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# R&D effects, risks and strategic decisions: evidence from listed firms in R&D-intensive countries

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**Abstract**

**Purpose** – *The purpose of this research is to look at the effects of research and development expenditures (R&D) on value and risks of publicly traded companies by studying returns on stock exchanges of R&D-intensive economies (Republic of Korea, Finland and Israel).*

**Design/methodology/approach** – *Empirical tests of multifactor asset pricing models were applied to demonstrate that R&D intensity could be considered as a pricing factor and affect investors' risk premiums on those markets. To discover the reasons behind the asset pricing R&D anomaly, this study investigated the nature of R&D risk further by looking into the interactions of R&D and currency risks.*

**Findings** – *This study discovered that investors in stock markets of R&D-intensive countries should require a positive equity risk premium. However, the reduction of R&D intensity may increase firms' risks and firms with higher R&D-intensity are less exposed to currency risks in R&D-intensive economies.*

**Originality/value** – *Many researchers have investigated the relationship between a firm's R&D and stock returns. But nearly all of them focus on the US Stock Market and attempt to determine the reasons for R&D's impact on firms' risks and market value. Meanwhile, the role of R&D and related risks for investors could be even more prominent for stock markets in R&D-intensive countries. To bridge this gap, this research studied stock returns on exchanges of three developed countries where the ratio of gross domestic expenditure on R&D (GERD) to GDP is among the highest worldwide. In this study, the methodology of asset pricing empirical studies was adopted and it was further developed to analyze the causes of R&D risks. The new methodology was applied to discover relationship between R&D intensity and currency risk exposure. The interesting findings could be used for development of firms' corporate strategies in those countries and for elaboration of policy decisions.*

**Keywords** *Asset pricing, R&D intensity, Stock returns, Currency risk, R&D anomaly, R&D-intensive countries*

**Paper type** *Research paper*

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## 1. Introduction

R&D impact on the development of a firm was well studied by researchers (Bloom *et al.*, 2013). A comprehensive review of the relevant literature conducted in the OECD (2017) paper showed that markets do not provide enough incentives for firms to invest heavily in R&D because social effects of such investment significantly overweigh private returns. At the same time, broad academic literature mostly exhibits evidence of the significant and mostly positive effect of firms' R&D intensity on stock returns. These controversial conclusions may be justified by different attitudes of investors to R&D risks, as well as drawbacks in implemented R&D strategies.

The risk premium for a higher R&D intensity is called "the R&D anomaly" (Fama and French, 2008) and it has been well studied on the US Stock Market. However, there exists no consensus about the cause of this anomaly. One group of studies is in favor of the mispricing approach (Eberhart *et al.*, 2004; Lev *et al.*, 2005, 2007), which constitutes that

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investors use unappropriated assumptions to estimate the R&D value for the firm. Indeed, according to the IFRS Accounting Framework, R&D expenditures are disclosed in its financial statements as a lump sum that is immediately expensed and rarely covered in detail by management. Such a drawback in accounting and information asymmetry poses a considerable impediment to the firm's investors, who attempt to evaluate its R&D expenditures and try to include the long-term positive effects of R&D into asset prices.

Other studies insist that stock returns should reflect higher risk compensation for R&D investments (Kothari *et al.*, 2002; Chambers *et al.*, 2002; Ho *et al.*, 2004; Saad and Zantout, 2012). They argue that the very nature of R&D makes the whole stock of the firm riskier. From the investor's point of view, intangible investments can bear additional risks (Daniel and Titman, 2006). R&D expenditures put a strain on the firms' retained earnings, which, together with vague return prospects, exposes R&D expenditures as a perilous investment. For example, Lev (2001) stresses that usually only a few R&D projects succeed. Hence, the high level of risky investments in R&D should be awarded by higher stock returns in the case of success in R&D projects.

Despite evidence in favor of the second approach (Leung *et al.*, 2016), we argue that risk compensation cannot be the only factor behind the R&D anomaly and furthermore, we assert that the mispricing approach may prevail. We agree with Anagnostopoulou and Levis (2008) and Kallunki *et al.* (2009) that the investors' attitude toward R&D depends not only on the industrial environment in which the firm operates, but also on the country of its origin. Kallunki and Sahlstrom (2003) use the example of Finland, where the GERD to GDP is among the highest in the world, to show that the stock market's response to R&D investments grows over time in line with the country's rising R&D intensity. Same findings were discovered for Korea (Min and Smyth, 2015), whose economy can also be considered R&D-intensive. Both countries had giant companies, i.e. Nokia in Finland and Samsung in Korea, that dominated their stock markets and invested heavily in R&D targeting global competitive advantages. We may suggest similar trends for Israel's R&D-intensive economy, where, according to Wonglimpiyarat (2016), the high-tech firms perform very well both on the domestic and international stock exchange markets. Korea, Finland and Israel were selected because for the past decade, they have occupied the top of a list that ranks countries according to gross domestic R&D expenditures (GERD) to GDP. According to OECD.stat data, in 2005-2015, GERD to GDP ratios were, on average, equal to 4.18, 3.62 and 3.41 for Israel, the Republic of Korea and Finland, respectively. Israel and the Republic of Korea are usually considered in the literature as (developed) emerging economies (Switzer and Picard, 2015), but given the recent strong STI performance, a large share of hi-tech sectors in their economies and friendly environment for foreign investments, all three countries, including Finland, may have many common characteristics.

We believe that in the considered countries, investors are not necessarily disturbed by higher levels of R&D at a firm and therefore do not always consider such a firm riskier. On the contrary, we suggest that active firm-level R&D investments in those countries benefit the long-term strategies and make their products and services more competitive on global markets (Nam and An, 2017) and decrease some firm's risks from an investor's point of view. We checked this hypothesis by studying the firms' exposure to systematic risks for stocks on the Korean, Finnish and Israeli markets. Keeping in mind that exchange rate fluctuations are much more important for company performance and more closely related to stock market volatility in emerging economies (Cho *et al.*, 2016), we may use currency risk exposure as a proxy for systematic risk.

The rest of the paper is organized as follows. We present a literature review of R&D's impact on stock returns and present the pricing model. Following in the footsteps of Lev and Sougiannis (1996), Chan *et al.* (2001), Eberhart *et al.* (2002), Hirshleifer *et al.* (2013) and Gu (2016), we compare different approaches to formulation of R&D-intensity pricing factors and introduce several new ones for estimating R&D-intensity risk premium. We utilize an asset pricing multifactor model and the two-step procedure of Fama and Macbeth (1973) as an approach to calculating R&D factor risk premium. To support our hypothesis that in R&D-intensive countries, investors might not require risk compensation for R&D investments, we tested R&D's relationship with systematic risks by looking closer at firms' currency risk exposure. Finally, we provide some conclusions and implications for corporate strategies.

## 2. Literature review and the model

Early studies of the level of R&D intensity and stock markets focus on the US market. Hirschey (1982) finds positive effects of R&D on stock returns. Sougiannis (1994) divides the impact of R&D into indirect and direct effects. The indirect effects impact market value through earnings. For the direct effects, new information from R&D directly affects share prices. According to Sougiannis (1994), the indirect effect is greater than the direct effect, which may support mispricing as the reason behind the R&D anomaly because investors do not necessarily require an additional premium for R&D.

The record of the investigations into the influence of R&D expenditures on a firm's value traces back to the study conducted by Lev and Sougiannis (1996). The authors apply a three-factor model to the sample of US public companies throughout the period 1975-1990 to test whether the discounted sum of the firms' R&D expenditures, which they called "R&D capital", is capable of contributing to a firm's stock return. As the results reveal, there was a significant positive relationship between the firms' R&D expenditures and their value, both in intertemporal and contemporaneous terms.

Another prominent contribution in the field of evaluating the interdependence between a firm's R&D expenditures and a cross section of stock returns is represented by the article published by Chan *et al.* (2001). Over the course of their research, the authors elaborate upon several measurements for a firm's R&D intensity, which arises as a ratio of R&D expenditures to revenue or to a firm's market capitalization. As such, the R&D intensity of the firm is then used collectively with its market capitalization throughout the process of portfolio formation, which is performed in line with the Fama and French (1993) procedure. Using a sample of US public firms for the period from 1975 to 1995, Chan, Lakonishok and Sougiannis discover that while relatively high R&D intensity measured as a ratio of the firm's R&D expenditures to its market capitalization indeed implies relatively high stock returns, this relationship ceases to exist when R&D intensity is measured with a "revenue" denominator.

Similar models are widely used in the literature. Branch and Chichirau (2010) uncovered the presence of a significant positive interconnection between the ratio of the firm's R&D intensity and its stock returns by examining an asset pricing model they constructed for a sample of US public firms. Cohen *et al.* (2013) used a Fama and Macbeth (1973) procedure on a sample of American, German and Japanese public companies to determine the presence of a positive interdependence between the firm's R&D-to-revenue ratio and its equity cost of capital. Hirshleifer *et al.* (2013) used a citations-to-R&D-expenditures ratio as a measure of the quality of such expenditures. The authors then calculated a risk premium corresponding to this factor and succeeded in discovering a significant positive relationship between the quality of the firm's R&D expenditures and its equity cost of capital among US firms. Gu (2016) used a self-constructed model on a sample of US public companies to demonstrate that equity values are prone to be affected by the firm's R&D-to-market capitalization ratio.

To construct the R&D pricing factor, we analyzed relevant studies, looking for different measurements for R&D intensity, their impact on stock prices and uses for asset pricing models. For example, Eberhart *et al.* (2002) use the ratio of R&D expenses to book value of equity or sales, while Shi (2003) uses R&D expenses to market value of equity. According to Eberhart *et al.* (2004), R&D intensity correlates with lower risk premiums and lower default risks. Eberhart *et al.* (2004) argue that Shi's R&D-intensity measurement is over-weighted because it includes the expectations for the value of R&D investments. We will investigate both approaches to R&D pricing.

Based on the contribution of Lev and Sougiannis (1996), Chan *et al.* (2001) and Lev *et al.* (2005), we constructed a measurement for R&D intensity as either the ratio of R&D expenditures to the firm's revenue or to its market capitalization:

$$RDI_{FY_t} = \frac{RD_{FY_t}}{RMC_{FY_t}} \tag{1}$$

where, RMC – firm's revenue or its market capitalization. Here and hereinafter, $FY_t$ denotes that the figures in the numerator and the denominator correspond to the financial year *t*.

Following the mispricing approach, we will investigate the lagging effect of R&D projects in the model, an effect that is not immediately priced by investors. Bublitz and Ettredge's (1989) findings about long-term R&D benefits is supported by Sougiannis (1994), who discovered that R&D benefits last for seven years. Lev *et al.* (2007) assumed that R&D benefits remain tangible for one to eight years. They note that the useful lifetime of R&D capital varies across industries. Contrary to Lev and Sougiannis (1996) and Amir *et al.* (2007), they suggest that the capitalization and amortization of R&D would improve the informational value of financial statements in some industries. According to Lev *et al.* (2007), in those industries, stock markets systematically undervalue R&D investments. Ciftci *et al.* (2009) study R&D-intensive companies' excess returns, dividing companies by industry-adjusted R&D intensity. They show that firms with high industry-adjusted R&D intensity have excess returns at levels that converge with the excess returns of low R&D-intensity firms after five years. They suggest that this reversal of returns is a consequence of mispricing.

Moving from the industry-level to the country-level perspective, we assert that R&D effects should be reflected in stock prices more rapidly in R&D-intensive economies. Accounting for the accumulated R&D effects (as in Sougiannis, 1994) in addition to the R&D-intensity variables [equation (1)], this paper uses three- and two-year moving averages of R&D intensities, which are calculated as follows:

$$\begin{cases} MA(RDI,3)_{FY_t} = \dfrac{1}{3}\displaystyle\sum_{i=0}^{2}\dfrac{RD_{FY_{t-i}}}{RMC_{FY_{t-i}}} & (2) \\ MA(RDI,2)_{FY_t} = \dfrac{1}{2}\displaystyle\sum_{i=0}^{2}\dfrac{RD_{FY_{t-i}}}{RMC_{FY_{t-i}}} & (3) \end{cases}$$

According to accounting standards applied to R&D investments (they are fully spent), earnings may drop after sharp increase in R&D, which may affect stock prices. Eberhart *et al.* (2004) study significant R&D increases. They use a multifactor pricing model to show positive abnormal risk-adjusted returns for a five-year period after the rise in R&D. Lev *et al.* (2005) introduce an R&D expenditures growth measure as the ratio of a firm's R&D expenditures in a given year to its R&D in the preceding year. The authors then examine the relationship between the growth of a firm's R&D expenditures and its equity cost of capital using their own model on a sample of US public firms. As Lev *et al.* discovered, the relative sharpness of a firm's increase in R&D expenditures tends to cause relatively high stock returns as compared to that firm's peers. Ali *et al.* (2012) further show that returns on rising R&D are concentrated in the subsequent earnings statements. The finding suggests that abnormal returns are at least partly due to mispricing, because returns on risk should not be concentrated heavily on the announcement dates (Ali *et al.*, 2012). On the contrary, according to Chan *et al.* (2010) and Saad and Zantout (2012), negative abnormal returns result from a company's aggressive risk-taking in excessive R&D investments and its failure to control the risks. The overinvestment hypothesis states that companies overinvest in tangible and intangible assets when they are in a good financial position.

The controversial conclusions of previous studies regarding R&D growth effects pushed us to analyze these effects in R&D-intensive countries. Keeping in mind the lagging impact of R&D, we use the following growth rates of a firm's R&D-intensity:

$$\begin{cases} RDI\ Growth_{FY_t} = \dfrac{\left(\dfrac{RD_{FY_t}}{RMC_{FY_t}}\right)}{\left(\dfrac{RD_{FY_{t-1}}}{RMC_{FY_{t-1}}}\right)} & (4) \\ RDI\ Growth_{FY_t} = \dfrac{\left(\dfrac{RD_{FY_t}}{RMC_{FY_t}}\right)}{\left(\dfrac{1}{2}\sum_{i=1}^{2}\dfrac{RD_{FY_{t-i}}}{RMC_{FY_{t-i}}}\right)} & (5) \end{cases}$$

Using the above R&D-intensity measurements [equations (1)-(5)], we follow the Fama and French (1993) procedure with Newey and West (1987) statistics and construct the stock portfolios formed annually on June 30. First of all, the stocks in the sample are ordered according to their market capitalization as of June 30 of the reporting year and divided them into five quintiles according to their market capitalization, which is represented in a ranking that ranges from "Big" (the first quintile) to "Small" firms (the last quintile). After that, within each of the five quintiles, the stocks are re-ordered based on the value of a given R&D intensity measurement for a firm and again create five quintiles, ranging from "High" (firms with the highest R&D intensity in comparison to their peers) to "Low" (firms with the lowest R&D intensity). As a result of the procedure, which reiterates every year, the sample is distributed across 25 (5 × 5) portfolios, whose returns, for a given R&D intensity measurement, are calculated either as value-weighted or equal-weighted returns on the studied stocks:

$$\begin{cases} R_{ik}^{equal-weighted=\frac{1}{N}\sum_{j=1}^{N} r_{jk}} \\ R_{ik}^{value-weighted} = \dfrac{\sum_{j=1}^{N} r_{jk} \ * \ Market\ Cap_j}{\sum_{j=1}^{N} Market\ Cap_j} \end{cases}$$

Where $R_{ik}$ represents the return on portfolio $i$ during month $k$, while $r_{jk}$ is the logarithmic return on stock $j$ in that portfolio during the same month, calculated as:

$$r_{jk} = \ln\left(\frac{P_{j,k}}{P_{j,k-1}}\right),$$

Where $P_{j,k}$ and $P_{j,k-1}$ act as the price for stock $j$ at the end of month $k$ and at the end of the preceding month, respectively.

Approaches to designing an asset pricing model that could be tested on stock returns from multiple countries were covered by Cochrane (2005) and Pereiro (2002). As the authors set forth, the choice of a suitable alternative capital asset pricing model (CAPM) was determined by the extent to which the stock markets of the countries under consideration were integrated in the global market. For instance, for developed countries with unrestricted access to stock markets, the global CAPM (O'Brien, 1999, Stulz, 1999, Schramm and Wang, 1999) is among the most appropriate ones, while for those with lower level of integration and higher inherent volatility, hybrid CAPM (Godfrey and Espinosa, 1996) and local CAPM (Harvey, 1995) are more fitting. In cases of Korea, Finland and

Israel, the domestic stock exchanges are very well integrated into global capital markets. Most high-tech stocks on these three markets are listed on both domestic and global (NASDAQ or others) exchanges. That is why, global indexes denominated in US dollars may serve as a good proxy for market portfolios without an additional volatility adjustment.

Hence, the returns on the portfolios are plugged into the amended global version of the three-factor model:

$$R_{ik} - r_{fk} = \beta_{im} * (E(R_{mk}) - r_{fk}) + \beta_{iSMB} * SMB_k + \beta_{iHMLRD} * HMLRD_k \tag{6}$$

where $r_{fk}$ is the return on the risk-free asset throughout the month $k$; $E(R_{mk})$, $SMB_k$ and $HMLRD_k$ are the returns on the corresponding risk factors during the same period; and $\beta_{im}$, $\beta_{iSMB}$ and $\beta_{iHMLRD}$ are the slopes in the time-series regression. $r_{fk}$ and $E(R_{mk})$ represent the risk-free rate and returns on the market portfolio. The return for the "small minus big" risk factor (SMB), which corresponds to the size of the firm, during the month $k$, $SMB_k$, is either derived from the Fama and French scientific database or calculated by the authors themselves in a manner described later in the text. Finally, $HMLRD_k$, "high minus low R&D-intensity", indicates the return on the risk factor compensating for the high (in comparison with peer companies) R&D-intensity of the firm.

The returns on the "small minus big" (in the cases where the returns delivered by the Fama and French database are not used) and the "high minus low R&D-intensity" risk factors are computed as follows. In line with the 25-portfolio-formation procedure, each year, the stocks in the sample are ordered according to their market capitalization as of June 30 of the studied year, although at this stage, they are divided into two groups: those with market capitalization higher than the median form the "big" set, while those whose market capitalization is lower than the median constitute the "small" one. Then, within each group, the stocks are re-ordered based on the value of the same measurement for R&D intensity that was used in the 25-portfolio-formation procedure. After that, stocks are divided into three groups with an equal number of companies in each, which range from "High" (firms with the highest R&D intensity in comparison with their peers) to "Low" (firms with the lowest R&D intensity). This procedure (Table I), which is repeated every year, yields the returns (either equal-weighted or value-weighted) on the six portfolios (2 × 3).

These are then used in calculating the returns on the factor-mimicking portfolio $SMB_k$, as well as on $HMLRD_k$:

$$\begin{cases} SMB_k = \frac{1}{2}((SH_k - BH_k) + (SL_k - BL_k)) \\ HMLRD_k = \frac{1}{2}((BL_k - BH_k) + (SL_k - SH_k)) \end{cases} \tag{7}$$

where $k$ denotes the period (month) for the given value of the realized return.

Having calculated the returns on each of the 25 portfolios for the selected R&D-intensity measurement, along with the returns on $SMB_k$ and $HMLRD_k$ and following Wu (2008), Li (2011), Hirshleifer *et al.* (2013), Cohen *et al.* (2013) and Gu (2016), we use the model (6) in the first stage of the Fama and MacBeth (1973) procedure.

The calculation of the risk premiums is conducted in two steps. First, the time series of the returns on the 25 portfolios are regressed against the returns on factor-mimicking portfolios and against excess market return to yield betas, or the slopes in the time series regression. In our case, the first stage is represented by the following equation:

**Table I** The six-portfolio-formation procedure

| *Size group* | *High (H)* | *R&D-intensity group*<br>*Medium (M)* | *Low (L)* |
|---|---|---|---|
| Big (B) | BH | BM | BL |
| Small (S) | SH | SM | SL |

$$\widehat{R_{i,k}} = \widehat{\alpha_i} + \widehat{\beta_{im}} * E(\widehat{R}_{m,k}) + \beta_{\widehat{iSMB}} * SMB_k + \beta_{\widehat{iHMLRD}} * HMLRD_k + \varepsilon_{i,k} \tag{8}$$

Where $i$ moves from 1 to 25, $k$ moves from 1 to $T$ (the number of available periods for a given R&D-intensity measurement), $\widehat{R_{i,k}}$ and $E(\widehat{R}_{m,k})$ stand for realized excess return on portfolio $i$ or the realized excess return on the market portfolio during month $k$, respectively and the dots denote equations omitted for the sake of space. The betas obtained as a result of the first stage of the procedure (8) are then used in the second step, which includes $T$ cross-section regressions. These are constructed as presented below:

$$\widehat{R_{i,k}} = \widehat{\alpha_i} + \widehat{\beta_{im}} * E(\widehat{\widehat{R}_{m,T}}) + \beta_{\widehat{iSMB}} * \widehat{SMB_T} + \beta_{\widehat{iHMLDR}} * \widehat{HMLRD_T} + \varepsilon_{i,T} \tag{9}$$

The second stage of the Fama and MacBeth procedure produced estimates for each of the factor loadings $E(\widehat{\widehat{R}_{m,k}})$, $\widehat{SMB}_k$ and $\widehat{HMLRD}_k$. Computing the respective arithmetic averages and $t$-statistics was then quite straightforward:

$$\begin{cases} \widehat{Mrkt} = \dfrac{1}{T}\sum_{t=1}^{T} E\left(\widehat{\widehat{R}_{m,t}}\right),\ t = \dfrac{\widehat{Mrkt}}{\dfrac{\sigma_{\widehat{Mrkt}}}{\sqrt{T}}} \sim t_{T-1} \\ \widehat{SMB} = \dfrac{1}{T}\sum_{t=1}^{T} \widehat{SMB}_t,\ t_{\widehat{SMB}} = \dfrac{\widehat{SMB}}{\dfrac{\sigma_{\widehat{SMB}}}{\sqrt{T}}} \sim t_{T-1} \\ \widehat{HMLRD} = \dfrac{1}{T}\sum_{t=1}^{T} \widehat{HMLRD}_t,\ t_{\widehat{HMLRD}} = \dfrac{\gamma_{\widehat{SMB}}}{\dfrac{\sigma_{\widehat{HMLRD}}}{\sqrt{T}}} \sim t_{T-1} \end{cases} \tag{10}$$

Those estimates allowed us to calculate the risk premium for each of the considered R&D-intensity factors.

## 3. R&D risk premiums

The sample for our empirical analysis was retrieved from the Thomson Reuters Datastream portal and initially consisted of approximately 2,300 public firms whose shares are traded on the Korean Exchange, Helsinki Stock Exchange or Tel Aviv Stock Exchange during the period from 2002 to 2016. The sample includes the revenue and R&D expenditures of the firms, their market capitalization as of year-end and as of June 30 for each year and the stock prices as of the end of each month throughout the period under consideration. At this stage, all missing values are omitted, while zeros (i.e. in the case where a firm does report R&D expenditures, although equal to zero) remain in the sample. All figures are denominated in US dollars. To participate in the portfolio formation process and thus contribute to its return in a given year, a firm must meet a number of conditions. Namely, it is necessary for the firm to exhibit market capitalization as of June 30 of the studied year and annual revenue for the previous financial year of over US$1m. In addition, its book value of equity may not fall below zero and its R&D expenditures for the previous financial year (or, alternatively, for several of the latest financial years, depending on the selected R&D-intensity measurement) should be reported, i.e. companies with missing values are omitted. Finally, stocks with extraordinarily high or low monthly returns (as compared to their peers) are excluded following the winsorizing procedure. The market portfolio, risk-free rate and SMB portfolio returns for the model were provided by the Fama and French database[1].

Table II contains information about the estimates of factor loadings produced by the Fama and MacBeth procedure with ten choices of the used R&D-intensity measurements. The two columns represent the different values produced by the value-weighted and equal-weighted approaches to portfolio formation.

**Table II** The premium (discount) for R&D pricing factors

| *R&D-intensity measure* | *Equal-weighted (%)* | *Value-weighted (%)* |
|---|---|---|
| R&D/TR | 2.64** | 1.38 |
| Mov. Avg. (R&D/TR, 3 years) | −1.20 | 0.36 |
| Mov. Avg. (R&D/TR, 2 years) | 1.37 | 2.02 |
| Growth (R&D/TR) | −5.02*** | −4.83** |
| Growth (R&D/TR, Mov. Avg.) | −7.39*** | −6.51*** |
| R&D/MC | −1.17 | −1.68 |
| Mov. Avg. (R&D/MC, 3 years) | −2.33 | −0.37 |
| Mov. Avg. (R&D/MC, 2 years) | −0.73 | −1.11 |
| Growth (R&D/MC) | −0.81 | −0.34 |
| Growth (R&D/MC, Mov. Avg.) | −2.15 | −0.50 |

**Note:** *, **, *** is significant at 10, 5 and 1% levels, respectively

The results of the empirical tests confirm the existence of a significant positive premium for the pricing factor that was constructed based on the ratio of firm R&D expenditures to firm revenue. In our case, the respective risk premium for an equally-weighted portfolio accounts for 2.64 per cent in annual terms. The finding is in line with the results of previous research conducted by Eberhart *et al.* (2004), Branch and Chichirau (2010), Cohen *et al.* (2013) and others, who have also discovered significant positive R&D risk premiums for US and other developed markets.

According to Table II, there should be a significant discount for the growth of R&D intensity. The discount for a relatively steep increase in a firm's R&D expenditures relative to its revenue is 5.02 per cent and 4.83 per cent in annual terms, calculated for the equally or value-weighted portfolio returns, respectively. Moreover, the firm that increases its R&D intensity in comparison to its two-year average more rapidly than its peers is inclined to see an even more drastic decline in its expected returns: more specifically, 7.39 and 6.51 per cent in annual terms, for equal-weighted and value-weighted returns, respectively.

The tests, however, fail to deliver any evidence for the existence of an interdependence between the ratio of firm R&D expenditures to firm market capitalization and its stock returns, while some previous studies succeed in this matter. For instance, Chan *et al.* (2001) and Gu (2016) confirm that firms with a higher R&D expenditures-to-market capitalization ratio encounter a higher required rate of return on equity.

## 4. The impact of R&D on currency risk

To further study the origins of risk premium, we investigated the impact of R&D on systematic risks for each firm. Many studies including those of Ho *et al.* (2004), Chan *et al.* (2001), Kothari *et al.* (2002), Chambers *et al.* (2002) and Amir *et al.* (2007), discovered that R&D intensity is positively related to stock return volatility. They demonstrate that the stocks of R&D-intensive firms have greater systematic risk. According to Ho *et al.* (2004), the higher systematic risk arises from higher business risk, which is determined by the volatility of sales. According to Ho *et al.*, the operational risk of the R&D-intensive companies is also greater. Bah and Dumontier (2001), among other researchers, noted that highly R&D-intensive firms are financially less leveraged. Li (2011) posited that R&D intensity predicts returns only among financially constrained firms. According to Li, financial constraints drive the potential positive stock return from R&D intensity, which supports the risk-related explanation of the R&D anomaly.

We may consider two components of stock volatility: one arises from idiosyncratic risk and the other comes from systematic risk. Ang *et al.* (2006) showed that idiosyncratic volatility has a negative effect on expected returns on the US stock market. Switzer and Picard (2015) developed empirical tests further demonstrating that, on the contrary, on emerging markets, diversifiable (or idiosyncratic) risks may have a positive impact on expected returns. Supporting the mispricing approach, we believe that R&D risk is essentially closer to diversifiable risk, especially on R&D-intensive emerging markets where, despite relatively high transparency, information asymmetry regarding R&D expenses is greater. R&D on those markets may represent an opportunity for a specific company to become more competitive on the market due to its unique advantages. That is why R&D intensity may be negatively related to the systematic risk faced by a firm. To check this hypothesis, we studied the relationship between R&D intensity and currency exposure, which is well-correlated with systematic risk on emerging markets (Cho *et al.*, 2016) and can be considered as its proxy.

We estimate currency risk by investigating the impact of exchange rate fluctuations on stock returns This influence has been well-studied in the literature (Jorion, 1990; Wu, 2008 and others). We developed a two-step procedure to calculate the effect of exchange risk exposure on R&D expenditures to evaluate the relationship between a firm's R&D intensity and its exchange risk.

An estimate of foreign exchange exposure was provided using various model specifications including those with or without a stock market return control variable (Booth and Rotenberg, 1990; Amihud, 1994; Bodnar and Gentry, 1993). We adjusted the approach of Miller and Reuer (1998) by using a coefficient of determination (instead of the *F* test values) as the proxy for exchange rate fluctuation exposure. At the first stage, we followed the simplest model, thus obtaining the regression determinant $R^2$ for each company on all three of the considered markets:

$$\widehat{R_{i,t}} = \widehat{\alpha_{i,t}} + \widehat{\beta_{ExR_t}} * ExR_t + \varepsilon_{i,t}, \quad (11)$$

where $ExR_t$ represents the country currency exchange rate and $R_{i,t}$ the stock return for firm i in period t.

In the second step, we estimated the impact of exchange risk exposure on R&D intensity for each company:

$$Z_i = \widehat{\alpha_i} + \widehat{\beta_i} * \widehat{\overline{RDII_i}} + \varepsilon_i \quad (12)$$

where $Z_i$ is the value of $1 - R^2$ for *i-th* firm and $\widehat{\overline{RDII_i}}$ is average R&D intensity measured in one of the four following ways: *RDI1* represents the firm's R&D expenditures to total sales, *RDI2* is the firm's R&D expenditures to total market capitalization, *RDI3* was calculated determining the ratio of average R&D expenditures to total revenues for each firm in the two previous years and *RDI4* represents two-year growth-moving averages ratios. We considered only those R&D-intensity measures that were able to represent a significant risk premium for expected returns in Table I.

We applied the same data set of stock returns and R&D values as above to test the model [equations (11)-(12)] and derived currency rate returns for each of three markets. The results of the empirical tests (Table III) confirm the existence of a significant negative relationship between the ratio of a firm's R&D expenditures to its revenue and the firm's exchange rate exposure on all three of the considered markets. The higher the R&D

**Table III** R&D intensity is negatively related to exchange rate exposure

| *R&D-intensity measure* | *Korea* | *Israel* | *Finland* |
|---|---|---|---|
| R&D/TR | 0.489* | 0.766** | 0.372* |
| R&D/MC | 0.241 | 0.522 | 0.297 |
| Growth (R&D/TR) | 0.006 | −0.289 | 0.066 |
| Growth (R&D/TR, Mov. Avg.) | 0.002 | −0.321 | 0.062 |

**Notes:** *, **, *** is significant at 10, 5 and 1% levels, respectively; the relationship between average R&D intensity over 10 years and the $1 - R^2$ variable from equation (11) intensity, the lower is the coefficient of determination of regression (11) and hence exchange rate fluctuations cannot explain the volatility of stock returns.

Our findings somewhat support the discoveries of Gavazzoni and Santacreu (2016), who showed that pairs of countries with intensive R&D spillovers possess highly correlated stock market returns and experience lower currency risk exposure. Indeed, all three considered R&D-intensive countries are very well connected to US research institutions and have established extensive collaboration with US R&D firms, which may in turn lead to lower US dollar to domestic currency exchange rate exposure as well.

## 5. Conclusions and implications for firm's strategy

This paper examines the impact of the R&D-related risks on expected stock returns. Using a sample of stock returns from the three most R&D-intensive countries, namely, South Korea, Finland and Israel, we discovered that a firm with a higher ratio of R&D expenditures to its revenue should face a higher required rate of return on its equity which generally supports the evidence from US and other developed markets. At the same time, a reduction in R&D intensity tends to facilitate an even more drastic compensation for risk. We could not discover any long-term effects of R&D investments on a firm's value. Probably this fact could be explained by the short-term R&D effects in the relatively large ICT sectors of South Korea, Finland and Israel.

Looking at origins of R&D risk premiums, we found some evidence in favor of mispricing owing to the very nature of R&D expenditures themselves rather than an indication of investors' cautious attitude toward R&D-generated risks in R&D-intensive countries. Based on significant negative relationship between the ratio of a firm's R&D intensity and the firm's exchange rate exposure, we conclude that R&D risk is not necessary related to systematic risk, which is closely correlated with currency risk exposure in the considered countries. Our findings contradict the well-documented notion of higher systematic risk for R&D-intensive firms on some developed markets, particularly the US market.

Our results can be used for development of an appropriate strategy for a firm in R&D-intensive countries. Building the strategy firm's management should be aware of possible negative short-term effects of R&D activities on risks premiums. At the same time, gradual growth of R&D expenditures will be appreciated by investors. It is important for management to control for R&D intensity and avoid its sharp fluctuations which may cause a drop in a firm's value or discourage risk averse investors in coming months. Finally, an additional incentive for the company to preserve the high level of R&D expenditures may be justified by negative correlation between R&D intensity and the firm's exchange rate exposure. These conclusions cannot be considered as a comprehensive list of recommendations for building corporate strategy but rather they can be used as an input for modelling of firm's future using strategic foresight technics (Vecchiato and Roveda, 2010). For example, according to Vishnevskiy and Karasev (2016), while applying foresight for a firm, it is reasonable to take into account a company's prospects and competitive advantages in R&D. Knowing possible effects of R&D on firm's value, risks and corresponding consequences for stakeholders could help to elaborate optimal strategic decisions.

Other applications of the current study may include policy implications for emerging countries. Currently, the level of R&D intensity for corporate sector is relatively low in such countries compared to USA and OECD. For example, in Russia, the private sector investments in R&D are twice lower than public investments. At the same time, high currency risk and public demand for innovations in Russia may be balanced by increase in R&D spending of private firms according to our findings. This could require some additional incentives from the government stimulating Russian firms to spend more on R&D.

Our research may be improved in several ways. First of all, industry- and country-specific factors should be included in the analysis. Secondly, the R&D reporting and regulation impact in considered countries should be studied. Finally, the obtained R&D effects were discovered on stock markets. Many other considerations regarding R&D impact on firm's globalization, spillovers. Transaction costs and other should be analyzed for development of sound corporate strategy. But such analysis could be provided in future research.

## Note

1. Current Research Returns // Kenneth R. French website, available at: http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html (accessed 10 September 2016).

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