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Abstract

Spending on R&D has grown faster than other investments. This may result in higher return and higher risk. We focus on the latter and examine how research and development (R&D) affects the risks of US firms. We analyze the impact on the firm's beta, its systematic and idiosyncratic risk, and the combination of the latter two (total risk). Because investors prefer upside to downside risk, we also analyze whether downside risk is also influenced by R&D. We use panel and quantile regressions and control for dividend payouts, growth, leverage, asset liquidity, firm size, earnings variability, firm age and industry competition. We then show that the impact is positive and highly significant for beta, systematic risk and total risk. The impact on systematic risk contrasts to the finding by McAlister et al. (2007) who find that R&D insulates firms from market downturns and thereby lowers systematic risk. The increases in risks are, moreover, stronger at higher relative levels of R&D spending. Unfortunately for investors, downside risk is also increasing with relative R&D spending. The latter result makes it more difficult for managers to defend R&D investments: while R&D may indeed generate future returns it also adds to the next year's downside risk of investors.

Keywords: R&D, beta, systematic risk, idiosyncratic risk, total risk, downside risk

JEL: G12; G14; G32

Introduction

Research and development (R&D) investments may lead to innovative products and services and thereby to a competitive advantage. Also, R&D is proven to be positively linked to the firm's profitability, firm value and stock returns (Capon, Farley, and Hoenig, 1990; Chan, Martin, and Kensinger, 1990; Chauvin and Hirschey, 1993; Eberhart, Maxwell, and Siddique, 2004). It may thus not be amazing that the spending on R&D has grown faster than other types of investments (Hirschey, Skiba, and Wintoki, 2012). However, finance theory suggests that returns and risks are positively related, and firm risk may thus also be positively related to R&D.

The literature indeed finds positive relations between R&D and firm risk. Because of the risk involved in R&D projects, Titman and Wessels (1988) indicate that firms with high R&D intensity tend to use more equity instead of debt financing. R&D projects may fail to result in output, and if there is output, there is uncertainty about the payoff because the pay-off of R&D projects depends on intermediate events and decisions (Perlitz, Peske, and Schrank, 1999). Hall (2002) indicates that there is information asymmetry, because it is difficult to distinguish between good and bad R&D intense projects, while there is also an agency problem, because managers do not want to invest in risky R&D projects. For these reasons investors might require a risk premium for high intensity R&D firms. Barth, Kasznik, and McNichols (2001) and Kothari, Laguerre, and Leone (2002) find that higher R&D investments are associated with more uncertainty about future earnings. These results are confirmed by Chambers, Jennings, and Thompson (2002), who indicate that the association between excess returns and levels of R&D investments stems from a risk factor associated with R&D.

In this study we address the empirical question whether the R&D intensity of a firm affects the market based risk measures. Berk, Green, and Naik (2004) show that R&D influences systematic risk and unsystematic risk. The impact on systematic risk results from uncertainty in ultimate cash flows while the impact on unsystematic risk results from technical risks. Consequently, we study the impact of R&D intensity not only on total risk, but also on systematic risk and idiosyncratic risk. Moreover, we also study the impact of R&D on downside risk.

Apart from its empirical relevance, this study could be of potential interest to practitioners and managers. While decisions on R&D are usually made from a product-market perspective, the financial market based perspective is important because if R&D impacts risk, it also affects access to capital markets and the cost of capital, and is then also relevant in performance measurement. In addition, this paper might be useful to investors who need insights on the effect of R&D on the total and idiosyncratic risk of a stock as well as how R&D contributes to systematic risk in a portfolio context.

To answer the question how R&D influences risk, panel least squares regressions are used, while we add quantile regression techniques- to trace the impact of R&D upon risk at various levels of R&D intensity. The sample employed in this study consists of 2,965 listed US firms, with 30,560 firm-year observations from 1986 up to and including 2011.

The remainder of this paper is organized as follows. In section 2 we present the literature of the relation between R&D intensity and risk as well as previous empirical research on the effects of R&D on risk. The section also presents the hypotheses. Section 3 details the data collection as well as methodology. Section 4 provides the results and section 5 concludes this study.

Literature review

Market determined and fundamental risk measures

Ultimately, the risk of a firm is determined by the fundamentals of the firm and market characteristics. Beaver, Kettler, and Scholes (1970) assume that several accounting risk measures attempt to explain earnings uncertainty and thus can be a proxy for total risk (variability of stock returns). Furthermore, based on the assumption that total risk and beta are strongly positively correlated, the following variables are associated with beta according to Beaver et al. (1970).

1. Higher dividend payout lowers beta. Since firms are reluctant to cut dividends and want to stabilize their payout, firms with greater earnings uncertainty will have lower payout ratios.
2. High growth firms are expected to be more risky since competition will erode away excess earnings.
3. Higher leverage leads to higher betas since debt financing increases the volatility of earnings.
4. Liquidity is negatively associated with risk since current assets are less volatile than fixed assets. However, Beaver et al. (1970) predict only a weak association since they find the role of fixed assets more important in explaining risk.
5. Firms with larger asset size are less risky.
6. Greater earnings variability increases risk.
7. Accounting beta measures the covariance of the earnings with the market, and should therefore be positively correlated with beta.

The study by Beaver et al. (1970) inspired other academics to investigate the link between fundamental firm characteristics and beta by considering new variables. For example, Rosenberg and Marathe (1975) review 101 variables and their influence on firm risk in order to generate a model with much predictive power. These early studies primarily focus on the systematic risk of a firm (based on the ideas behind the Capital Asset Pricing Model (CAPM) developed by Sharpe (1964), Lintner (1965) and Mossin (1966)). More recently, however, an increase in idiosyncratic volatility relative to systematic volatility (Campbell, Lettau, Malkiel, and Xu, 2001) is documented and it has been demonstrated that not only systematic risk, but also idiosyncratic risk is positively associated with returns (Merton, 1987; Fu, 2009) and that such risk is also relevant for ratings of analysts (Lui, Markov and Tamayo, 2007). One of the explanations for the increase in idiosyncratic risk is the increase in growth options (Cao, Simin, and Zhao, 2010), which may be generated by R&D[1]. For these reasons, we do not only study the effect of R&D intensity on systematic risk, but also on idiosyncratic risk.

Previous research and hypotheses

Chan, Lakonishok, and Sougiannis (2001) examine the impact of R&D intensity on stock return risk. For a sample of U.S. stocks they find that R&D intensity and stock return variability (total risk) are positively interrelated. Xu and Zhang (2004) perform a similar study for the Japanese market. They find that the relation is not stable over three sub periods. Only during the last sub period there is a significant and positive association between R&D intensity and return variability. Ho, Xu, and Yap (2004) examine the relation between R&D intensity and systematic risk. Following Mandelker and Rhee (1984), Ho et al. (2004) decompose systematic risk into three components, namely intrinsic business risk, operating leverage, and financial leverage. They find by using simulation and correlation analysis that R&D positively and significantly correlates with systematic risk, mostly through the intrinsic business risk component[2]. The finding by Campbell et al. (2001) that idiosyncratic risk has increased led to a study by Mazzucato and Tancioni (2008) who argue that innovation could be related to this increase. They focus on five industries and use R&D intensity as a proxy for innovation but acknowledge that R&D is only the input and not the output, which for example could be a patent. For idiosyncratic risk they use a proxy namely the ratio of firm-level return variance over market return variance. Mazzucato and Tancioni (2008) find that R&D intensity significantly and positively impacts upon idiosyncratic risk. Their model specification however lacks a clear theoretical basis[3]. Relatedly, Bartram, Brown, and Stulz (2012) research the question why U.S. stocks are more volatile than stocks from other countries. They conclude that the higher return volatility is mainly caused by higher idiosyncratic risk and that higher R&D intensity is one of the reasons why idiosyncratic risk is higher for U.S. stocks. Chen, Peng, and Wei (2012) examine the effect of R&D intensity on systematic risk as well as idiosyncratic risk. In addition to OLS they employ quantile regressions to account for the non-normality of risk and heteroskedasticity. This technique also enables them to compare the impact of R&D on low-risk and high-risk firms. They find that higher R&D intensity increases the beta as well as idiosyncratic risk, especially for firms with median to high risk.

While the literature is not fully conclusive on the impact of R&D on risk in stock returns most of the studies indicate a positive relation. Therefore, we formulate the following set of hypotheses:

H_0: There is no relationship between R&D intensity and the market risk measures of a firm.

H_1: Firms with higher R&D intensity will show higher market risk measures.

As risk measures we use total market risk, beta, systematic market risk, idiosyncratic risk, and downside risk. This risk measure considers negative returns only and therefore does not treat upside potential as risk. This measure thus relates closely to the loss aversion which may be relevant for individual investors.

Data and methodology

Sample selection and data collection

Following Ho et al. (2004), McAlister et al. (2007), and Chen et al. (2012) this study uses a sample which consists of firms listed in the U.S.[4]. The first step in selecting the sample was to obtain

1. Other explanations are an increase in general economy-wide competition (Irvine and Pontiff, 2009), new listings by risker companies (Brown and Kapadia, 2007), and retail ownership (Brandt, Brav, Graham and Kumar, 2010).
2. McAlister, Srinivasan and Kim (2007) are an exception, as they find statistically significant support for their hypothesis that R&D leads to lower systematic risk. They argue that R&D effort insulates a firm from market downturns.
3. Their model includes a constant, a R&D intensity variable, fixed or random effects, and market value of equity as control variable.
4. U.S. accounting regulations rule that R&D expenditures should be expensed immediately. Therefore, the decision to use U.S. listed firms ensures that the measure of R&D is representative and reliable across observations.

constituents of major stock indexes and stock exchanges at various points in time. The following constituent lists were collected from Thomson DataStream: S&P 500 at the end of September 1989; S&P 1500 at the end of December 1994, February 2002 and February 2013; NASDAQ Composite at the end of April 2004 and February 2013; and finally all constituents of the New York Stock Exchange (NYSE) at the end of February 2013. After removing duplicates based on the International Security Identification Number (ISIN) and removing entities for which the ISIN is not available, a list of 9,334 listed entities remains. Furthermore, based on the Industry Classification Benchmark (ICB) data, several sectors are filtered out of the sample, namely Equity Investment Instruments, Nonequity Investment Instruments, and Real Estate Investment Trusts. This procedure results in a base sample of 7,323 companies.

The data used to test the hypotheses were collected from Thomson DataStream. First, static information such as industry classification, location, and date of incorporation were obtained. Second, total return indices were collected for the period from January 1981 until December 2011 as well as price index data on the S&P 500 index which serves as market index. Third, yearly time series data were obtained for the same period including accounting, financial, and market data. These data types are: market value of common equity (share price times number of shares), total assets, revenues, net income, R&D expenditures, cash dividends, market-to-book ratio, current ratio, total liabilities, and the number of shares.

Methodology

Although the extensive model specifications of Rosenberg and Marathe (1975) may improve the fit relative to the specification by Beaver et al. (1970), the high number of variables makes it harder to understand the model, also due to possibly counterintuitive or conflicting coefficients. Therefore, we stick to the simpler model by Beaver et al. (1970) as reviewed above. Consequently, the general model for the panel data set with five-year moving averages has the structure as described in equation (1):

$$risk\ measure_{i,t} = \gamma_0 + \gamma_1 R\&Dint_{i,t-1} + \gamma_\chi \boldsymbol{x}_{i,t} + \varepsilon_{i,t} \tag{1}$$

In this equation the dependent variable is one of the risk measures: beta, total risk, systematic volatility, idiosyncratic risk, or downside risk for firm *i* at time *t*. The γ_0 is a constant, $R\&Dint_{i,t-1}$ is the main variable of interest (R&D intensity) which like in McAlister et al. (2007) and Chen et al. (2012) is lagged because of an anticipated lagged effect due to the payoff properties of R&D. In addition, it functions as a basic method of ruling out reverse causality. The $\boldsymbol{x}_{i,t}$ vector contains the control variables as described in the literature review above, except for accounting beta since five observations are not sufficient for an efficient estimate. In addition, two other control variables are included. First, firm age, which is statistically significant in McAlister et al. (2007). Second, a measure of competitive intensity is included because Meng (2008) argues that in a highly competitive environment, higher R&D intensity will result in higher betas as well as greater total return volatility. Also, both McAlister et al. (2007) and Chen et al. (2012) identify competitive intensity as a significant predictor. The γ_χ vector contains the coefficients for these various control variables *x*. The error term is indicated by $\varepsilon_{i,t}$.

After calculating logarithmic returns based on the total return indices (and price index for the market index) the various risk measures can be determined. For this purpose the market model, or the practical application of the CAPM, is assumed to be the return generating process (Blume, 1970). Thus, equation (2) describes returns.

$$R_{i,t} = \alpha_i + \beta_{i,t} R_{mkt,t} + \varepsilon_{i,t} \tag{2}$$

$R_{i,t}$ is the return of firm *i* at time *t*, $\beta_{i,t}$ is the beta of firm *i* at time *t*, $R_{mkt,t}$ is the return on the market portfolio (S&P 500) at time *t*, and $\varepsilon_{i,t}$ is an error term.

This study uses a panel data set and consequently moving windows are used for estimating beta, ex post, based on equation (2) using 60 monthly stock returns. Thus, for firm *i* and year *t* in the data set, 60 monthly returns from year *t-4* up to and including year *t* are used. Furthermore, for inclusion in the regression model sample it is required that all 60 monthly stock returns are actually available for a firm. Figure 1 shows timelines to illustrate the measurement of beta as well as all other variables. It also clarifies the moving window procedure used in this study.

Figure 1 Variable measurement and moving windows procedure

Window	Variable(s)	Measurement, time (t) -5	-4	-3	-2	-1	0	1
1 (observation t=0)	Risk measure Control variables Lagged R&D intensity							
2 (observation t=1)	Risk measure Control variables Lagged R&D intensity							
etcetera								

In addition to β-risk, other measures of risk are also used as dependent variables. Total risk (TR) for firm *i* at time *t* is calculated as the standard deviation of the 60 monthly stock returns. Systematic risk (SR), as opposed to beta which is a proxy for systematic risk, can be calculated as follows:

$$SR_{i,t} = \sqrt{\beta_{i,t}^2 \sigma_{mkt,t}^2} \tag{3}$$

σ represents the standard deviation operator and thus the second item is the squared total risk (variance) of the market index. The reason for including systematic risk in addition to beta is that this results in three risk measures using equal units of measurement. Accordingly, idiosyncratic risk (IR) equals the standard deviation of the residuals from equation (2) and can be calculated as follows:

$$IR_{i,t} = \sqrt{TR_{i,t}^2 - SR_{i,t}^2} \tag{4}$$

This is a measure of idiosyncratic risk and not a proxy as for example used by Mazzucato and Tancioni (2008) and the deviation can be clarified from the example of a hypothetical firm which follows the market index with a multiplier of four. This security would thus have a market model beta of four and the ratio of firm-level return variance to market variance (used by Mazzucato and Tancioni (2008)), would be considerably higher than one[1]. However, the market explains all of this firm's return variance and idiosyncratic risk would therefore actually be measured to be zero. Finally, the last measure of risk, downside risk, δ, can be calculated as follows (Sortino and Van der Meer, 1991):

$$\delta_{i,t} = \sqrt{\frac{1}{60}\sum_{t-59}^{t}\left(R_{i,t} - R_{mar}\right)^2} \ \forall R_{i,t} < R_{mar} \tag{5}$$

R_{mar} is the minimal acceptable rate of return which equals zero such that all negative returns are considered.

Following McAlister et al. (2007) and Chen et al. (2012), R&D intensity is measured as the five-year moving average[2] of R&D expenditures to revenues:

$$R\&D\,intensity_{i,t} = \frac{1}{5}\sum_{t-4}^{t}\frac{R\&D\,expenditures_{i,t}}{revenues_{i,t}} \tag{6}$$

The accounting variables which are all measured using book values, and which are included as control variables just as McAlister et al. (2007)[3] do are defined as follows:

$$dividend\ payout_{i,t} = \frac{1}{5}\sum_{t-4}^{t}\frac{cash\,dividends_{i,t}}{net\,income_{i,t}} \tag{7}$$

$$asset\ growth_{i,t} = \frac{1}{5}\ln\frac{total\ assets_{i,t}}{total\ assets_{i,t-4}} \tag{8}$$

$$leverage_{i,t} = \frac{1}{5}\sum_{t-4}^{t}\frac{total\,liabilities_{i,t}}{total\ assets_{i,t}} \tag{9}$$

1. The exact level of the ratio depends on the distribution of the returns. The higher the degree of uniformity of the distribution, the higher is the ratio.
2. Five-year averages are used to reduce the impact of noise (Beaver et al., 1970).
3. Chen et al. (2012) use a subset of these control variables, namely asset growth, leverage, liquidity, and total assets.

$$\log total\ assets_{i,t} = \frac{1}{5}\sum_{t-4}^{t}\log\left(total\ assets_{i,t}\right) \tag{10}$$

$$liquidity_{i,t} = \frac{1}{5}\sum_{t-4}^{t} current\ ratio_{i,t} \tag{11}$$

$$earnings\ variability_{i,t} = \sqrt{\frac{1}{5}\sum_{t-4}^{t}\left(EP_{i,t} - \overline{EP}_i\right)^2} \tag{12}$$

$EP_{i,t}$ is the earnings-price ratio for firm i at time t which is calculated as:

$$EP_{i,t} = \frac{net\ income_{i,t}}{market\ value_{i,t-1}}$$

$\overline{EP}_{i,t}$ is the average value of the earnings-price ratio for firm i in a certain window. The market value refers to the end of year market value of outstanding shares. This earnings-price ratio can therefore be interpreted as an accounting measure of return with net income in contrast to capital gains plus dividends as used in the market measure of return.

In addition to these accounting control variables the two other control variables, firm age and the Herfindahl-Hirschman index (HHI) as measure of competitive intensity, are defined as follows:

$$firm\ age_{i,t} = \max[0, \log((t\text{-}year\ of\ incorporation)+1)] \tag{13}$$

$$HHI_{i,t} = \sum_{i=1}^{N}\left(\frac{revenues_{i,t}}{\sum_{i=1}^{N} revenues_{i,t}}\right)^2 \ \forall\ firms\ i\ classified\ in\ sector\ k \tag{14}$$

HHI is the sum of squared market shares for a certain sector k. Thus, all firms i at time t belonging to industry k have the same HHI. The 19 super sectors as identified by ICB are used for the classification of the firms. This measure of competitive intensity equals one in the case of one firm with a market share of 100% in sector k and approaches zero in the case of many firms with roughly equal market shares in sector k. Based on the results by McAlister et al. (2007), the expected sign of the variable firm age is negative, such that older firms are less risky. With regard to the HHI, a negative sign is expected, such that more competitive industries (a lower HHI) are associated with higher levels of risk. Returning to the accounting variables, the expected signs follow from the relations as described above in the literature review. Thus, dividend payout is expected to have a negative coefficient. A positive sign is expected for asset growth. Also for leverage a positive relation is to be expected. Next, liquidity is expected to have a negative sign. Firm size as measured by the average of the natural logarithm of book value of total assets is expected to be negatively related to risk. Naturally, the expected sign for the relation between stock return risk and earnings variability is a positive one.

In addition, we test for the effects of R&D intensity in a model which follows the original specification by Beaver et al. (1970) more closely. Therefore, the variable accounting beta is added to the model which is calculated based on 10 years of data. While the market beta measures the co-variability of market returns, the accounting beta measures the co-variability of earnings. If *covar* represents the covariance operator and *var* the variance operator:

$$accounting\ \beta_{i,t} = \frac{covar\left(EP_{i,t}, EP_{mkt,t}\right)}{var\left(EP_{mkt,t}\right)}, \tag{15}$$

Where $EP_{mkt,t} = \frac{1}{N}\sum_{i=1}^{N} EP_{i,t}$

This earnings-price ratio for the market is therefore the accounting return on the "market index". If correctly specified, the accounting beta is expected to have a positive correlation with market beta and consequently also a positive sign in the regression model. However, since we assume that the sample equals the whole market, the accounting beta measure might be inaccurate which is why it is not included in the main model and also probably why previous researchers do not include it.

In addition, the calculation of the earnings variability will also be based upon 10 years of data to achieve a better estimation.

While this study uses OLS to examine the impact of R&D on risk and the robustness of this relation, quantile regression is also employed following Chen et al. (2010). This regression technique put forward by Koenker and Basset (1978) minimizes the absolute deviations relative to a quantile in the empirical distribution through linear programming. According to Koenker and Basset (1978) the estimator has comparable efficiency to least squares while being robust to extreme values of the dependent variable. Furthermore, quantile regression minimizes bias in case of a skewed distribution (Koenker and Hallock, 2001). Patton (2009) shows that that returns are often non-normally distributed and that there may be heterogeneity of risk and argues that quantile regression is an appropriate choice in these circumstances.

Data description

Since the first four years are solely serving for input purposes and the independent variable of main interest is lagged, 26 periods are included in the adjusted sample, leading to a theoretical maximum of 190,398 observations. In addition, after adjusting firms which are dead at time *t* or did not trade on the stock market for five years, 70,528 observations remain. Furthermore, stocks with prices below $2 are excluded to avoid potential problems with low priced stocks (Ball, Kothari and Shanken, 1995; Hertzel, Lemmon, Linck and Rees, 2002) as well as stocks with negative market-to-book ratios (Chen et al., 2012). As a result the theoretical maximum of observations equals 67,072. Also, observations of firms recording negative revenues are filtered out of the sample. Finally, due to great non-normality of the R&D intensity variable as a consequence of extreme (high) values the raw R&D intensity data series is trimmed[1]. More specifically, the top 2.5% of this data series is removed from the sample. Upon estimating the regression models an unbalanced panel data sample of 30,560 (31,031 without trimming, thus a reduction in sample size of roughly 1.5%) observations remain for which all variables have data recorded. This reduction relative to the theoretical maximum is primarily caused by missing observations for the data item R&D expenditures in the DataStream database. However, this sample is much larger than the 3,198 observations by McAlister et al. (2007) and the 1,354 and 1,396 observations for the β-risk and idiosyncratic risk models by Chen et al. (2012) respectively. From the 7,323 companies as identified in Section 3.1 on sample selection and data collection, a total of 2,965 firms account for the 30,560 observations. Table 1 shows the descriptive statistics for the data sample.

Table 1

Descriptive statistics for the sample of 2,965 firms during 1986-2011

This table shows descriptive statistics on all independent and dependent variables in the main regression sample which contains 30,560 firm-year observations. The dependent variables are beta as in equation (2), systematic risk as in equation (3), total risk as the standard deviation of 60 monthly stock returns, idiosyncratic risk as in equation (4), and finally downside risk as in equation (5). The independent variables are the R&D intensity ratio, the dividend payout ratio, the average logarithmic asset growth, the leverage ratio, the liquidity ratio, the log of total assets, the five-year variability of the earnings-price ratio, the log of firm age, and the Herfindahl-Hirschman index as measure of competitive intensity. The Jarque-Bera test for normality rejects the null hypothesis of a normal distribution for all variables.

Variable	Mean	Median	Max.	Min.	St. dev.	Skewness	Kurtosis
Beta	1.1448	1.0358	6.213	-3.612	0.7478	1.144	5.909
Syst. risk	0.0538	0.0457	0.347	0.000	0.0378	1.479	6.477
Total risk	0.1393	0.1241	0.809	0.028	0.0679	1.236	5.366
Idiosync. risk	0.1247	0.1099	0.809	0.025	0.0643	1.284	5.715
Down. risk	0.0942	0.0833	0.631	0.012	0.0512	1.510	7.333
Lagged R&D int.	0.1303	0.0195	6.158	0.000	0.4604	7.413	67.638
Div. payout	0.2209	0.0000	76.150	-102.261	2.5081	0.658	680.751
Growth	0.0737	0.0632	2.058	-1.117	0.1307	0.933	12.292
Leverage	0.4578	0.4588	20.205	-0.307	0.2998	30.605	1,900.058

1. Trimming variables which are measured on a ratio level to remove extreme values which can seriously distort results is common practice in corporate finance literature.

Liquidity	3.0345	2.2100	121.356	0.108	3.4480	11.053	238.770
Total assets (log)	12.9474	12.8544	20.459	5.849	1.9800	0.222	2.740
Earnings var.	0.1134	0.0494	27.627	0.001	0.4167	35.113	1,855.532
Firm age (log)	3.2418	3.1781	5.247	0.000	0.8112	-0.266	3.238
HHI	0.0387	0.0283	0.293	0.014	0.0279	3.651	22.605

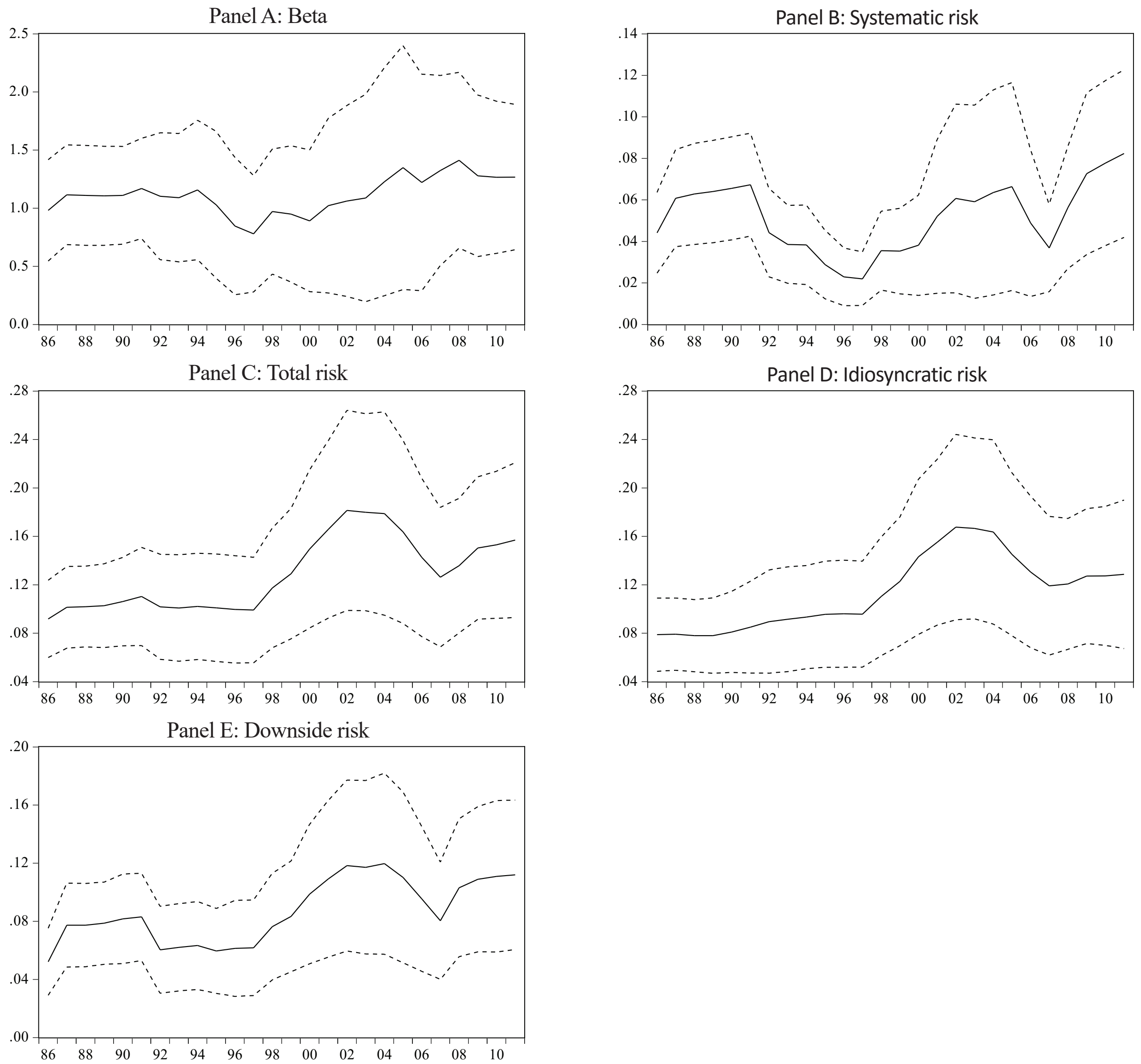
For all dependent variables the mean value is higher than the median value, for example for beta the mean is 1.14 whereas the median is 1.04. Also, the R&D intensity variable shows a mean which is 0.13[1] whereas the median is 0.02. Next, the median value for dividend payout is 0.00 (mean is 0.22) which implies that the sample contains relatively many firms which do not payout dividends, which are most likely younger firms. On average, as indicated by growth and leverage, the firms in the sample are growing firms financed with slightly more equity than debt. As is apparent from the skewness and kurtosis statistics none of the variables, including the dependent variables, follows a normal distribution which makes a comparison between the coefficients of the OLS regression equation and the median quantile regression equation interesting. At first glance, The HHI does not seem to be wrongly measured because its mean is 0.039 (median is 0.028) ranging from 0.014 to 0.29. The antitrust division of the U.S. Department of Justice[2] considers markets where the HHI is between 0.15 and 0.25 to be moderately concentrated and markets with a HHI higher than 0.25 to be highly concentrated.

Figure 2 shows how the measures of risk evolve over the sample period. In addition, it shows the one standard deviation boundaries. Due to the sampling procedure these graphs do not necessarily represent the total U.S. stock market. However, we can see that, possibly due to time effects but also as a result of the sampling procedure, the dependent variables are not stable over time. Of the measures of risk, beta (Panel A) as proxy for systematic risk is the most stable. While the pattern of systematic risk (Panel B) over time looks like that of beta, it is clear that systematic risk itself is more volatile. Also, we see that total risk (Panel C), idiosyncratic risk (Panel D), and downside risk (Panel E) follow each other closely. Though, around the financial crisis of 2007/2008 the increase of downside risk is naturally steeper than for the other two measures. The increase of total return volatility, leading up to the peak in the sample, however takes place before inclusion of many NASDAQ listed firms. Appendix A1 presents the correlation matrix for all variables for the sample as described above. As row 6 of Appendix A1 indicates, R&D intensity is positively and significantly correlated with the various risk measures which corresponds with the findings in previous literature. Furthermore, the correlations between R&D intensity and systematic risk as well as its proxy, beta, are smaller than the correlations with the other risk measures suggesting that the impact of R&D intensity on risk runs mainly through idiosyncratic risk which is consistent with Bartram et al. (2012). Among the correlation coefficients between the explanatory variables, the highest correlation of -0.319 occurs between leverage and liquidity. Based upon the basic method of looking at the correlations, multicollinearity issues, while not impacting upon coefficient estimates, are not expected to hamper drawing inferences or introduce instability in the estimates as a consequence of adjusting the model specification (Brooks, 2008). The correlation coefficient between systematic risk and beta is, as expected, high at 0.905 whereas the correlations of these with idiosyncratic risk are 0.403 or lower. These coefficients provide opportunity for a comparison between the impacts upon systematic risk and idiosyncratic risk. However, due to the high correlation between total risk and idiosyncratic risk the impacts upon these two variables are expected to be the comparable. Furthermore, the high correlation between downside risk and total risk as well as idiosyncratic risk, which is not surprising given the method of measurement, raises the question whether the investigation of the impact upon downside risk adds value.

Figure 2 Means of the measures of risk during the sample period 1986-2011

1. Without trimming, the mean would be 1.93 and the maximum 3.775. Thus, this justifies the trimming procedure since investments in R&D equal to 193% of revenues, on average, is unlikely.
2. http://www.justice.gov/atr/public/guidelines/hhi.html last visited April 26, 2013

For the various risk measures, these graphs plot the means over time, for 30,560 observations. Panel A does this for beta, which is measured as in equation (2). Panel B does this for systematic risk, which is measured as in equation (3). Panel C does this for total risk, which is measured as the standard deviation of 60 monthly stock returns. Panel D does this for idiosyncratic risk, which is mesaured as in equation (4). And, finally, Panel E does this for downside risk, which is measured as in equation (5). The dotted lines represent the plus and minus one standard deviation boundaries. The vertical axes represent the means, the horizontal axes the years.



Results

Panel regressions

The results of the panel regressions (1) are shown in Table 2. To take advantage of the panel data structure firm fixed effects are added to the model specification to control for potential unobserved heterogeneity and omitted variable bias. Like McAlister et al. (2007) we use firm fixed effects in our model, which also take into account the fact report that R&D spending is clustered within certain industries (Hirschey et al., 2012). In addition, time fixed effects are also included in the regression model. These might be relevant because of evolution of risk over the sample period as displayed in Figure 2, Section 3.3. Fixed effects tests indicate that both firm and time effects are indeed present and significant for all risk measures.

First, the signs of the control variables will be compared to expectations as well as previous research by McAlister et al. (1970), and Chen et al. (2012), with the beta regression being the reference point. As expected dividend payout is negatively associated with beta, as well as with all other measures of risk. Interestingly, growth takes the unexpected negative sign meaning that higher growth is actually associated with lower risk. This result is consistent across risk measures however the effect on beta is not statistically significant. Leverage impacts, following the correlation coefficient, negatively on systematic risk as well as beta at 5%. This contradicts theoretical implications and results by Beaver et al. (1970) and McAlister et al. (2007). However Chen et al. (2012) also find a negative sign for this variable. While Chen et al. (2012) find a positive relation between debt financing and idiosyncratic risk, we hardly find significant coefficients for these relations. In correspondence with the expectations of Beaver et al. (1970), liquidity is negatively and significantly related to total risk and idiosyncratic risk. However, as predicted the relationship is weak. Total assets impacts positively upon systematic risk (also beta), which contrasts with the other authors. However, for the other risk measures it has the expected sign. And, the last of the Beaver et al. (1970) control variables, earnings variability has the expected significant and positive association with risk. Turning to the other two control variables, firm age is significantly negatively associated with risk as expected. Looking at competitive intensity as predictor of total risk and idiosyncratic risk we find the expected negative sign. For beta the relationship is also negative with a large coefficient but not statistically significant.

In summary, we see that in regressions with systematic risk or beta as dependent variable, more coefficients have the unexpected sign than for risk measures which are not relevant according to the CAPM. In addition, the explanatory power of the models for systematic risk measures is considerably lower than for other risk measures. These two observations apply to all model specifications and show that it is quite hard to fundamentally model the concept systematic risk. Bowman (1979) also argues that from the seven variables as used by Beaver et al. (1970) only accounting beta and leverage have a theoretical link with market beta. In addition, according to Da, Guo, and Jagannathan (2012) the CAPM and thus the market model cannot explain stock returns for firms with many real options. As mentioned above, R&D projects are often seen as real options. The reason for this poor fit is that stock returns are non-linear functions of the returns on these R&D projects (Da et al., 2012). Consequently, having a sample which is possibly biased toward high-tech industries might introduce a bias in the estimations with regard to measures of systematic risk. Therefore, this could be a potential explanation for counterintuitive signs of coefficients for regressions for beta and systematic risk, such as seen for leverage and total assets.

Second, the hypothesized effects of the main variable of interest, R&D intensity, will be explored. The results indicate that the higher a firm's R&D intensity the higher its risk, which is in support of the alternative hypotheses. The impact is significant at 1% in case of systematic risk (also beta) as well as total risk, at 10% in case of idiosyncratic risk, and at 5% in case of downside risk. This contradicts the finding of McAlister et al. (2007) that R&D lowers systematic risk, but is in accordance with other literature that R&D, if significant, increases risk. Whereas Bartram et al. (2012) suggested that the influence of R&D on total risk is mainly through idiosyncratic risk, Table 2 shows that the impact mainly runs through systematic risk. However, the coefficients are small when compared with previous studies. To examine the economic significance of these small coefficients, the impact of spending, on average, 10% of revenues on R&D (or 10% more than currently or than a comparable firm) upon the risk measures and how this relates to the means and standard deviations will be explored. The 10% is chosen instead of a difference equal to a certain number times the standard deviation of R&D intensity because of non-normal distribution. However, the decision of investing 10% (more) of revenues into R&D activities is something which will severely affect a business strategically.

Table 2

Panel fixed effects regression results for the impact of R&D on risk

This table details all the regression coefficients from the panel least squares regression estimations with cross-section fixed effects and time fixed effects for the various risk measures. Below the coefficients, between parentheses, are the t-ratios. The equations have been estimated using robust standard errors (with adjustment of the degrees of freedom) clustered at the cross-section to allow for heteroskedasticity and serial correlation within a cross section. Hausman tests for correlated random effects indicate, for all dependent variables, that the effects are of a fixed nature. Furthermore, both effects are statistically significant.

The dependent variables are beta as in equation (2), systematic risk as in equation (3), total risk as the standard deviation of 60 monthly stock returns, idiosyncratic risk as in equation (4), and finally downside risk as in equation (5). The independent variables are the R&D intensity ratio, the dividend payout ratio, the average logarithmic asset growth, the leverage ratio, the liquidity ratio, the log of total assets, the five-year variability of the earnings-price ratio, the log of firm age, and the Herfindahl-Hirschman index as measure of competitive intensity.

Variable	Beta	Syst. risk	Total risk	Idiosync. risk	Down. risk
Constant	1.0136	0.0391	0.3098	0.3114	0.1759
	(3.932)***	(3.118)***	(18.649)***	(21.338)***	(12.019)***
Lagged R&D int.	0.1036	0.0047	0.0061	0.0038	0.0046
	(2.816)***	(3.220)***	(2.586)***	(1.729)*	(1.979)**
Div. payout	-0.0055	-0.0002	-0.0003	-0.0003	-0.0002
	(-2.335)**	(-2.086)**	(-2.639)***	(-2.492)**	(-2.220)**
Growth	-0.0854	-0.0081	-0.0172	-0.0135	-0.0260
	(-1.314)	(-2.522)**	(-3.766)***	(-3.332)***	(-6.202)***
Leverage	-0.0568	-0.0025	0.0104	0.0122	0.0064
	(-2.259)**	(-2.362)**	(1.431)	(1.648)*	(1.353)
Liquidity	-0.0028	0.0000	-0.0010	-0.0011	-0.0005
	(-0.665)	(-0.121)	(-3.492)***	(-4.127)***	(-1.709)*
Total assets (log)	0.0496	0.0028	-0.0099	-0.0117	-0.0039
	(2.739)***	(3.192)***	(-8.745)***	(-11.792)***	(-3.882)***
Earnings var.	0.1525	0.0102	0.0459	0.0438	0.0302
	(2.93)***	(4.325)***	(10.076)***	(10.143)***	(8.128)***
Firm age (log)	-0.1505	-0.0068	-0.0141	-0.0119	-0.0101
	(-4.271)***	(-3.885)***	(-5.930)***	(-5.948)***	(-4.651)***
HHI	-0.3128	0.0142	-0.0613	-0.0748	-0.0517
	(-0.810)	(0.746)	(-2.347)**	(-3.429)***	(-2.228)**
No. observations	30,560	30,560	30,560	30,560	30,560
F-statistic	12.975***	16.998***	40.978***	49.664***	22.077***
Adjusted R-squared	54.0%	61.1%	79.7%	82.7%	67.4%
Cross-section effects	Fixed	Fixed	Fixed	Fixed	Fixed
Time dummies	Yes	Yes	Yes	Yes	Yes

**** statistically significant at 1%, ** at 5%, * at 10%*

**** statistically significant at 1%, ** at 5%, * at 10%*

Ceteris paribus, a 10% higher R&D intensity would result in a beta which is 0.01036 higher. Relating this difference in beta to its mean we see that this is about 0.905%. Furthermore, this corresponds to a difference in beta of about 1.386% of the standard deviation of beta. These three numbers are 0.00047, 0.875%, and 1.244% for systematic risk. For total risk they are 0.00061, 0.436%, and 0.895%. With regard to idiosyncratic risk the magnitudes are 0.00038, 0.307%, and 0.596%. Finally, for downside risk these numbers are 0.00046, 0.486%, and 0.895% respectively. Thus, while the impacts are statistically significant, from an economic standpoint these impacts of R&D upon risk are rather small in magnitude. However, when comparing the sizes of coefficients we see that for beta and systematic risk the impact of R&D intensity on risk is larger than the impacts of some of the other accounting-based ratios such as dividend payout, leverage, or growth. For the other risk measures there are coefficients related to accounting numbers which are of greater size. Consider the average firm of this sample which has a market beta of 1.14 and imagine a situation in which this firm decides to adapt its strategy by spending 10% more of its revenues on R&D activities so as to innovate. As a result, the firm will have a beta of 1.16 (rounded). For such a major business decision the financial consequences are rather small. These results, however, reconfirm that the finding of McAlister et al. (1970) that R&D lowers beta seems fragile. In addition, it supports the finding by Chen et al. (2012) and Ho et al. (2004) that the higher the R&D intensity of the firm the higher its beta. However, these results from Table 2 seem more robust due to precluding an omitted variable bias by using fixed effects and controlling for heteroskedasticity and serial correlation within a cross-section.

As mentioned above the accounting beta measure as specified by Beaver et al. (1970) is also part of the study. The in-sample correlation between beta and accounting beta is -0.0027 and thus very small and negative. In the regression with dependent variable beta it also has a negative sign and is not statistically significant[1]. Thus, as expected, the measurement of the accounting beta seems to be inaccurate. To achieve a better measurement, a market portfolio for the earnings which is more stable would probably need to be defined, for example all S&P 500 firms each year. In addition, this measure might be more accurate for more mature firms than for smaller firms from the NYSE and NASDAQ as also included in the unadjusted sample. With regard to the earnings variability, using ten years of data instead of five years hardly impacts upon the coefficient (except for beta) and lowers the explanatory power as measured by the adjusted R-squared. As a consequence, we return to using the main model specification as in equation (1) again.

Quantile regressions

Chen et al. (2012) use quantile regression since this technique is more robust to non-normality of the dependent variable. In addition, it allows for examining the impact of the variables at different points in the distribution of the dependent variable so as to explore the impact for several risk quantiles (Patton, 2009).[2] The tables detailing the results for the impact of R&D intensity on the risk measures can be found in Table 3.

Table 3

Quantile regression results for the impact of R&D on risk measures

This table details all the regression coefficients of lagged R&D intensity from the quantile regression estimations (from risk decile 0.1 through 0.9). Besides the R&D intensity ratio, the dividend payout ratio, the average logarithmic asset growth, the leverage ratio, the liquidity ratio, the log of total assets, the five-year variability of the earnings-price ratio, the log of firm age, and the Herfindahl-Hirschman index as measure of competitive intensity are used as independent variables. Below the coefficients, between parentheses, are the t-ratios. The number of observations is 30,560.

Variable	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Beta	0.0891	0.1340	0.1613	0.1971	0.2170	0.2337	0.2430	0.2637	0.3114
	(8.846)***	(13.53)***	(10.466)***	(15.651)***	(10.63)***	(11.632)***	(10.106)***	(6.833)***	(5.418)***
Systematic risk	0.0044	0.0068	0.0074	0.0088	0.0098	0.0100	0.0103	0.0101	0.0096
	(7.839)***	(13.172)***	(13.17)***	(10.339)***	(14.775)***	(10.485)***	(10.632)***	(7.206)***	(2.645)***
Total risk	0.0209	0.0224	0.0230	0.0242	0.0261	0.0264	0.0280	0.0299	0.0382
	(29.295)***	(26.884)***	(25.082)***	(22.564)***	(15.522)***	(19.798)***	(16.732)***	(10.653)***	(6.151)***
Idiosyncratic risk	0.0197	0.0207	0.0221	0.0229	0.0240	0.0250	0.0265	0.0285	0.0376
	(26.761)***	(28.294)***	(27.427)***	(20.371)***	(19.916)***	(17.389)***	(14.816)***	(10.887)***	(5.51)***
Downside risk	0.0111	0.0128	0.0148	0.0157	0.0173	0.0190	0.0237	0.0241	0.0219
	(16.423)***	(21.322)***	(16.645)***	(16.745)***	(13.663)***	(17.13)***	(10.32)***	(12.566)***	(8.08)***

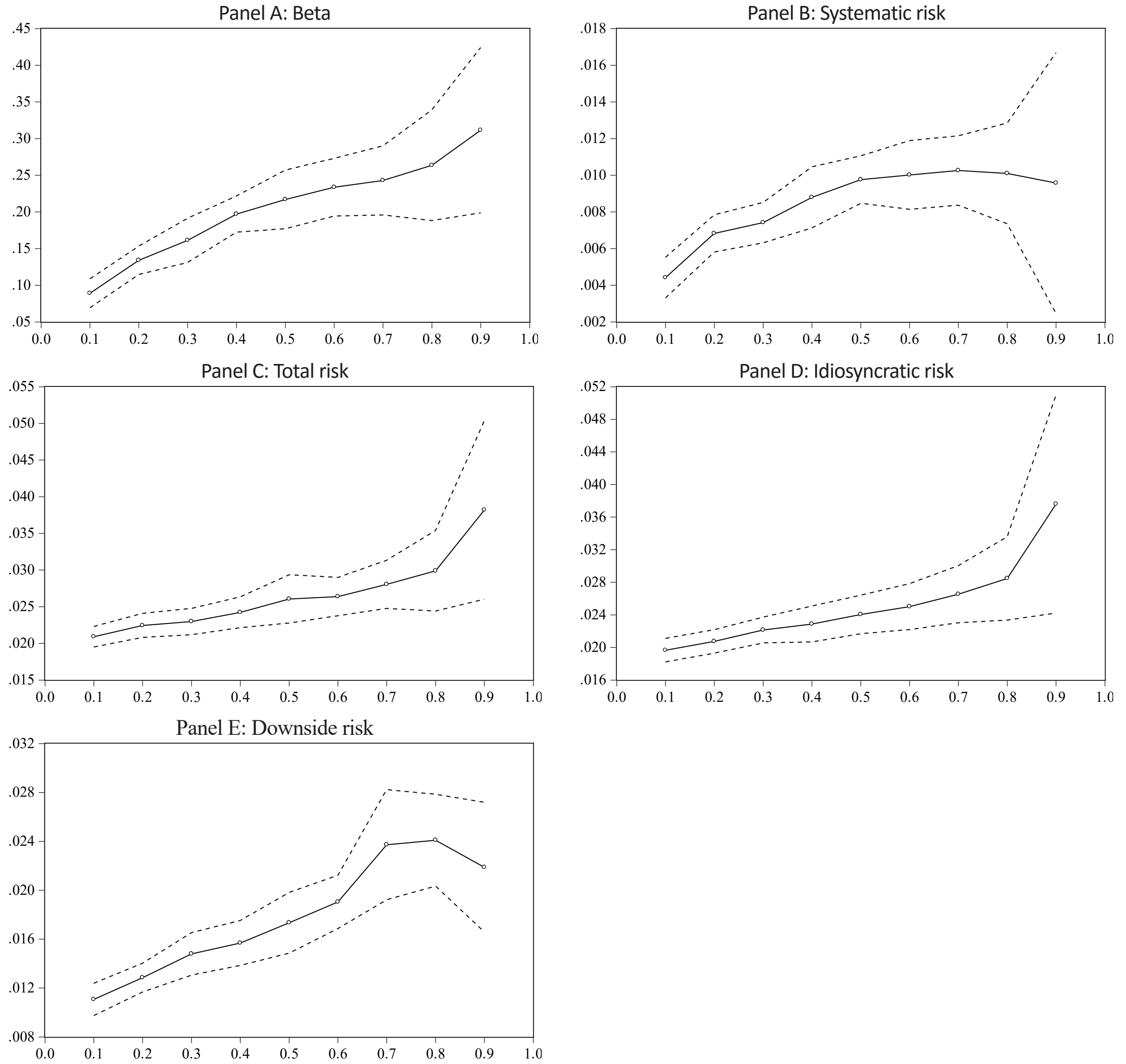
**** statistically significant at 1%, ** at 5%, * at 10%*

Like Chen et al. (2012), we also find that for higher risk firms, the impact of R&D intensity on firm risk becomes larger. Figure 3 graphs the coefficients at the various deciles for the R&D intensity variable with respect to the various risk measures. The consistently increasing coefficients as identified by Chen et al. (2012) are also visible, except for the high deciles of systematic and downside risk.

Figure 3 Quantile regression coefficients for the impact of R&D on risk

These graphs show the coefficients of the lagged R&D intensity variable in the quantile regression models for the various risk measures. Panel A does this for beta, which is measured as in equation (2). Panel B does this for systematic risk, which is measured as in equation (3). Panel C does this for total risk, which is measured as the standard deviation of 60 monthly stock returns. Panel D does this for idiosyncratic risk, which is mesaured as in equation (4). And, finally, Panel E does this for downside risk, which is measured as in equation (5). The dotted lines represent the 95% confidence interval. The vertical axes represent the coefficients, the horizontal axes the deciles of the distribution of the dependent variable.

1. This result is not tabulated but is available upon request, as is applicable for other unreported results.
2. There are also drawbacks to the use of this method as it does not allow for inclusion of fixed effects, nor for using robust standard errors.



For all measures of risk the 95% confidence intervals are rather narrow, but widen up for very high risk firms at the 9th decile. In comparison with the panel regression results, the coefficients for the R&D intensity variable are of larger size, on average and at the median. This is probably due to the absence of estimates with firm fixed effects. However, at all deciles in the distribution, and for all risk measures, we see a positive and significant effect of R&D on firm risk. These findings provide further support for the alternative hypothesis 1.

Robustness checks

Since R&D is often used as proxy for growth opportunities (Hirschey et al., 2012), it is important to check whether the impact of R&D intensity is really due to investments so as to innovate or whether it proxies growth opportunities. Another variable which is often used to proxy growth opportunities is the market-to-book ratio (Fama and French, 1993). Although the growth of assets is already included in the model, the market-to-book ratio measures a different concept. While the growth of assets measures historical growth of an accounting measure during the last five years, the market-to-book ratio includes the market-based valuation by shareholders who are forward looking. The inclusion of the market-to-book ratio in the model does not alter the results on the impact of R&D intensity on risk. All coefficients hardly change and for none of the risk measures there is a noticeable shift in statistical significance for any of the explanatory variables. With regard to the market-to-book ratio there is, as expected, a positive impact upon risk for all risk measures, however only statistically significant at 5% for total risk and idiosyncratic risk. Thus, growth opportunities do not seem to be responsible for the results related to the R&D intensity of a firm.

Panel fixed effects regression results for impact of R&D on risk with market-to-book

This table details all the regression coefficients from the panel least squares regression estimations with cross-section fixed effects and time fixed effects for the various risk measures. Below the coefficients, between parentheses, are the t-ratios. The equations have been estimated using robust standard errors (with adjustment of the degrees of freedom) clustered at the cross-section to allow for heteroskedasticity and serial correlation within a cross section. Hausman tests for correlated random effects indicate, for all dependent variables, that the effects are of a fixed nature. Furthermore, both effects are statistically significant.
The dependent variables are beta as in equation (2), systematic risk as in equation (3), total risk as the standard deviation of 60 monthly stock returns, idiosyncratic risk as in equation (4), and finally downside risk as in equation (5). The independent variables are the R&D intensity ratio, the squared R&D intensity ratio, the dividend payout ratio, the average logarithmic asset growth, the leverage ratio, the liquidity ratio, the log of total assets, the five-year variability of the earnings-price ratio, the log of firm age, the Herfindahl-Hirschman index as measure of competitive intensity, and the market-to-book ratio.

Variable	Beta	Syst. risk	Total risk	Idiosync. risk	Down. risk
Constant	1.0092	0.0387	0.3094	0.3111	0.1756
	(3.916)***	(3.090)***	(18.644)***	(21.347)***	(12.013)***
Lagged R&D int.	0.1031	0.0047	0.0060	0.0038	0.0045
	(2.797)***	(3.193)***	(2.564)**	(1.713)*	(1.968)**
Div. payout	-0.0055	-0.0002	-0.0003	-0.0003	-0.0002
	(-2.334)**	(-2.084)**	(-2.633)***	(-2.487)**	(-2.218)**
Growth	-0.0844	-0.0080	-0.0171	-0.0134	-0.0259
	(-1.298)	(-2.496)**	(-3.746)***	(-3.316)***	(-6.186)***
Leverage	-0.0580	-0.0026	0.0103	0.0121	0.0063
	(-2.334)**	(-2.502)**	(1.430)	(1.648)*	(1.352)
Liquidity	-0.0028	0.0000	-0.0010	-0.0011	-0.0005
	(-0.660)	(-0.113)	(-3.491)***	(-4.129)***	(-1.706)*
Total assets	0.0499	0.0028	-0.0099	-0.0117	-0.0039
	(2.759)***	(3.222)***	(-8.722)***	(-11.773)***	(-3.867)***
Earnings var.	0.1520	0.0101	0.0458	0.0438	0.0301
	(2.917)***	(4.309)***	(10.071)***	(10.135)***	(8.124)***
Firm age	-0.1505	-0.0068	-0.0141	-0.0119	-0.0101
	(-4.271)***	(-3.885)***	(-5.929)***	(-5.947)***	(-4.651)***
HHI	-0.3068	0.0146	-0.0607	-0.0744	-0.0513
	(-0.795)	(0.772)	(-2.326)**	(-3.410)***	(-2.211)**
Market-to-book	0.0003	0.0000	0.0000	0.0000	0.0000
	(0.684)	(1.492)	(2.049)**	(2.457)**	(1.543)
No. observations	30,560	30,560	30,560	30,560	30,560
F-statistic	12.973***	17.003***	40.982***	49.661***	22.074***
Adjusted R-squared	54.0%	61.1%	79.7%	82.7%	67.4%
Cross-section effects	Fixed	Fixed	Fixed	Fixed	Fixed
Time dummies	Yes	Yes	Yes	Yes	Yes

**** statistically significant at 1%, ** at 5%, * at 10%*

While standard errors robust to serial correlation are used for drawing inferences about the coefficients estimated using panel OLS techniques, taking first differences of all variables as specified in equation (1) also serves as a robustness check. Under the efficient market hypothesis it is suggested that returns follow a random walk, possibly with drift (Fama, 1970). This implies a data generating process with a unit root as driver of the measures of stock return risk. As a consequence, due to non-stationary of variables, these variables should be treated differently from variables which are stationary (Brooks, 2008). To mitigate this potential problem regressions are performed on first differences. What would be consistent with the hypotheses about the effects of R&D, which is in contrast to what McAlister et al. (2007) show, is that an increase in R&D intensity results in a higher beta (or any of the other measures of risk). We use the first differences of equation specification (1) based on yearly measures (in-stead of a 5 year moving average which is used before). The same trimming procedure, namely removing the top 2.5% of the raw R&D relative to revenues data series, is employed to remove extreme values based on yearly figures. The results are that an increase in R&D intensity results in higher firm risk. For systematic risk this impact is significant at 1%, for total risk at 5%, and for downside risk at 10%. In short, the results from these first difference analyses show a positive effect and provide further statistical support for some of the alternative hypotheses.

Table 5

Panel fixed effects regression results using first differences of the yearly measures

This table details all the regression coefficients from the panel least squares regression estimations with cross-section fixed effects and time fixed effects for the various risk measures. Below the coefficients, between parentheses, are the t-ratios. The equations have been estimated using robust standard errors (with adjustment of the degrees of freedom) clustered at the cross-section to allow for heteroskedasticity and serial correlation within a cross section. Hausman tests for correlated random effects indicate, for all dependent variables, that the effects are of a fixed nature. Furthermore, both effects are statistically significant.
The dependent variables are the first differences of beta as in equation (2), systematic risk as in equation (3), total risk as the standard deviation of 60 monthly stock returns, idiosyncratic risk as in equation (4), and finally downside risk as in equation (5). The independent variables are the changes in the yearly measures of the R&D intensity ratio, the dividend payout ratio, the average logarithmic asset growth, the leverage ratio, the liquidity ratio, the log of total assets, the five-year variability of the earnings-price ratio, the log of firm age, and the Herfindahl-Hirschman index as measure of competitive intensity.

(Change in) Variable	Beta	Syst. risk	Total risk	Idiosync. risk	Down. risk
Constant	-0.0098	0.0010	-0.0010	-0.0016	-0.0001
	(-2.722)***	(6.541)***	(-4.317)***	(-8.036)***	(-0.315)
Lagged R&D int.	0.1493	0.0123	0.0099	0.0056	0.0090
	(1.611)	(3.158)***	(2.134)**	(1.310)	(1.749)*
Div. payout	0.0003	0.0000	0.0000	0.0000	0.0000
	(1.493)	(0.222)	(0.386)	(0.519)	(0.525)
Growth	-0.0750	-0.0041	0.0011	0.0028	-0.0028
	(-4.990)***	(-6.566)***	(1.592)	(4.379)***	(-3.396)***
Leverage	0.0430	0.0044	0.0036	0.0017	0.0076
	(1.112)	(2.652)***	(1.682)*	(0.830)	(3.462)***
Liquidity	0.0027	0.0001	0.0001	0.0001	0.0002
	(1.84)*	(2.182)**	(1.666)*	(1.070)	(1.600)
Total assets	0.0785	0.0030	-0.0042	-0.0053	-0.0006
	(3.605)***	(3.132)***	(-3.674)***	(-5.006)***	(-0.476)
Earnings var.	-0.0218	0.0003	0.0053	0.0056	0.0019
	(-1.342)	(0.544)	(2.942)***	(2.798)***	(1.750)*
Firm age	-0.0075	-0.0020	-0.0007	0.0002	-0.0025
	(-0.127)	(-0.843)	(-0.187)	(0.063)	(-0.742)
HHI	-0.3830	0.0201	-0.0612	-0.0699	-0.0650
	(-1.099)	(1.300)	(-2.595)***	(-3.093)***	(-3.139)***
No. observations	25,759	25,759	25,759	25,759	25,759
F-statistic	1.428***	5.625***	5.728***	4.579***	3.900***
Adjusted R-squared	4.2%	32.0%	32.4%	26.7%	22.8%
Cross-section effects	Fixed	Fixed	Fixed	Fixed	Fixed
Time dummies	Yes	Yes	Yes	Yes	Yes

**** statistically significant at 1%, ** at 5%, * at 10%*

Non-linearity

If there is a non-linear relation between stock returns and R&D (Da et al., 2012), then there might also be a non-linear relation between R&D intensity and risk. Following McAlister et al. (2007) the possibility of a non-linear impact of the R&D intensity on risk is explored by the addition of the squared R&D intensity to the model for the adjusted sample in table 6. For all the various risk measures, both the ordinary and the squared R&D intensity variables are highly statistically significant at 1%. In all cases, the ordinary R&D intensity variable has a positive and relatively high coefficient (higher than the OLS coefficient), whereas the squared R&D intensity variable has a negative and relatively low coefficient (lower than the OLS coefficient).

Panel fixed effects regression results for the non-linear impact of R&D on risk

This table details all the regression coefficients from the panel least squares regression estimations with cross-section fixed effects and time fixed effects for the various risk measures. Below the coefficients, between parentheses, are the t-ratios. The equations have been estimated using robust standard errors (with adjustment of the degrees of freedom) clustered at the cross-section to allow for heteroskedasticity and serial correlation within a cross section. Hausman tests for correlated random effects indicate, for all dependent variables, that the effects are of a fixed nature. Furthermore, both effects are statistically significant.
The dependent variables are beta as in equation (2), systematic risk as in equation (3), total risk as the standard deviation of 60 monthly stock returns, idiosyncratic risk as in equation (4), and finally downside risk as in equation (5). The independent variables are the lagged R&D intensity ratio, the lagged squared R&D intensity ratio, the dividend payout ratio, the average logarithmic asset growth, the leverage ratio, the liquidity ratio, the log of total assets, the five-year variability of the earnings-price ratio, the log of firm age, and the Herfindahl-Hirschman index as measure of competitive intensity.

Variable	Beta	Syst. risk	Total risk	Idiosync. risk	Down. risk
Constant	0.9520	0.0361	0.3042	0.3071	0.1713
	(3.655)***	(2.852)***	(18.313)***	(21.120)***	(11.737)***
Lagged R&D int.	0.3216	0.0152	0.0259	0.0192	0.0208
	(3.574)***	(4.153)***	(4.608)***	(3.601)***	(3.900)***
Squared R&D int.	-0.0455	-0.0022	-0.0041	-0.0032	-0.0034
	(-3.026)***	(-3.474)***	(-3.737)***	(-3.013)***	(-3.165)***
Div. payout	-0.0055	-0.0002	-0.0003	-0.0003	-0.0002
	(-2.335)**	(-2.084)**	(-2.632)***	(-2.482)**	(-2.213)**
Growth	-0.0763	-0.0077	-0.0164	-0.0128	-0.0253
	(-1.175)	(-2.385)**	(-3.580)***	(-3.162)***	(-6.037)***
Leverage	-0.0561	-0.0024	0.0105	0.0123	0.0064
	(-2.232)**	(-2.328)**	(1.435)	(1.650)*	(1.359)
Liquidity	-0.0032	0.0000	-0.0011	-0.0011	-0.0006
	(-0.798)	(-0.229)	(-3.707)***	(-4.305)***	(-1.850)*
Total assets	0.0527	0.0030	-0.0097	-0.0115	-0.0037
	(2.888)***	(3.338)***	(-8.541)***	(-11.667)***	(-3.681)***
Earnings var.	0.1536	0.0102	0.0460	0.0439	0.0302
	(2.951)***	(4.34)***	(10.084)***	(10.151)***	(8.141)***
Firm age	-0.1495	-0.0068	-0.0140	-0.0118	-0.0100
	(-4.244)***	(-3.858)***	(-5.901)***	(-5.923)***	(-4.621)***
HHI	-0.2923	0.0152	-0.0594	-0.0734	-0.0502
	(-0.759)	(0.800)	(-2.286)**	(-3.375)***	(-2.170)**
No. observations	30,560	30,560	30,560	30,560	30,560
F-statistic	13.002***	17.032***	41.126***	49.797***	22.143***
Adjusted R-squared	54.1%	61.1%	79.7%	82.7%	67.5%
Cross-section effects	Fixed	Fixed	Fixed	Fixed	Fixed
Time dummies	Yes	Yes	Yes	Yes	Yes

**** statistically significant at 1%, ** at 5%, * at 10%*

Further elaborating on this impact pattern, it might be that it is not the intensity of R&D that influences risk, but the decision whether to invest in R&D or not. Conditional on the existence of R&D expenditures, the effects of the degree of R&D intensity might be less important which could be related to the observation by Hirschey et al. (2012) that R&D is concentrated within a small number of more high-tech industries. In this case, the interpretation is that a R&D dummy variable might proxy for membership of certain high-tech industries for which the resulting influence on risk is not accounted for by firm fixed effects. To test this possibility, we add a dummy variable which equals 1 if a firm had R&D expenditures greater than zero the previous year, and 0 otherwise, to the model specification including firm and period fixed effects as well as the market-to-book ratio. Table 7 shows that the linear and squared R&D intensity variables are still highly significant (p-values < 1%) for all risk measures. The indicator variable is also significant at 5% for both measures of systematic risk and at 10% for total risk, but is not significant for idiosyncratic risk and downside risk. For all risk measures the dummy variable has a positive coefficient, the ordinary R&D intensity variable a relatively high and positive coefficient, and the squared R&D intensity variable a relatively low and negative coefficient. Thus, it does not seem to be correct that only the decision to invest in R&D matters; also its intensity is important.

Table 7

Panel fixed effects regression results for the non-linear impact with dummy

This table details all the regression coefficients from the panel least squares regression estimations with cross-section fixed effects and time fixed effects for the various risk measures. Below the coefficients, between parentheses, are the t-ratios. The equations have been estimated using robust standard errors (with adjustment of the degrees of freedom) clustered at the cross-section to allow for heteroskedasticity and serial correlation within a cross section. Hausman tests for correlated random effects indicate, for all dependent variables, that the effects are of a fixed nature. Furthermore, both effects are statistically significant.

The dependent variables are beta as in equation (2), systematic risk as in equation (3), total risk as the standard deviation of 60 monthly stock returns, idiosyncratic risk as in equation (4), and finally downside risk as in equation (5). The independent variables are the lagged R&D intensity ratio, the lagged squared R&D intensity ratio, the R&D indicator dummy, the dividend payout ratio, the average logarithmic asset growth, the leverage ratio, the liquidity ratio, the log of total assets, the five-year variability of the earnings-price ratio, the log of firm age, and the Herfindahl-Hirschman index as measure of competitive intensity.

Variable	Beta	Syst. risk	Total risk	Idiosync. risk	Down. risk
Constant	0.9494	0.0366	0.3044	0.3072	0.1725
	(3.499)***	(2.749)***	(17.183)***	(19.935)***	(11.058)***
Lag. R&D int.	0.3676	0.0166	0.0255	0.0182	0.0192
	(4.56)***	(4.608)***	(4.162)***	(3.148)***	(3.392)***
Lag. Sqd. R&D int.	-0.0528	-0.0024	-0.0040	-0.0030	-0.0031
	(-3.634)***	(-3.766)***	(-3.368)***	(-2.608)***	(-2.694)***
R&D dummy	0.1004	0.0048	0.0061	0.0045	0.0039
	(2.104)**	(2.097)**	(1.917)*	(1.593)	(1.374)
Div. payout	-0.0057	-0.0002	-0.0004	-0.0003	-0.0003
	(-2.345)**	(-2.073)**	(-2.677)***	(-2.591)***	(-2.295)**
Growth	-0.0903	-0.0084	-0.0164	-0.0124	-0.0250
	(-1.324)	(-2.505)**	(-3.419)***	(-2.908)***	(-5.634)***
Leverage	-0.0388	-0.0017	0.0127	0.0143	0.0078
	(-1.298)	(-1.343)	(1.592)	(1.769)*	(1.545)
Liquidity	0.0017	0.0003	-0.0009	-0.0010	-0.0004
	(0.304)	(0.974)	(-2.016)**	(-2.679)***	(-0.989)
Total assets	0.0505	0.0029	-0.0098	-0.0117	-0.0037
	(2.652)***	(3.091)***	(-8.179)***	(-11.306)***	(-3.503)***
Earnings var.	0.1425	0.0102	0.0457	0.0436	0.0299
	(2.553)**	(4.076)***	(9.313)***	(9.344)***	(7.46)***
Firm age	-0.1603	-0.0076	-0.0150	-0.0123	-0.0108
	(-4.436)***	(-4.221)***	(-5.962)***	(-5.791)***	(-4.748)***
HHI	-0.4874	0.0043	-0.0683	-0.0761	-0.0650
	(-1.243)	(0.225)	(-2.57)**	(-3.432)***	(-2.774)***
No. observations	28,205	28,205	28,205	28,205	28,205
F-statistic	12.209***	16.163***	38.588***	47.15***	20.853***
Adjusted R-squared	53.5%	60.9%	79.4%	82.6%	67.1%
Cross-section effects	Fixed	Fixed	Fixed	Fixed	Fixed
Time dummies	Yes	Yes	Yes	Yes	Yes

**** statistically significant at 1%, ** at 5%, * at 10%*

Conclusion

We investigate whether R&D affects firm risk. Besides the effects on the systematic risk, also effects are analyzed for total risk, idiosyncratic risk and downwards risk. R&D investments significantly increase systematic risk (and beta), total return variance and -unfortunately for investors- also downside risk. The results may make it also more difficult for managers to defend R&D investments. R&D may indeed generate future returns, but also adds to the next year's risk. The impact on systematic risk contrasts to the finding by McAlister et al. (2007) that R&D insulates firms from market downturns and thereby lowers systematic risk. While the magnitudes of the effects are small, the impact is relevant when compared with other accounting variables included in the model, especially for beta and systematic risk. Apart from this, there are strong indications that the hypothesized relation is non-linear. Finally, we also find that it is not only the decision to invest in R&D that matters; also its intensity is important.

References

1. Ball, R., Kothari, S., and Shanken, J. (1995), "Problems in measuring portfolio performance: an application to contrarian investment strategies", *Journal of Financial Economics,* no. 38, pp. 79–107.
2. Barnes, M., and Hughes, A. (2002), "A quantile regression analysis of the cross section of stock market returns". Unpublished working paper, Federal Reserve Bank of Boston.
3. Barth, M., Kasznik, R., and McNichols, M. (2001), "Analyst coverage and intangible assets", *Journal of Accounting Research,* no. 39, pp. 1–34.
4. Bartram, S., Brown, G., and Stulz, R. (2012), "Why are U.S. stocks more volatile?", *Journal of Finance,* no. 67, pp. 1329–1370.
5. Beaver, W., Kettler, P., and Scholes, M. (1970), "The association between market determined and accounting determined risk measures", *Accounting Review*, no. 45, pp. 654–682.
6. Berk, J., Green, R., and Naik, V. (2004), "Valuation and return dynamics of new ventures", *Review of Financial Studies*, no. 17, pp. 1–35.
7. Blume, M. (1970), "Portfolio theory: a step toward its practical application", *Journal of Business*, no. 43, pp. 152–173.
8. Bowman, R. (1979), "The theoretical relationship between systematic and financial (accounting) variables", *Journal of Finance*, no. 34, pp. 617–630.
9. Brandt, M., Brav, A., Graham, J., and Kumar, A. (2010), "The idiosyncratic volatility puzzle: time trend or speculative episodes?", *Review of Financial Studies*, no. 23, pp. 863–899.
10. Brooks, C. (2008), *"Introductory Econometrics for Finance"*. Cambridge University Press, Cambridge, United Kingdom.
11. Brown, G., and Kapadia, N. (2007), "Firm-specific risk and equity market development", *Journal of Financial Economics*, no. 84, pp. 358–388.
12. Campbell, J., Lettau, M., Malkiel, B., and Xu, Y. (2001), "Have individual stocks become more volatile? An empirical exploration of idiosyncratic risk", *Journal of Finance*, no. 56, pp.1–43.
13. Cao, C., Simin, T., and Zhao, J. (2008), "Can growth options explain the trend in idiosyncratic risk?", *Review of Financial Studies*, no. 21, pp. 2599–2633.
14. Capon, N., Farley, J., and Hoenig, S. (1990), "Determinants of financial performance: a meta-analysis", *Management Science*, no. 36, pp. 1143–1159.
15. Chambers, D., Jennings, R., and Thompson, R. (2002), "Excess returns to R&D-intensive firms", *Review of Accounting Studies*, no. 7, pp. 133–158.
16. Chan, L., Lakonishok, J., and Sougiannis, T. (2001), "The stock market valuation of research & development expenditures", *Journal of Finance*, no. 56, pp. 2431–2456.
17. Chan, S., Martin, J., and Kensinger, J. (1990), "Corporate research and development expenditures and share value", *Journal of Financial Economics,* no. 26, pp. 255–276.
18. Chauvin, K., and Hirschey, M. (1993), "Advertising, R&D expenditures and the market value of the firm", *Financial Management*, no. 22, pp. 128–140.

19. Chen, M., Peng, C., and Wei, A. (2012), "Advertising, research and development, and capital market risk: higher risk firms versus lower risk firms", *Journal of Business Economics and Management*, no. 13, pp. 724–744.
20. Da, Z., Guo, R., and Jagannathan, R. (2012), "CAPM for estimating the cost of equity capital: interpreting the empirical evidence", *Journal of Financial Economics*, no. 103, pp. 204–220.
21. Eberhart, A., Maxwell, W., and Siddique, A. (2004), "An examination of long-term abnormal stock returns and operating performance following R&D increases", *Journal of Finance*, no. 59, pp. 623–650.
22. Fama, E. (1970), "Efficient capital markets: a review of theory and empirical work", *Journal of Finance*, no. 25, pp. 383–417.
23. Fama, E., and French, K. (1993), "Common risk factors in the returns on stocks and bonds", :Journal of Financial Economics", no. 33, pp. 3–56.
24. Fu, F. (2009), "Idiosyncratic risk and the cross-section of expected stock returns", *Journal of Financial Economics*, no. 91, pp. 24–37.
25. Hall, B. (2002), "The financing of research and development", *Oxford Review of Economic Policy*, no. 18, pp. 35–51.
26. Hertzel, M., Lemmon, M., Linck, J., and Rees, L. (2002), "Long-run performance following private placements of equity", *Journal of Finance*, no. 57, pp. 2595–2617.
27. Hirschey, M., Skiba, H., and Wintoki, M. (2012), "The size, concentration and evolution of corporate R&D spending in U.S. firms from 1976 to 2010: evidence and implications", *Journal of Corporate Finance*, no. 18, pp. 496–518.
28. Ho, Y., Xu, Z., and Yap, C. (2004), "R&D investment and systematic risk", *Accounting and Finance*, no. 44, pp. 393–418.
29. Irvine, P., and Pontiff, J. (2009), "Idiosyncratic return volatility, cash flows, and product market competition", *Review of Financial Studies*, no. 22, pp. 1149–1177.
30. Koenker, R., and Basset G. (1978), "Regression quantiles", *Econometrica*, no. 46, pp. 33–50.
31. Koenker, R., and Hallock, K. (2001), "Quantile regression", *Journal of Economic Perspectives*, no. 15, pp. 143–156.
32. Kothari, S., Laguerre, T., and Leone, A. (2002), "Capitalization versus expensing: evidence on the uncertainty of future earnings from capital expenditures versus R&D outlays", *Review of Accounting Studies*, no. 7, pp. 355–382.
33. Lintner, J. (1965), "The valuation of risk assets and the selection of risky investments in stock portfolios and capital budgets", *Review of Economics and Statistics*, no. 47, pp. 13–37.
34. Lui, D., Markov, S., and Tamayo, A. (2007), "What makes a stock risky? Evidence from sell-side analysts' ratings", *Journal of Accounting Research*, no. 45, pp. 629–665.
35. Mandelker, G., and Rhee, S. (1984), "The impact of the degrees of operating and financial leverage on systematic risk of common stock", *Journal of Financial and Quantitative Analysis*, no. 19, pp. 45–57.
36. Markowitz, H. (1952), "Portfolio selection", *Journal of Finance*, no. 7, pp. 77–91.
37. Mazzucato, M., and Tancioni, M. (2008), "Innovation and idiosyncratic risk: an industry- and firm-level analysis", *Industrial and Corporate Change*, no. 17, pp. 779–811.
38. McAlister, L., Srinivasan, R., and Kim, M. (2007), "Advertising, research and development, and systematic risk of the firm", *Journal of Marketing*, no. 71, pp. 35–48.
39. Meng, R. (2008), "A patent race in a real options setting: investment strategy, valuation, CAPM beta, and return volatility", *Journal of Economic Dynamics and Control*, no. 32, pp. 3192–3217.

40. Merton, R. (1987), "A simple model of capital market equilibrium with incomplete information", *Journal of Finance*, no. 42, pp. 483–510.

41. Mossin, J. (1966), "Equilibrium in a capital asset market", *Econometrica*, no. 34, pp. 768–783.

42. Patton, A. (2009), "Are "market neutral" hedge funds really market neutral?", *Review of Financial Studies*, no. 22, pp. 2495–2530.

43. Perlitz, M., Peske, T., and Schrank, R. (1999), "Real options valuation: the new frontier in R&D project evalution?", *R&D Management*, no. 29, pp. 255–270.

44. Petersen, M. (2009), "Estimating standard errors in finance panel data sets: comparing approaches", *Review of Financial Studies*, no. 22, pp. 435–480.

45. Ritter, J., and Welch, I. (2002), "A review of IPO activity, pricing, and allocations", *Journal of Finance*, no. 57, pp. 1795–1828.

46. Roll, R. (1977), "A critique of the asset pricing theory's tests part I: on past and potential testability of the theory", *Journal of Financial Economics*, no. 4, pp. 129–176.

47. Rosenberg, B. (1974), "Extra-market components of covariance in security returns", *Journal of Financial and Quantitative Analysis*, no. 9, pp. 263–274.

48. Rosenberg, B., and Marathe, V. (1975), "The prediction of investment risk: systematic and residual risk". Unpublished working paper, Proceedings of the Center for Research in Security Prices Seminar, University of Chicago.

49. Sharpe, W. (1964), "Capital asset prices: a theory of market equilibrium under conditions of risk", *Journal of Finance*, no. 19, pp. 425-442.

50. Sortino, F., and Van der Meer, R. (1991), "Downside risk", *Journal of Portfolio Management*, no. 17, pp. 27-31.

51. Titman, S., and Wessels, R. (1988), "The determinants of capital structure choice", *Journal of Finance*, no. 43, pp. 1–19.

52. Xu, M., and Zhang, C. (2004), "The explanatory power of R&D for the cross-section of stock returns: Japan 1985–2000", *Pacific-Basin Finance Journal*, no. 12, pp. 245–269.