RELATIONSHIP BETWEEN R&D EXPENSE AND STOCK PERFORMANCE

by

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Abstract

The objective of this project is to analyze whether a higher level of research and development (R&D) expense generates a higher stock return for firms. Data include firms from all industries in North America in 1980-2017. The empirical methods are the firm-year approach and calendar-time approach. Our results show that a high R&D expense impacts the stock performance positively. Further, equal-weighted calendar-time portfolios that are long high R&D firms and short low R&D firms result in a significant alpha.

Keywords: research and development; abnormal return; calendar-time approach; portfolio strategy

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1. Introduction

Research and development expenditure (hence, R&D) in US public firms have been increasing since the 1970s. Moreover, this increase in R&D expenditures is faster than the capital expenditures (Jensen, 1993; Skinner, 2008). According to R&D magazine (rdmag.com), the R&D spending of the market in North America is about 27.7% of the total R&D expenditure of the overall 116 countries. Das et al. (2009) find that companies with high R&D investment tend to have higher returns as long as their innovative products or services can be widely-traded. These results suggest that R&D may be value-increasing for companies.

Baruch Lev (1999) stated that: “research and development is the major driver of the technological change -- hence the central role of economic growth and welfare improvement. The impact of R&D and technological change on economic growth has long been recognized by proponents of free-market economies such as Adam Smith, Marshall, Keynes, and Solow. Even two of the most ardent critics of capitalist societies, Marx and Engels, argued in the Communist Manifesto that capitalism depends for its very existence on the constant introduction of new products and processes.” Hou (2016) concluded that R&D plays a significant role in determining the growth and uncertainty of a firm’s long-term value.

Increasing innovation ability and production efficiency is one way to increase a company's profitability, and thus, to increase the stock return. Companies either capitalize or expense their research and developing products or machines. Typically, high development cost products, such as medicine or software, are recorded as R&D within the income statement, before the product is capitalized according to GAAP. That is one way how R&D expense is different from the capital expense. Whether R&D creates value for shareholders or not is a challenging question because R&D entails much information asymmetry. Companies tend to be over-optimistic about their development and hide their problems and therefore it is difficult for non-specialist researchers to value the future profitability of the R&D expenditure. The objective of this project is analyzing whether a higher level of R&D generates a higher return. Hence, we believe it is necessary and interesting to examine whether it is a superior strategy for a company to engage in high R&D levels and whether the market rewards such activity.

In this paper, we examine the relationship between R&D expenditure and stock returns in North America. We analyze whether higher R&D leads to higher stock returns or vice versa. Our analysis is based on data starting from 1980 to 2017 due to the limitation of R&D before 1980 -- the earlier part of the R&D data on Compustat is mostly missing. Our research is based on the entire universe of CRSP/Compustat firms instead of just specific industries. We believe this approach can exclude the limitation of deriving results that are inclusive of some industries but not on others. We do not classify the firms into R&D-intensive and R&D non-intensive industries, but instead, classify firms based on each R&D level compared to the mean in the industry (2 digit sic code) during the year. This process implies that any results that we uncover are not industry specific, but instead are general results about the effect of R&D on firms' profitability.

Overall, our study shows that high R&D expense tends to generate a high stock return. The usefulness of that for generating trading profits is limited because sorting stocks into portfolios based on R&D does not generate a significant alpha in a value-weighted calendar time portfolio approach, which implies that the R&D effect is driven primarily by small firms. Nevertheless, the equal-weight portfolio approach shows a higher alpha for stocks that invest highly in R&D compared to those that invest a low amount in R&D.

This paper proceeds as follows. Section 2 reviews the literature. Section 3 describes the data, as well as the methodology of our research. Section 4 states the empirical results. Section 5 concludes results.

2. Literature review

The impact of R&D on firm performance has aroused considerable interest in both academic and professional circles. The interest reflects the recent widespread technological change, together with the dazzling growth of science- and knowledge-based industries, which are especially active in R&D (Chan L et al., 2001). The Big Four companies, Amazon, Apple, Google, and Facebook take the R&D investment strategy as an indispensable factor that can seriously help their business grow. Anecdotal evidence suggests that the percentage of the reinvestment on R&D

expenditure seems to have an increasing trend. Take Amazon as an example, which spent about 23 billion USD on R&D last year, which is about 50% higher from the previous year (see o Rani Molla, redcode.net, 2018). Such changes show the importance that R&D has on the attention of companies. However, whether the high increase in R&D is justified remains a question. Many R&D-intensive companies are priced at high prices, with sometimes unjustified high multiples. Under such circumstances, perhaps it is not a good idea to invest in them, as they may underperform compared to what the market expects (Chan et al., 2001).

R&D expenditure is not a new topic. It has been studied from different perspectives since the 20th century. Theodore (1994) finds that R&D expenditure enhances firm value, but it cannot directly enhance a firm's future benefits. Lev et al. (1996) discovered a positive correlation between the lagged R&D expense and economic growth. Hsieh et al. (2003) also found a positive correlation between R&D expenditure and firm performance. Chan et al. (2001) studied the impacts of information asymmetry on the excess return of both high and low R&D intensify firms. Hirshleifer et al. (2017) studied the undervaluation of a firm with higher innovation levels, suggesting that R&D is not sufficiently priced by market participants.

However, there are contradictory views; some claim that investors overvalue firms with R&D expenses. For example, many firms' R&D investments are not profitable, but investors systematically overlook this possibility, which leads to overvaluation

(Jensen, 1993). Although many investors are enamored with technology stocks and believe them to be excellent investments, the historical evidence suggests otherwise. The average return on stocks that do R&D is comparable to the return on stocks with no R&D (Chan et al., 2001). Chan (2001) finds no relation between R&D and stock return in general, but they mention that R&D is not sufficiently informative from accounting standards. Ciftci (2011) argues that it is essential to identify whether the risk-adjusted return of R&D intensity firms is from business risk or information risk. Their result implies that the undervaluation is cut by half after earning guidance discussing R&D are released.

Even though the extant literature finds no solid conclusion about the relationship between R&D and stock performance, there is value to have an extensive analysis based on a large data set. Since the 2000s our understanding of abnormal return has increased, and it is now common to use the calendar portfolio approach to see if one can generate positive alphas. That is our primary motivation. We realized that science advances in small steps, and we wish to have an elaborate study on whether there is a significant relation between abnormal return (alpha) and R&D.

3. Data and methodology

3.1 Data

The data used in the analysis is obtained from the Compustat-Capital IQ of the

Wharton Research Data Service (WRDS). The period of the data collected starts in 1980 and ends in 2017. The entire data set is downloaded from the North America market including all 18 sectors. They are mining, construction, manufacturing, wholesale trade, retail, transportation, communications, electric, gas, sanitary service, finance, insurance, real estate, service, public administration, agriculture, forestry, and fishing. Though the research includes all sectors in the economy, we consider R&D expenditure relative to the two-digit SIC industry. This consideration includes that companies' R&D varies cross-sectors and that we do not end up with portfolios tilted towards some industries versus others. We consider throughout most of the study the industry adjusted R&D level as the primary independent variable since different industries will have the different standard of the R&D expenditures. So, making the industry adjustments on the R&D expenditure can make it comparable among all the industries. The calculation methodology is mentioned at 3.2.1.

3.1.1 Balance sheet data and income statement data

To determine the R&D expense, and classify the companies into different industries, 151,499 observations are downloaded from the Balance Sheet Data and Income statement data (Compustat-Capital IQ) first, including XRD (Research and Development Expense), AT (Total Asset), REVT (Total Revenue), Sales (SAL)

3.1.2 Stock data

In order to generate the stock return and calculate the return of the companies over the risk-free rate, 1,007,954 observations are gathered from Stock Data (CRSP monthly file). Data used in this category includes variables of RET (Returns) and SHROUT (number of shares outstanding), PRC (price).

3.1.3 Fama-French factors

To regress return with the Fama-French three-factor model and Carhart momentum factor, we collect 453 monthly observations from the Fama-French factors and Carhart momentum factor. The downloaded monthly data at this category corresponds to the monthly return data of stocks. There are overall five variables included: MKTRF(value-weighted return minus risk-free return), SMB(Small-minus-Big Return), HML(High-minus-Low Return), RF(Risk-Free Return Rate (One Month Treasury Bill Rate)), and UMD (Momentum Factor).

3.1.4 New generalized variables from the raw data sets

To better identify the effects of the R&D expense of companies on their stock returns, we create two new variables, RDIN (Average of R&D ratio in the industry; where R&D ratio is R&D expense divided by total Assets of the company; industry corresponds to 2 digit sic code) and SDIN (Standard Deviation of the R&D ratio within the industry). The ratio is used since the R&D expense of companies with different market size is incomparable..

3.2 Methodology

Industry adjusted R&D/Assets ratio is calculated using data that had been downloaded. Monthly data are classified into different Industry adjusted R&D/Assets ratio groups from low level to high level from 1980 to 2017. Industry adjusted R&D/Assets is the value of the R&D/Assets ratio minus the industry (2 digit SIC code) average ratio and divided by the standard deviation within the industry at the given year. The means of raw return and excess return (return minus value-weighted market return) for each group are calculated. The mean of alpha, as well as the mean of return and excess return together, show the tendency of the stock performance of the ten portfolios.

To analyze the relationship between abnormal return (Alpha) and industry-adjusted R&D/Asset ratio, we use two approaches. One is the simple firm-year regression approach, and another is the calendar-time portfolio approach. In order to get an abnormal return (Alpha) for each company every year, we use the Fama-French (1993) three-factor model and Carhart (1997) momentum factor regression model. Then we use alpha as dependent variables and other variables including industry adjusted R&D/Assets as independent variables to run the regression. In calendar-time portfolio approach, ten portfolios (with the same-equal number of stocks) are built based on the ordinal value of industry-adjusted R&D. Value-weighted and equal-weighted returns are calculated for each portfolio every month. Then the regression is run on a single time series where the independent variable are the Fama-French three-factors and Carhart (1997) momentum factor.

3.2.1 R&D ratio measurement and group

The main dependent variable for classifying firms into portfolios is adjusted R&D, defined as:

$$ARD_{i,t} = \frac{\left(RD_{i,t} - \overline{RD_{\imath,\imath nd,t}}\right)}{\sigma_{ind,t}}$$

Where $ARD_{i,t}$ is the industry adjusted R&D expense of firm *i* at year *t*; $RD_{i,t}$ is the research expense ratio defined as research and expense (Compustat item XRD) divided by total value of asset (compustat itme AT) of firm *i* at year *t*; $\overline{RD_{\imath,\imath nd,t}}$ is the average (equal-weighted) research and expense ratio of all firms that belong to the same industry (2 digit sic code) in year *t*; $\overline{\sigma_{\imath nd,t}}$ is the standard deviation of the research expense ratio of the industry in year *t*. $ARD_{i,t}$ is used throughout most of the study to classify firms into portfolios.

Stocks are sorted into ten equal-sized groups by the adjusted R&D/Assets. In Figure 1, it can be seen that the average R&D/Assets ratio of group 1 to group 6 are stable. The average numbers separately are 0, 0.0015, 0.0045, 0.0129, 0,0249, 0,0419. The average R&D/Assets from group 7 to group 10 increase sharply. They separately are 0.0652, 0.0967, 0.146, 0. 381.

Two groups are also used to measure portfolio alpha. Under two group situation, Group 1 has adjusted R&D/Assets ratio range from -0.5047 to -0.0428 with the number of observations of 141120. Group 2 has adjusted R&D/Assets ratio range from -0.0819 to -16.8907 with the number of observations of 119520.

3.2.2 Raw return and excess return

For the following description, m represents month from January to December. Mean of raw return ($\overline{r_{m,t+1}}$) and excess return ($\overline{r_{m,t+1}}$ - $\overline{rf_{m,t+1}}$) for each group are calculated by data in year t+1 at each month m to show the trend from group 1 to group 10. Excess return is calculated by using raw return for each firm-month minus market return at that month

3.2.3 Abnormal return for firm-year regression approach

In order to know the mean of abnormal return for each group and the relation between abnormal return and adjusted R&D/Assets ratio, abnormal return for each company every year is generated by the following four-factor regression:

$$r_{i,m,t+1} - rf_{m,t+1} = a_{i,t+1} + b*(Mkt-rf)_{m,t+1} + s*SMB_{m,t+1} + h*HML_{m,t+1} + u*UMD_{m,t+1} + e$$

Where $r_{i,m,t+1}$ is the return of each stock at every month m of year t+1 (CRSP item RET), $rf_{m,t+1}$ is the risk-free return rate. $a_{i,t+1}$ is a common constant, which is generated by regression and represent the abnormal return (alpha) for each firm in year t+1.$(Mkt-rf)_{m,t+1}$ is the difference between market return and risk-free return rate at every month of year t+1 (CRSP item MKTRF). $SMB_{m,t+1}$ is the difference between small-firms return and big-firms return at every month of year t+1 (CRSP item SMB). $HML_{m,t+1}$ is the difference between high book-to-market equity return and low book-to-market equity return at every month of year t+1 (CRSP item HML). $UMD_{m,t+1}$ is the momentum factor at every month of year t+1 (CRSP item UMD), and e represents the error term.

3.2.4 Firm-year alpha regression approach

We use the alpha generated from firm-year regression to get some insights whether adjusted R&D ratio is related to alpha. The relationship of alpha against Industry adjusted R&D/Assets is tested by the following three regression equations:

$Alpha_{i,t+1}$ = a + b *$ARD_{i,t}$ + c *$Size_{i,t}$

$Alpha_{i,t+1}$ = a + b *$ARD_{i,t}$ + c *$Size_{i,t}$ + i.$Year$

$Alpha_{i,t+1}$ = a + b *$ARD_{i,t}$ + c *$Size_{i,t}$ + i.$Year$ + i.$Company$

Where

$Alpha_{i,t+1}$ is abnormal return generated from firm-year regression that are done every year t+1 (12 monthly observations for a firm).$ARD_{i,t}$ is the industry adjusted R&D/Assets for each firm i in the year t.$Size_{i,t}$ is the market value of each company i at the end of the year t prior to the year t when $Alpha_{i,t+1}$ is calculated. $Year$ is dummy indicator.$Company$ is dummy indicator by (Compustat item permno). The coefficient and t-statistics for each independent variable are generated to know the relationship between dependent and independent variables, as well as the significant level of such relationship. The period of the regression is from 1980 to 2017.

3.2.5 Calendar-time portfolio approach and long short

Portfolios are formed at the end of every year (at December) based on the adjusted R&D variable. Both value-weighted and equal weighted return is calculated for each of the ten portfolios in every month from 1980 to 2017 in ordinal value. The following equation calculates Value-weighted return:

$Vwret_{p,m}$ = $\sum(Markw_{i,m}/Mval_{p,m}*(r_{i,m} - rf_m))$

Where m represents every different month from 1980 to 2017. $Mval_{p,m}$ is the market value of each portfolio p at the beginning of each month m. $Markw_{i,m}$ is the market value of each company i at the beginning of each month m. $r_{i,m}$ - rf_m is the monthly raw return of each company i minus the risk-free rate.

Equal-weighted return is the mean of ($r_{i,m}$ - rf_m) for each portfolio in each month. Consequently, you end up with one time-series regression as done in the calendar-time approach. The alpha is the intercept (a) of the following two regression:

$Vwret_{p,m}$= $a_{p,m}$ + b *$(Mkt - rf)_m$ + s*SMB_m +h*HML_m + u*UMD_m +e

$Ewret_{p,m}$= $a_{p,m}$ + b *$(Mkt - rf)_m$ + s*SMB_m +h*HML_m + u*UMD_m +e

where the independent variables are the same with the description in section 3.2.3 except now the month is in ordinal value. $Vwret_{p,m}$ and $Ewret_{p,m}$ are value-weighted return and equal-weighted return.

Abnormal returns of the long-short strategy is calculated as follows. The first step is to calculate the return difference between groups, and then run the four-factor regression with the return difference as the dependent variable. In this research, the first long-short group is long portfolio 10 and short portfolio 1, and the second long-short group is long portfolio 10&9 and short portfolio 1&2. The third long-short group is long portfolio that is above the median ARD and short portfolio that is below the median ARD.

4. Results

Table 1 provides the raw returns, excess returns and the average alpha of the ten portfolios from the year 1980 to 2017, where return data is partitioned based on their industry adjusted R&D/Assets. Firms are equally divided into those ten groups, and industry-adjusted R&D/Assets ordinally increase from portfolio 1 to portfolio 10. The value of return is the mean of returns in each portfolio. Alpha is the intercept of a regression where the dependent variable is the daily excess return, and the independent variables include the three Fama and French (1993) and Carhart (1997) momentum factors. Hence, the alpha is generated for each company every year based on 12 annual observations, in the year following the portfolio formation year. It can be seen from the table, the returns of portfolio 1 to portfolio 6 do not show a consistent pattern, and the returns of portfolio 7 to portfolio 9 obviously increase. The excess returns show increasing trend from portfolio 5 to portfolio 9 and alphas show an increasing trend from portfolio 7 to portfolio 9. Compared with the trend of industry-adjusted R&D, it indicates the performance of the stock is improved for the high industry adjusted R&D/Asset ratio companies.

Table 2 shows regression results where the dependent variable is the alpha (intercept of the four-factor model from the firm-year analysis of alpha). The independent variables are either size, year dummy or company dummy in addition to R&D ratio. The effect of the size is not significant when it is solely included with R&D ratio. However, the effect becomes significant and turns negative when other variables are included which partly shows that abnormal returns for small firms are larger and significant. The effect of the year is significant. It makes sense since when innovation is generated at a specific year, the market is not so well informed with future profitability. It can be observed from the third column of the table that when the company indicator is not included, alpha shows a positive correlation with the R&D ratio, and the result is significant. When the company fixed effect is included, the R-squared increase significantly, and the coefficient of R&D turns to negative. This result implies that the explanatory power in the cross-section differs from that of the time-series, something that is worth further investigation in future research.

Figure 2 shows the trend of equal-weighted return and value-weighted return. The trend of equal-weighted return has been described before. The trend of value-weighted return is less significant, but portfolio 8 to 10 still show the apparent increasing trend. Value weighted returns are calculated by the weighted average return for every company each year. It is obvious that high industry adjusted R&D/Asset ratio portfolios have the higher return than low industry adjusted R&D/Asset ratio portfolios. The profitability for high R&D portfolios is more pronounced in the equal-weighted analysis than value-weighted analysis. That means that R&D may be a better signal to follow for small companies than large companies.

Table 3 shows the alphas for each portfolio. When we use two portfolios, we equally divide over all firms at the end of the calendar year. Portfolio alpha and long-short portfolio return alphas is the intercept of regression between returns and the three Fama and French (1993) and Carhart (1997) momentum factors. For both 2 portfolios approach and 10 portfolios approach, alphas of equal-weighted return are significant. It shows an increasing trend from portfolio 6 to portfolio 10. The long-short alpha is also very significant for equal-weighted return. The alpha of value-weighted portfolio is not significant except for portfolio 1 in 2 portfolios and portfolio 3 in 10 portfolios. The long-short value-weighted alpha is not significant either but still, the very high R&D ratio portfolio has a higher alpha than the low R&D ratio portfolio.

5. Conclusion

This study analyzes the effect of R&D expense on stock performance. Investors are interested to know which firms perform better--firms that highly invest in R&D or firms that invest only a small amount in R&D. The purpose of this paper is to analyze which firms do better. Our research result show very high R&D expense stock generate a relatively higher return which partly may suggest that the four-factor model does not capture R&D risk. There is a significant difference in returns between the R&D group in both equal-weighted and value-weighted portfolios. However, there is an insignificant difference in the abnormal returns between the value-weighted groups. This result implies that small market-value firm with high R&D expenditure may have abnormal return compared to large firms. Overall, our test result is consistent with the predictions based on a model with limited attention to R&D expenditure.

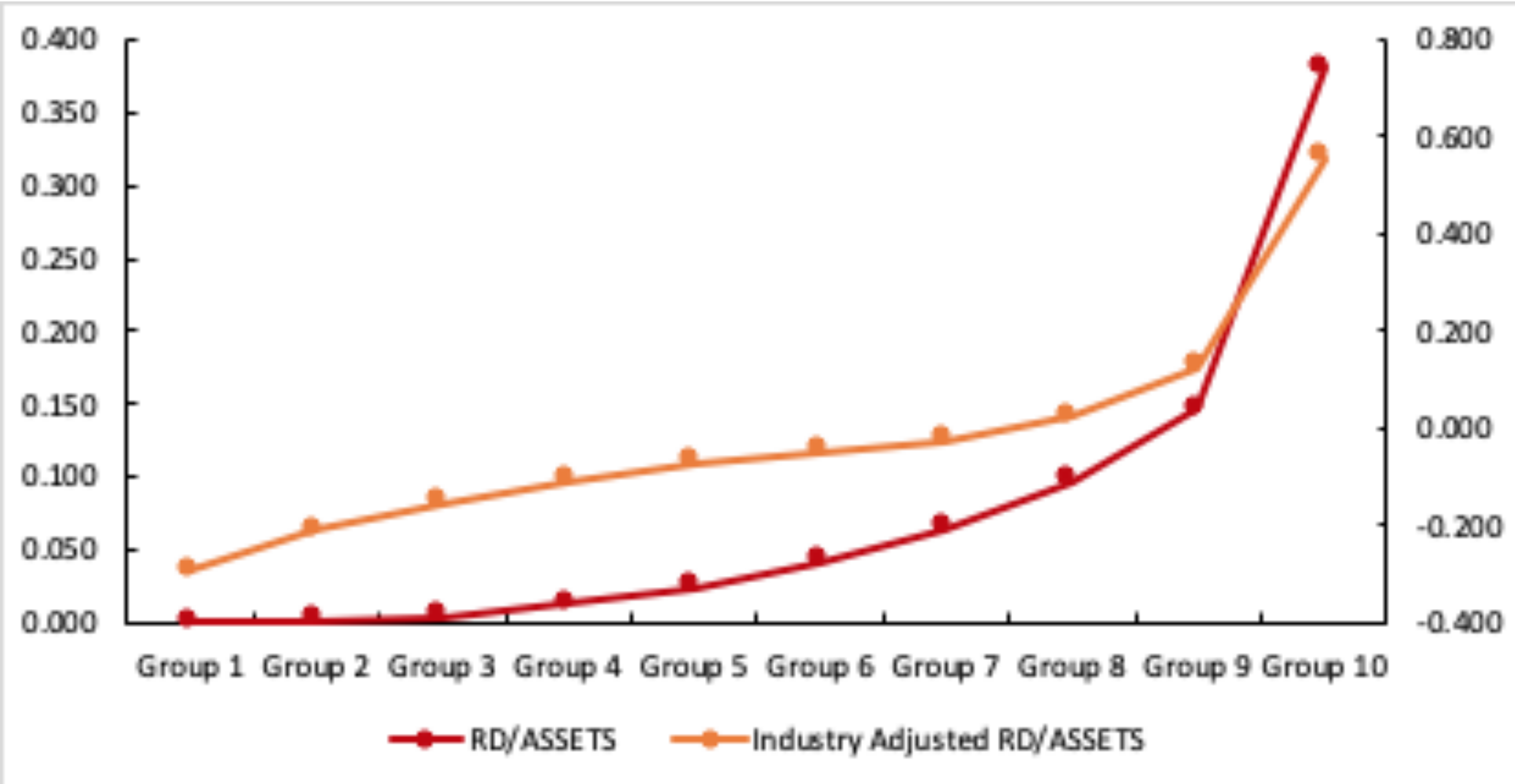

Figure 1: **R&D/Assets and industry adjusted R&D/Assets across the 10 Groups**
The sample includes all firm-year observations in CRSP except for firms with missing R&D expense data and except for firms without 12-month data. We partition the sample into 10 ordinal groups based on the level of R&D/Assets and industry adjusted R&D/Assets. Group 1 is the lowest level of the ratios and group 10 is the highest level of the ratios. The y-axis shows the average value for both R&D/Sales and R&D/ Assets across the firms in the group and over the period of the sample of 1980 to 2017.

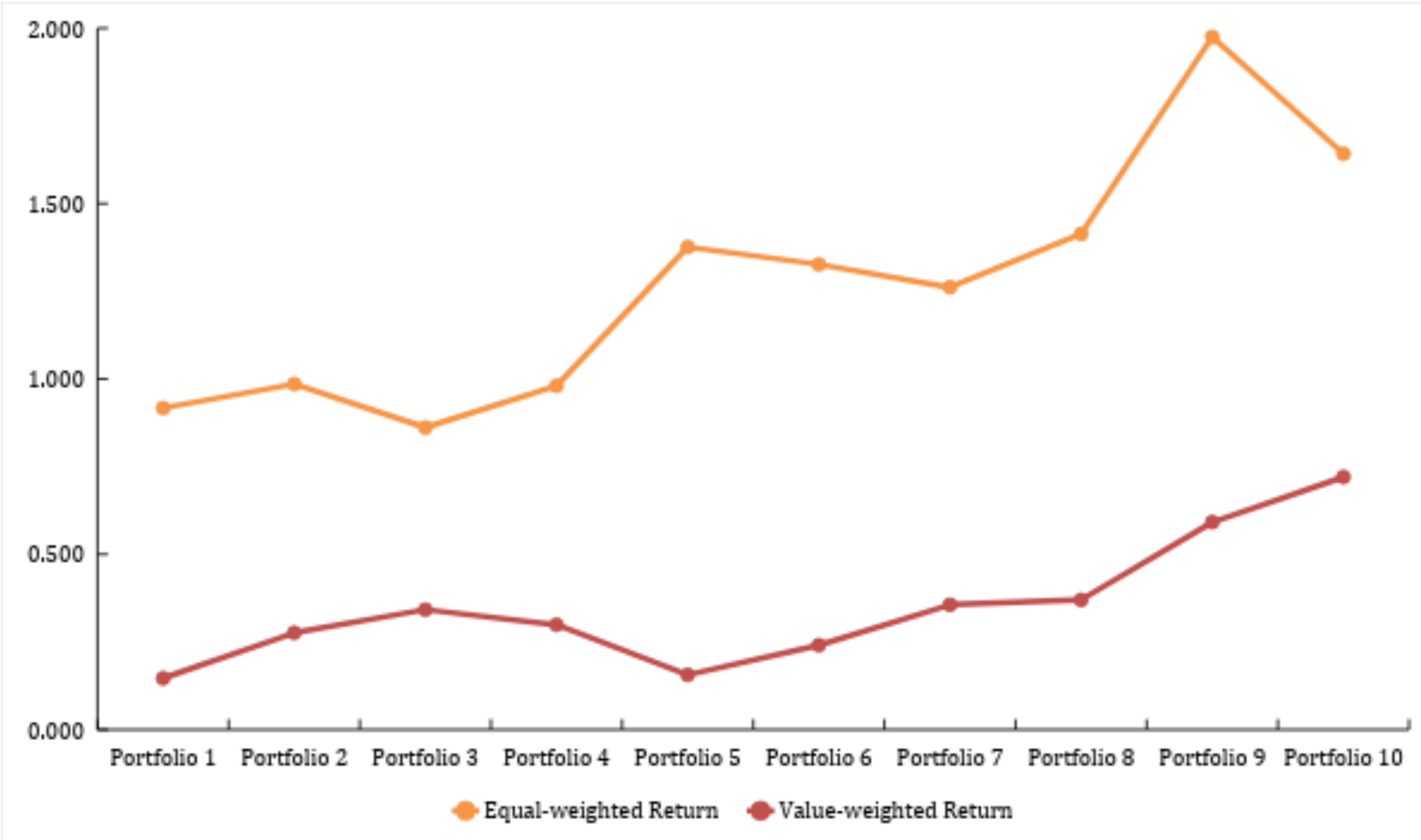

Figure 2**: Returns of equal-weighted and value-weighted portfolios**
The figure provides both value-weighted and equal-weighted calendar-time returns. Portfolios number are ordered based on the adjusted R&D/Assets at the end of each calendar year. (The rebalancing of the portfolio is at year end.) Adjusted R&D/Assets is the value of the R&D/Assets ratio minus the industry (2 digit SIC code) ratio during the year and divided by the standard deviation of the industry ratio during the year.

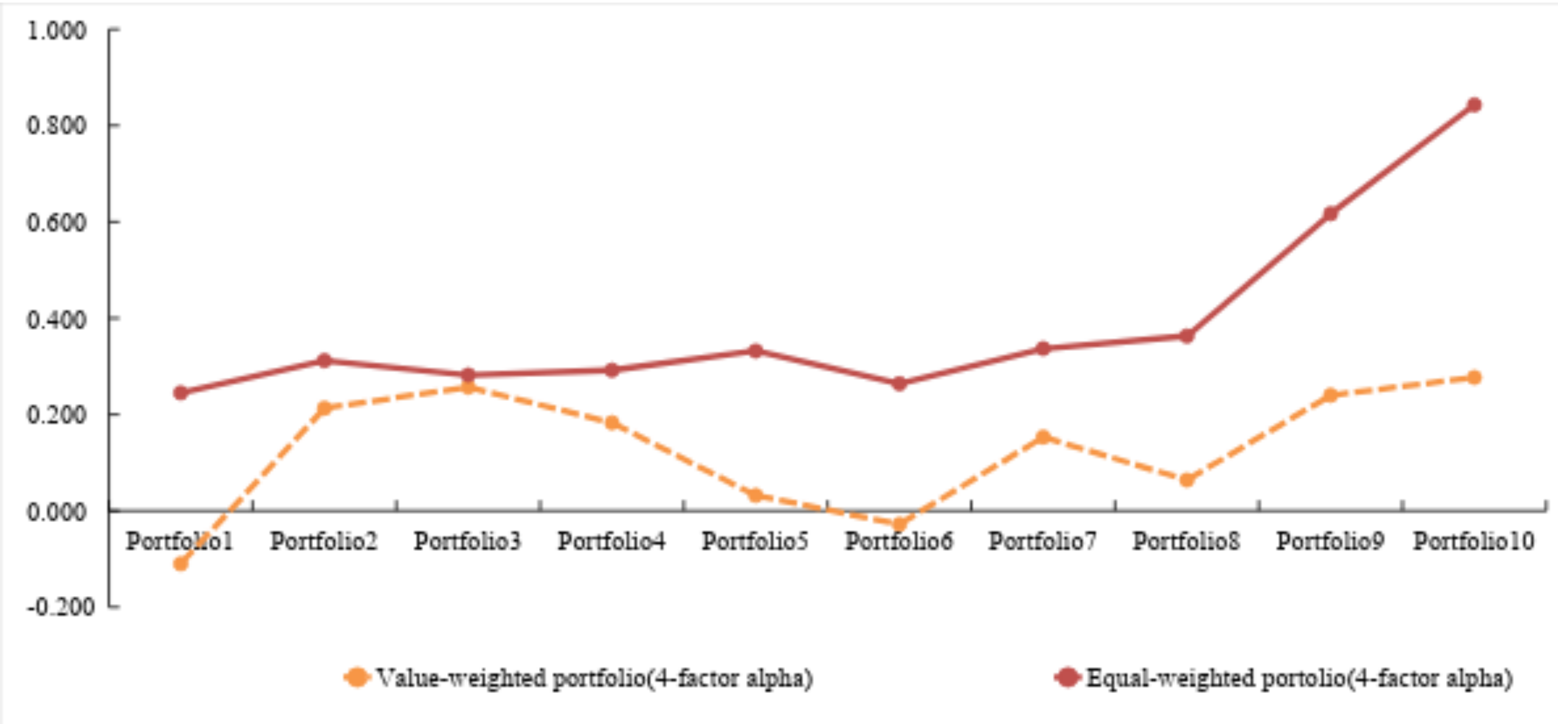

Figure 3: **Alpha of value-weighted return and equal-weighted return of the 10 portfolios**
The figure provides both value-weighted and equal-weighted calendar-time alpha of the 4-factor model. Portfolios number are ordered based on the adjusted R&D/Assets at the end of each calendar year. (The rebalancing of the portfolio is at year end.) Adjusted R&D/Assets is the value of the R&D/Assets ratio minus the industry (2 digit SIC code) ratio during the year and divided by the standard deviation of the industry ratio during the year.

Table 1: R&D expense and raw returns

The table provides monthly returns and excess returns (in percentage) for portfolios of adjusted R&D/Assets based on standard industry classification. Adjusted R&D/Assets is the value of the R&D/Assets ratio minus the industry (2 digit SIC code) ratio during the year, and divided by the standard deviation of the industry ratio during the year. The alpha is calculated for each firm-year in the year following the year in which the firm is assigned to a specific portfolio based on its adjusted R&D/Assets. Alpha is based on the four-factor model and is the intercept of a regression based on 12 monthly return observations. The sample includes all firms in CRSP except firms without values of R&D, assets or SIC code. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Results of both tables are in percentile.

Table 1: Raw return, market-adjusted return, and alpha

Portfolios	Observation	Return(%)	Return – Market(%)	Alpha(%)
1	67263	1.163	0.101	-0.091
2	66861	1.274	0.182	0.428***
3	67003	1.368	0.285	0.387
4	68430	1.182	0.143	0.277
5	69316	1.137	0.031	0.150
6	68336	1.327	0.213	0.080
7	63181	1.262	0.218	0.324
8	65498	1.414	0.294	0.379
9	66953	1.975	0.811	1.034***
10	66802	1.642	0.545	0.902

Table 2: Other variables and alpha

The table provides regression results where the dependent variable is the firm-year level alpha generated from a four factor model. Adjusted R&D is defined in Table 1. Size is market value of firm in the previous year end (in billions $). *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Results of both tables are in percentile.

	(1)	(2)	(3)
R&D	0.0071 ***	0.0069 ***	- 0.0126 ***
Size	0.0004	-0.0006	-0.0127***
Year dummy		Yes	Yes
Company dummy			Yes
Number of firms (obs)	19,371	19,371	19,371
R-squared	0.0020	0.0145	0.2310

Table 3: R&D expense and calendar-time alphas

The table provides monthly alphas for two portfolios formed based on industry adjusted R&D/ASSETS based on standard industry classification. Definition of adjusted R&D/Assets appears in Table 1. Panel A and B provide calendar-time predictive alphas for the four-factor model for portfolios based on the industry adjusted R&D; where firms are divided into two groups (above and below median ratio level at the end of the year) and ten groups, respectively. The bottom lines of each panel provide the alpha generated from a long minus short trading strategies. . *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. Results of both tables are in percentile.

Portfolio	**Panel A: Alpha based on industry adjusted R&D/Assets**	
	Value-weighted portfolio(%) (4-factor alpha)	Equal-weighted portfolio(%) (4-factor alpha)
1	0.158***	0.312***
2	0.026	0.486***
long-short strategies		
[Portfolio 2] - [Portfolio 1]	-0.132	0.174**

Panel B: Alpha based on industry adjusted R&D/Assets

Portfolio	Value-weighted portfolio(%)(4-factor alpha)	Equal-weighted portfolio(%)(4-factor alpha)
1	-0.110	0.245**
2	0.213	0.312***
3	0.257**	0.282***
4	0.183	0.292***
5	0.032	0.332***
6	-0.028	0.264**
7	0.153	0.337***
8	0.064	0.363***
9	0.240	0.617***
10	0.277	0.843***
long-short strategies:		
[Group10]-[Group1]	0.387	0.599***
[Group9&10]-[Group1&2]	0.131	0.440***

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