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Abnormal research and development investments and stock returns

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ABSTRACT

We investigate the relation between abnormal research and development (R&D) investments change and expected stock returns. We provide evidence that firms that abnormally increase their R&D investments (*RDI*) earn higher returns in comparison to the market portfolio. Specifically, our findings document an economically significant annual positive abnormal *RDI* returns that ranges from 3.2% to 11.5%. These findings are robust to well-established risk factors in the literature and suggest that the abnormal increases in RDI impacts stock returns.

1. Introduction

Many researchers (Hall, 1993; Stein, 1988) argue that investors focus excessively on short-term profits and do not value research and development (R&D) investments which create new strategic options for firms. So, firms with significant R&D investments may be undervalued. Many R&D investments are not profitable and hence the valuation of some R&D-intensive stocks is excessively high and leads to value destructive action of the managers (Jensen, 1993, 2005). Further, R&D investments generate more uncertain future benefits than investment in tangible assets (Kothari, Laguerre, and Leone (2002). Current literature documents that, due to limited investor attention, prices do not fully and immediately impound the relevant public information, specifically when such information is less noticeable (e.g., Barber & Odean, 2008; DellaVigna & Pollet, 2009; Fang & Peress, 2009; Hirshleifer, Lim, & Teoh, 2009; Hirshleifer & Teoh, 2003; Hong & Stein, 1999; Hou, Xiong, & Peng, 2009; Huberman & Regev, 2001; Klibanoff, Lamont, and Wizman,1998; Peng & Xiong, 2006; Yuan, 2015). Accordingly, we expect investors to have difficulty processing information that is less tangible and more ambiguous (such as unexpected increases in R&D investments). In other words, it is highly likely that information about the prospects of a firm developing new products, technologies or other innovations is difficult to efficiently impound into the stock pricing process. This is mainly due to the significance of such news upon strategic options and potential disruptions in the industry. Additionally, it is documented that individuals/investors pay less attention to information that is harder to process (Corwin & Coughenour, 2008; Song & Schwarz, 2010). Collectively, these discussions raise the question of whether stock market values of companies reflect the changes in large intangible assets associated with R&D expenditures. Furthermore, there is a dearth of empirical literature that investigates the relations between the changes in R&D investments and stock returns. One of the main reasons behind the limited scope of the literature is that the accounting value of R&D expenditures provides an aggregate value, and hence does not provide clear information about the content of these investments.

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Therefore, investors using traditional measures (i.e., market-to-book, earnings-to-price) could misprice these stocks. Also, poor disclosure of R&D expenditures under the current accounting standards leads to information asymmetry and gains to insiders (Aboody & Lev, 2000).

Empirical evidence in the literature on whether investors in U.S. capital markets value corporate R&D investment efficiently is mixed. The main strand of the literature that focuses on examining the market reaction to the announcement of R&D expenditures (Chan, Martin, & Kensinger, 1990; Woolridge, 1988; Zantout & Tsetsekos, 1994) using event study method document inconclusive results (i.e. both positive and negative abnormal returns). For instance, Szewczyk, Tsetsekos, and Zantout (1996) investigate the role of investment opportunities and free cash flow in explaining R&D-induced abnormal returns. They document a significant positive relation between a firm's Tobin's Q and its stock price reaction to announcements of increases in R&D expenditures in support of investment opportunities hypothesis. Another strand of the literature studies the relation between R&D expenditures and stock returns and documents inconclusive results. For instance, Chan, Lakonishok, and Sougiannis (2001) examine whether the stock prices fully reflect firms' expenditures on R&D using data over the period of 1975–1995. They specifically study the relation between R&D spending and subsequent stock price performance by comparing the firms with R&D expenditure and firms with no R&D expenditure and find that "...*firms engaged in R&D do not experience superior stock price performance, compared to firms with no R&D*". Accordingly, they argue that "...*the absence of any differences is consistent with the notion that the market price on average incorporates fully the benefits of R&D spending*". Eberhart, Maxwell, and Siddique (2004) investigate the long-term abnormal stock returns and operating performance following R&D increases and find significant positive abnormal stock returns during the five-year period following the increases and conclude that market initially undervalues R&D investment. More recently, Li (2011) reports that high R&D-intensive firms earn higher average stock returns than low R&D-intensive firms.

Given the question of whether investors value R&D-investing firms efficiently and inconclusive findings in the literature, we investigate whether a portfolio with positive abnormal R&D investment changes perform better than market portfolio over the 1975–2015 period for all domestic, primary stocks listed on the NYSE, Amex, and Nasdaq stock markets. Our sample of firm-year observations includes cases of R&D investment increases and R&D investment decreases. We adopt a modified version of measure developed by Titman, Wei, and Xie (2004) to calculate the abnormal R&D investment changes (*RDI*) and examine stock returns following these changes.

We contribute to the literature in many ways. First studies in the literature (i.e. Eberhart et al. 2004) relating to R&D and the stock returns examine only the increase in R&D intensity but do not consider an abnormal/unexpected change. Our study is different since we focus on the abnormal change in R&D investments and use the last three-year average R&D expenditures to project the firm's formation year's benchmark R&D investment, and interpret firms with positive (negative) *RDI* as positive (negative) R&D investors. We present that firms with abnormal increase in *RDI* earn higher returns than market portfolio. Our findings show abnormal and positive *RDI* returns as we find economically and statistically significant alpha values in all models. The alpha in the models ranges between 46 basis points per month to 97 basis points. These results indicate annual significantly positive abnormal *RDI* returns that range from 5.5% to 11.6%. Moreover, our results are robust to well-established risk factors in the literature. Second, we examine whether our results differ across certain groups of firms since previous literature show that there is a difference between the R&D investments and stock returns in terms of size, technological endowments (Chan et al., 1990), and investment opportunities (Szewczyk et al., 1996). Hence, we split our sample into three sub groups; (i) small and large (ii) high-tech and low-tech, and (iii) high-growth and low-growth. We find that in all three groups of stocks that increase in *RDI* earn significantly higher abnormal stock returns compared to the market portfolio. Specifically, small size, high-growth, and high tech stocks that increase *RDI* earn higher returns. However, *RDI* effect prevails regardless of the size, growth, and technological endowments of the firms. Third, our study expands and complements the literature on the relation between R&D investments and stock returns (e.g., Chambers, Jennings, & Thompson 2002; Chan et al., 1990; Chu, 2007; Li, 2011; Lin, 2012; Li, Liu & Xue, 2014). Our results also address the puzzle regarding R&D investment and physical investment. That is high R&D-intensive firms earn higher average stock returns compared to low R&D-intensive firms (e.g., Chan et al., 2001; Li, 2011), and high physical investment intensive firms earn lower average stock returns compared to low physical investment intensive firms (e.g., Titman et al., 2004; Xing, 2008) since we use the method which is employed to examine the relation between the physical investment and stock prices. Specifically, our results point out that the puzzle is a result of the failure of the previous studies to employ comparable measures.

The remainder of the paper is organized as follows. Section 2 presents the method, data, estimated models, and the construction the testing portfolios. Section 3 exhibits the empirical tests and discusses the results. Finally, Section 4 concludes.

2. Method and data

To test the relation between abnormal R&D investments and subsequent stock returns we examine the returns on portfolios formed on the basis of abnormal levels of R&D investment following the methodology employed in Titman et al. (2004). More specifically, we test whether returns on portfolios with positive abnormal R&D investment changes are significantly different than those with negative abnormal R&D investment changes.

To conduct the tests, we consider all domestic stocks listed on the New York Stock Exchange (NYSE), American Stock Exchange (AMEX), and NASDAQ over the 1975–2015 period. Following Titman et al. (2004), we exclude ADRs, closed-end funds, trusts, REITs, units of beneficial interest, and other financial institutions; we also excluded utilities since item 46

(R&D expenditures) is not available for utilities in the COMPUSTAT database. We obtain monthly data on stock returns, stock prices, and number of shares outstanding from the Center for Research in Security Prices (CRSP). We use the U.S. one-month Treasury bill rates as risk-free rates. We gather accounting data from the COMPUSTAT database and collect the Fama-French risk factors and Pastor-Stambaugh (2003) liquidity factors from Ken French's website[1] and Pastor-Stambaugh (2003) liquidity factors from Robert F. Stambaugh's website[2]. We winsorize our measures at one percent level at each tail[3] Our sample consists of firms in the intersection of CRSP and COMPUSTAT that have sufficient accounting and returns data available. We require a firm to have at least four years of data to first compute its abnormal research and development investment and then to match with the subsequent stock returns. Moreover, we exclude firms that do not meet data requirements on sales and book equity. We define a firm's market equity (*ME*) as its price multiplied by the number of shares outstanding, and its market size (*Size*) is measured as the *ME* at the end of June of year t. The book-to-market equity ratio (*BM*) is computed as the ratio of the book equity (*BE*) of a firm for the fiscal year ending in calendar year $t-1$ to the firm's ME at the end of December of $t-1$. Following Fama and French (1993), we define book equity as the COMPUSTAT book value of stockholders' equity, plus balance sheet deferred taxes and investment tax credits, minus the book value of the preferred stock. Finally, we exclude firms with missing stock returns in the testing period and hence our final sample size is 51,122 firm-year observations for 4561 firms.

In the results reported in this paper, we calculate the measure of abnormal R&D investment (RDI_{t-1}) for the formation year t as follows:

$$RDI_{t-1} = \frac{RDE_{t-1}}{(RDE_{t-2} + RDE_{t-3} + RDE_{t-4})/3} - 1 \tag{1}$$

where RDE_{t-1} is a firm's R&D expenditures (COMPUSTAT item #46) scaled by its total assets in year $t-1$. We use the prior three-year average R&D expenditures to project the firm's formation year's benchmark R&D investment, and interpret firms with positive (negative) *RDI* as positive (negative) R&D investors.[4] The formation year t is the year when the year $t-1$ *RDI* is measured and the *RDI* portfolios are formed (i.e., the returns from July of year t to June of year $t+1$ are matched against RDI_{t-1}). Using total assets as the denominator, we assume that the benchmark level of R&D expenditures will grow in proportion with assets. By this definition, a *RDI* value equal to (greater than, less than) zero indicates that the formation year's R&D investment is the same as (greater than, less than) the prior three years' average. This definition of *RDI* can be considered as a measure of abnormal R&D investment.

To test the abnormal returns, we use four models. In the first model we regress the abnormal stock returns using the market model. Second, we use the Fama-French three-factor model as shown in Eq. (2):

$$R_{p,t} - R_{ft} = \alpha_p + (R_{mt-}R_{ft}) + sSMB_t + hHML_t + \varepsilon_{p,t} \tag{2}$$

where $R_{p,t}$ is the average raw returns generated from a long position in an equally-weighted portfolio of stocks with positive RDI and a short position in the market portfolio in calendar month t, R_{ft} is the one-month T-bill return, R_{mt} is the CRSP value-weighted market index return, SMB_t is the return on a portfolio of small stocks minus the return on a portfolio of large stocks, HML_t is the return on a portfolio of stocks with high book-to-market ratios minus the return on a portfolio of stocks with low book-to-market ratios.

Third, we also estimate the abnormal stock returns with a momentum factor (i.e., *UMD*; return on high momentum stocks minus the return on low momentum stocks) included as an additional risk factor. Then the Fama-French three factor model becomes what is known as Carhart four-factor model:

$$R_{p,t} - R_{ft} = \alpha_p + (R_{mt-}R_{ft}) + sSMB_t + hHML_t + mUMD_t + \varepsilon_{p,t} \tag{3}$$

Lastly, we estimate the abnormal stock returns with a five-factor model that includes the Pastor-Stambaugh (2003) liquidity factor which is included as an additional risk factor controls for stocks' exposure to the market-wide liquidity risk. Accordingly, our equation (4) becomes;

$$R_{p,t} - R_{ft} = \alpha_p + (R_{mt-}R_{ft}) + sSMB_t + hHML_t + mUMD_t + lPS_{LIQ} + \varepsilon_{p,t} \tag{4}$$

In all abovementioned models the estimated intercepts (i.e. alphas) captures the risk-adjusted returns (i.e. abnormal returns) on our *RDI*-ranked portfolios.

Table 1 reports the distribution of 51,122 firm-year observations for 4561 firms in our sample by calendar year, *RDI*, and industry classifications. The table provides several insights. In Panel A, we see that firm-year observations evenly distributed among the positive *RDI* (24,092) and negative *RDI* (27,030). We also observe that, the number of firm-year observations for positive (negative) *RDI* sample during a given year ranges from 302 (271) to 915 (1066). We see an increasing number of observations over the sample period for both positive and negative RDI samples. The mean value for positive (negative) *RDI* for sample during a given year ranges from 43% (minus 40%) to 181% (minus 32%) and does not seem to show any

1 http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

2 http://finance.wharton.upenn.edu/~stambaugh/liq_data_1962_2016.txt

3 Also, we winsorize our measures at half of a percent level at each tail and find qualitatively similar results. These results are available upon request.

4 Only firms with more than a 5% abnormal increase are considered as abnormal positive RDI investors, and only firms with an abnormal decrease exceeding −5% are considered as abnormal negative RDI. We also run our models at 1% (−1%) and (10%) levels and find qualitatively similar results. These results are available upon request.

Table 1
RDI by calendar year and industry.

Panel A. Distribution by calendar year and RDI of firm-year observations

Year	No. of Obs.		Percent		Positive RDI		Negative RDI	
	Positive RDI	Negative RDI	Positive RDI	Negative RDI	Mean	Median	Mean	Median
1975	398	430	48	52	1.81	0.43	−0.38	−0.22
1976	304	390	44	56	1.70	0.30	−0.40	−0.25
1977	328	423	44	56	0.73	0.28	−0.39	−0.25
1978	330	384	46	54	0.46	0.22	−0.39	−0.24
1979	323	351	48	52	0.45	0.20	−0.37	−0.23
1980	310	333	48	52	0.43	0.18	−0.35	−0.20
1981	302	273	53	47	0.45	0.20	−0.36	−0.21
1982	361	271	57	43	0.46	0.22	−0.39	−0.23
1983	469	314	60	40	0.44	0.24	−0.39	−0.24
1984	516	386	57	43	0.51	0.26	−0.38	−0.25
1985	510	406	56	44	0.50	0.24	−0.36	−0.24
1986	511	442	54	46	0.55	0.25	−0.34	−0.24
1987	481	484	50	50	0.49	0.24	−0.36	−0.26
1988	428	489	47	53	0.48	0.23	−0.36	−0.26
1989	433	525	45	55	0.47	0.24	−0.35	−0.25
1990	483	503	49	51	0.51	0.25	−0.35	−0.25
1991	512	523	49	51	0.63	0.25	−0.33	−0.22
1992	525	510	51	49	0.52	0.25	−0.33	−0.22
1993	564	517	52	48	0.79	0.24	−0.33	−0.23
1994	588	577	50	50	0.59	0.27	−0.33	−0.24
1995	573	639	47	53	0.72	0.30	−0.32	−0.24
1996	549	725	43	57	0.75	0.31	−0.33	−0.25
1997	581	780	43	57	0.66	0.30	−0.36	−0.27
1998	651	813	44	56	0.66	0.33	−0.36	−0.28
1999	752	897	46	54	0.76	0.37	−0.36	−0.29
2000	743	940	44	56	0.80	0.36	−0.38	−0.30
2001	617	969	39	61	0.94	0.34	−0.40	−0.32
2002	720	1066	40	60	0.88	0.32	−0.39	−0.33
2003	838	994	46	54	0.65	0.33	−0.36	−0.29
2004	826	966	46	54	0.61	0.33	−0.34	−0.27
2005	680	1017	40	60	0.58	0.29	−0.34	−0.27
2006	693	997	41	59	0.54	0.27	−0.34	−0.27
2007	748	892	46	54	0.59	0.26	−0.33	−0.27
2008	775	820	49	51	0.66	0.28	−0.32	−0.27
2009	906	797	53	47	0.73	0.33	−0.33	−0.25
2010	915	807	53	47	0.65	0.33	−0.32	−0.25
2011	741	916	45	55	0.57	0.27	−0.33	−0.25
2012	726	903	45	55	0.51	0.24	−0.34	−0.26
2013	809	835	49	51	0.71	0.25	−0.33	−0.24
2014	784	811	49	51	0.68	0.26	−0.32	−0.23
2015	789	915	46	54	0.53	0.26	−0.33	−0.25
Total	24,092	27,030						

Panel B. Industry distribution of sample firms

Industry	SIC	No. of Obs.		Percent		Positive RDI		Negative RDI	
		Positive RDI	Negative RDI	Positive RDI	Negative RDI	Mean	Median	Mean	Median
Agriculture	<1000	8	10	44	56	0.30	0.14	−0.39	−0.33
Mining	1000–1499	29	55	35	65	0.48	0.25	−0.47	−0.40
Construction	1500–1999	7	9	44	56	2.80	0.20	−0.39	−0.20
Manufacturing	2000–3999	1,831	1,423	56	44	0.47	0.17	−0.27	−0.16
Transportation	4000–4899	48	67	42	58	0.84	0.39	−0.53	−0.50
Wholesale trade	5000–5199	24	42	36	64	1.30	0.65	−0.52	−0.38
Retail trade	5200–5999	16	26	38	62	0.57	0.29	−0.56	−0.68
Services	7000–8999	461	500	48	52	0.55	0.25	−0.33	−0.24
Public Admin.	9100–9999	3	2	60	40	0.85	0.58	−0.04	−0.04

This table presents the number of observations and average R&D investments (RDI) by year (Panel A) and by industry (Panel B). There are a total of 51,122 firm-year observations for 4561 firms.

apparent time trend. Moreover, for both samples the median *RDI* has a relatively smaller range of distribution. In Panel B, we report four-digit industry distribution of our sample. Not surprisingly, Manufacturing (SIC code 2000–3999) and Services (SIC code 7000–8999) are the two largest industries represented in our sample. We observe firms that operate in Manufacturing constitute around 71% of the sample and have mean positive RDI of 47% and negative RDI of minus 27%.

Table 2 presents the descriptive statistics of the pooled mean and median for the full sample, as well as positive RDI, and negative RDI samples. On average (median), our sample firms have sales of $2.77 billion ($151 million) a year. The average

Table 2
Summary statistics.

Characteristic	Full Sample		Positive RDI		Negative RDI	
	Mean	Median	Mean	Median	Mean	Median
Sales (10^6)	2,774	151	2,564	150	2,819	137
Total Assets (10^6)	3,454	165	3,108	152	3,626	163
Size (10^6)	4,102	230	3,677	207	4,235	241
Book-to-Market	0.599	0.494	0.647	0.519	0.561	0.461
R&D expenses (10^6)	95.99	8	101	9.917	88.80	6.434
R&D/Sales (%)	3.808	0.043	5.110	0.053	2.746	0.037
R&D/Size (%)	10.93	3.303	16.377	4.459	5.323	2.542
Δ R&D in dollars (%)	22.73	−1.444	56.90	10.86	1.002	−2.756
ΔRDI (%)	−37.25	0	−61.64	−27.19	−22.40	0
Sales growth (%)	40.81	3.435	24.68	4.330	50.69	2.671
Assets growth (%)	40.146	1.470	9.590	0	58.75	3.092

This table provides pooled mean and median statistics for the sample of 51,121 abnormal RDI by 4,561 firms. At the end of June of year t we sort firms into two groups (positive and negative) based on the RDI in year t – 1. The portfolios are formed every year from 1975 to 2015. Size calculated as price per share times the number of shares outstanding (item 25) at the end of June of year t. Total Sales is item 12 (the annual sales for the sample firm); Total Assets, Compustat item 6; R&D investments (RDI) equals item R&D expenditures (item 46) scaled by Total Assets (item6). Book-to-market (BM) is the ratio of book equity of fiscal year ending in year t – 1 to market equity at the end (December) of year t – 1. Book equity is Compustat book value per share (BKVLPS) times common shares outstanding (CSHO) plus deferred taxes (TXDB) minus preferred stock (PSTK). In 2015 dollars except ΔRDI.

(median) sales of positive RDI firms are $2.56 billion ($150 million) and very similar to the $2.82 billion ($137 million) of negative RDI firms. The average (median) levels of book value of assets and market capitalizations for the full sample are $3.45 billion ($165 million) and $4.10 billion ($230 million) respectively. Again we observe similar figures for positive and negative RDI samples. From Table 2 we also observe that, the average of R&D intensity (R&D expense over sales) is 3.80% for the full sample. The average R&D intensity for positive RDI stocks is 5.11% and is higher than the 2.75% of negative RDI firms.

3. RDI and stock returns

In this section, we examine the relation between *RDI* changes and stock returns. We first analyze raw returns in univariate analysis, and afterwards study abnormal returns to account for various risk factors using the models discussed above.

3.1. Univariate analysis

Table 3 reports average returns of stocks double-sorted by firm characteristics and *RDI*. We bifurcate stocks various firm characteristics, such as size and book-to-market. Next, we sort characteristic-based samples into two *RDI* portfolios: negative and positive. We tabulate the return of each portfolio during the following month. The first row of Table 3 shows that, unconditionally, the average monthly returns for stocks with positive and negative *RDI* are 2.27% and 1.63%, respectively. The difference between the two *RDI* groups is a statistically and economically significant 0.64% per month (or 7.6% per year). As a consequence, sorting stocks on RDI solely generates a significant return differential and points to abnormal returns related with positive *RDI* stocks.

We double-sort RDI samples in Panels A through Panel E to separately control for firm characteristics (size, book-to-market, returns, price, high-tech vs. low-tech). We find that, in all samples positive RDI firms provide higher returns than negative RDI firms. In Panel A, we control for size and see that the difference between the two *RDI* groups is a statistically insignificant 0.11% per month (or 1.32% per year) in the lower half and statistically significant 0.01% per month or (0.12% per year) in the higher half. We also examine the difference with this panel and find that the lower half of our stocks have higher monthly average returns than the higher half of the sample for negative RDI sample. This result indicates that RDI and stock returns relation is concentrated among relatively small stocks for the negative RDI sample. In Panel B, we control for book-to-market and find similar results to Panel A. However, we do observe statistically insignificant differences between the lower and upper halves. So, we conclude that there is no concentration of returns based on book-to-market. In Panel C, we control for returns and find no difference between the positive RDI and negative RDI in the lower half. However, we find that in the upper half positive RDI has statistically significant higher stock returns. Again, we see statistically significant differences between the lower and upper halves. This result indicates that RDI and stock returns relation is concentrated among relatively high return stocks. In Panel D, we control for stock price and find significant differences between positive RDI and negative RDI in only the lower half. We also find significant differences between the lower and upper halves. This result shows that RDI and stock returns relation is concentrated among relatively high priced stocks. Finally, in Panel E, we focus on the technology intensity of the *RDI* firms since it is documented that the market reacts differently to the changes in the R&D expenses of high-technology firms in comparison to low-tech firms. For instance, Chan et al. (1990) show that the

Table 3
RDI and Raw Stock Returns: Univariate Comparison.

		Average Monthly Return by RDI		
		Negative	Positive	t-test (Negative-Positive)
All Stocks		0.0163***	0.0227***	−1.79*
Panel A: by Size				
	Low	0.017***	0.028***	−1.57
	High	0.016***	0.017***	−1.89*
Low-High	t	1.69*	1.59	
Panel B: by Book-to-Market				
	Low	0.017***	0.027***	1.48
	High	0.017***	0.020***	−2.71***
Low-High	t	−1.04	−0.69	
Panel C: by Returns				
	Low	−0.094***	−0.093***	−0.52
	High	0.132***	0.141***	−1.77*
Low-High	t	−223.90***	−46.84***	
Panel D: by Price				
	Low	−0.001	0.007***	−5.58***
	High	0.034***	0.045***	−1.33
Low-High	t	−27.19***	−4.40***	
Panel E: by Technology				
	Low	0.016***	0.025***	−1.59
	High	0.017***	0.019***	−1.50
Low-High	t	−1.06	0.99	

This table provides average monthly stock returns for the sample of 24,092 positive RDI and 27,030 negative RDI by 4,561 firms from 1975 to 2015. Each year, we divide our sample of firms into two RDI portfolios: negative and positive. We also compute the return difference for subsamples of firms sorted by size, book-to-market ratio, current and past month returns, price, and technology intensity. We also report the differences in means (t- test). *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 4
Long positive RDI stocks, short market portfolio.

Alpha	(1) MM	(2) FF 3-Factor	(3) Carhart 4-Factor	(4) PS Liquidity
Value Weighted	0.0074***	0.0059***	0.0073***	0.0068***
Market Portfolio	(3.38)	(3.49)	(4.39)	(3.59)
Equal Weighted	0.0049***	0.0052***	0.0052***	0.0046***
Market Portfolio	(2.98)	(3.33)	(3.29)	(2.67)
S&P Portfolio	0.0097***	0.0079***	0.0093***	0.0089***
	(4.06)	(4.73)	(5.57)	(4.68)

This table examines the profitability of a trading strategy that longs stocks with positive RDI and shorts market portfolios. Each year, stocks are sorted according to the sign of the RDI value. Both the long and short positions are equally weighted, and held for 1 year after portfolio formation and rebalanced yearly. The resulting time-series returns on the long–short portfolio are regressed on risk factors from MM (Market Model), Fama and French 3 factor model (1993), Carhart (1997) four factor model and PS Liquidity models. We report the alpha values for from all models. p-values are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

market reacts positively to increases in R&D expenditures of high-tech firms while shows a negative reaction to low-tech firms.[5] We find significant difference between the positive RDI and negative RDI in only the lower half and do not find any significant differences between the lower and upper halves. Overall, these results indicate that RDI and stock returns relation is concentrated among relatively small stocks (Panel A) and high past Return (Panel C) and high stock Price (Panel D). So we conclude that our findings support the unconditional results.

3.2. Long RDI and short market portfolios

Table 4 presents the results of profitability of an arbitrage strategy where we long stocks with positive RDI and shorts market portfolios. Each year we compute the return in the following year on a zero-investment portfolio that longs the stocks with positive RDI and shorts the stocks in the market portfolio. We use the following portfolios as a proxy for the market portfolio; (i) value-weighted market portfolio, (ii) equally-weighted market portfolio, (iii) S&P 500. We collect the market

[5] We use the high-tech low-tech classification based on SIC codes and PERMNOs in Loughran and Ritter (2004).

returns from CRSP. We repeat this process every year and hence obtain a time series of returns for our zero-investment portfolio. Then, we regress the time-series returns on factors known to affect the returns using the models explained in Section 2. If the return difference between positive RDI and market portfolio is fully explained by the risk factors in these models, then the estimated alpha should be insignificantly different from zero.

We report the results of our risk factor models in Table 4. The table shows that there is positive abnormal *RDI* returns as we find significant intercept (alpha) values in all four models. The alpha in the models range between 46 basis points per month to 97 basis points. These results indicate an annual significant positive abnormal RDI returns of that ranges between 5.5% and 11.6%. Our results show that, even after accounting for risk factors, we still find significantly positive abnormal stock returns for positive *RDI* stocks.

Table 5
Long positive RDI stocks, short market portfolio-subsamples.***

		(1) MM	(2) FF 3-Factor	(3) Carhart 4-Factor	(4) PS Liquidity
Alpha Panel A: Size					
Large					
	Value Weighted	0.0042**	0.0035***	0.0044***	0.0031**
	Market Portfolio	(2.58)	(2.75)	(3.51)	(2.22)
	Equal Weighted	0.0016	0.0028**	0.0023	0.0009
	Market Portfolio	(1.13)	(1.98)	(1.60)	(0.56)
	S&P Portfolio	0.0065***	0.0055***	0.0064***	0.0052***
		(3.55)	(4.42)	(5.09)	(3.67)
Small					
	Value Weighted	0.0103***	0.0079***	0.0098***	0.0099***
	Market Portfolio	(3.14)	(2.85)	(3.51)	(3.02)
	Equal Weighted	0.0077***	0.0073***	0.0077***	0.0077**
	Market Portfolio	(2.90)	(2.82)	(2.94)	(2.56)
	S&P Portfolio	0.0123***	0.0100***	0.0118***	0.0120***
		(3.66)	(3.59)	(4.21)	(3.66)
Alpha Panel B: Technology					
High-tech					
	Value Weighted	0.0066**	0.0055***	0.0067***	0.0058***
	Market Portfolio	(2.49)	(2.73)	(3.25)	(2.64)
	Equal Weighted	0.004**	0.0049***	0.0046**	0.0036*
	Market Portfolio	(1.97)	(2.60)	(2.38)	(1.82)
	S&P Portfolio	0.0089***	0.0076***	0.0087***	0.0079***
		(3.12)	(3.73)	(4.19)	(3.59)
Low-tech					
	Value Weighted	0.0085***	0.0065***	0.008***	0.0075***
	Market Portfolio	(3.54)	(3.13)	(3.86)	(3.09)
	Equal Weighted	0.0059***	0.0058***	0.0059***	0.0053**
	Market Portfolio	(2.96)	(2.91)	(2.91)	(2.27)
	S&P Portfolio	0.0107***	0.0085***	0.0100***	0.0096***
		(4.23)	(4.14)	(4.83)	(3.95)
Alpha Panel C: Growth					
High					
	Value Weighted	0.0061**	0.0052***	0.0064***	0.0061***
	Market Portfolio	(2.51)	(2.60)	(3.16)	(2.69)
	Equal Weighted	0.0036*	0.0046**	0.0043**	0.0039*
	Market Portfolio	(1.75)	(2.32)	(2.15)	(1.79)
	S&P Portfolio	0.0084***	0.0073***	0.0084***	0.0082***
		(3.21)	(3.63)	(4.14)	(3.60)
Low					
	Value Weighted	0.0104***	0.0077***	0.0106***	0.0107***
	Market Portfolio	(3.31)	(2.61)	(3.60)	(2.89)
	Equal Weighted	0.0076***	0.0070**	0.0084***	0.0085**
	Market Portfolio	(2.81)	(2.53)	(3.00)	(2.39)
	S&P Portfolio	0.0126***	0.0097***	0.0125***	0.0128***
		(3.91)	(3.31)	(4.28)	(3.46)

This table examines the profitability of a trading strategy that longs stocks with positive RDI and shorts market portfolios. This table in subsamples of firms bifurcated by various firm characteristics. Panel A reports alphas for size in which firms are designated as small and large on their size measures explained in Table 2. Panel B reports the alphas for the technological intensity in which firms are designated into high and low-tech with their four-digit SIC codes as in Loughran and Ritter (2004). Panel C reports the alphas for growth in which firms are designated as high to low-growth based on Book-to-Market ratios (BM < 1 is defined as high growth) similar to Eberhart et al. (2004). Each year, stocks are sorted according to the sign of the RDI value. Both the long and short positions are equally weighted, and held for 1 year after portfolio formation and rebalanced yearly. The resulting time-series returns on the long–short portfolio are regressed on risk factors from MM (Market Model), Fama and French 3 factor model (1993), Carhart (1997) four factor model and PS Liquidity models. p-values are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

These results support the widely documented findings that investors pay less attention to information that is harder to process (e.g. Song & Schwarz, 2010). Moreover, our results contradict the findings of Chan et al. (2001) that the market price fully incorporates the benefits of R&D spending and supports the findings of Eberhart et al. (2004) that market undervalues increase in R&D investment.

Table 5 examines the positive *RDI* effect in subsamples sorted by size, technology, and growth. In this analysis, within each half, we control the relevant characteristic in two ways: by sorting and by regression to find the subsets of stocks in which the RDI effect is the strongest. Panel A reports the alpha values for the size subsample (i.e. market capitalization) and shows the *RDI* effect existing among both small stocks and in large stocks. This suggests that the *RDI* effect is not driven by size. Panel B reports the alphas for the technology subsample in which firms are designated as high-tech to low-tech based on four-digit SIC codes as in Loughran and Ritter (2004). Our findings for alphas show that a positive *RDI* effect again exists. Alphas are statistically significant for both sub-samples. Hence we can argue that positive *RDI* effect is not driven by the technological endowments of the firms.

Panel C reports the alphas for growth subsample in which firms are designated as high to low-growth based on book-to-market ratios (BM < 1 is defined as high growth). The results for alphas show that positive *RDI* effect is also existent among both low-growth stocks and high growth stocks. Again, both alpha values are statistically and economically significant for both sub-samples. Hence, we conclude that *RDI* effect is not driven by the growth of the firms even though firm growth affects its scale. Collectively, our results contradict the results of the previous literature (Chan et al., 1990; Szewczyk et al., 1996) that there is a difference between the R&D investments and stock returns in terms of size, technological endowments, and investment opportunities. We find that the *RDI* effect prevails regardless of the size, investment opportunities, and technological endowments of the firms.

3.3. Alternative measures of RDI

We conduct a variety of robustness checks regarding the RDI measure. Accordingly, we use alternative measures of RDE where we replace the denominator total assets with the following measure; capital expenditures, sales, number of employees, and market value of equity following (Li, 2011). We also replace the numerator by substituting R&D Expenditures with R&D Capital following Chan et al. (2001) and compute R&D capital as the five-year cumulative R&D expenditures, assuming an annual depreciation rate of 20%.

Table 6 presents the univariate findings with these alternative values for both the positive and negative RDI samples and compare their means with a *t*-test. We see the positive RDI firms have significantly higher average monthly returns when R&D Expenditures is scaled by Capital Expenditures and Market Equity, and when R&D Capital substitutes R&D Expenditures. On the other hand, when scaled by Sales and Number of Employees there is no statistical difference between the positive and negative *RDI* firms. Overall, we conclude that *RDI* effect is sensitive to the calculation of the measure.

Table 7 presents the results of profitability of an arbitrage strategy where we long stocks with positive *RDI* and shorts market portfolios with alternative measures of *RDI.* We use the same process we used in Table 4 to estimate the profitability of an arbitrage strategy where we long stocks with positive *RDI* and shorts market portfolios with alternative measures of *RDI.* The table shows that there is a positive RDI abnormal returns as we find significant intercept (alpha) values in all five panels for all the models. The alpha in the models ranges between 27 basis points per month to 96 basis points. These results indicate an annual significant positive RDI abnormal returns that ranges from 3.2% to 11.5%. These results show that, even

Table 6
RDI and raw stock returns: univariate comparison.

R&D Scaled by	Average Monthly Return by RDI		
	Negative	Positive	t-test (Negative-Positive)
Capital Expenditures	0.0165***	0.0222***	−1.76*
Sales	0.0215***	0.0173***	1.25
Number of Employees	0.0185***	0.0198***	−0.43
Market Equity	0.0145***	0.0245***	−2.77***
R&D Capital	0.0144***	0.0230***	−2.73***

This table provides average monthly stock returns for the sample of 24,092 positive RDI and 27,030 negative RDI by 4,561 firms from 1975 to 2015. Each year, we divide our sample of firms into two RDI portfolios: negative and positive. Average return numbers are in percentages. We also report the differences in means (*t*- test). *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. The variables in this table represent alternative measures of RDI. Each alternative measure is calculated with R&D Expenditures divided by one of the following variables: Capital Expenditures, Sales, Number of Employees, or Market Equity. R&D Capital/Total Assets. R&D Capital as per Chan, Lakonishok, and Sougiannis (2001). We compute R&D capital as the five-year cumulative R&D expenditures, assuming an annual depreciation rate of 20%. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 7
Long positive RDI stocks, short market portfolios with alternative RDI calculations.

Alpha	(1) MM	(2) FF 3-Factor	(3) Carhart 4-Factor	(4) PS Liquidity
Panel A. Scaled by Capital Expenditures				
Value Weighted	0.0067***	0.0050***	0.0068***	0.0067***
Market Portfolio	(3.23)	(3.07)	(4.21)	(3.51)
Equal Weighted	0.0041***	0.0044***	0.0047***	0.0045**
Market Portfolio	(2.68)	(2.90)	(3.06)	(2.55)
S&P Portfolio	0.0090***	0.0071***	0.0088***	0.0088***
	(3.99)	(4.35)	(5.44)	(4.62)
Panel B. Scaled by Sales				
Value Weighted	0.0053***	0.0038***	0.0054***	0.0053***
Market Portfolio	(3.07)	(3.30)	(4.81)	(4.16)
Equal Weighted	0.0027**	0.0032***	0.0033***	0.0031***
Market Portfolio	(2.46)	(3.03)	(3.07)	(2.64)
S&P Portfolio	0.0075***	0.0059***	0.0074***	0.0074***
	(3.90)	(5.09)	(6.54)	(5.72)
Panel C. Scaled by Number of Employees				
Value Weighted	0.0062***	0.0049***	0.0064***	0.0062***
Market Portfolio	(3.29)	(3.50)	(4.56)	(4.00)
Equal Weighted	0.0037***	0.0043***	0.0043***	0.0040***
Market Portfolio	(2.60)	(3.11)	(3.04)	(2.66)
S&P Portfolio	0.0085***	0.0070***	0.0083***	0.0083***
	(4.06)	(4.96)	(5.95)	(5.32)
Panel D. Scaled by Market Equity				
Value Weighted	0.0067***	0.0047***	0.0062***	0.0059***
Market Portfolio	(3.23)	(3.00)	(4.02)	(3.31)
Equal Weighted	0.0041***	0.0040***	0.0041***	0.0037**
Market Portfolio	(2.75)	(2.77)	(2.77)	(2.24)
S&P Portfolio	0.0090***	0.0067***	0.0082***	0.0080***
	(3.97)	(4.35)	(5.32)	(4.48)
Panel E. R&D Capital				
Value Weighted	0.0074***	0.0059***	0.0075***	0.0067***
Market Portfolio	(3.51)	(3.81)	(4.97)	(3.66)
Equal Weighted	0.0048***	0.0052***	0.0054***	0.0045***
Market Portfolio	(3.22)	(3.70)	(3.79)	(2.69)
S&P Portfolio	0.0096***	0.0079***	0.0095***	0.0088***
	(4.18)	(5.15)	(6.25)	(4.78)

This table examines the profitability of a trading strategy that longs stocks with positive RDI and shorts market portfolios. In Panel A R&D expenditure scaled by capital expenditure. In Panel B R&D expenditure scaled by sales. In Panel C R&D expenditure scaled by number of employees. In Panel D. R&D expenditure scaled by year-end market equity. In Panel E. R&D capital is the weighted sum of a firm's R&D expenditure over the past five years, assuming annual amortization rate of 20%. Both the long and short positions are equally weighted, and held for 1 year after portfolio formation and rebalanced yearly. The resulting time-series returns on the long–short portfolios are regressed on risk factors from MM (Market Model), Fama and French 3 factor model (1993), Carhart (1997) four factor model and PS Liquidity models. We report the alpha values for from all models. p-values are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 8
Fama-Macbeth regressions – Long positive RDI stocks, short market portfolio.

	(1) MM	(2) FF 3-Factor	(3) Carhart 4-Factor	(4) PS Liquidity
Value Weighted	0.0071**	0.0057**	0.0055**	0.0035
Market Portfolio	(2.56)	(2.32)	(2.24)	(1.37)
Equal Weighted	0.0046**	0.0053***	0.0051**	0.0033
Market Portfolio	(2.38)	(2.65)	(2.32)	(1.45)
S&P Portfolio	0.0095***	0.0077***	0.0076***	0.0059**
	(3.22)	(3.26)	(3.21)	(2.30)

This table examines the profitability of a trading strategy that longs stocks with positive RDI and shorts market portfolios with Fama-Macbeth regressions when monthly returns are regressed on the risk factors. Each year, stocks are sorted according to the sign of the RDI value. Both the long and short positions are equally weighted, and held for 1 year after portfolio formation and rebalanced yearly. The resulting time-series returns on the long–short portfolios are regressed on risk factors from MM (Market Model), Fama and French 3 factor model (1993), Carhart (1997) four factor model and PS Liquidity models. Newey and West (1987) correction is applied to account for possible autocorrelation in the estimates. p-values are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. + Heteroscedasticity Consistent.

after accounting for risk factors and scaling with alternative measures, we still find significantly positive abnormal stock returns for positive *RDI* stocks.

3.4. Fama–MacBeth regressions

As a robustness check for the above empirical results now we perform Fama and MacBeth (1973) regressions. In these regressions, we regress the excess average returns against the loadings of stocks/portfolio returns on the zero-investment

Table 9
Fama-Macbeth regressions – long positive RDI stocks, short market portfolio-subsamples.

		MM	FF 3-Factor	Carhart 4-Factor	PS Liquidity^{+}
Panel A: Size					
Large					
	Value Weighted	0.0045**	0.0044**	0.0039**	0.0021
	Market Portfolio	(2.29)	(2.59)	(2.10)	(1.11)
	Equal Weighted	0.0020	0.0041**	0.0035*	0.0018
	Market Portfolio	(1.06)	(2.37)	(1.83)	(0.92)
	S&P Portfolio	0.0068***	0.0064***	0.0059***	0.0045**
		(3.29)	(3.98)	(3.34)	(2.43)
Small					
	Value Weighted	0.0095**	0.0066*	0.0069*	0.0045
	Market Portfolio	(2.37)	(1.77)	(1.82)	(1.06)
	Equal Weighted	0.007**	0.0062**	0.0064*	0.0043
	Market Portfolio	(2.35)	(1.96)	(1.89)	(1.12)
	S&P Portfolio	0.0119***	0.0086**	0.0089**	0.0069
		(2.85)	(2.35)	(2.43)	(1.63)
Panel B: Technology					
High-tech					
	Value Weighted	0.0059*	0.0054*	0.0051	0.0027
	Market Portfolio	(1.84)	(1.86)	(1.63)	(0.79)
	Equal Weighted	0.0034	0.0050*	0.0047	0.0024
	Market Portfolio	(1.47)	(1.93)	(1.57)	(0.76)
	S&P Portfolio	0.0082**	0.0073**	0.0071**	0.0051
		(2.46)	(2.65)	(2.37)	(1.51)
Low-tech					
	Value Weighted	0.0084***	0.0062**	0.0056**	0.0032
	Market Portfolio	(2.95)	(2.20)	(2.03)	(1.04)
	Equal Weighted	0.0059***	0.0058**	0.0052**	0.0030
	Market Portfolio	(2.81)	(2.45)	(2.09)	(1.05)
	S&P Portfolio	0.0107***	0.0081***	0.0076***	0.0056*
		(3.59)	(2.98)	(2.85)	(1.82)
Panel C: Growth					
High					
	Value Weighted	0.0062**	0.0051**	0.0044*	0.0035
	Market Portfolio	(2.08)	(2.07)	(1.72)	(1.27)
	Equal Weighted	0.0037	0.0047**	0.0040*	0.0032
	Market Portfolio	(1.62)	(2.31)	(1.70)	(1.33)
	S&P Portfolio	0.0085***	0.0070***	0.0065**	0.0059**
		(2.74)	(2.97)	(2.61)	(2.13)
Low					
	Value Weighted	0.0092***	0.0079*	0.0098**	0.0053
	Market Portfolio	(2.79)	(1.93)	(2.36)	(1.05)
	Equal Weighted	0.0065**	0.0074**	0.0092**	0.0049
	Market Portfolio	(2.51)	(1.97)	(2.37)	(1.03)
	S&P Portfolio	0.0115***	0.0098**	0.0118***	0.0076
		(3.38)	(2.45)	(2.91)	(1.54)

This table examines the profitability of a trading strategy that longs stocks with positive RDI and shorts market portfolios with Fama-Macbeth regressions when monthly returns are regressed on the risk factors. In subsamples firms are bifurcated by various firm characteristics. Panel A reports alphas for size in which firms are designated as small and large on their size measures explained in Table 2. Panel B reports the alphas for the technological intensity in which firms are designated into high and low-tech with their four-digit SIC codes as in Loughran and Ritter (2004). Panel C reports the alphas for growth in which firms are designated as high to low-growth based on Book-to-Market ratios (BM < 1 is defined as high growth) similar to Eberhart et al. (2004). Each year, stocks are sorted according to the sign of the RDI value. Both the long and short positions are equally weighted, and held for 1 year after portfolio formation and rebalanced yearly. The resulting time-series returns on the long–short portfolio are regressed on risk factors from MM (Market Model), Fama and French 3 factor model (1993), Carhart (1997) four factor model and PS Liquidity models. p-values are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. $^{+}$ Heteroscedasticity Consistent.

portfolio. The time-series averages of the alphas from the Fama-MacBeth regressions are reported in Tables 8–10. We discuss the findings for each table below

In Table 8 the abnormal *RDI* returns range between 33 basis points per month to 95 basis points. These results indicate an annual significant positive abnormal *RDI* returns that ranges between 4.0% and 11.4. Our results show that, even after accounting for risk factors, we still find significantly positive abnormal *RDI* returns. Thus, the returns of the long-short portfolio, namely, one that buys stocks with positive *RDI* and sells market portfolio, are positive for both value-weighted and equal-weighted portfolios. We note that in two models (VW an EW portfolios with PS liquidity factor in the last columns) abnormal RDI returns are positive yet insignificant. However, we still observe significant abnormal RDI returns with the S&P portfolio.

In Table 9 we examine the positive abnormal *RDI* returns in subsamples sorted by size, technology, and growth. In this analysis, within each half, we control the relevant characteristic in two ways: by sorting and by Fama-MacBeth regressions to find the subsets of stocks in which the positive abnormal RDI return is the strongest. Panel A reports the values for the size subsample (i.e. market capitalization) and shows that positive abnormal *RDI* return exists among both small stocks and in large stocks. This suggests that positive abnormal *RDI* return is not driven by size. Panel B reports the alphas for the technology subsample in which firms are designated as high-tech to low-tech based on four-digit SIC codes as in Loughran

Table 10
Fama-Macbeth regressions – long positive RDI stocks, short market portfolio.

	(1) MM	(2) FF 3-Factor	(3) Carhart 4-Factor	(4) PS Liquidity+
AlphaPanel A. Scaled by Capital Expenditures				
Value Weighted	0.0066**	0.0049**	0.0048**	0.0033
Market Portfolio	(2.52)	(2.28)	(2.24)	(1.41)
Equal Weighted	0.0041**	0.0045***	0.0043**	0.0031
Market Portfolio	(2.45)	(2.83)	(2.38)	(1.53)
S&P Portfolio	0.0090***	0.0068***	0.0068***	0.0057**
	(3.20)	(3.32)	(3.30)	(2.46)
Alpha Panel B. Scaled by Sales				
Value Weighted	0.0050**	0.0036**	0.0041**	0.0033*
Market Portfolio	(2.42)	(2.02)	(2.21)	(1.70)
Equal Weighted	0.0026*	0.0032**	0.0037**	0.0031*
Market Portfolio	(1.95)	(2.15)	(2.13)	(1.71)
S&P Portfolio	0.0074***	0.0056***	0.0061***	0.0057***
	(3.24)	(3.33)	(3.50)	(2.97)
Alpha Panel C. Scaled by Number of Employees				
Value Weighted	0.0062***	0.0050***	0.0058***	0.0044**
Market Portfolio	(2.68)	(2.79)	(2.94)	(2.12)
Equal Weighted	0.0037**	0.0047***	0.0054***	0.0041**
Market Portfolio	(2.26)	(3.17)	(3.01)	(2.25)
S&P Portfolio	0.0086***	0.0070***	0.0078***	0.0068***
	(3.43)	(4.13)	(4.16)	(3.30)
Alpha Panel D. Scaled by Market Equity				
Value Weighted	0.0067**	0.0053**	0.0056**	0.0046*
Market Portfolio	(2.39)	(2.20)	(2.27)	(1.80)
Equal Weighted	0.0042**	0.0050**	0.0052**	0.0044**
Market Portfolio	(2.15)	(2.57)	(2.45)	(2.06)
S&P Portfolio	0.0091***	0.0073***	0.0077***	0.0070***
	(3.07)	(3.12)	(3.22)	(2.76)
Alpha Panel E. Scaled by R&D Capital				
Value Weighted	0.0075***	0.0061***	0.0057***	0.0031
Market Portfolio	(2.80)	(2.69)	(2.58)	(1.31)
Equal Weighted	0.0050***	0.0057***	0.0053***	0.0029
Market Portfolio	(2.91)	(3.15)	(2.70)	(1.36)
S&P Portfolio	0.0099***	0.0080***	0.0078***	0.0055**
	(3.43)	(3.69)	(3.64)	(2.32)

This table examines the profitability of a trading strategy that longs stocks with positive RDI and shorts market portfolio with Fama-Macbeth regressions when monthly returns are regressed on the risk factors. In Panel A R&D expenditure scaled by capital expenditure. In Panel B R&D expenditure scaled by sales. In Panel C R&D expenditure scaled by number of employees. In Panel D. R&D expenditure scaled by year-end market equity. In Panel E. R&D capital is the weighted sum of a firm's R&D expenditure over the past five years, assuming annual amortization rate of 20%. Both the long and short positions are equally weighted, and held for 1 year after portfolio formation and rebalanced yearly. The resulting time-series returns on the long–short portfolio are regressed on risk factors from MM (Market Model), Fama and French 3 factor model (1993), Carhart (1997) four factor model and PS Liquidity models. p-values are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. + Heteroscedasticity Consistent.

and Ritter (2004). Our findings show that positive abnormal *RDI* return present in both subsamples albeit it is stronger for Low-Tech companies. Hence, we can argue that positive abnormal *RDI* return is up to a degree driven by the technological endowments of the firms. Panel C reports the results for growth subsample in which firms are designated as high to low-growth based on book-to-market ratios (BM < 1 is defined as high growth). The results show that positive abnormal *RDI* return is also present among both low-growth stocks and high growth stocks. Hence, we conclude that *RDI* effect is not driven by the growth of the firms even though firm growth affects its magnitude.

Table 10 presents the results of profitability of an arbitrage strategy where we long stocks with positive RDI and shorts market portfolios with alternative measures of RDI with Fama-MacBeth regressions. The results show that there are positive abnormal *RDI* returns in all five panels. These abnormal returns in these models range between 31 basis points per month to 99 basis points. Our findings show an annual significant positive abnormal RDI return that ranges from 3.7% to 11.9%. These results show that, even after accounting for risk factors and scaling with alternative measures, we still find significantly positive abnormal RDI returns.

3.5. Investment factor

As an additional and relevant control variable, we looked into the Investment Factor developed by Lyandres, Sun, and Zhang (2007). The key element and main driver of this factor is the *Investment-to-Asset ratio*. This ratio measures the changes in investments of a firm from year to year.[6] However, our change in R&D variable is a subset of the Investment-to-Asset ratio. That makes our R&D variable a confounder since it has a causal effect on the Investment Factor and on the dependent variable; hence the Investment Factor is endogenous and inappropriate to use in the model. Furthermore, in order to look into the potential endogeneity issue, we calculated the monthly Investment Factors as per Lyandres et al. (2007). First, we included the Investment Factors in our regression models. The parameters and t-values for the Investment Factor were extremely high which supported our suspicion of endogeneity. We then performed a Hausman specification test which corroborated endogeneity between the Investment Factor and the dependent variable. Accordingly, we decided to omit the Investment Factor from our study.

4. Conclusions

This study extends the literature that examines the relations between R&D expenditures and stock returns. Specifically, we scrutinize whether the stocks of firms with positive abnormal changes in R&D investments perform better than the market portfolio. We study a sample of 4561 firms that abnormally change their R&D over our 1975–2015 sample period. We find consistently strong evidence that portfolios of stocks of firms with positive *RDI* perform better in comparison to the market portfolio. We also find that positive *RDI* firms provide higher returns than negative *RDI* firms. This effect is especially higher among smaller, higher priced, higher past returns stock.

We examine profitability of an arbitrage strategy where we long stocks with positive *RDI* and shorts market portfolios. We document abnormal RDI returns. Specifically, we find economically and statistically significant intercept (an alpha range from 46 to 97 basis points) values in all models. These findings indicate an annual significant positive *RDI* abnormal returns that ranges from 5.5% to 11.6%. We also show that *RDI* effect is not driven by size, technological endowments or growth of the firms. As a robustness check, we use alternative measures of *RDI* and still find significant intercept (alpha) values in all five panels. The alpha in these alternative models range from 27 basis points per month to 90 basis points. Finally, we utilize the Fama-Macbeth approach to calculate abnormal RDI returns and find results similar to regression approach. Overall, our results also provide evidence that investors systematically underreact to positive changes in *RDI*. Based on our findings we argue that, due to limited investor attention and the difficulty of processing information that is less tangible and more ambiguous, stock prices do not fully and immediately impound the relevant public information about the abnormal R&D changes.

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[6] The Investment-to-Asset ratio is calculated as (△ Property, Plant, & Equipment + △ Inventories)/lag (Book Value of Assets)

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