Journal of Business Economics and Management
ISSN 1611-1699 / eISSN 2029-4433
2022 Volume 23 Issue 5: 1234–1256
https://doi.org/10.3846/jbem.2022.17844

FINANCIAL MARKET REACTION TO R&D VOLATILITY IN THE PHARMACEUTICAL INDUSTRY. A MULTI-COUNTRY STUDY

Marilena MIRONIUC [1*], Maria Carmen HUIAN [1], Alina ȚARAN [2], Mihaela CUREA [3]

[1]Department of Accounting, Business Information Systems and Statistics, Faculty of Economics and Business Administration, "Alexandru Ioan Cuza" University of Iasi, Iasi, Romania
[2]Business Administration Department, Faculty of Business and Administrative Sciences, Istanbul Okan University, Istanbul, Turkey
[3]Doctoral School of Economics and Business Administration, "Alexandru Ioan Cuza" University of Iasi, Iasi, Romania

Received 11 February 2022; accepted 29 August 2022

Abstract. Corporate management is often accused of short-term oriented behaviour related to R&D expenditures. This study analyses the influence of R&D volatility and R&D intensity on the market capitalization of pharmaceutical and medical research companies from Europe, considering the institutional context and several firm characteristics. Panel regression estimations on a sample of 217 companies for 2014–2019 indicate that R&D volatility adversely affects market value. The analysis is conducted on the entire sample and on sub-samples determined based on the positive and negative values of the R&D volatility. This differentiates between the continuous and the disrupting effect of R&D activities and the firm's shift between exploratory and exploitative innovations. The positive volatility sub-sample provides consistent evidence of a significant negative influence of the R&D volatility on the market value. For the negative volatility sub-sample, R&D intensity and its interaction with R&D volatility have a significant positive effect, consistent over the alternative estimations. We conclude that the market influence of the R&D expenditure is related to the sign of volatility and depends on the proportion of R&D expenditure, especially when the volatility is negative. Our findings provide valuable insights for managers, investors, analysts, and other stakeholders about the market reaction to R&D volatility.

Keywords: R&D volatility, R&D intensity, market value, positive volatility, negative volatility, corporate management.

JEL Classification: O32, E22, M21.

*Corresponding author. E-mail: *marilena@uaic.ro*

Introduction

Investments in R&D are essential for the competitive position of many firms, and consequently, they are included in a company's strategy for long-term value creation. According to Mozafari (2017), the R&D expenditure should persist over time to develop sustainable competitive advantages, maintain the firm's performance, or avoid high costs of adjusting R&D activity. Justifiably or opportunistically, corporate insiders can significantly change or simply adjust the level of R&D budgets, creating information asymmetry, which influences the share price movement for outside investors. Guo et al. (2021) mention that the level of disclosure of R&D expenditure, the characteristics of R&D activities or specific accounting treatments make the R&D activity a substantial contributor to information asymmetry in the investment and financing process.

Aboody and Lev (2000) perceive R&D expenditure as an important input for the potential profit of high-tech companies but its incomplete disclosure is detrimental to the external investors, affecting their valuation and perspective about the prospects of companies. As many R&D projects are unique to the firms that initiate them, investors cannot compare the information about efficiency and value of R&D expenditure with that of similar projects developed by other firms. In addition, there are no organised markets for R&D, similar to those existing for tangible and financial assets, where trading prices convey important information to outside investors.

The role of R&D activities is to improve the innovation process and its results through the widespread commercialisation of innovation. Looking at the characteristics of research and development activities, Guo et al. (2021) point out that the long-time span for completing investments in R&D does not allow for immediate benefits and increases investors' uncertainty regarding the value added by the R&D projects. The very fine line between successful and failed research projects (Jeny & Moldovan, 2018) increases the risk exposure of investors and managers. R&D expenditure thus inherently causes information asymmetry (Dargenidou et al., 2021) and increases the forecasting error of financial analysts.

Accounting treatments exacerbate the information asymmetries associated with R&D (Aboody & Lev, 2000) by not recognizing internally generated intangible assets and by expensing the costs related to the research phase of internal projects. This determines differences between the level of R&D expenditure invested and the value of intangible assets recognised in the annual financial statements, i.e., understated intangible assets. Thus, external investors may face difficulties and uncertainty in assessing the future benefits of R&D investment (Kothari et al., 2002; Lakhal & Dedaj, 2020). At the same time, accounting treatments specific to R&D expenditure expose corporate insiders to earnings management practices, which in long run affect the value of the company or enhance underestimation of the Initial Public Offering. Knowing that outside investors associate intensive investments with risk and information asymmetry, companies are sending a favourable signal to the foreign market by lowering the IPO.

Hai et al. (2019) link the volatility of R&D expenditure to two distinct innovation strategies (exploratory innovation and exploitative innovation), which compete in terms of corporate resources and create organizational tensions. The exploratory innovation strategy or radical innovation involves the development of new technologies and opportunities, creates new market segments for products/processes (Wang et al., 2022) and targets the future viability of the company. Because it involves exploring new knowledge, using unfamiliar technologies, creating products with unknown demand, substantial technical risk, long time, and high costs for failed experiments (Greve, 2007), exploratory innovation is associated with high R&D expenditures. The exploitative innovation strategy or incremental innovation deepens the knowledge base through a process of streamlining existing technologies and exploiting old certainties in order to maintain competitive advantages (Zhang & Luo, 2020; Greve, 2007). The risks associated with this innovation strategy are low, the time to market the results of innovation and to obtain profit is short, and R&D spending is lower. Companies in leading industries are wavering between exploratory innovation and exploitative innovation, driven by the technological rivalry between incumbents and new entrants (Bustinza et al., 2019), which results in R&D expenditure variation. Hai et al. (2019) assign the name of "positive volatility" to the increase in R&D expenditure due to the transition of companies from exploitative innovation to exploratory innovation. The compression of R&D expenditure resulted from the replacement of the exploratory innovation strategy with the exploitative innovation, reflects the "negative volatility" of R&D expenditure.

Like the volatility of financial instruments, the high volatility of R&D expenditure is unfavourable for investors (Jeny & Moldovan, 2018) because it causes investment risk that increases investors' probability of gain or loss. Aboody and Lev (2000) document that once the causes of R&D volatility are revealed, the volatility of R&D expenditure is positively associated with the return on shares, signalling that investors have improved their understanding of the benefits and risks of R&D projects.

The magnitude and impact of the R&D volatility on the market value of companies have been highly explored by researchers over the last two decades (Duppati et al., 2017; Lakhal & Dedaj, 2020; Patel et al., 2018; Xiang et al., 2020). The difficulty in demonstrating the link between the volatility of R&D expenditure and the value of the company means that this topic continues to be of interest in the literature. Previous scientific evidence shows that fluctuations in the market value of entities correlate with the volatility of R&D expenditure (Hai et al., 2019). Other studies indicate a heterogeneous and weak link between R&D expenditure and share price, thus casting doubt on the assumed importance of R&D expenditure and their volatility for investors (Jeny & Moldovan, 2018).

Due to the mixed evidence and the unclear impact of changes in R&D expenditure on the market value of companies, we aim to contribute to this debate with theoretical and empirical evidence on listed European companies from the Pharmaceuticals, Biotechnology and Medical Research industry (PB&MR).

The PB&MR provides a good setting to scrutinize the financial market reaction to the volatility of R&D expenditure. First, official R&D figures compiled by the European Commission (2021) point out that, the health sector is one of the top R&D investors in Europe right after Information and Communications Technology producers. The taxonomy proposed by Galindo-Rueda and Verger (2016) classifies industries according to their R&D intensity and the pharmaceutical industry is characterised as highly R&D intensive. Second, PB&MR companies perform both incremental and radical innovations. This involves larger variations in R&D expenditure than any other innovation-friendly industry, which explains why the capital markets, as the main funders of their projects, perceive the risk rather than the benefits related to R&D results.

Our research is guided by a series of questions: Is R&D expenditure relevant to investors targeting PB&MR? How intense is the link between the volatility of R&D expenditure and the market value of listed companies in PB&MR? Does the market value of these companies react more broadly to positive volatility or negative volatility of the R&D expenditure?

The analysis is carried out on the entire sample and on two sub-samples determined based on the sign of R&D volatility. The entire sample analysis indicates that R&D volatility has a negative effect on market value, whereas R&D intensity has a positive effect. The interaction term between R&D volatility and intensity indicates a negative influence of the R&D volatility on market value depending on the proportion of R&D expenditure. The negative relationship between R&D volatility and market value is also demonstrated in the case of the positive volatility sub-sample. Regarding the negative volatility sub-sample, R&D intensity and its interaction with R&D volatility bear a strong positive impact on market value.

To our knowledge, this is the first study to explore the impact of R&D volatility on the market value of listed European companies in PB&MR, considering corporate characteristics and the country-level institutional context reflected by the corruption index. The present study investigates a recent time horizon (2012–2019) and a region not addressed by other researchers. At international level, the volatility of R&D expenditure has been previously researched on companies from other business sectors (Consumer, Manufacturing, High Technology, Health, and Other) and in other contexts (USA – Swift, 2013; Xiang et al., 2020; Iran – Mozafari, 2017; Korea – Kang et al., 2017; China – Hai et al., 2019; Ireland and Spain – Duppati et al., 2017). Enriching the existing knowledge on this topic, our results provide valuable insights for managers, investors, analysts, and other stakeholders about the market reaction to R&D information and possible industry-specific reasons for the volatility of R&D expenditure.

The rest of the paper includes: the section of literature review and hypotheses development, the research methodology section, and the results section, followed by the conclusions.

1. Literature review and hypotheses development

1.1. Volatility of R&D expenditure, an indication of earnings management

Compared to investments in tangible assets, investments in R&D generate more information asymmetry between managers and external investors (Kothari et al., 2002). Cohen and Walsh (2000) attest that firms investing substantially in R&D are less inclined to disclose detailed information about their projects to protect their innovations and maintain their competitive advantage. At the same time, the informational content and the quality of the financial reports are affected by the non-recognition of assets arising from the research phase of internal projects when, according to the conservatism principle, it is not possible to demonstrate their existence and the future economic benefits generated. Lakhal and Dedaj (2020) point out that a weak information environment exacerbates managerial discretion, leading to earnings management practices.

Gharbi et al. (2014) indicate a high rate of failure of R&D projects, even beyond the research phase, with negative consequences for the expected financial results. Kothari et al. (2002) argue that a dollar of R&D expenditure is associated with a variation in future results approximately four times higher than a dollar of capital expenditure (Lev et al., 2021). Diminishing future results by overinvestment in R&D leads, in the managers' opinion, to losses of value to shareholders, which negatively affect the compensation of managers or even imperil the management position (Lev et al., 2016). Baber et al. (1991) provide evidence that R&D decisions are influenced by managers' concern to report a rosy picture, incentivised by earnings-based bonuses.

A significant stream of research discusses the tendency of managers to resort to deceitful practices, adjusting or reducing R&D expenditure to smooth earnings, when they anticipate that the expected financial results will not meet analysts' forecasts, the company faces financial constraints or for other personal reasons (Tong & Zhang, 2014; Xiang et al., 2020). Duppati et al. (2017) talk about the myopic behaviour of managers, with reference to their decision to frequently reduce the level of R&D expenditure in favour of short-term results, sacrificing the long-term value of companies. Tong and Zhang (2014) infer that the capital market penalises managerial myopia, especially in companies with complex R&D investments. Xiang et al. (2020) explain, inspired by Swift (2013), how the volatility of R&D expenditure stemming from earnings management practices causes companies to perform poorly, by disrupting the R&D function and by generating high adjustment costs (the highly skilled human resource) associated with reducing or ceasing funding for R&D projects.

1.2. Volatility of R&D expenditure, an expression of corporate governance

According to Swift (2013), the persistence of R&D expenditure can be an expression of the agency problem between CEO and technocrats (project managers). Thus, the latter are reluctant to stop investing in research projects even if there is evidence that they will generate fewer future economic benefits. Abandonment would reveal the failure of the projects and the non-performance of the executive, while the persistence of R&D expenditure or overinvestment may hide the quality of the projects and the poor reputation of the project manager (Dargenidou et al., 2021). Literature calls this situation, which hinders innovation and corporate performance, managerial entrenchment. Bowman and Hurry (1993) indicate as a solution to mitigate the rooting of technocrats in the project, the reduction of R&D expenditure. CEO controls the opportunistic behaviour of technocrats by implementing governance practices.

The volatility of R&D expenditure, as a result of corporate governance mechanisms, induces discipline in the innovation efforts by discontinuing less valuable projects. Moreover, it increases internal competition for the R&D budget and turns managerial attention on viable projects (Duppati et al., 2017; Patel et al., 2018). Xiang et al. (2020) point out that the volatility of R&D expenditure improves a company value by strengthening governance and reducing overinvestment. Patel et al. (2018) regard corporate governance as a means of reducing myopic investment behaviour that aligns management interests to harnessing the volatility of R&D and thus improving long-term performance. Mudambi and Swift (2011) and Xiang et al. (2020) consider R&D volatility as a proxy for assessing proactive management in achieving the intended results. The proactive management of the R&D function is manifested by an extremely volatile model of R&D expenditure, which creates performance by differentiating viable projects from those without prospects in real-time and channelling more resources into viable projects (Swift, 2013).

1.3. Volatility of R&D expenditure, technological capacity and financial constraints

Other scientific approaches link the volatility of R&D expenditure to the technological capacity of companies, defined as their ability to absorb and use technical knowledge to create new knowledge (Kang et al., 2017). Innovative companies operate in an environment characterised by radical technological change (disruptive technologies), and regularly face the need for fundamental transformation. Lev et al. (2016) document that, on average, firms in the disruptive technologies industries spend 3% of their market value on R&D. Pennetier et al. (2018) believe that, in an uncertain environment, research opportunities are constantly opening, some areas of research become interesting perspectives, others lose their attractiveness as discoveries are made, and companies' capacity to absorb new technologies is advancing. Therefore, the volatility of R&D expenditure is a natural response to changing opportunities, and a form of budget and strategy adjustment of the company to mitigate the effects of uncertainty.

Management studies state that, to gain sustainable competitive advantages, companies can "explore new possibilities" and "exploit old certainty" (Markus & Swift, 2020). Fluctuations in R&D expenditure at company level may result from this shift from exploitation to exploration, both considered organisational learning phases (Swift, 2013).

Hai et al. (2019) deepen the topic and classify the volatility of R&D expenditure into positive and negative. Positive volatilities stem from the shift from exploitative innovation to exploratory innovation, while the reverse changeover leads to negative volatilities of R&D. Exploratory innovation is riskier, demands higher R&D spending than exploitative innovation, and helps firms to change technology and gain competitive advantages that will positively influence market value. Most companies return to exploitative innovation once R&D exploration has produced new forms of competitive advantage, leading to reduced R&D expenditure, helping firms to strengthen their competitive advantages and achieve better economic performance (Hai et al., 2019).

Kang et al. (2017) establish that the volatility of R&D expenditure may also be caused by the dependence of firms on domestic financing, particularly those that invest intensively in R&D or those with low technological capacity. The latter face higher external financing costs, as the likelihood of success of their R&D projects is low, which increases the risk for investors. Generally, intangible assets cannot be used as collateral. Because they are firm-specific, trading in the market significantly decreases their value, no matter how well they may be used outside it, so firms with a larger stock of R&D intangible assets cannot borrow as much as other firms.

1.4. Volatility of R&D in the context of pharmaceuticals, biotechnology and medical research

Of all industries, Pharmaceuticals has exponential R&D investment rates, being the industry that relies heavily on biotechnology for the development of medicines, medical devices, and diagnostics, and brings considerable social benefits (Peña et al., 2021). As a percentage of turnover, R&D expenditure in Pharmaceuticals is three times higher than the average in other industries and focuses mainly on fundamental research (Bentata, 2016).

Since innovation is a key factor in PB&MR, its effects are expected to be reflected in the increase in the corporate market value as a consequence of the reaction of financial markets to "signals" represented by the R&D expenditure and patenting rate. Using India as a research setting, Nandy (2022) provides evidence that the R&D activities of pharmaceutical companies positively influence their financial performance, proxied by market capitalization, albeit the impact is time-lagged. In the analysis of Chinese pharmaceutical companies, Su et al. (2021) infer that the impact of R&D on growth starts in the second year after R&D spending and it rises subsequently. Growth expectations based on the dynamics of innovation often do not become a reality because technological innovation is a very risky, time-consuming process (up to 17 years from the start of the research until the commercialization of new medicines), extremely costly (testing consumes about 63 % of R&D costs for the project), with a very high failure rate (only 1 of 10.000 compounds reach the approval phase for commercialization) (Mazzucato & Tancioni, 2013). The exploratory nature of this industry and the uncertainty about the results make it risky for investors, offering relatively low returns (8% in 2015), compared to other industries (7% in aeronautics, 10% in aviation) (Bentata, 2016).

A feature of entities in the pharmaceutical industry is that they reduce their risk exposure by investing in portfolios of R&D projects at different stages of development or by mergers and acquisitions of new companies, thereby ensuring their viability. Project portfolio management is a dynamic decision-making process whereby R&D projects are constantly reviewed, new projects are evaluated, selected, and prioritised, some of the existing ones are accelerated and others suspended, resources being reallocated to active projects (Gino & Pisano, 2006). Pertaining to R&D management, Howells et al. (2008) document that PB&MR companies develop alliances with contract research organisations to outsource clinical trial and testing work. Outsourcing clinical trials may absorb considerable amounts from the total R&D budgets, but at the same time it may increase R&D expenditure transparency. These strategies for adjusting innovation cause the amount of R&D expenditure and funding to change significantly, with consequences for the market value of the companies.

Demirel and Mazzucato (2012) note, through a study on US pharmaceutical companies between 1950 and 2008, that the impact of R&D expenditure on the growth of companies is conditioned by a combination of characteristics (size, patentability, and persistence in patentability), while in large pharmaceutical firms the increase in R&D expenditure may have a negative impact on their growth.

As PB&MR industry is marked by certain financing specificities, the amount of debt is limited to the value of pledgeable assets, equity dominates debts in the R&D financing structure, and PB&MR companies are highly dependent on the quality of the financial markets, R&D financing include a significant systemic risk component (Lo & Thakor, 2021; Sanford

& Yang, 2022). The decline of stock markets, even in the short term, can cause PB&MR companies to abandon early-stage projects or develop inefficient alliances for R&D funding (Mace, 2020; Lo & Thakor, 2021).

Garattini et al. (2022) opine that the pharmaceutical industry has become largely private and multinational, but medicines are mainly financed by public expenditure in sound health systems, such as those in Western European countries. In such a situation, Arslan-Ayaydin et al. (2014) claim that pharmaceutical firms are prone to moral hazard by directing some of the government funding for R&D to cover other expenditures (personnel, marketing). Thakor and Lo (2017) point out that the technical nature of R&D and the specialized expertise needed to assess project perspectives in PB&MR, combined with their low probabilities of success, make it harder to detect agency problems and moral hazard, which aggravates the problem of their financing and causes the volatility of R&D expenditure.

In addition to volatility, R&D intensity reflects the proportion of R&D expenditures in the wealth of the company, expressed in the literature by different measures such as total assets or sales, which capture the size of the company. Thus, R&D intensity is a measure of innovation (Karbowski, 2019) which set in motion the volatility of R&D expenditure and indicates how much the R&D financial effort of a firm is.

Jiang et al. (2021) report that highly R&D intensive companies have a weaker reaction of the share price. This negative relationship is explained by the interest of financially constrained firms to disclose more information about R&D activity in order to mitigate outside investors' risk exposure. Contrary to this view, Mazzucato and Tancioni (2013) find a positive relationship between the intensity of R&D and the reaction of the share price, able to capture information relevant to the estimation of the R&D investments risk. Xu (2006) discovers that in the early stages of R&D projects, when there are uncertainties regarding their success rates, the share price varies significantly for biotech firms. As R&D projects progress, a proportionate decrease in the volatility of the stock price should be observed if financial markets recognise the diminishing uncertainty inherent in the life cycle of an R&D project.

It can be inferred that the impact of R&D volatility on market value lacks consensus in the literature. As Xiang et al. (2020) point out, "R&D expenditure can increase or destroy wealth". For example, the volatility of R&D expenditure is welcomed by the market and perceived as a proactive management tool in the case of dynamic industries and large organisations, or, on the contrary, the negative relationship between R&D volatility and market value is motivated by opportunistic management behaviour. A closer analysis of stratified samples shows that both positive and negative volatilities caused by disruptive technologies are associated with higher market values (Hai et al., 2019). Also, the effect of the volatility of R&D expenditure on market value differ in intensity or direction depending on a parameter (moderating variable) that matters to investors, such as R&D intensity, which scales the proportion to R&D expenditure to firm size, and implicitly affects R&D volatility and corporate market value.

Further research is needed to empirically clarify the nature of the relationship between the volatility of R&D expenditure and the market value of companies. Therefore, we aim to test the following assumptions, for the companies in PB&MR:

H1. The market value is negatively influenced by the volatility of R&D expenditure.

H2. The relationship between market value and volatility of R&D expenditure is moderated by R&D intensity.

2. Research methodology

2.1. Sample and variables

An initial sample of 370 companies, representing all PB&MR companies both incorporated and listed in the European countries, was determined according to the Refinitiv Eikon database. Due to lack of data related to research and development expenditures, the selected sample was reduced to 217 companies for the period 2012–2019, resulting in a balanced sample of 1736 annual observations. The calculation of the variables of interest on the volatility of R&D expenditure involved the elimination of the data from the first two years (2012 and 2013), obtaining a sample of 1302 annual observations. In the next stage, observations were also eliminated when data related to other variables used in the models were missing, resulting in an unbalanced final sample, consisting of 1153 annual observations. Thus, the period of analysis is 2014–2019. The analysis is conducted on the entire sample and on sub-samples determined based on the positive and negative values of R&D volatility to highlight the contrast between the effects of continuous and disrupting R&D activities, as well as the consequences of the transition from exploratory to exploitative innovation on market value (Hai et al., 2019). The two sub-samples have 724 observations (positive volatility) and 429 observations (negative volatility) respectively and are also unbalanced.

The *dependent variable* reflecting the corporate market value is market capitalization at the end of fiscal year (*LnMV*), in line with Hai et al. (2019).

The main *independent variable* is the volatility of R&D expenditure (*RDV*), calculated as the standard deviation of the residuals of the R&D expenditure trend for the period 2012–2019, thus measuring the net volatility of the R&D expenditure growth. This calculation was performed in two steps, according to the studies of Mudambi and Swift (2011) and Patel et al. (2018). The first step was to analyse the regression of the R&D expenditures on a linear time trend for the eight-year period, according to Equation (1):

$$Rd\exp_{it} = \alpha_i + \beta_{it} + \varepsilon_{it}, \tag{1}$$

where *t* takes values from 1 to 8, corresponding to the period 2012–2019, for each company *i* in the sample.

In the second step, we calculated the standard deviation of the regression residuals from Equation (1) for a rolling three-year period (σi) and the mean R&D expenditure, over the same period $(\overline{RD\exp_i})$. The two indicators were subsequently placed in Equation (2) to calculate the volatility of the R&D expenditure ($Rdexp_{vol}$) for each company *i*.

$$RDV = \frac{\sigma_i}{\overline{RD^{-}}_{i}}. \tag{2}$$

The second step is necessary to ensure data comparability, as the standard deviation of companies with higher R&D expenditure is larger (Mudambi & Swift, 2011), which makes it necessary to divide it by the mean, to consider the size of the R&D expenditure.

Other independent variable is R&D intensity, which is defined as a ratio of R&D expenditure to total assets (*RD_TA*) (Kim et al., 2018; Koh & Reeb, 2015). The ability of the firms to obtain final products as a result of their R&D activities is proxied by the number of authorizations for medicines (*A_NO*) issued by the European Medicines Agency, as a measure of R&D output (Gascón et al., 2017).

Control variables have also been included in the analysis. In line with prior literature (Coluccia et al., 2020; Koh & Reeb, 2015; Patel et al., 2018; Xiang et al., 2020), corporate financial and governance characteristics with effect on market value are reflected by control variables such as: Kaplan-Zingales index (*KZ*) as a proxy for financial constraints (Xiang et al., 2020); natural logarithm of total assets (*LnTA*) as a measure of firm size; type of financial auditor (big four or not big four) to differentiate between the quality of audit and the market perception of corporate results based on the auditor (*Auditor*); and application of IFRS for financial reporting, with potential influence on market value (*IFRS*). Institutional support, quality of institutions and country-level context for pharmaceutical industry and R&D exports are reflected by the reverse value of the corruption index for the public sector (*CPI_R*) reported by Transparency International based on the perceptions of business executives and country experts. Corruption is widespread in countries with lack of transparency, in sectors where information asymmetry is favoured (Mazzi et al., 2019). Companies operating in corrupt states are traded at lower values (Lee & Ng, 2006). One aspect of corruption in PB&MR industry is the inclusion of marketing costs for the promotion of new products as R&D expenditure. This is questionable from an accounting point of view as such costs are to be classified as education and health (Mazzi et al., 2019). Free-float proportion in total corporate shares (*Freefloat*) indicates the financial market exposure and dependency. Of particular interest is the *KZ* index as previous literature (Hall et al., 2016) demonstrates that R&D activities are susceptible to financial constraints on account of lack of collateral value and information asymmetry. Therefore, our model considers the dependence on external financing and includes the *KZ* index. Following Xiang et al. (2020), the *KZ* index is computed as follows:

$$KZ = -1.001909 \times \frac{Cashflow}{PPE} + 0.2826389 * Tobin'sQ + 3.139193 \times \frac{Debt}{TotalCapital} - 39.3678 \times \frac{Dividends}{PPE} - 1.314759 \times \frac{Cash}{PPE}, \quad (3)$$

where *PPE* refers to net property, plant, and equipment, and total capital is calculated as the sum of debt and equity.

To divide the sample into sub-samples, according to the volatility sign of the R&D expenditure, the change in the size of the indicator (*RDVabs*) was calculated based on Equation (4). Thus, the positive values of *RDVabs* define the positive volatility sub-sample, whereas negative values of *RDVabs* define the negative volatility sub-sample.

$$RDVabs = \frac{RD\exp_t - RD\exp_{t-1}}{RD\exp_{t-1}}. \quad (4)$$

For robustness purposes, alternative measures of R&D volatility (expressed as *RDVstd*) and corporate financial constraints (proxied by return on equity *ROE* and *Debt Ratio DEBT/TEQ*) are used. The alternative measurement of the R&D expenditure volatility (*RDVstd*), according to Xiang et al. (2020), is based on the coefficient of variation. This volatility is computed as the ratio between the three-year rolling standard deviation of a company's R&D

expenditure ($Sdev_i$) and its mean three-year R&D expenditures ($Mean_i$), according to Equation (5).

$$RDVstd = \frac{Sdev_i}{Mean_i}. \quad (5)$$

Both robustness models are estimated based on panel regression analysis with period fixed effects.

2.2. Empirical models

Our research employs a quantitative approach to examine the relationship between R&D volatility and market value of the European PB&MR companies. The results of the Hausman test indicate that the fixed effects model (FEM) is favoured over the random effects model (REM). Following Pennetier et al. (2018), all our regressions include year fixed effects with the aim of controlling for the effects ascribable to peculiar investment shocks, which can be encountered by all firms, such as global economic fluctuations. To capture the contemporary effects, not only long-term ones rendered by FEM, we further apply the generalised method of moments (GMM) technique.

Therefore, to test the two hypotheses, the following models are developed (Equations (6) and (7)):

$$LNMV = \beta_0 + \beta_1 RDV + \beta_2 RD\_TA + \beta_3 A\_NO + \beta_4 KZ + \beta_5 LnTA + \beta_6 Auditor + \beta_7 IFRS + \beta_8 CPI\_R + \beta_9 Freefloat; \quad (6)$$

$$LNMV = \beta_0 + \beta_1 RDV + \beta_2 RD\_TA + \beta_3 RDV \times RD\_TA + \beta_4 A\_NO + \beta_5 KZ + \beta_6 LnTA + \beta_7 Auditor + \beta_8 IFRS + \beta_9 CPI\_R + \beta_{10} Freefloat. \quad (7)$$

Equation (6) indicates the basic model for the relation between R&D related variables and market value and includes control variables, while Equation (7) represents the model with the aggregate effect of R&D volatility and intensity as interaction term. The volatility in R&D is assumed to depend on the volume or intensity of R&D expenditure, as it may be determined by financial resources available for R&D projects (Gino & Pisano, 2006) related to firm size. Thus, the interaction term captures the effect of R&D expenditure volatility conditional to the scale of R&D expenditure allocated during the period.

3. Results and discussions

3.1. Descriptive statistics and correlation

Descriptive statistics indicators and correlation matrix across the whole sample are given in Table 1. On average, the market value (MV) of the sampled companies is USD 6,270,465,449.47 for the period considered. Characterised by an average volatility of R&D expenditure (RDV) of 112.86% and an average R&D intensity (RD_TA) equal to 42.83% of total assets, the companies analysed allocate significant amounts to innovation projects. Over the analysed period, the companies obtained on average 0.0616 authorisations (A_NO) to place medicines on the market. Average KZ (–190.07) points to a weak financial constraint on the sampled firms.

Table 1. Descriptive statistics and correlation matrix (entire sample)

Variables	Mean	Max.	Min.	1	2	3	4	5	6	7	8	9	10
1.LnMV	19.25	26.44	13.64	1.00									
2.RDV	1.13	124.83	0	–0.1***	1.00								
3.RD_TA	0.43	34.96	0	–0.2***	–0.03	1.00							
4.A_NO	0.06	6	0	0.33***	–0.03	–0.05*	1.00						
5.KZ	–190.07	7582	–53394	0.02	0.01	0.02	0.02	1.00					
6.lnTA	18.09	25.71	3.69	0.88***	–0.07**	–0.2***	0.34***	0.03	1.00				
7.Auditor	0.52	1	0	0.18***	–0.07**	–0.03	0.10***	–0.01	0.23***	1.00			
8.IFRS	0.91	1	0	0.11***	–0.04	–0.1***	0.04	0.04	0.13***	0.01	1.00		
9.CPI_R	0.01	0.004	0.011	–0.01	–0.00	–0.06**	–0.01	–0.02	0.09***	0.01	0.07**	1.00	
10.Freefloat	0.71	1	0.04	0.10***	–0.05	–0.01	0.07**	0.004	0.06*	0.09***	–0.1***	–0.3***	1.00

Note: *significant to 10%; **significant to 5%; and ***significant to 1%.

The average size of firms, measured by total asset (TA), is USD 3,475,222,449.68. On average, 51.11% of the auditors (Auditors) of the firms under review are Big Four and 90.61% of firms apply IFRS. The average Corruption Perception Index (CPI_R), equal to 0.0134, indicates a good quality of the institution, a low level of corruption and an innovation-friendly context. The facilitation of trading activities in the analysed financial markets (liquid, with good protection for minority investors, overseen by multiple stakeholders, and low investment risk) is highlighted by the Freefloat average (70.80%). The analysis of correlation coefficients does not indicate problems of multicollinearity. The descriptive statistics indicators for the two sub-samples (Table 2) have values close to those obtained for the total sample.

Table 2. Descriptive statistics (positive and negative volatility sample)

	Positive volatility sample			Negative volatility sample		
Variables	Mean	Max.	Min.	Mean	Max.	Min.
1.LnMV	19.27	26.44	13.93	19.2204	26.2113	13.6435
2.RDV	1.12	125	0	1.1507	78.6889	0.00623
3.RD_TA	0.47	23.64	0	0.3763	34.9582	0
4.A_NO	0.06	4	0	0.0649	6	1
5.KZ	–206	6769	–45192	–169.51	7581.92	–53394
6.lnTA	18.13	25.70	3.69	18.0325	25.6142	8.9105
7.Auditor	0.51	1	0	0.5105	1	0
8.IFRS	0.90	1	0	0.9132	1	0
9.CPI_R	0.01	0.04	0.01	0.0134	0.0385	0.0109
10.Freefloat	0.72	1	0.07	0.6942	1	0.0423

3.2. Regression analysis

The estimates for the entire sample (Model 1), as shown in Table 3, show the negative effect of the volatility of R&D expenditure on the market value of companies in PB&MR, statistically significant within the fixed effects model.

Specifically, an increase of 1% in the volatility of R&D expenditure leads to a 0.0089% fall in market value. This result, confirmed only by the FEM analysis, is in line with our expectations (H1) and with studies suggesting that the specificity and exploratory nature of innovation in these industries call for persistence or even overinvestment in R&D, motivated by incentives for companies to develop new products, despite the risk of project failure, the adjustment costs associated with the loss of the initial investment and potential commercial gains, with a negative impact on the market value in the long term (Demirel & Mazzucato, 2012; Gino & Pisano, 2006; Mazzucato & Tancioni, 2013; Xiang et al., 2020). On the other hand, the results show that the rise of R&D intensity with 1% has a positive effect on market value (0.1034%). Our finding is in line with Mazzucato and Tancioni (2013) that note that firms with a higher R&D intensity (in our sample, the average is 42.83 %) have a smaller variation in the share price because they voluntarily disclose more information about R&D, thus leading to an increase in their market value. Kim et al. (2020) who conclude that the R&D intensity favourably influences the market value of US listed companies report a similar result.

GMM analysis does not provide statistically significant results on the relationships between R&D volatility and market value or R&D intensity and market value. The contrasting results between FEM and GMM, obtained by other researchers (Dalwai & Mohammadi, 2020), could be explained by the nature of the estimator (static-FEM vs dynamic-GMM), which capture different perspectives on the data analysed. The number of authorisations, which guarantee the safety and therapeutic efficacy of medicines placed on the market, has a positive and significant impact on the market value of companies in PB&MR.

Turning to the control variables, we note that, except for IFRS, the coefficients are statistically significant in both estimations (FEM, GMM). Thus, KZ adversely influences market value. This result concurs with the conclusion of Li (2011) that the impact of financial constraints on market value is very severe for firms that invest intensively in R&D and are likely to suspend/discontinue R&D. The size of companies positively influences the market value (β_{FEM} = 0.8338, β_{GMM} = 0.8316). This is consistent with the findings of Ibhagui (2019) that the relationship between R&D and Tobin's Q changes with company size, the positive impact of R&D on performance being more pronounced for large firms. An inverse relationship is also noted between the type of auditor and the market value. Even developed countries/markets show lack of compliance and managerial discretion in financial reporting (Mazzi et al., 2019). The use of the professional services of brand auditors (Big Four) is a way to identify aggressive earnings management practices. It also reduces information asymmetry (Ahmadi & Bouri, 2019) by disclosing information capable of clarifying investors' perception of the risks associated with R&D projects, with an impact on market value. In line with previous studies (Brown et al., 2021; Lee & Ng, 2006; Thakur et al., 2021) the link between corruption and market value is negative and significant.

Over the past decades, the integrity and transparency of the analysed industries have been discussed considering the questionable safety and efficacy of some medicines, which has compromised their image and position on the capital market (Paul et al., 2010). A positive, statistically significant influence at 10 % level is also exerted by the freefloat, as a result of increased liquidity and the movement of stock prices to increase the market value of listed companies. The firms under review can finance themselves on the capital market, knowing that because of the risk of R&D investment and the information asymmetry "indebtedness is an inappropriate source of funding for the R&D investment" (Hall & Lerner, 2010).

At the level of the sub-sample with positive volatility (Table 4), the volatility of R&D expenditure has a negative impact on the market value of the analysed firms, in line with Demirel and Mazzucato (2012) and Mazzucato and Tancioni (2013). A possible explanation for this result would be that firms in this sub-sample own R&D projects at an embryonic stage, when the R&D expenditure and the risks associated with the exploratory innovation are significant, leading to a negative reaction from the capital market. The result is confirmed by both the FEM and the GMM and is significant at 10% level. The link between R&D intensity and market value is not statistically significant. The positive and significant impact of the total assets and the negative influence of KZ and corruption on the market value remain valid at the level of the sub-sample. Differences are recorded for the KZ index, where the significance of the results increases to 5%.

For the sub-sample with negative volatility (Table 5), the volatility of R&D expenditure, even though as an absolute average is higher than the positive volatility (115.07% vs 111.53%), does not influence the dependent variable and has no statistical significance. The reaction of market value is, therefore, more visible in the case of the upward trend in R&D expenditure, with no influence over the downward trend. The R&D intensity has a positive and significant impact on market value (β_{FEM} = 0.9595, β_{GMM} = 0.9718), confirmed by Mazzucato and Tancioni (2013) and Gharbi et al. (2014) for high-tech firms. The R&D intensity, on average lower than for the positive volatility sample (37.63% vs 47.04%), shows the decrease in R&D investment, either as projects advance and the risk of failure diminishes, or by switching to exploitative innovation and strengthening competitive advantages. Total assets have a strong positive influence on market value, the impact of corruption remains negative, and a negative relationship is observed between auditor type and market value. The relationships between market value and KZ, IFRS and freefloat are not statistically significant. We, therefore, corroborate H1 on the total sample and on the positive volatility sub-sample.

Model 2 highlights the moderating effect of R&D intensity on the relationship between the volatility of R&D expenditure and market value. At the level of the entire sample, the interaction term indicates a negative influence of the volatility of R&D expenditure depending on the proportion of R&D expenditure, but of a lower magnitude (–0.13880) than the non-interacted R&D volatility (–0.0089). Practically, the FEM analysis shows that the effect of the volatility of R&D expenditure on the market value is lower if the proportion of R&D expenditure in the total assets is higher. This finding is consistent with the results of Jiang et al. (2021). However, the interaction variable is not statistically significant in the GMM analysis. For firms with positive values of R&D volatility, the influence of interaction on market value is statistically insignificant. In the sample with negative volatility, we observe a positive impact of the volatility of R&D expenditure which depends on the proportion of R&D expenditure and is confirmed by both the FEM and the GMM, in contrast to the results achieved across the entire sample. Both analyses suggest that the effect of negative volatility of R&D expenditure on the market value of firms is more pronounced if the R&D intensity is higher. Therefore, the decrease in R&D expenditure, in the case of the sub-sample with negative volatility, enhanced by the R&D intensity controlled by corporate governance mechanisms and proactive management aimed at the early differentiation of efficient R&D projects from those without prospects, increases the market value. Our second hypothesis is confirmed for the whole sample and for the negative volatility sub-sample.

3.3. Robustness checks

Lastly, we conduct two additional tests to ensure the reliability of our findings. Model estimations with alternative measures of R&D volatility (expressed as RDV_std) and corporate financial constraints (proxied by return on equity ROE and Debt Ratio DEBT/TEQ) provide robust results. A glimpse of Tables 3, 4, and 5 shows that the findings of these supplementary analyses are largely consonant with those presented in the baseline analysis. Because the signs and significance of most of the estimated coefficients do not differ substantially, we will not further detail those results.

Table 3. Regression results and robustness checks: alternative measure for R&D volatility (a) and Kaplan-Zingales Index (b) (entire sample)

Variables	Model 1		Model 2		Model 1 – robustness test		Model 2 – robustness test	
					(a)	(b)	(a)	(b)
	FEM	GMM	FEM	GMM	FEM	FEM	FEM	FEM
RDV	–0.0089*	–0.0076	–0.0062	–0.0055		–0.0070		–0.0039
RD_TA	0.1034*	0.0882	0.2136**	0.1758*	0.1251**	0.0751	0.2725**	0.2018**
A_NO	0.1861***	0.1856***	0.1838***	0.1841***	0.1793***	0.1403***	0.1749***	0.1374***
KZ	–0.0000*	–0.0000*	–0.0000*	–0.0000*	–0.0000		–0.0000*	
lnTA	0.8338***	0.8316***	0.8364***	0.8332***	0.8193***	0.8644***	0.8277***	0.8673***
Auditor	–0.1248**	–0.1292**	–0.1242**	–0.1283**	–0.1219**	–0.1755***	–0.1226**	–0.1747***
IFRS	0.0367	0.0249	0.0545	0.0432	0.0469	0.0433	0.0570	0.0673
CPI_R	–75.2181***	–73.5993***	–75.2447***	–73.6205***	–71.5626***	–54.3234***	–71.2836***	–54.5224***
Freefloat	0.2199*	0.2271*	0.2105*	0.2204*	0.1890	0.3994***	0.1876	0.3896***
RDV*RD_TA			–0.1388*	–0.1113				–0.1558**
RDVstd					–0.3865***		–0.3164***	
RDVstd*RD_TA							–0.1454*	
ROE						–0.0137**		–0.0130**
DEBT/TEQ						0.0023		0.0022
Constant term	4.8188***	4.8497***	4.7453***	4.7954***	5.1770***	3.8395***	4.9626***	3.7556***
Obs.	1153	1153	1153	1153	1153	1068	1153	1068
R^2	0.8062	0.8019	0.8071	0.8023	0.8092	0.8316	0.8102	0.8325
Adj. R^2	0.8038	0.7994	0.8045	0.7997	0.8069	0.8292	0.8077	0.8299

Note: *significant to 10%; **significant to 5%; and ***significant to 1%.

Table 4. Regression results and robustness checks: alternative measure for R&D volatility (a) and Kaplan-Zingales Index (b) (positive volatility sample)

Variables	Model 1		Model 2		Model 1 – robustness test		Model 2 – robustness test	
					(a)	(b)	(a)	(b)
	FEM	GMM	FEM	GMM	FEM	FEM	FEM	FEM
RDV	–0.0130*	–0.0115*	–0.0113*	–0.0099*		–0.0123*		–0.0104*
RD_TA	0.0405	0.0378	0.1350	0.1179	0.0655	0.0308	0.1370	0.1355
A_NO	0.0408	0.0454	0.0404	0.0408	0.0480	0.0118	0.0469	0.0112
KZ	–0.0000**	–0.0000**	–0.0000**	–0.0000**	–0.0000***		–0.0000***	
lnTA	0.8501***	0.8505***	0.8524***	0.8501***	0.8339***	0.8703***	0.8381***	0.8729***
Auditor	–0.0737	–0.0775	–0.0725	–0.0737	–0.0810	–0.1418*	–0.0807	–0.1411*
IFRS	–0.0211	–0.0249	0.0047	–0.0211	–0.0050	–0.0688	0.0063	–0.0387
CPI_R	–79.3990***	–81.2088***	–79.0467***	–79.3990***	–75.9346***	–55.9304***	–75.7696***	–55.5668***
Freefloat	0.1501	0.1758	0.1472	0.1501	0.0942	0.2860*	0.0982	0.2842*
RDV*RD_TA			–0.1115	–0.0984				–0.1226
RDVstd					–0.3792***		–0.3434***	
RDVstd*RD_TA							–0.0667	
ROE						–0.0251		–0.0241
DEBT/TEQ						–0.0023***		–0.0022***
Constant term	4.7023***	4.7060***	4.6189***	4.6385***	5.1192***	3.9817***	4.9993***	3.8864***
Obs.	724	724	724	724	724	686	724	686
R^2	0.8144	0.8118	0.8151	0.8123	0.8170	0.8284	0.8171	0.8291
Adj. R^2	0.8107	0.8081	0.8112	0.8083	0.8134	0.8246	0.8133	0.8250

Note: *significant to 10%; **significant to 5%; and ***significant to 1%.

Table 5. Regression results and robustness checks: alternative measure for R&D volatility (a) and Kaplan-Zingales Index (b) (negative volatility sample)

Variables	Model 1		Model 2		Model 1 – robustness test		Model 2 – robustness test	
					(a)	(b)	(a)	(b)
	FEM	GMM	FEM	GMM	FEM	FEM	FEM	FEM
RDV	0.0004	0.0044	–0.0084	–0.0045		0.0041		–0.0019
RD_TA	0.9595***	0.9718***	0.8307***	0.8356***	0.9256***	0.9584***	0.4524	0.9042***
A_NO	0.2781***	0.3137***	0.2694***	0.3074***	0.2724***	0.2157***	0.2591***	0.2109***
KZ	0.0000	0.0000	0.0000	0.0000	0.0000		0.0000	
lnTA	0.8647***	0.8589***	0.8685***	0.8634***	0.8560***	0.8990***	0.8523***	0.9020***
Auditor	–0.1862*	–0.2028*	–0.1849*	–0.2014*	–0.1777*	–0.1849*	–0.1975**	–0.1813*
IFRS	–0.0065	–0.0313	–0.0087	–0.0356	0.0096	0.1848	0.0083	0.1825
CPI_R	–61.6443**	–56.8073**	–58.4982**	–54.6167**	–59.7339**	–48.1280**	–58.8214**	–45.7094*
Freefloat	0.1719	0.1452	0.1991	0.1660	0.1713	0.4443**	0.1680	0.4609**
RDV*RD_TA			0.3664**	0.3795**				0.2632**
RDVstd					–0.1835		–0.4036*	
RDVstd*RD_TA							1.3094***	
ROE						–0.0013		–0.0002
DEBT/TEQ						0.0041***		0.0041***
Constant term	3.9371***	4.0199***	3.8099***	3.8993***	4.1182***	2.7031***	4.2771***	2.6007***
Obs.	429	429	429	429	429	382	429	382
R^2	0.8221	0.8070	0.8240	0.8086	0.8225	0.8596	0.8258	0.8608
Adj. R^2	0.8161	0.8005	0.8176	0.8016	0.8165	0.8539	0.8195	0.8547

Note: *significant to 10%; **significant to 5%; and ***significant to 1%.

Conclusions

The purpose of this research is to explore the influence of the volatility of R&D expenditure and R&D intensity on the market value of listed European companies in PB&MR, considering the institutional context in the sampled countries and several company characteristics. In the total sample, the volatility of R&D expenditure has a negative and weak influence on the market value of the investigated companies, whereas the market value reacts positively but moderately to the increase in R&D intensity. Moreover, the interaction term indicates a negative influence of R&D volatility that depends on the proportion of R&D expenditure. These findings justify our view that the level of R&D expenditure and its behaviour (volatility and intensity) are of little relevance to reluctant investors, according to the literature, in connection with the performance of R&D investments and investors' aversion to earnings management practices. Through their specificities, the analysed companies carry out exploratory innovation and research of a competitive nature, focused on investing in new products which are "candidates" for medicine status with long clinical experimentation times, whose shortcomings occur in the last stages of the development process, which raise the R&D expenditure. Thus, the probability of failure and the asymmetric information environment increase the volatility of R&D expenditure and negatively affect corporate market value. However, the effect of the volatility of R&D expenditure on market value is lower at a higher R&D investment intensity, which is assumed to lead to better disclosure of R&D information to investors. The market value of the analysed companies is favourable and significantly influenced by the increase in the number of authorisations for the placing on the market of medicines, which are the final, actual expression of the success of the R&D projects.

It should be noted that market value is severely affected by the weakening of the quality of institutions, in the national contexts considered, reflected by the increase in corruption, in a sector with considerable public amounts being invested, and with transparency and integrity regulations. Excessive regulation of pharmaceutical prices in European countries and government incentives to develop new medicines, but not always clinically superior, create a trade-off between the affordability of cheap pharmaceuticals and the companies' willingness to invest in R&D. Basically, the price regulation controls the R&D expenditure, creates an inauspicious context for innovation, and increases the risk of R&D investments (through divergent economic and medical interests, and through information asymmetry between pharmaceutical companies and customers, parallel trade in medicines, lobbying activities etc).

Some of the characteristics of the analysed companies influence the link between the volatility of R&D expenditure and the market value. Thus, the impact of financial constraints on market value is relatively severe, which affects the investment strategy of the companies. Our sample includes large companies, with innovative potential and R&D routines, which indirectly increases their market value. The managerial discretion in reporting R&D expenditure, revealed by the audit services, affects their market value. Moreover, increasing trading activity in the capital markets of the analysed countries creates a favourable environment for increasing the market value of the companies.

The positive volatility sub-sample provides consistent evidence of a significant negative influence of R&D volatility on market value. This sub-sample may group companies with R&D projects at an embryonic stage when R&D expenditure and the associated exploratory innovation risks are significant and affect their market value. For the negative volatility sub-sample, R&D intensity and its interaction with R&D volatility have a significant positive effect consistent over the alternative estimations. Thus, the reduction in R&D expenditure, in this sub-sample, supported by an R&D intensity focused on improving existing products and controlled by corporate governance mechanisms, increases the market value.

We believe that the views and results of our research enrich the academic debate on the questionable and unresolved interactions between volatility of R&D expenditure and market value in a science-driven industry. For practitioners (managers, investors, policymakers), understanding the causalities between the key analysed variables can help to accept the volatility of R&D expenditure as a dimension of the innovation strategy and raise their interest in using innovation governance and proactive R&D management as a means of achieving business performance and improve communication with the capital market, to reduce information asymmetry.

Given that in the analysed industry the effects of R&D investment are visible in the long term, a longer research horizon could have led to more robust results, this being a limitation of our research. In the perspective, we will extend the study of this phenomenon to other business sectors, on a wider time horizon, including cultural specifications.

References

Aboody, D., & Lev, B. (2000). Information asymmetry, R&D, and insider gains. *Journal of Finance*, *55*(6), 2747–2766. https://doi.org/10.1111/0022-1082.00305

Ahmadi, A., & Bouri, A. (2019). The effect of audit quality on the extent of voluntary disclosure: Companies listed in the Tunisian Stock Exchange. *Journal of the Knowledge Economy*, *10*, 59–73. https://doi.org/10.1007/s13132-016-0444-y

Arslan-Ayaydin, Ö., Barnum, D. T., Karan, M. B., & Ozdemir, A. (2014). How is moral hazard related to financing R&D and innovations?. *European Research Studies Journal*, *17*(4), 111–131. https://doi.org/10.2139/ssrn.2377788

Baber, W. R., Fairfield, P. M., & Haggard, J. A. (1991). The effect of concern about reported income on discretionary spending decisions: the case of research and development. *Accounting Review*, *66*, 818–829. https://doi.org/10.1016/j.jacceco.2006.01.002

Bentata, P. (2016). *Médicaments innovants: les prix sont-ils trop élevés?*. Note économique de l'IEM, Institut Économique Molinari. https://www.institutmolinari.org/2016/10/03/medicaments-innovants-les-prix-sont-ils-trop-eleves/

Bowman, E. H., & Hurry, D. (1993). Strategy through the option lens: an integrated view of ressource investments and the incremental-choice process. *Academy of Management Review*, *18*(4), 760–782. https://doi.org/10.2307/258597

Brown, N. C., Smith, J. D., White, R. M., & Zutter, C. J. (2021). Political corruption and firm value in the U.S.: Do rents and monitoring matter?. *Journal of Business Ethics*, *168*(2), 335–351. https://doi.org/10.1007/s10551-019-04181-0

Bustinza, O. F., Gomes, E., Vendrell-Herrero, F., & Baines, T. (2017). Product-service innovation and performance: The role of collaborative partnerships and R&D intensity. *R&D Management*, *49*(1), 33–45. https://doi.org/10.1111/radm.12269

Cohen, W. M., & Walsh, J. P. (2000). R&D spillovers, appropriability and R&D intensity. *The Economic Evaluation of Technological Change*, *75*, 22–29. https://doi.org/10.1007/s007120200000

Coluccia, D., Dabić, M., Del Giudice, M., Fontana, S., & Solimene, S. (2020). R&D innovation indicator and its effects on the market. An empirical assessment from a financial perspective. *Journal of Business Research*, *119*, 259–271. https://doi.org/10.1016/j.jbusres.2019.04.015

Dalwai, T., & Mohammadi, S. S. (2020). Intellectual capital and corporate governance: An evaluation of Oman's financial sector companies. *Journal of Intellectual Capital*, *21*(6), 1125–1152. https://doi.org/10.1108/JIC-09-2018-0151

Dargenidou, C., Jackson, R. H. G., Tsalavoutas, I., & Tsoligkas, F. (2021). Capitalisation of R&D and the informativeness of stock prices: Pre and post IFRS evidence. *The British Accounting Review*, *53*(4), 1–55. https://doi.org/10.1016/j.bar.2021.100998

Demirel, P., & Mazzucato, M. (2012). Innovation and firm growth: Is R&D worth it?. *Industry and Innovation*, *19*(1), 45–62. https://doi.org/10.1080/13662716.2012.649057

Duppati, G., Sune, S., & Navajyoti, S. (2017). Corporate governance, research and development volatility and firm performance – Evidence from Spain and Ireland. *Cogent Economics & Finance*, *5*(1), 1317117. https://doi.org/10.1080/23322039.2017.1317117

European Commission. (2021). *EU industrial R&D investment scoreboard*. https://op.europa.eu/en/publication-detail/-/publication/fb50fc5e-570e-11ec-91ac-01aa75ed71a1/language-en

Galindo-Rueda, F., & Verger, F. (2016). *OECD taxonomy of economic activities based on R&D intensity* (Technology and Industry Working Papers No. 2016/04). OECD Science.

Garattini, L., Finazzi, B., & Mannucci, P. M. (2022). Pharmaceutical pricing in Europe: Time to take the right direction. *Internal and Emergency Medicine*, *17*, 945–948. https://doi.org/10.1007/s11739-022-02960-8

Gascón, F., Lozano, J., Ponte, B., & de la Fuente, D. (2017). Measuring the efficiency of large pharmaceutical companies: An industry analysis. *European Journal of Health Economics*, *18*(5), 587–608. https://doi.org/10.1007/s10198-016-0812-3

Greve, R. H. (2007). Exploration and exploitation in product innovation. *Industrial and Corporate Change*, *16*(5), 945–975. https://doi.org/10.1093/icc/dtm013

Gharbi, S., Sahut, J. M., & Teulon, F. (2014). *Research & development and volatility of equity returns in the French market* (Working Paper 2014-120). Ipag Business School.

Gino, F., & Pisano, G. P. (2006). *Do manager's heuristics affect R&D performance volatility?: A simulation informed by the pharmaceutical industry* (HBS Working Paper 05-015). Harvard Business School.

Guo, X., Li, K., Yu, S., & Wei, B. (2021). Enterprises' R&D investment, venture capital syndication and IPO underpricing. *Sustainability*, *13*(13), 7290. https://doi.org/10.3390/su13137290

Hai, B., Gao, Q., Yin, X., & Chen, J. (2019). R&D volatility and market value: The role of executive overconfidence. *Chinese Management Studies*, *14*(2), 411–431. https://doi.org/10.1108/CMS-05-2019-0170

Hall, B. H., & Lerner, J. (2010). The financing of R&D and innovation. In B. H. Hall & N. Rosenberg (Eds.), *Handbook of the economics of innovation* (Vol. 1, pp. 609–639). North Holland. https://doi.org/10.1016/S0169-7218(10)01014-2

Hall, B. H., Moncada-Paternò-Castello, P., Montresor, S., & Vezzani, A. (2016). Financing constraints, R&D investments and innovative performances: New empirical evidence at the firm level for Europe. *Economics of Innovation and New Technology*, *25*(3), 183–196. https://doi.org/10.1080/10438599.2015.1076194

Howells, J., Gagliardi, D., & Malik, K. (2008). The growth and management of R&D outsourcing: Evidence from UK pharmaceuticals. *R&D Management*, *38*(2), 205–219. https://doi.org/10.1111/j.1467-9310.2008.00508.x

Ibhagui, O. (2019). Do large firms benefit more from R&D investment?. *The European Journal of Applied Economics*, *16*(2), 155–173. https://doi.org/10.5937/EJAE16-21770

Jeny, A., & Moldovan, R. (2018). *Recognition and disclosure of intangible assets – a meta-analysis review.* SSRN. https://doi.org/10.2139/ssrn.3120397

Jiang, Y., Wang, D., & Zeng, Q. (2021). Can founders' dual roles facilitate innovation? – from the perspective of founders' R&D network characteristics. *Journal of Business Economics and Management*, *22*(5), 1288–1307. https://doi.org/10.3846/jbem.2021.14950

Kang, T., Baekb, Ch., & Lee, J. D. (2017). The persistency and volatility of the firm R&D investment: Revisited from the perspective of technological capability. *Research Policy*, *46*, 1570–1579. https://doi.org/10.1016/j.respol.2017.07.006

Karbowski, A. (2019). Cooperative and non-cooperative R&D in product innovation and firm performance. *Journal of Business Economics and Management*, *20*(6), 1121–1142. https://doi.org/10.3846/jbem.2019.11050

Kim, J. M., Yang, I., Yang, T., & Koveos, P. (2020). The impact of R&D intensity, financial constraints, and dividend payout policy on firm value. *Finance Research Letters*, *40*, 101802. https://doi.org/10.1016/j.frl.2020.101802

Kim, W. S., Park, K., Lee, S. H., & Kim, H. (2018). R&D investments and firm value: Evidence from China. *Sustainability*, *10*(11), 4133. https://doi.org/10.3390/su10114133

Koh, P. S., & Reeb, D. M. (2015). Missing R&D. *Journal of Accounting and Economics*, *60*(1), 73–94. https://doi.org/10.1016/j.jacceco.2015.03.004

Kothari, S. P., Laguerre, T. E., & Leone, A. J. (2002). Capitalization versus expensing: Evidence on the uncertainty of future earnings from capital expenditures versus R&D outlays. *Review of Accounting Studies*, *7*, 355–382. https://doi.org/10.1023/A:1020764227390

Lakhal, N., & Dedaj, B. (2020). R&D disclosures and earnings management: The moderating effects of IFRS and the global financial crisis. *Journal of Financial Reporting and Accounting*, *18*(1), 111–130. https://doi.org/10.1108/JFRA-10-2019-0129

Lee, C. M. C., & Ng, D. (2006). *Corruption and international valuation: Does virtue pay?* (Research Paper No. 41-06). Johnson School. https://doi.org/10.2139/ssrn.945629

Lev, B., Radhakrishnan, S., & Tong, J. (2016). *R&D volatility drivers* (FIRN Research Paper No. 2763369). SSRN. https://doi.org/10.2139/ssrn.2763369

Lev, B., Radhakrishnan, S., & Tong, J. Y. (2021). Earnings component volatilities: Capital versus R&D expenditures. *Production and Operations Management*, *30*(5), 1475–1492. https://doi.org/10.1111/poms.13333

Li, D. (2011). Financial constraints, R&D investment, and stock returns. *Review of Financial Studies*, *24*(9), 2974–3007. https://doi.org/10.1093/rfs/hhr043

Lo, A. W., & Thakor, R. T. (2021). *Financing medical innovation* (CSM Working Paper Series). Carlson School of Management.

Mace, C. (2020). The real effects of secondary markets on innovation. https://doi.org/10.2139/ssrn.3348102

Markus, A., & Swift, T. (2020). Corporate governance and the impact to the R&D lab. *Journal of Strategy and Management*, *13*(1), 91–110. https://doi.org/10.1108/JSMA-06-2019-0100

Mazzi, F., Slack, R., Tsalavoutas, I., & Tsoligkas, F. (2019). Country-level corruption and accounting choice: Research & development capitalization under IFRS. *The British Accounting Review*, *51*(5), 100821. https://doi.org/10.1016/j.bar.2019.02.003

Mazzucato, M., & Tancioni, M. (2013). R&D, Patents and stock return volatility. In A. Pyka, & E. Andersen (Eds.), *Long term economic development. Economic complexity and evolution* (pp. 341–362). Springer. https://doi.org/10.1007/978-3-642-35125-9_15

Mozafari, S. (2017). The impact of R&D expenditure volatility on stock return of the listed companies in Tehran stock exchange. *Specialty Journal of Accounting and Economics*, *3*(2), 7–11.

Mudambi, R., & Swift, T. (2011). Proactive R&D management and firm growth: A punctuated equilibrium model. *Research Policy*, *40*(3), 429–440. https://doi.org/10.1016/j.respol.2010.10.014

Nandy, M. (2022). Impact of R&D activities on the financial performance: Empirical evidence from Indian pharmaceutical companies. *International Journal of Pharmaceutical and Healthcare* Marketing, *16*(2), 182–203. https://doi.org/10.1108/IJPHM-08-2020-0067

Patel, C. P., Guedes, M. J., Soares, N., & da Conceição Gonçalves, V. (2018). Strength of the association between R&D volatility and firm growth: The roles of corporate governance and tangible asset volatility. *Journal of Business Research*, *88*, 282–288. https://doi.org/10.1016/j.jbusres.2017.12.033

Paul, S. M., Mytelka, D. S., Dunwiddie, C. T., Persinger, C. C., Munos, B. H., Lindborg, S. R., & Schacht, A. L. (2010). How to improve R&D productivity: The pharmaceutical industry's grand challenge. *Nature Reviews Drug Discovery*, *9*(3), 203–214. https://doi.org/10.1038/nrd3078

Peña, O. I. G., López Zavala, M. Á., & Cabral Ruelas, H. (2021). Pharmaceuticals market, consumption trends and disease incidence are not driving the pharmaceutical research on water and wastewater. *International Journal of Environmental Research and Public Health*, *18*(5), 2532. https://doi.org/10.3390/ijerph18052532

Pennetier, C., Girotra, K., & Mihm, J. (2018). *R&D Spending: Dynamic or persistent ?* (INSEAD Working Paper No. 2018/03/TOM). INSEAD. https://doi.org/10.2139/ssrn.2671828

Sanford, A., & Yang, M. J. (2022). Corporate investment and growth opportunities: The role of R&D-capital complementarity. *Journal of Corporate Finance*, *72*, 102130. https://doi.org/10.1016/j.jcorpfin.2021.102130

Su, C. Y., Guo, Y. N., Chai, K. C., & Kong, W. W. (2021). R&D investments, debt capital, and ownership concentration: A three-way interaction and lag effects on firm performance in China's pharmaceutical industry. *Frontiers in Public Health*, *9*. https://doi.org/10.3389/fpubh.2021.708832

Swift, T. (2013). R&D expenditure volatility and firm performance: Organizational and environmental contexts. *International Journal of Innovation and Technology Management*, *10*(04), 1350013. https://doi.org/10.1142/S0219877013500132

Thakor, R. T., & Lo, A. W. (2017). *Optimal financing for R&D-intensive firms* (NBER Working Paper Series w23831). National Bureau of Economic Research. https://doi.org/10.3386/w23831

Thakur, B. P. S., Kannadhasan, M., Charan, P., & Gupta, C. P. (2021). Corruption and firm value: Evidence from emerging market economies. *Emerging Markets Finance and Trade*, *57*(4), 1182–1197. https://doi.org/10.1080/1540496X.2019.1613643

Tong, Y. J., & Zhang, F. (2014). More evidence that corporate R&D investment (and effective boards) can increase firm value. *Journal of Applied Corporate Finance*, *26*(2), 94–100. https://doi.org/10.1111/jacf.12071

Wang, G., Wang, Y., Ju, X., & Rui, X. (2022). Effects of political networking capability and strategic capability on exploratory and exploitative innovation: evidence from traditional manufacturing firms in China. *Journal of Manufacturing Technology Management*, *33*(3), 618–642. https://doi.org/10.1108/JMTM-07-2021-0237

Xiang, E., Gasbarro, D., Cullen, G., & Ruan, W. (2020). Does R&D expenditure volatility affect stock return?. *Journal of Contemporary Accounting and Economics*, *16*(3), 100211. https://doi.org/10.1016/j.jcae.2020.100211

Xu, B. (2006). R&D progress, stock price volatility, and post-announcement drift: An empirical investigation into biotech firms. *Review of Quantitative Finance and Accounting*, *26*, 391–408. https://doi.org/10.1007/s11156-006-7439-x

Zhang, Z., & Luo, T. (2020). Network capital, exploitative and exploratory innovations – from the perspective of network dynamics. *Technological Forecasting and Social Change*, *152*, 119910. https://doi.org/10.1016/j.techfore.2020.119910