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The Effect of R&D Expenditures on Stock Returns, Price and Volatility

A study on biotechnological and pharmaceutical industry in the US market

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THE EFFECT OF R&D EXPENDITURES ON STOCK RETURNS, PRICE AND VOLATILITY

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Abstract

This paper examines how stock returns, price and volatility are affected by R&D expenditures for biotechnological and pharmaceutical firms in the US during the period 2002 – 2013. We test three hypotheses; R&D expenditures are related with significant positive stock returns; R&D expenditures have a positive effect on stock price; R&D expenditures and volatility are positively linked. Based on our results we fail to reject the first hypothesis, while we reject the second and the third hypothesis. We make a robustness check and divide the sample in two groups based on their R&D expenditures. For firms with more than $100 million in R&D expenditures we observe: a positive significant effect of R&D to market value on stock returns; a positive significant effect of R&D capital to sales and R&D intensity on stock price; and a negative significant effect of R&D capital to sales on stock price volatility.

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Aleksandra Titi, November 2014

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1. Introduction

1.1 Background of the study

The valuation of intangible assets, or in a more specific context the market valuation of Research and Development expenditures (R&D), has been an interesting topic for many studies over the past decades. For the average S&P500 company between years 1982 – 1992 the value of intangible assets increased from 38% to 62%. This phenomenon of increased intangible assets drew the attention of researchers. Griliches (1981, 1987) and Pakes (1985) show the first confirmation to support the notion that higher R&D activities are linked with higher market values. Later studies of Lev and Sougiannis (1996) provide evidence of a positive relationship between R&D expenditures and a firm´s economic growth, its future income and its productivity progress.

This study focuses on the valuation of R&D expenditures in the biotechnological and pharmaceutical industry in the United States between years 2002 - 2013. The biotechnological and pharmaceutical sectors were chosen to study together due to the high collaboration between them. There are few studies that focus only in these two industries in order to study the R&D effect and we could say, being almost sure that there is no study made until the moment of writing, that studies the impact of R&D on stock returns, price and volatility at the same time. Biotechnological and pharmaceutical firms are considered as High R&D intensive because of the large amounts of spending on R&D (see the 2013 EU Industrial R&D Investment Scoreboard). During the time frame 2002 - 2013 we can distinguish the R&D expenditures for H5N1 bird flue 2003 – 2007, for H1N1 swine flue 2009 which were world wide viruses requiring the assistance of the biggest pharmaceutical companies.
The biotechnological and pharmaceutical sector in the US drive the global development of medicine compared to EU, Japan and the rest of the countries refer to the graph 1 in the appendix that shows how pharmaceutical R&D in the US compares to other countries data from the National Trade Associations.

In 1974 the Financial Accounting Standards Board (FASB) did not see any relation between the R&D expenditures and subsequent future profits therefore the full expensing of R&D expenditures in firms financial report was required.

Currently, according to the Generally Accepted Accounting Principles (GAAP) used in the US, Research and Development costs are generally expensed, because the future economic profit occurring from development of the asset is uncertain. While the costs of intangible assets obtained from R&D activities are expensed depending on if the asset has a future alternative use. If so, then it becomes a capitalized asset and depreciates in value over its useful life and the amortization costs are expensed. Otherwise if the asset has no other use, its cost is expensed upon acquisition.

According to the 2013 EU Industrial R&D Investment Scoreboard, which contains data for the world´s top 2000 companies based on their R&D investments, the biotechnology and pharmaceutical industries are dominated by big companies where the top 10 biotech companies account for 63% of the industry´s R&D spending, while the top 10 pharmaceutical companies account for 58% of the industry´s R&D spending. The Pharmaceutical and Biotechnology sector is ranked first worldwide in the R&D ranking by having a share of 18.1% followed by the Technology Hardware & Equipment sector with a share of 16.4%. In the US the share of R&D investments is as follows: 25.2% for the Technology Hardware & Equipment, 22.1% for the Pharmaceutical & Biotechnology and 6.6% for the Automobiles & Parts. The increase in R&D during the latest 3 years has been 5.7% for the Pharmaceutical & Biotechnology sector in the US, while only 3.3% in the EU. For the biotechnology sector from the top 30 companies of R&D expenditures a total of 25 are from the US, and for the pharmaceutical sector a total of 9 out of 30 are from the US.

1.2 Study objectives, hypotheses and main results

The objective of this study is to see whether stock price fully incorporates the value of R&D expenditures. Does the efficient market hypothesis, a theory by Eugene Fama, that at any given time a security price will fully reflect all the available information, hold. This would mean that the stock price impounds the value of the R&D capital, resulting in no link between R&D and future stock returns, or instead we will observe a positive significant relationship of R&D on returns, price and volatility.

The main results of this paper consist of: R&D to market value has a significant positive effect on returns, especially for firms which spend more than $100 million on R&D. R&D capital to sales has a negative effect and no indication of R&D intensity´s effect on returns is observed. Referring to the effect of R&D on price, there is a negative significant effect of R&D capital to sales, and R&D to market value, although when controlling for firms which spend more than $100 million on R&D, a positive significant effect of R&D capital to sales and R&D intensity is detected. R&D has a significant effect on price volatility only when we control for firms that spend more than $100 million on R&D. It is a negative significant effect of R&D capital to sales on price volatility.

1.3 Limitation of the study

This study is based on data downloaded from Bloomberg terminal. It is focused on biotechnology and pharmaceutical companies, two of the main industries regarding investments in R&D spending in the US during the time period of 2002 - 2013. A limitation of panel data is actually the limited time series that might result in imprecise estimates of R&D on stock return, price and volatility. Hence the results received are based on the sample of data used for the study. Therefore based on the data and the results of our representative sample we make general assumptions regarding these two industries. However, the main findings may to some extent be applied to other sectors such as Technology Hardware & Equipment, an industry also distinguished by the huge amounts of spending in R&D.

1.4 Study outline

The remainder of the paper is organized as follows. Section two contains literature review and hypothesis development while section three describes data and methodology together with model specifications. Section four introduces and analyses results together with robustness whereas section five gives a discussion and conclusions of the study.

2. Literature Review and Hypotheses development

2.1 Literature review

This literature review presents major previous studies that relate to the hypotheses being tested in this study. Studies have been made during the latest years investigating the effect of R&D expenses on a firm's market value. Previous studies by Johnson (1967), as referred in Sougiannis (1994) also Newman (1968) and Milburn (1971) used cross-sectional correlation for regression analysis and the relationship they observe between R&D and future benefits was not significant. Sougiannis (1994) explains that the results for the previous studies may be due to the econometrics techniques used, the sample size being too small and the quality of the R&D data. As mentioned in Sougiannis (1994), Benzion (1978), Griliches (1981), Hirchey (1982), Hirschey and Weygandt (1985) and Shevlin (1991) studies found a significant relationship between R&D expenditures and market value, bringing to the conclusion that the capitalization and amortization of R&D would be a better accounting treatment than expensing. But according to FASB Statement No. 2: "A direct relationship between research and development costs and specific future revenue generally has not been demonstrated". FASB being unable to establish a relationship between R&D costs and future profits required the full expensing of R&D expenditures in a firm´s financial report.

Lev and Sougiannis (1996, 1999) find a significant intertemporal link between R&D capital and subsequent stock returns. According to Lev and Sougiannis (1996) study "The estimated R&D capital does not appear to be fully reflected contemporaneously in stock prices, since R&D capital is associated with subsequent stock returns." Sougiannis (1999) studies the connection of R&D and subsequent stock returns. His findings show that R&D capital is significantly linked with subsequent returns and for firms intensive in R&D, the R&D capital absorbs the book-to-market effect. This means that the book-to-market ratio, which measures the current market price to its book value, is not related with subsequent returns when the R&D capital is included in the regression. Bloch (2003) investigates the effect of R&D expenditures on stock market returns for Danish firms. The paper uses panel data analysis and divides stocks up into several portfolios to study how R&D affects returns and how firms engaged in R&D are valued by the stock market. He does not find that R&D intensive firms earn greater returns while through the portfolio analysis he finds small excess returns for high R&D firms when it comes to R&D to sales. There is weak evidence that firms that invest considerably in R&D are systematically undervalued or that there is risk premium associated with them. Nevertheless this is not an indication that R&D does not have any effect on returns because when controlling for the book to market ratio, R&D to market has a positive effect on returns to a higher degree than R&D to sales.

Chan et al. (2001) examine whether stock prices fully value R&D expenditures. The study suggests that investors should adjust valuation measures for the long-term profits of R&D, to avoid possible mispricing. The data of the study does not find evidence to support the relationship between R&D expenditures and future stock price. This falls in line with the hypotheses that the market incorporates investors´ unbiased beliefs regarding the value of R&D. According to Eberhart (2004): " So their findings suggest that the market correctly incorporates R&D intensity into stock valuations, but they do not imply that the market correctly values R&D increases because high R&D intensity firms may not have increased their R&D recently (i.e., unexpectedly and by an economically significant amount)". Chan et al. (2001) make a portfolio analysis based on R&D relative to sales and R&D relative to market value. There is weak evidence that R&D to sales is linked to future returns but the evidence that R&D to market value is linked to future returns is stronger, especially for the stocks with high R&D to market ratio. A major finding of the study is showing that R&D intensity is linked with return volatility. There is a positive economic important relationship between return volatility and R&D intensity especially for the high R&D intensive firms. Eberhart et al. (2004) found evidence of positive long-term abnormal stock returns due to an unexpected increase in R&D expenditures. Eberhart et al. (2004) provides evidence that the above result holds for different groups of firms, even though the high-tech firms have better abnormal operating performance than low-tech firms. Furthermore the results show that the market is slow in fully incorporating the value of R&D investments. This is interpreted as a proof that investors underreact to the benefit of R&D increase. This benefit of R&D increase means experiencing significant abnormal operating performance. Elberhart et al. (2004): "In short, our findings suggest that R&D increases are beneficial investments, and that the market is slow to recognize the full extend of this benefit". There is also provided evidence that the shareholders during a five year period experience significant abnormal stock returns. A main difference between Elberhart et al. (2004) study and Chan et al. (2001) is that Elberhart el al. (2004) measures an unexpected increase in R&D defined as an increase of the ratio R&D to assets while Chan et al. measure is R&D intensity defined as a ratio of R&D to sales. Franzen and Radhakrishnan (2009) find different results when it comes to the effect of R&D expenditures on stock price. They use the residual income model and they find out that R&D expenditures are positively linked with stock prices for loss firms, and negatively linked with stock prices for profit firms. Callen and Morel (2005) use time series valuation model and they find weak indications of the value relevance of R&D on stock prices.

Fung (2000) questions the validity of the Efficient Market Hypothesis due to a high volatility of stock prices. He studies if an increase in R&D expenditure activities would result in an increase in stock volatility. His model suggests that R&D activities with uncertain future outputs will result in an increase of stock volatility, while dividends and consumptions would not change. Empirical results from Chan et al. (2001) also indicate that R&D intensity is positively associated to stock volatility. This could be due to asymmetric information regarding R&D expenditures that result into a positive association between R&D expenditures and stock volatility, Fung (2000).

Other studies have been made specifically for the biotechnology industry if there exists any relationship between R&D strategies and share price volatility, which is the relative rate of the ups and downs prices of a security over a given period of time. Xu (2006) findings suggest that the high diversification in drug portfolios result into lower share price volatilities and instead a more concentrated drug portfolio results into higher share price volatility. Whether R&D information leads to large fluctuations in price and overreaction was studied by Rodriguez and Valcarcel (2012). Their study uses cumulative abnormal returns and does not find any indication of market overreaction. Another study by Mazzucato and Tancioni (2008) tries to find if there is any relationship between the dynamics of stock price volatility and innovation in the pharmaceutical industry. They measured innovation in terms of the level of R&D and patent data. The results obtained indicate that both the level and volatility of stock prices are actually linked to innovation.

2.2 Hypotheses and R&D capital measurements

In this study we will test three hypotheses which are:

H_1: R&D expenditures have a significant positive effect on stock returns

H_2: R&D expenditures have a significant positive effect on stock price

H_3: R&D expenditures and stock volatility are positively related

According to Kothari and Zimmerman (1995), studies that include the model of returns and the model of price generate more persuasive results.

Since R&D expenditures according to the US GAAP are immediately expensed it is needed to create a measure of the stock of R&D capital. According to existing literature there is no general agreement on the amortization rate of the R&D expenditures. There exist a few methods for measuring the stock of R&D capital. Chan et al. (2001) and Bloch (2003) use more than one method of calculating R&D capital and in both times they receive similar results.

Hall (1992, 1993) uses a perpetual inventory model to calculate the R&D capital where:

$$RDC_t = (1 - \delta) * RDC_{t-1} + RD_t,$$

RDC_t is the R&D capital at time t, δ is the rate of depreciation and RD_t is the R&D expenditures at time t.

Lev and Sougiannis (1996) and Bayer (2003) use another method which is interesting from an economic point of view but the method needs estimations using lagged values of R&D, and might not be that accurate due to the sample size of this study. This method consists of estimating the contribution of R&D spending to earnings, and then used to create estimates of depreciation rates for R&D, which is used later to form a measure of R&D capital.

In this paper we will incorporate the same method used by Chan et al. (2001). Chan et al. (2001) argues that this method is more practical, more realistic and easier to use compared to others. Those are also the reasons why this paper adapts the same approach.

Chan et al. (2001) method assumes that the productivity of R&D spending declines linearly by 20% every year. Chan et al. (2001) assumption of calculating R&D capital is based on the work of Lev and Sougiannis (1996) where they value for different industries the effect of past and current R&D expenditures on earnings. Chan et al. (2001) writes "Our assumed capital amortization rate turns out to be close to the one used (15 percent) in a highly influential database compiled on R&D activity by the National Bureau of Economic Research (see Hall et al. (1988))". Through this method the stock of R&D capital would be:

$$RDC_t = RD_t + 0.8 * RD_{t-1} + 0.6 * RD_{t-2} + 0.4 * RD_{t-3} + 0.2 * RD_{t-4}$$

where RDC_t is the R&D capital at time t, and RD_t is the R&D expenditure at time t.

3. Data, Methodology and Model Specifications

3.1 Sample data

This study uses data extracted from Bloomberg terminal from year 2002 to 2013 for biotechnological and pharmaceutical companies in the US. Initially the data was downloaded for 723 companies listed on Bloomberg´s website. The initial sample size is quite big since we expect a large drop out due to missing data. Eberhart (2004) started with a sample of 35406 firm year observation and his final sample was 8313 firm year observation. The goal was to compile a balanced panel data. After filtering for companies that contained enough data for the study, we ended up with the final sample consisting of 122 companies, which falls in line with our anticipation of 100 – 200 firms. The time frame was chosen to studying the effect of R&D expenditures on stock price, stock return and volatility for the last decade. The data used are annual and following Fama and French (1992) by supposing that the fiscal year coincides with calendar year for all firms. The data used in this study are: R&D measured in $ millions, R&D/Sales - ratio, sales - $ millions, price - $, returns - ratio, shares outstanding - $ millions, ROE - %, ROA - %, tangible assets - $ millions, disclosed intangible asset - $ millions, volatility 360 days - %, market value - $ millions, market value to book value - ratio.

3.2 Data description

In this section we will provide some general descriptive statistics of the data used in this study.

Table 1 – Statistics summary

Variable	Mean	Median	Std. Dev.	Min	Max
RD	7520.354	51.36	31715.81	0	453000
RD/SALES	1.6729	0.1964	9.7119	0	204.4756
RDC	19398.34	129.3606	85153.34	0.016	946800
RDC/SALES	4.7114	0.5159	28.3029	0.0014	603.9488
RD/MV	41.5029	0.0767	500.6341	0	15218
ROE	-25.5255	3.6505	211.4081	-6873.97	140.2672
ROA	-19.2427	2.2453	110.1685	-1998.037	126.1287
TanA	108361.2	298.3635	622738.8	0	1.09e+07
IntA	12613.97	32.1295	76702	0	1689735
IntA/MV	2.3853	0.0639	25.6904	0	687.8087
VOL	43.8228	40.6205	42.5760	0	421.517
MV	15868.47	527.6707	38036.13	0	269621.7
MTBV	4.9624	1.8884	48.0640	-32.7716	1570.473
BMV	0.2211	0.1583	0.4307	-5.08647	3.6818
Returns	1.0625	0.0605	13.0206	-1	370.8462
SALES	107226.2	150.7295	824986.2	0	1.60e+07
PRICE	23.2865	12.395	30.4465	0	280
SHARES_OUT	884.1474	69.095	4425.177	0	50780.07

RD is the R&D expenditures, RD/Sales is RD intensity (RDI) which is measured as a ratio of R&D and Sales; RDC is R&D capital and RDC/Sales is the ratio of R&D capital to sales, RD/MV is the ratio of R&D to market value; ROE refers to Return on Equity, ROA refers to Return on Assets; TanA refers to Tangible assets, IntA refers to Intangible Assets, IntA/MV is ratio of Intangible assets to market value; Vol refers to the volatility of the stock price, MTBV refers to Market value to Book value, BMV refers to book to market value, Returns is the stock return. Price refers to the price of the shares; Shares_out is the number of shares outstanding

Comparing the mean with the median of the variables provides an indication if they are left or right skewed. Table 1 indicates that except for ROE and ROA all the other variables have a higher mean than median meaning that they are skewed to the right. While the variables such as ROE and ROA have a higher median than mean meaning that they are skewed to the left. Regarding our variables of interest we have the following results: R&D mean is 7520.354 and the median is 51.36. This clearly indicates that the sector is dominated by a few firms that spend huge amounts on R&D. We will refer back to this in our robustness check. R&D intensity ratio has a mean of 1.6729 and a median of 0.1964. R&D capital has a mean of 19398.34 and a median of 129.3606.

While the ratio of R&D capital to sales has a mean of 4.7114 and its median is 0.5159. R&D to market value has a mean of 41.5029 and its median is 0.0767. When dealing with variables that are right skewed taking the natural logarithm of those variables helps fitting them into a model. By making the log transformation we make right skewed distribution more normal.

3.3 Methodology

3.3.1 Cross-Sectional approach vs. Panel data

Fama and French (1992) and Lev and Sougiannis (1996) employ a cross-sectional approach to examine the association between R&D and subsequent earnings. From the cross sectional regressions they calculate time series averages and t statistics. Due to having more advantages, panel data estimation method is used in the regression analysis of this study instead of the cross-sectional approach. With a panel data set we have data on a cross-section of observations at repeated times, since it is a combination of time-series and cross-sectional data. The main panel data assumption is that observations in every cross-section are independent of each other. The power of panel data originates from two assumptions, the cross-sectional independence and the ability to "pool" the data. Panel data offers more accurate inference of model parameters by containing more degrees of freedom and more sample variability. It contains information on the intertemporal dynamics and the individuality of the entities, which makes it easier to control for unobserved variables. According to Pakes and Griliches (1984) while using panel data the inter-individual differences will reduce the collinearity between current and lag variables to estimate unrestricted time-adjustment patterns. Finally while the cross-sectional approach neglects the within-firm variation, panel data could probably explain which forms of variation are most important in explaining returns, cross-sectional differences or within-firm fluctuations.

3.3.2. Fixed effect models

According to Brooks (2008) we have the following equation

$$y_{it} = \alpha + \beta x_{it} + u_{it}$$

where y_{it} is the dependent variable, α is the intercept, β is a $\kappa \times 1$ vector of parameters to be estimated, x_{it} is a $1 \times \kappa$ vector of observations, $t = 1, \ldots, T$; $i = 1, \ldots, N$. The disturbance term could be expressed as

$$u_{it} = \mu_{it} + \nu_{it}$$

where μ_i is an individual specific effect that captures all the variables that affect y_{it} cross sectionally but do not vary over time and ν_{it} is a "remainder disturbance" that varies over time and entities.

This model could be estimated by using dummy variables, but to avoid estimating many dummy variables we use the within transformation method. To quote Brooks (2008) "This transformation, known as the within transformation, involves subtracting the time-mean, of each entity away from the values of the variable". The time-mean of observations on y for cross-sectional unit i is

$$\bar{y}_{it} = \frac{1}{T}\sum_{t=1}^{T} y_{it}$$

From each variable we subtract the time-means to obtain the regression of demeaned variables. This regression will have no intercept since the dependent variable will have zero mean by construction. So the demeaned variable model is

$$y_{it} - \bar{y}_i = \beta(x_{it} - \bar{x}_i) + u_{it} - \bar{u}_i$$

which can be rewritten as

$$\ddot{y}_{it} = \beta \ddot{x}_{it} + \ddot{u}_{it}$$

where the double dots indicate the demeaned values. A disadvantage of this model is that we cannot observe variables that do not vary over time but that affect y_{it}.

3.3.3. Random effect models

A major advantage of using random effects is that it allows us to observe time invariant variables. We can write the random effect model as

$$y_{it} = \alpha + \beta x_{it} + \gamma_{it}$$

where, $\gamma_{it} = \epsilon_i + \nu_{it}$ and x_{it} is a $1{\times}k$ vector. Under this model the assumption that the cross-sectional error term ϵ_i has zero mean, is independent of the individual error term ν_{it}, has constant variance σ_ϵ^2, and is independent of the explanatory variables, must hold.

In this case OLS is inefficient in estimating the parameters, so instead we use the generalised least squares GLS. That means that we subtract a weighted mean of the y_{it}. We define the $\bar{y}_i$ and $\bar{x}_i$ as the means over time for y_{it} and x_{it} and the "quasi-demeaned" data as $y_{it}^* = y_{it} - \delta\bar{y}_i$ and $x_{it}^* = x_{it} - \delta\bar{x}_i$ where δ is defined as

$$\delta = 1 - \frac{\sigma_\nu}{\sqrt{T\sigma_\epsilon^2 + \sigma_\nu^2}}$$

3.3.4. Fixed vs. random effect models

In order to define which model fixed effects versus random effects fits our data best we perform The Hausman specification test. The null hypothesis of this test is that individual effects are uncorrelated with other regressors (Hausman 1978). If we fail to reject the null hypothesis then we can use the random effect. If the null hypothesis is rejected the fixed effect model is preferred instead since the random effect model violates one of the Gauss-Markov assumptions and therefore produces biased estimators.

The Breusch and Pagan Lagrangian multiplier test for random effects helps us decide between a random effect regression and a simple OLS regression. The null hypothesis in the Lagrange multiplier (LM) test is that variances across entities are zero and if we fail to reject it, we can conclude that the random effect is not appropriate; therefore we can run a simple OLS regression instead.

3.4 Model specifications

3.4.1 Model 1 - Returns

In order to explain expected returns, Lev and Sougiannis (1999) regress monthly stock returns on a number of variables. In this study some variables in the equations are based on the Lev and Sougiannis (1999) study with the addition of some other variables hypothesized to explain expected returns.

Our first model will consist of examining the effect of R&D on the stock returns. The dependent variable will be returns, and the independent variable will be R&D intensity (the natural logarithm), R&D to market value and R&D capital to sales, are individually entering into the regression with other independent variables.

$$R_{i,t} = \beta_0 + \beta_1 * lnRDI_{i,t} + \beta_2 * lnMV_{i,t} + \beta_3 * BMV_{i,t} + \beta_4 * VOL_{i,t} + \beta_5 * IntA/MV_{it} + \beta_6 * ROE_{i,t} + \beta_7 * ROA_{i,t} + \varepsilon_{i,t}$$

$$i = 1 \dots N; t = 1 \dots T$$

$R_{i,t}$ is the yearly stock return for firm i, RDI is the ratio of R&D expenditures to sales. MV is the firm´s market value, estimated multiplying its stock prices with the number of shares outstanding. BMV is the ratio of book to market value. VOL is the yearly volatility of the stock price. IntA/MV is the ratio of intangible assets over market value. ROE and ROA are the return on equity and the return on asset.

R&D intensity can be used as an indication of how much resources a firm allocates to R&D. R&D capital to sales is almost the same measure with the difference that the R&D capital accounts for amortization of the R&D expenditures, which instead of being expensed in the current year it is capitalized for future periods. R&D to market value is a ratio, which takes in consideration how R&D expenditures fluctuate comparison to the market value of the firm.

Market value is used as a measure of company´s size, while taking in consideration the company´s growth potential. Book to market value together with market value have been examined in empirical studies and a direct effect on returns is observed. Intangible assets over market value is a measure of other intangible assets, which do not include R&D expenditures over market value. ROE and ROA are used as a measure of profitability.

3.4.2 Model 2 - Price

The second model studies the effect of R&D on stock price. The variables of R&D intensity, R&D to market value and R&D capital to sales will be used independently in the regression analysis to see their effect on price together with other variables that are suspected for having an effect on stock price.

$$lnPrice_{i,t} = \beta_0 + \beta_1 * lnRDI_{i,t} + \beta_2 * lnMV_{i,t} + \beta_3 * BMV_{i,t} + \beta_4 * VOL_{i,t} + \beta_5 * IntA/MV_{it} + \beta_6 * ROE_{i,t} + \beta_7 * ROA_{i,t} + \varepsilon_{i,t}$$

$$i = 1 \dots N; t = 1 \dots T$$

3.4.3 Model 3 - Volatility

In this model we will study the effect of R&D on stock volatility. Like in the two previous models we will include the same dependent variables, R&D intensity, R&D to market value and R&D capital to sales. The variables being tested are included in the following regression:

$$Volatility_{i,t} = \beta_0 + \beta_1 * lnRDI_{i,t} + \beta_2 * lnMV_{i,t} + \beta_3 * BMV_{i,t} + \beta_4 * IntA/MV_{it} + \beta_5 * ROE_{i,t} + \beta_6 * ROA_{i,t} + \varepsilon_{i,t}$$

$$i = 1 \dots N; t = 1 \dots T$$

4. Empirical Results and Analysis

In this section we will present the results of the panel data regressions performed for three different models, with three different dependant variables. The first model studies the effect of R&D on stock returns. The second and third model, study the effect of R&D on stock price and volatility.

Initially we run an OLS regression that is a pooled linear regression without fixed and/or random effects, which assumes a constant intercept and slopes unrelated to groups and time periods. Although this model fits well, we suspect for fixed and random effects. We estimate fixed effects using the least square dummy variable (LSDV) technique and the random effect using the generalized least squares (GLS) technique. Later we run a Hausman specification test to see which estimator fits our data best.

4.1 Model 1 - Returns

The results are reported on Table 2.

Interpreting the results from Table 2, it can be seen that R&D capital to sales (referring to column 1 and 2) is significant at the 1% level at both fixed and random effects. We focus on fixed effect estimation method, which is more efficient than the random effect due to high chi-squared value received from the Hausman specification test. R&D capital to sales with a coefficient of -0.8228 has a negative effect on returns. We could interpret this coefficient as a 100% change in R&D capital to sales generates a 0.8228 unit of percent decrease in the rate of returns, holding all other variables constant.

Market value is also significant at the 1% level and has a negative effect on returns with a coefficient of -0.7496. While book to market value is significant at the 10% significance level and also has a negative effect on returns. Usually a statistical significance of 10% level is not typically considered to indicate a strong casual relationship between two variables. Referring to column 3 and 4 we investigate whether R&D intensity has an effect on returns. According to column 3 the coefficient for R&D intensity is insignificant. However market value and return on assets are significant at the 1% level with market value having a negative effect on returns and

ROA having a positive effect on returns. The book to market value is also significant at the 5% level with a negative effect on returns.

Looking at column 5 we can conclude that R&D to market value is significant at the 10% level with a positive effect on returns. Market value is significant at the 1% level with a negative effect on returns and Intangible assets over market capitalization is significant at the 5% level with a positive effect on returns.

The results from Table 2 do not fall in line with other previous studies which find that R&D capital is associated with subsequent stock returns, Lev and Sougiannis (1996). At best we could find a weakly significant positive effect of R&D to market on returns. Our results are partly similar to the ones from Chan et al. (2001) where no strong evidence is observed that R&D intensity is linked with future returns, however there is stronger evidence that R&D to market value is linked with future returns.

Referring to previous literature, market value is used as a measure of size and results show a significant effect on returns. This could be an indication that firms increasing in market value have decreasing stock returns in the future rather that larger firms have lower risk premiums Bloch (2003).

Table 2 – Regressions Results

Estimation	FE (1)	RE (2)	FE (3)	RE (4)	FE (5)	RE (6)
Dep. Var.	**Returns**	**Returns**	**Returns**	**Returns**	**Returns**	**Returns**
Intercept	6.6524***	7.7189***	13.2299***	10.2194***	12.2488***	7.5099***
	(1.6678)	(1.5146)	(4.3081)	(1.683)	(4.1666)	(1.5406)
lnRDC/SALES	-0.8228***	-0.5904***				
	(0.2444)	(0.2149)				
lnRDI			-0.0382	-0.8513***		
			(0.3848)	(0.2104)		
lnRD/MV					0.4557*	-0.2046
					(0.6710)	(0.2126)
lnMV	-0.7496***	-0.853***	-1.5546***	-0.7009***	-1.2811***	-0.8175***
	(0.1733)	(0.1642)	(0.5159)	(0.1636)	(0.6478)	(0.1646)
BMV	-3.4757*	-3.6309***	-2.9525**	-3.6615***	-2.9379	-3.5277***
	(1.8207)	(0.9241)	(1.1544)	(0.923))	(1.1535)	(0.9281)
VOL	0.0029	0.0005	-0.005	0.0005	-0.0054	-0.0064
	(0.0153)	(0.0106)	(0.0162)	(0.0105)	(0.0162)	(0.0104)
IntA/MV	0.0207	0.0133	0.002	0.0129	0.0014**	0.0227
	(0.0200)	(0.014)	(0.0187)	(0.014)	(0.0187)	(0.0145)
ROE	0.0011	-0.0008	-0.003	-0.001	-0.003	-0.0003
	(0.0044)	(0.0017)	(0.002)	(0.0017)	(0.002)	(0.0017)
ROA	0.0001	0.0076**	0.0208***	0.0077**	0.0211	0.0078**
	(0.0065)	(0.0038)	(0.0058)	(0.0038)	(0.0058)	(0.0039)
Number of obs.	1383	1383	1382	1382	1383	1383
F statistics	6.11		3.47		4.69	
R-sq	0.2819	0.2476	0.1095	0.2576	0.1098	0.1767
Hausman		19.93		14.73		18.19
(p value)		*(0.0057)*		*(0.0397)*		*(0.0111)*

*Estimation methods: FE is fixed effects and RE is random effects. FE is estimated using the LSDV method, and RE is estimated using the GLS. The regression analysis is performed using Stata 12.0. Standard errors corrected for heteroskedasticity. ***, **, * indicate statistical significance at the 1%, 5% and 10% level respectively. Hausman is the Hausman specification test which is Chi-squared distributed. High values mean that we reject the null hypothesis and that fixed effect is favoured over the random effect.*

4.2 Model 2 - Price

The regression results are presented in Table 3. Taking in consideration the results from the Hausman specification test we see that the random effect estimator is biased and inconsistent, therefore our analysis will be based on the fixed effect estimator results. Looking at column 1, R&D capital to sales seems to be significant at the 1% level with a negative effect on price, meaning that a 100% change in R&D capital to sales would generate a 8.2% decrease in price. Market value, book to market value and intangible assets to market capitalization are significant at the 1%, 5% and 1% level respectively, with a positive effect on stock price. Volatility and ROA are significant at the 1% level and have a negative effect on price. ROE is significant at the 10% level with a negative effect on price. When we include R&D intensity in the analysis (column 3) the results show that we have a positive effect on price but the coefficient of R&D intensity is not significant. The rest of the results align with the results as when RDC to sales was used. Market value, book to market value and intangible assets to market capitalization have a positive effect on price while volatility, ROE and ROA have a negative effect on price. The results on column 5, when we include in the regression the R&D to market variable are the same like when we included in the regression the R&D capital to sales.

Our findings compare with Chan et al. (1990) observations that a significant negative stock price response is observed for low-tech group when there is an increase in R&D expenditures. We could explain this negative reaction of the stock price because of the investors' concern regarding the rate of success from the R&D investment.

Table 3 – Regressions Results

Dep. Var.	FE (1) Price	RE (2) Price	FE (3) Price	RE (4) Price	FE (5) Price	RE (6) Price
Intercept	-2.8114***	-2.2050***	-2.8969***	-2.3308***	-2.7108***	-2.1084***
	(0.1293)	(0.1491)	(0.1410)	(0.1584)	(0.1362)	(0.1486)
lnRDC/SALES	-0.0820***	-0.0451***				
	(0.0158)	(0,0162)				
lnRDI			0.0202	0.0334**		
			(0.0126)	(0.0131)		
lnRD/MV					-0.0562**	-0.1367***
					(0.0219)	(0.0196)
lnMV	0.7459***	0.6611***	0.7529***	0.6656***	0.7172***	0.6045***
	(0.0166)	(0.0160)	(0.0168)	(0.0161)	(0.0211)	(0.0181)
BMV	0.0802**	0.0707*	0.0891**	0.0772*	0.0861**	0.0748**
	(0.0374)	(0.0401)	(0.0378)	(0.0402)	(0.0377)	(0.0393)
VOL	-0.0025***	-0.0026***	-0.0026	-0.0026***	-0.0025***	-0.0025***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
IntA/MV	0.0035***	0.0025***	0.0036***	0.0025***	0.0036***	0.0029***
	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)
ROE	-0.0001*	-0.0001	-0.0001*	-0.0001	-0.0001*	-0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
ROA	-0.0006***	-0.0006***	-0.0004**	-0.0005***	-0.0005***	-0.0006***
	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0001)
Number of obs.	1384	1384	1383	1383	1384	1384
F statistics	59.239		370.21		372.36	
R-sq	0.9316	0.4552	0.9303	0.4748	0.9305	0.4816
Hausman		340		280.03		214.29
(p value)		(0.0000)		(0.0000)		(0.0000)

4.3 Model 3 – Volatility

The results of panel data regressions using fixed effects and random effects method are presented in Table 4. The Hausman specification test indicates that the fixed effect method is preferred to analyse the data. The coefficient of R&D capital to sales is not significant (column 1), but the market value and book to market value coefficients are significant at the 1% level with a negative effect on volatility. The coefficient of ROE is significant at the 5% level and has a negative effect on volatility. When we include R&D intensity in the regression we get almost the same as when we include R&D capital. R&D intensity is not statistically significant however market value and book to market value are statistically significant at the 1% level, with a negative effect on volatility. The same results are observed when we include the R&D to market value in the regression, refer to column 5. These results do not fall in line with previous studies by Chan et al. (2001) and Fung (2000) who observe a positive relationship between R&D intensity and the stock volatility.

Table 4 – Regressions results

Dep. Var.	FE (1) Volatility	RE (2) Volatility	FE (3) Volatility	RE (4) Volatility	FE (5) Volatility	RE (6) Volatility
Intercept	128.5673***	113.1038***	131.6321***	112.6561***	125.3258***	114.9073***
	(5.8847)	(4.7726)	(6.4729)	(5.4146)	(6.2965)	(4.8944)
lnRDC/SALES	0.3776	1.5605**				
	(0.8472)	(0.7283)				
lnRDI			-0.0740	0.2974		
			(0.6680)	(0.6185)		
lnRD/MV					1.6877	0.3642
					(1.1642)	(0.8094)
lnMV	-11.7088***	-9.5550***	-11.8178***	-9.7055***	-10.7147***	-9.7608***
	(0.8273)	(0.6026)	(0.8292)	(0.6020)	(1.0828)	(0.6556)
BMV	-6.3480***	-3.5742***	-6.4339***	-3.7175*	-6.3275***	-4.0058**
	(1.9980)	(1.9803)	(1.9969)	(1.9833)	(1.9953)	(1.9743)
IntA/MV	-0.0437	-0.0503	-0.0443	-0.0535*	-0.0458	-0.0543*
	(0.0325)	(0.0321)	(0.0325)	(0.0322)	(0.0325)	(0.0323)
ROE	-0.0074**	-0.0069**	-.0075**	-0.0070**	-0.0074**	-0.0071**
	(0.0034)	(0.0035)	(0.0034)	(0.0035)	(0.0034)	(0.0035)
ROA	-0.0126	-0.0214**	-0.0143	-0.0230**	-0.0121	-0.0223**
	(0.0102)	(0.0097)	(0.0101)	(0.0097)	(0.0101)	(0.0096)
Number of obs.	1385	1385	1384	1384	1385	1385
F statistics	37.87		38.06		38.24	
R-sq	0.7326	0.4162	0.7326	0.3981	0.7330	0.3873
Hausman		58.93		24.15		56.55
(p value)		(0.0000)		(0.0005)		(0.0000)

4.4 Robustness

Taking in consideration the descriptive statistics of R&D, mean $7520.354 million and median $51.36 million we perform a robustness check. The reason for the difference in mean and median, is because the top 10 companies account for more than half of the industry´s total R&D, see 2013 EU Industrial R&D Investment Scoreboard. We have divided our initial sample into two groups based on their R&D expenditures. Group one consists of 77 firms with R&D expenditures less than $100 million and group two consists of 48 firms with R&D expenditures more than $100 million. We use the same models and regressions as in part 4.1, 4.2 and 4.3.

4.4.1 Model 1 - Returns

When we look at the whole sample (see Table 2), R&D capital to sales and R&D to market value are statistically significant at the 10% and 1% level respectively but pulling in two different directions. R&D capital to sales has a negative effect on returns while R&D to market value has a positive effect on returns. Market value is statistically significant the 1% level with a negative effect on returns when we control for R&D capital to sales and R&D intensity. However, book to market value is statistically significant at the 10% level and 5% level with a negative effect on returns when controlling for R&D capital to sales and R&D intensity.

For firms with less than $100 million in R&D expenditures (see Table 5), R&D capital to sales, R&D intensity and R&D to market value are not statistically significant. Market value is statistically significant at the 5% level with a negative effect only when we control for R&D capital to sales and R&D intensity. Book to market value is statistically significant when we control for R&D capital to sales, R&D intensity and R&D to market value with a negative effect on returns at the 1%, 1% and 5% level respectively.

For firms with more than $100 million in R&D expenditures (see Table 6), only R&D to market value is statistically significant at the 5% level with a positive effect on returns. Market value still has a negative effect on returns and is significant at the 5% level only when we control for R&D capital to sales and R&D intensity. Book to market value is not statistically significant for these firms.

R&D capital to sales has a negative effect on stock returns, but R&D to market value has a positive effect on returns.

For firms with less than $100 million in R&D expenditures, no effect of R&D on returns is observed. Although for firms with more than $100 million in R&D expenditures, R&D to market value appears to have a positive effect on stock returns.

Table 5 – Regressions Results

<100	**FE (1)**	**RE (2)**	**FE (3)**	**RE (4)**	**FE (5)**	**RE (6)**
Dep. Var.	**Returns**	**Returns**	**Returns**	**Returns**	**Returns**	**Returns**
Intercept	11.5652**	12.2711***	11.7863**	14.2270***	11.4433**	10.1761***
	(4.7774)	*(2.5167)*	*(5.1121)*	*(2.6343)*	*(4.7888)*	*(2.6631)*
lnRDC/SALES	0.8114	-0.4630				
	(0.6767)	*(0.2975)*				
lnRDI			-0.0092	-0.5810**		
			(0.4972)	*(0.2864)*		
lnRD/MV					-0.0318	-1.0085*
					(1.0730)	*(0.5330)*
lnMV	-1.4941**	-1.6622***	-1.5521**	-1.6418***	-1.5245	-1.7925***
	(0.7303)	*(0.3489)*	*(0.7077)*	*(0.3431)*	*(0.9897)*	*(0.3713)*
BMV	-4.0374***	-5.0132***	-4.1173***	-4.8918***	-3.4576**	-4.4739***
	(1.5628)	*(1.2574)*	*(1.5364)*	*(1.2335)*	*(1.5590)*	*(1.2524)*
VOL	-0.0101	-0.0070	-0.0091	-0.0074	-0.0127	-0.0104
	(0.0211)	*(0.0146)*	*(0.0207)*	*(0.0142)*	*(0.0210)*	*(0.0144)*
IntA/MV	5.1254**	4.4433**	5.1383**	4.2207**	4.9171*	4.9290**
	(2.5324)	*(1.9859)*	*(2.5094)*	*(1.9684)*	*(2.5252)*	*(1.9530)*
ROE	-0.0030	-0.0010	-0.0030	-0.0011	-0.0030	-0.0012
	(0.0025)	*(0.0022)*	*(0.0024)*	*(0.0021)*	*(0.0025)*	*(0.0022)*
ROA	0.0226***	0.0108**	0.0215***	0.0106**	0.0206***	0.0112**
	(0.0073)	*(0.0049)*	*(0.0072)*	*(0.0048)*	*(0.0073)*	*(0.0050)*
Number of obs.	873	873	873	873	856	856
F statistics	3.03		2.86		2.45	
R-sq	0.113	0.286	0.111	0.293	0.11	0.25
Hausman		8.81		6.33		5.01
(p value)		*(0.2665)*		*(0.5022)*		*(0.6588)*

Table 6 – Regressions Results

>100 Dep. Var.	**FE (1)** **Returns**	**RE (2)** **Returns**	**FE (3)** **Returns**	**RE (4)** **Returns**	**FE (5)** **Returns**	**RE (6)** **Returns**
Intercept	8.2723**	1.7063*	8.0254**	2.7887**	5.1161	1.4313
	(3.4141)	*(0.9857)*	*(3.5329)*	*(1.1281)*	*(3.5888)*	*(1.0752)*
lnRDC/SALES	0.2069	-0.2849*				
	(0.4118)	*(0.1716)*				
lnRDI			-0.0506	-0.2844*		
			(0.3281)	*(0.1668)*		
lnRD/MV					1.1011**	0.0890
					(0.5279)	*(0.1063)*
lnMV	-0.8269**	-0.1845*	-0.8028**	-0.1899*	-0.3000	-0.1324
	(0.3415)	*(0.1028)*	*(0.3385)*	*(0.1021)*	*(0.4161)*	*(0.1160)*
BMV	-0.3601	-0.9360	-0.1883	-0.9723	-1.3508	-0.1016
	(1.9276)	*(0.9987)*	*(1.9055)*	*(1.0004)*	*(1.9707)*	*(1.0235)*
VOL	-0.0082	0.0017	-0.0091	0.0027	-0.0065	0.0025
	(0.0195)	*(0.0087)*	*(0.0193)*	*(0.0088)*	*(0.0193)*	*(0.0093)*
IntA/MV	0.0043	0.0213***	0.0043	0.0215***	0.0025	0.0227***
	(0.0057)	*(0.0044)*	*(0.0057)*	*(0.0044)*	*(0.0057)*	*(0.0044)*
ROE	-0.0022	-0.0019	-0.0020	-0.0020	-0.0034	0.0003
	(0.0086)	*(0.0066)*	*(0.0086)*	*(0.0065)*	*(0.0086)*	*(0.0067)*
ROA	0.0115	0.0057	0.0064	0.0081	0.0129	0.0093
	(0.0266)	*(0.0187)*	*(0.0244)*	*(0.0173)*	*(0.0242)*	*(0.0179)*
Number of obs.	543	543	545	545	545	545
F statistics	1.13		1.10		1.71	
R-sq	0.1273	0.8367	0.1267	0.8346	0.1343	0.8134
Hausman		24.19		23.85		31.85
(p value)		*(0.0011)*		*(0.0012)*		*(0.0000)*

4.4.2 Model 2 - Price

In this model we perform the robustness check for the effect of R&D on stock price. Considering our whole sample (see Table 3), we observe that R&D capital to sales and R&D to market value are statistically significant 1% and 5% level respectively. Market value is statistically significant 1% level with a positive effect on price, while book to market value is statistically significant 5% level with a positive effect on price.

For firms with less than $100 million in R&D expenditures (see Table 7), only R&D capital to sales is statistically significant at 1% level with a negative effect. The results for market value and book to market value are the same as for the entire sample.

For firms with more than $100 million in R&D expenditures (see Table 8), R&D capital to sales is significant at 1% level but with a positive effect on price. R&D intensity is statistically significant at the 1% with a positive effect on price. R&D to market value is not statistically significant whereas market value is statistically significant at 1% level with a positive effect on price similar to the total sample. Book to market value is only significant when we control for R&D capital to sales at the 5% level with a negative effect on price.

R&D expenditures have a negative effect on stock price, and this effect is maintained for firms with less than $100 million in R&D expenditures, however for firms with more than $100 million in R&D expenditures there is a positive effect of R&D on stock price.

Table 7 – Regressions results

<100 **Dep. Var.**	**FE (1)** **Price**	**RE (2)** **Price**	**FE (3)** **Price**	**RE (4)** **Price**	**FE (5)** **Price**	**RE (6)** **Price**
Intercept	-2.1355***	-2.0058***	-2.1778***	-2.0748***	-2.1236***	-1.9900***
	(0.1452)	*(0.1687)*	*(0.1599)*	*(0.1792)*	*(0.1471)*	*(0.1688)*
lnRDC/SALES	-0.1086***	-0.0755***				
	(0.0205)	*(0.0197)*				
lnRDI			0.0179	0.0268*		
			(0.0155)	*(0.0153)*		
lnRD/MV					-0.0497	-0.0735**
					(0.0330)	*(0.0312)*
lnMV	0.7350***	0.7085***	0.7364***	0.7081***	0.7146***	0.6736***
	(0.0222)	*(0.0216)*	*(0.0221)*	*(0.0214)*	*(0.0304)*	*(0.0278)*
BMV	0.1267***	0.1514***	0.1349***	0.1522***	0.1124**	0.1319***
	(0.0475)	*(0.0485)*	*(0.0481)*	*(0.0487)*	*(0.0479)*	*(0.0485)*
VOL	-0.0024***	-0.0020***	-0.0026***	-0.0023***	-0.0025***	-0.0021***
	(0.0006)	*(0.0006)*	*(0.0006)*	*(0.0006)*	*(0.0006)*	*(0.0006)*
IntA/MV	-0.2068***	-0.2812***	-0.2079***	-0.2727***	-0.1929**	-0.2609***
	(0.0770)	*(0.0788)*	*(0.0785)*	*(0.0797)*	*(0.0776)*	*(0.0787)*
ROE	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001
	(0.0001)	*(0.0001)*	*(0.0001)*	*(0.0001)*	*(0.0001)*	*(0.0001)*
ROA	-0.0007***	-0.0008***	-0.0005**	-0.0006***	-0.0005***	-0.0006***
	(0.0002)	*(0.0002)*	*(0.0002)*	*(0.0002)*	*(0.0002)*	*(0.0002)*
Number of obs.	862	862	874	874	857	857
F statistics	230.11		224.35		224.35	
R-sq	0.8871	0.67	0.8823	0.6597	0.8825	0.6684
Hausman		94.38		45.88		38.87
(p value)		*(0.0000)*		*(0.0000)*		*(0.0000)*

Table 8 – Regressions Results

>100 **Dep. Var.**	**FE (1)** **Price**	**RE (2)** **Price**	**FE (3)** **Price**	**RE (4)** **Price**	**FE (5)** **Price**	**RE (6)** **Price**
Intercept	-3.9862***	-3.4863***	-4.3388***	-3.9245***	-4.0890***	-3.4111***
	(0.2001)	*(0.2401)*	*(0.2102)*	*(0.2531)*	*(0.2166)*	*(0.2549)*
lnRDC/SALES	0.0858***	0.1197***				
	(0.0241)	*(0.0261)*				
lnRDI			0.0610***	0.0742***		
			(0.0195)	*(0.0216)*		
lnRD/MV					-0.0101	-0.0819***
					(0.0318)	*(0.0299)*
lnMV	0.7767***	0.7258***	0.7902***	0.7409***	0.7799***	0.6941***
	(0.0200)	*(0.0211)*	*(0.0201)*	*(0.0214)*	*(0.0251)*	*(0.0256)*
BMV	-0.2223**	-0.2258*	-0.1858	-0.1754	-0.1532	-0.0883
	(0.1129)	*(0.1243)*	*(0.1134)*	*(0.1255)*	*(0.1189)*	*(0.1284)*
VOL	0.0001	0.0001	-0.0005	-0.0007	-0.0004	-0.0009
	(0.0011)	*(0.0012)*	*(0.0011)*	*(0.0012)*	*(0.0011)*	*(0.0012)*
IntA/MV	0.0038***	0.0034***	0.0038***	0.0034***	0.0038***	0.0035***
	(0.0003)	*(0.0003)*	*(0.0003)*	*(0.0003)*	*(0.0003)*	*(0.0003)*
ROE	-0.0004	-0.0006	-0.0003	-0.0005	-0.0003	-0.0004
	(0.0005)	*(0.0005)*	*(0.0005)*	*(0.0005)*	*(0.0005)*	*(0.0005)*
ROA	0.0054***	0.0057***	0.0044***	0.0043***	0.0036**	0.0030*
	(0.0015)	*(0.0017)*	*(0.0014)*	*(0.0016)*	*(0.0014)*	*(0.0016)*
Number of obs.	543	543	545	545	545	545
F statistics	282.05		274.23		262.70	
R-sq	0.9748	0.7989	0.9744	0.7984	0.9739	0.7861
Hausman		33.84		53.56		40.85
(p value)		(0.0000)		(0.0000)		(0.0000)

4.4.3 Model 3 - Volatility

In this last model the robustness check will be performed regarding the effect of R&D on stock volatility. Firms with less than $100 million in R&D expenditures (see Table 9), have the same results as the total sample. Meaning that R&D capital to sales, R&D intensity and R&D to market value are not statistically significant. However market value and book to market value are statistically significant at the 1% level and have a negative effect on volatility. For firms with more than $100 million in R&D expenditures (see Table 10), only R&D capital to sales seems to be statistically significant at the 5% level with a negative effect on volatility. Market value is statistically significant at the 1% level with a negative effect on volatility, whereas book to market value is not significant.

R&D expenditures have no effect on stock volatility. Although it seems for firms with more than $100 million in R&D expenditures, R&D capital to sales has a negative effect on volatility.

Table 9 – Regressions Results

<100	FE (1)	RE (2)	FE (3)	RE (4)	FE (5)	RE (6)
Dep. Var.	**Volatility**	**Volatility**	**Volatility**	**Volatility**	**Volatility**	**Volatility**
Intercept	132.0056***	123.1796***	135.0626***	123.0234***	130.5945***	124.4348***
	(6.5154)	*(6.3359)*	*(7.2639)*	*(7.0469)*	*(6.6513)*	*(6.3249)*
lnRDC/SALES	0.9983	2.4564***				
	(1.1428)	*(0.9473)*				
lnRDI			-0.7106	0.4782		
			(0.8491)	*(0.7811)*		
lnRD/MV					2.0156	3.8971***
					(1.8275)	*(1.5154)*
lnMV	-12.9925***	-11.5213***	-13.0254***	-11.7451***	-11.7502***	-9.8068***
	(1.1392)	*(0.9886)*	*(1.1127)*	*(0.9746)*	*(1.6320)*	*(1.2474)*
BMV	-8.5209***	-6.0699**	-9.0001***	-6.6554***	-8.3044***	-6.0853**
	(2.6243)	*(2.5791)*	*(2.6053)*	*(2.5715)*	*(2.6410)*	*(2.5957)*
IntA/MV	8.7643**	7.8948*	8.9422**	7.8666*	8.9594**	7.4131*
	(4.2695)	*(4.1983)*	*(4.2754)*	*(4.2223)*	*(4.2928)*	*(4.2193)*
ROE	-0.0072*	-0.0066	-0.0074*	-0.0068	-0.0072*	-0.0062
	(0.0042)	*(0.0042)*	*(0.0042)*	*(0.0042)*	*(0.0042)*	*(0.0042)*
ROA	-0.0103	-0.0183	-0.0126	-0.0198*	-0.0098	-0.0212*
	(0.0124)	*(0.0116)*	*(0.0124)*	*(0.0116)*	*(0.0124)*	*(0.0116)*
Number of obs.	863	863	875	875	858	858
F statistics	28.13		28.02		27.77	
R-sq	0.6417	0.2658	0.6411	0.2282	0.6418	0.2444
Hausman		26.48		54.83		47.87
(p value)		*(0.0000)*		*(0.0000)*		*(0.0000)*

Table 10 – Regressions Results

>100 **Dep. Var.**	**FE (1)** **Volatility**	**RE (2)** **Volatility**	**FE (3)** **Volatility**	**RE (4)** **Volatility**	**FE (5)** **Volatility**	**RE (6)** **Volatility**
Intercept	62.0828***	53.9481***	64.6399***	51.9439***	72.1326***	63.2714***
	(7.3815)	*(6.8378)*	*(7.6819)*	*(7.2980)*	*(7.6949)*	*(6.6878)*
lnRDC/SALES	-2.3277**	-1.6556*				
	(0.9467)	*(0.8855)*				
lnRDI			0.5472	1.0041		
			(0.7625)	*(0.7436)*		
lnRD/MV					-1.8673	-3.6307***
					(1.2259)	*(0.7780)*
lnMV	-4.5938***	-3.7708***	-4.8502***	-3.7393***	-5.8568***	-5.3073***
	(0.7620)	*(0.6705)*	*(0.7564)*	*(0.6698)*	*(0.9319)*	*(0.7274)*
BMV	6.4378	11.5154***	4.6590	10.9559**	6.7749	12.7284***
	(4.4483)	*(4.3255)*	*(4.4252)*	*(4.3157)*	*(4.5764)*	*(4.2473)*
IntA/MV	-0.0198	-0.0206	-0.0196	-0.0186	-0.0171	-0.0103
	(0.0132)	*(0.0135)*	*(0.0132)*	*(0.0135)*	*(0.0133)*	*(0.0135)*
ROE	0.0265	0.0116	0.0243	0.0099	0.0253	0.0102
	(0.0200)	*(0.0205)*	*(0.0200)*	*(0.0204)*	*(0.0200)*	*(0.0203)*
ROA	-0.0718	-0.0546	-0.0163	-0.0015	-0.0320	-0.0202
	(0.0614)	*(0.0626)*	*(0.0569)*	*(0.0581)*	*(0.0563)*	*(0.0568)*
Number of obs.	543	543	545	545	545	545
F statistics	9.74		8.73		9.34	
R-sq	0.8683	0.1005	0.8571	0.0886	0.8576	0.0912
Hausman		89.38		166.70		122.60
(p value)		*(0.0000)*		*(0.0000)*		*(0.0000)*

5. Discussion and Conclusions

Previous studies have shown that R&D is an important factor that influences returns, prices, stock volatility and also the firm value in general. This study examines how R&D intensive firms in the pharmaceutical and biotechnological industry in the US are valued by the stock market using panel data. The main objective is to study the effect of R&D expenditures on stock returns, price and volatility. Unlike other studies, we observe the relationship of returns, price and volatility with R&D expenditures at the same time. Our three hypotheses to verify are: R&D expenditures are linked with significant positive stock returns; R&D expenditures have a positive effect on stock price; R&D expenditures and volatility are positively linked. We expect to observe a positive significant relationship between R&D and our dependant variables. We run panel data regressions on the returns, price and volatility model and we make a robustness check by dividing our sample into two groups based on their R&D expenditures.

We fail to reject the first hypothesis stating a positive effect of R&D expenditures on stock returns. The results show that R&D to market value has a positive effect on returns and supports previous findings by Lev and Sougiannis (1996); Chan et al. (2001); Chambers et al. (2002). However, we receive contradicting results for R&D capital to sales, which show a negative significant effect on stock returns. A possible explanation could be huge amounts of spending in R&D projects, which result in being unsuccessful and therefore effecting returns negatively. The R&D to market effect is stronger for firms with more than $100 million in R&D expenditures. Firms with more than $100 million in R&D expenditures have a higher ratio of R&D to market (see Table 11 in appendix). According to Chan et al. (2001) stocks with high R&D to market ratio, tend to be stocks with poor past returns and the market discounts heavily the likelihood of their future recovery by underreacting to managers' signals. Chan et al. (2001) states that managers are willing to maintain R&D spending because they are confident that the future opportunities will improve.
Regarding the effect of R&D intensity on stock returns, we find no evidence to support any significant relationship among these two, which supports previous findings by Chan et al. (2001).

We reject the second hypothesis of R&D expenditures having a positive effect on stock price. The effect of R&D capital to sales and R&D to market value on price is significant and has a negative effect. However, R&D capital to sales and R&D intensity have a positive effect on price for firms with more than $100 million in R&D expenditures. Our findings suggest that if firms spend less than $100 million in R&D expenditures R&D capital to sales has a negative effect on price. According to Franzen and Radhakrishnan (2009) study, R&D expenditures is negatively associated with stock prices for profit firms, and positively with loss firms. The results of Franzen and Radhakrishnan (2009), could be an explanation for the findings above, but further investigation is needed whether we are dealing with profit or loss firms.

We reject the third hypothesis, which states a positive effect of R&D expenditure on stock volatility. R&D expenditures seem to have no significant effect on stock price volatility but when controlling for firms, which spend more than $100 million in R&D expenditures, a significant negative effect of R&D capital to sales on volatility is observed. A possible explanation could be that firms with more than $100 million in R&D expenditures have more diversified drug portfolios. According to Xu (2006): "Firms that have more diversified drug portfolios are associated with lower share price volatilities."

A contribution to the academic literature is the focus on two sectors that are distinguished for the high collaboration between them and they are being ranked first in the R&D expenditures ranking. This allows us to do a more specific search on the effect of R&D expenditures on stock returns, price and volatility. The second contribution is related with the results of our robustness check. It is surprising that by dividing our sample into two groups, less than $100 million in R&D expenditures and more than $100 million in R&D expenditures, the effect of R&D expenditures differs on the variables stock returns, price and volatility. There seems to be a threshold in R&D expenditures, and firms surpassing this threshold experience a positive effect on stock returns and price, and a negative effect on volatility.

Further studies could include the European biotechnology and pharmaceutical sector and observe the differences and similarities between these two markets. We would suggest using the cross sectional approach instead of panel data and see if there exist any differences in valuation methods. An alternative robustness check would be using a different measure of R&D intensity, see Eberhart (2004) where R&D intensity is defined as R&D expenditures to total assets. A final suggestion would be using portfolio analysis, refer to Lev and Sougiannis (1999) where they rank all observations in ten book to market portfolios.

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Appendix

Graph 1 – Share of total pharma R&D of leading pharma R&D countries

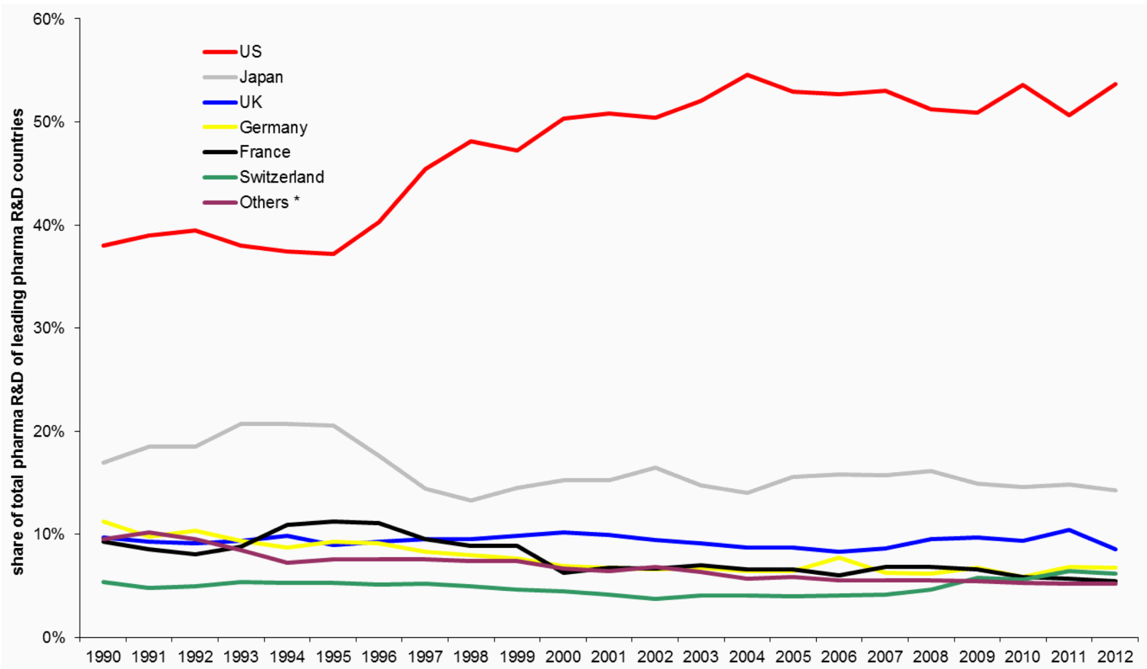

Table 11 – R&D to market value comparison

Variable	Obs	Mean	Std. Dev.	Min	Max
RD/MV <100	924	1.115581	5.341946	0	55.7
RD/MV >100	576	103.7003	794.523	0	15218