18%	0.12%	1.02	0.67	0.12	87%
			3.21	2.41	1.16	21.29	10.09	1.38	
High R&D Expenditure / Capital Expenditure	23	198	1.62%	0.79%	0.80%	1.02	1.29	-0.25	78%
			3.66	5.14	3.62	17.00	12.13	-2.92	
High - Low	23 - 21		0.62%	0.70%	0.72%	0.03	0.56	-0.71	51%
			2.43	3.39	3.70	0.51	4.56	-7.52	
High KZ									
Low R&D Expenditure / Capital Expenditure	31	162	0.86%	0.01%	-0.19%	1.01	0.86	0.50	71%
			2.64	0.06	-1.03	20.86	7.52	5.21	
Middle R&D Expenditure / Capital Expenditure	32	164	1.20%	0.43%	0.10%	1.14	1.02	0.34	80%
			3.25	3.26	0.57	24.46	9.55	3.94	
High R&D Expenditure / Capital Expenditure	33	162	1.75%	1.13%	0.70%	1.11	1.60	-0.18	72%
			3.34	4.94	2.67	14.66	10.73	-1.31	
High - Low	33 - 31		0.89%	1.12%	0.88%	0.10	0.74	-0.69	44%
			2.75	4.33	3.65	1.47	5.36	-5.70	

Table 16: This table shows the relation between postranking stock returns and R&D intensity for different level of KZ groups. The portfolios are formed in each June on a conditional two-way sorts on the lagged KZ index first and then on the lagged R&D intensity. Monthly portfolio returns are then computed over the next 12 months. The excess return is the difference between the raw portfolio return and the one-month T-bill rate. The matching portfolio adjusted return is based on the difference between the individual stock return and the return of its matching portfolio by size and book-to-market ranks. The alphas are estimated as intercepts from the regressions of excess portfolio postranking returns on the Fama-French factor returns. m is the coefficient of the market factor; s is the coefficient of the size factor; h is the coefficient of the book-to-market factor. For each portfolio, the first line reports the mean returns and the regression estimates, and the second line reports heteroscedasticity-robust t statistics. All portfolio returns are adjusted for delisting bias. The sample period is from January 1975 to December 2004.

R&D Intensity and Stock Returns within Financial Constraints (WW) Groups

Portfolio	Label	Number of Firms	Monthly Excess Return	Matching Portfolio Adjusted Return	alpha	m	s	h	Adjusted R-Square
Low WW									
Low R&D Expenditure / MVE	11	183	0.62%	-0.02%	-0.23%	1.07	0.36	0.26	86%
			2.21	-0.16	-1.97	32.50	4.81	4.38	
Middle R&D Expenditure / MVE	12	185	0.58%	-0.01%	-0.21%	1.09	0.28	0.16	89%
			2.07	-0.16	-1.97	34.97	4.69	2.96	
High R&D Expenditure / MVE	13	183	1.01%	0.28%	0.04%	1.19	0.56	0.25	86%
			3.09	2.90	0.31	31.93	9.00	3.95	
High - Low	13 -11		0.39%	0.30%	0.27%	0.12	0.20	-0.01	12%
			2.78	2.18	1.91	3.13	3.72	-0.15	
Middle WW									
Low R&D Expenditure / MVE	21	182	0.52%	-0.23%	-0.44%	1.08	0.83	0.21	83%
			1.55	-1.76	-3.08	24.97	7.95	2.62	
Middle R&D Expenditure / MVE	22	178	0.76%	0.09%	-0.01%	1.08	0.96	-0.34	88%
			1.95	0.99	-0.07	23.47	12.73	-4.78	
High R&D Expenditure / MVE	23	183	1.38%	0.51%	0.35%	1.16	1.34	-0.11	84%
			3.07	3.05	1.93	20.91	15.93	-1.28	
High - Low	23 - 21		0.86%	0.74%	0.79%	0.08	0.51	-0.32	35%
			3.96	3.36	4.19	1.38	4.48	-3.55	
High WW									
Low R&D Expenditure / MVE	31	199	0.83%	0.15%	-0.10%	0.95	1.09	0.12	71%
			2.19	0.91	-0.49	18.45	10.12	1.15	
Middle R&D Expenditure / MVE	32	203	1.15%	0.54%	0.22%	1.03	1.41	-0.24	79%
			2.48	3.55	1.06	16.57	12.51	-2.24	
High R&D Expenditure / MVE	33	199	2.35%	1.47%	1.35%	0.98	1.78	-0.24	72%
			4.38	5.56	4.58	11.49	10.26	-1.68	
High - Low	33 - 31		1.53%	1.32%	1.45%	0.03	0.70	-0.36	34%
			5.71	4.56	6.28	0.39	3.87	-2.91	

Table 17: This table shows the relation between postranking stock returns and R&D intensity for different level of WW groups. The R&D intensity is measured as the ratio of R&D expenditure to year-end market value of equity. The portfolios are formed in each June on a conditional two-way sorts on the lagged WW index first and then on the lagged R&D intensity. Monthly portfolio returns are then computed over the next 12 months. The excess return is the difference between the raw portfolio return and the one-month T-bill rate. The matching portfolio adjusted return is based on the difference between the individual stock return and the return of its matching portfolio by size and book-to-market ranks. The alphas are estimated as intercepts from the regressions of excess portfolio postranking returns on the Fama-French factor returns. m is the coefficient of the market factor; s is the coefficient of the size factor; h is the coefficient of the book-to-market factor. For each portfolio, the first line reports the mean returns and the regression estimates, and the second line reports heteroscedasticity-robust t statistics. All portfolio returns are adjusted for delisting bias. The sample period is from January 1975 to December 2004.