R&D SPENDING AND FINANCIAL PERFORMANCE: THE MODERATION OF ENGAGEMENT IN KEY TECHNOLOGIES

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Abstract

This study examines the relationship between Research and Development intensity and firm financial performance, with a specific focus on how engagement in key technologies moderates this relationship. Using a panel dataset of 45 firms listed on the Dutch stock exchange from 2018 to 2023, the research employs regression analyses to assess both current and lagged effects of R&D investment on return on assets and earnings per share. The findings suggest that while R&D intensity negatively impacts financial performance, engagement in key technologies moderates this effect. The engagement in key technologies and its extent are seen to mitigate the negative impact on operational performance as measured by ROA. However, no significant moderation effect is found for the operational performance as measured by EPS which is said to be due to this variable not being focused solely on operating performance but incorporating some market factors. These results contribute to the debate on the financial implications of R&D investment on firm performance and provide insights for policymakers and business leaders aiming to strengthen technological competitiveness and optimize the position the business is in.

Keywords: R&D investment, Firm performance, Financial performance, Return on Assets, Earnings per Share, Key Technologies, Dutch firms, lagged effect, Multiple regression

Contents

1. Introduction

The Netherlands allocates a lower proportion of its GDP to research and development (R&D) compared to neighboring countries. While Germany and Belgium have increased their R&D expenditures, the Netherlands has not followed this trend. In 2022, R&D spending in the Netherlands amounted to 2.3% of GDP, falling below the European Union's target of 3%, as reported by TNO (2023).

Research and development is seen as an important factor in establishing a key competitive advantage and can be strategically leveraged to enhance the value added to an industry's business performance (Chen et al., 2019).

The Dutch government recognizes the value research and development has and will have for the Dutch economy as well. The government aims to make sure the competitive advantages that are present in parts of the Dutch economy are sustained and intends to foster the creation of new competitive advantages.

To do this the Dutch government set out to find which technologies and markets present the greatest opportunities for the future of the Netherlands. The government collaborated with entrepreneurs and researchers to answer the question of what these technologies are. By investing in these "key technologies" these partners expect to strengthen the future earnings potential of the country, expect to be able to tackle unwanted dependencies and societal challenges and expect to make technological leadership feasible for the Dutch companies.

The ten key technologies that were chosen are the following: optical systems and integrated photonics, quantum technologies, process technology, biomolecular and cell technologies, imaging technology, mechatronics and opto-mechatronics, artificial intelligence and data science, energy materials, semiconductor technologies, and cybersecurity technologies. (Ministerie van EZK, 2024)

These investments in research and development are meant to form the companies into a foundation for the future of a healthy Dutch economy where the Netherlands is on the cutting edge of these technologies. Therefore it is important that these investments succeed and have a great impact on the growth within these industries as intended. To test this the impact of multiple factors on companies within these markets will be investigated. The R&D intensity and the extent of the engagement in the technologies that were mentioned in the National Technology Strategy (2024) of the Netherlands will be researched. This paper will investigate whether R&D intensity is a significant factor in the financial performance of companies and whether this relationship is different in companies engaging in key technologies to different extents. The research questions answered in this thesis are: "***What is the relationship between R&D intensity and firm performance?"*** *and* ***"Does the engagement in key technologies and its extent moderate the relationship between R&D intensity and firm performance?***"

In the literature, R&D spending has been researched extensively. As long as 30 years ago a study was done on the R&D expenditure of companies. This study looked at 118 companies and investigated the relationship between R&D expenditure, operating performance (measured by profits), and stockholder returns (measured by market value). This study found a significant positive relationship with both the operating performance and the market value of firms (Sougiannis, 1994). A study more relevant to this research in terms of timeframe and the focus on certain forms of high tech was done by Chen, Guo, and Wei (2019). They did a study on Taiwanese semiconductors in which they found support for a lagged positive effect of R&D investment on business performance and found R&D intensity to be negatively correlated with companies' current business performance.

2. Literature review

In this chapter, the literature from which the hypotheses follow and which forms the basis of this paper will be laid out.

a. Research and development intensity

Research and Development (R&D) investment represents investment in knowledge which in turn affects the technology which improves productivity (Minasian,1962). This R&D is becoming a critical element in generating the (sustainable) competitive advantage of companies and economies, causing them to invest persistently in R&D activities (Ravšelj & Aristovnik, 2020). The R&D Intensity has also increased as this expenditure relative to the total expenditure among OECD countries increased from 2,4% of their expenditures in 2018 to 2,5% in 2019.

1. Research and Development advantages

Whereas the improved performance from a single innovation may not last long, the research by Artz et al. (2010) does provide arguments for high profits to last if a firm is able to keep up the innovations and launch multiple innovations over a longer time. The innovations may lead the company to have somewhat of a monopolistic position which they could exploit. Not only that but it is also argued that a firm being an effective innovator for a longer period acts as an entry-deterring mechanism that reduces the number of firms and level of competition within an industry (Artz et al., 2010) thus allowing the company to reach for more profits freely.

Innovations do not have to be made publicly to gain positive results from investing in R&D though as Hall (1987) found that the R&D intensity positively influences the probability that a firm survives, this probability is even higher if no patents were applied for.

The innovations that have been made public could also lead to positive financial results. The management could make use of the signaling theory for which Spence (1973) defines the requirements to be the existence of signaling costs negatively related to the individual's productivity and a sufficient number of signals within the appropriate cost range being present. As the R&D expenditures could be used to signal within the appropriate cost range, could be made in sufficient numbers, and are negatively related to its immediate financial performance they can be used as credible signals. The firm could signal its strategic positioning (Lantz & Sahut, 2005)which might encourage investors to pay a higher price for their shares or it could signal the availability of technological opportunity which is valuable as laid out by Lee, Wu & Pao (2014).

2. Research and Development disadvantages

This does not mean that investment in research and development only has advantages. It requires significant opportunity costs. There are often more opportunities to finance in terms of research and development than an entrepreneur has the resources for (Andrade, 2019). These financial constraints could lead the entrepreneur to be enticed by loans. This could in turn make the investment in research and development even riskier as the leverage would increase and the investment in the research and development is not guaranteed to succeed.

It is even posed in the paper by Zhang (2015) that the uncertainty involved with investing in R&D negatively affects the survival of firms. R&D investment is seen as an inflexible investment and companies with a higher R&D intensity are posed to be more likely to discontinue projects, resulting in losses.

R&D intensity itself is said to have a significant effect on learning and technological trajectories within a firm(Goossen & Brandonjic, 2014). The R&D intensity of a firm was seen to harm the ability to learn from alliance partners and thus seemingly demotivated employees to gain external intelligence as they are aware of the availability of their internal resources and capabilities (Goossen & Brandonjic, 2014). The reduced learning from alliance partners could result in lost opportunities that would have been available in the absence of this high level of R&D.

3. Research and Development and firm performance

There is a lot of literature to draw from as research and development is a well-researched topic. This does not mean an all-encompassing conclusion has been made as the conclusions that were drawn are inconsistent across different papers.

The inconsistencies among these papers could be a result of a different, less relevant time period compared to now, due to the use of a different research methodology and different ways to calculate the performance measures of the studies. This shows that the results of one study have limitations in its applicability to a general sample.

The past research on the financial performance of companies investing in research and development can show an insight into how these investments impact the financial performance of the companies both in market performance and operational performance.

One of the early studies into R&D expenditure and its impact on both operating- and market performance is the study by Sougiannis (1994) which used cross-sectional data of companies listed on the New York Stock Exchange and the American Exchange from 1975 to 1985 to estimate a model for the impact of R&D on earnings and thus operational value and market value. The study finds that, on average, a one-dollar increase in R&D leads to a two-dollar increase in profit over a seven-year period and a five-dollar increase in market value. They deemed the long-run impact of R&D on market value to consist of an indirect and a direct effect. The indirect effect is the effect of the gained profit and thus operational performance realized into market value and the direct effect being the signaling effect of the R&D variables on the market value. They found that the indirect, operational effect was on average much larger which shows that R&D is valued on whether or not it results in earnings.

There are many papers showing similar results regarding the relationship between the R&D intensity of firms and their performance. Some papers will be reviewed in this section. The results of these papers will be summarized in Table 1.

3.1 R&D and immediate impact on operational performance

Chen et al. (2019) studied firms in Taiwan's semiconductor industry and found that R&D intensity of the current year has a negative relationship with the companies' operational performance in the current year, which was attributed to the R&D costs being recorded as operating expenses in the financial statement leading to a lower return. This result is supported by the findings of Pantagakis, Terzakis, and Arvanitis (2012) as they researched 39 publicly traded high technology companies within the eurozone from 2006 to 2010 and found a negative relationship between the R&D to net sales and firm performance as measured through the ROA of the current year. There is also literature pointing out negative results within the broader technological industry as Lantz and Sahut (2005) tested 213 firms in the technological sector for the year 2004 and found significantly lower financial performances for companies with more intensive investments in R&D. Another paper that found this relationship is the paper by Rao, Yu, and Cao (2013) that did research on publicly listed Chinese and Japanese companies within technique intensive industries companies, using data between 2007 and 2011. They found a negative effect between R&D and business performance in the current year. The research by Haque, Siddique and Kumar (2024) on 4800 companies in the US manufacturing sector for the period from 1992 to 2019 found a negative relationship between R&D intensity and ROA, noting that it is a risk factor as it is seen to result in a reduction in the firm's financial performance.

One paper that did find immediate positive results is the paper by Andras and Srinivasan (2003) in which financial information from the year 2000 was collected on 196 consumer product companies and 876 manufacturing product companies. They found a significant positive relationship between the R&D Intensity and the profit margin of the companies in that same year.

One model that could be seen to encapsulate all of these results on the operational performance is the three-stage S-curve model as described by Yang, Chiao, and Kuo (2010). In a sample of 477 listed Taiwanese high-tech manufacturing firms and 179 non-high-tech firms, they found that high-tech firms conformed to the S-curve model. This three-stage curve model shows that R&D efforts are negatively related to profitability at the early stage due to low marginal productivity, but poses that these effects will be offset by the benefits gained from higher levels of R&D investment after a certain threshold has been passed. Then the firm reaches its optimal level of R&D investment after which further expenditure forms a negative relationship with firm profitability. Next to the nonlinear effect this paper provided evidence for there to be a difference between industries and contexts which it suggests to be studied as this paper intends to do.

3.2 R&D and lagged impact on operational performance

Within the literature lagged versions of the R&D variable are often used to explain the relationship between the intensity of R&D investment and the financial performance. This time lag has been described as early as 1976 as Cooper and Schendel noted that new innovations regularly did not lead to immediate financial returns and sometimes even led to immediate challenges for the companies that invested in innovation.

Chen et al. (2019) posed that the lagged effect could have possibly have been due to the increased R&D spending improving the efficiency of operating processes and the quality of the products and it being able to give firms an edge in developing new products and securing the right patents, no longer being able to be hurt from patent issues later on.

Chen et al. (2019) found a positive relationship, providing evidence that R&D spending has a positive impact on business performance, especially within the semiconductor industry which is part of the key technologies. Rao, Yu, and Cao (2013) found a positive effect when lagging the R&D costs. They found that for China the costs had to be lagged 2 years and for Japan only 1 year which they posed to be due to a better innovation environment for Japan. This positive effect was also stated to only be seen in one year, not over a longer term which is theorized to be due to the continuous rapid innovation found within technique-intensive industries. The paper by Leung and Sharma (2021) was not in line with these results as they researched a panel of 385 firms listed on the Shanghai and Shenzhen stock exchanges and found a negative effect of the lagged R&D intensity on financial performance.

These results were also supported by Yang, Chiao, and Kuo (2010) as they found that after the threshold they set before R&D efforts lead to increased profitability was reached R&D investments are not expected to contribute to an increase in profits until at least a year has passed. The negative initial results Pantagakis et al. (2012) had were also explained to be due to time lag and they suggested doing more research on the time lagged values which they thus also suggested to be needed to see a positive effect on firm performance.

3.3 R&D and cross-country impact on operational performance

The results described were also found to be true in different countries as Ravšelj and Aristovnik (2020) found when researching two different datasets, one Slovenian and one covering the EU, the US, China, and Japan from 2015 to 2017. They deemed R&D expenditures an important determinant of operating performance. For operating performance, they found that R&D expenditures have a negative relationship with current operating performance and a positive impact on operating performance in the future. These results were the same for both the Slovenian sample and the sample covering companies in the world's major economies. This effect being the same cross-country can also be found in the paper by Rao, Yu, and Cao (2013) as they found these same effects regarding the operating performance of companies in both Japan and China.

3.4 R&D and market performance

The literature does not provide such conforming results for the market performance, this starts from the measures used to operationalize the performance which are varied.

There is literature pointing out negative results specifically within technological firms as Lantz and Sahut (2005) tested firms in the technological sector and found that the annual market return was 2 times lower and the beta 2 times higher for companies that have an intensive investment strategy in R&D. Pantagakis et al. (2012) showed both a positive and a negative relationship as a positive relationship between R&D and market capitalization was found until companies invest 41% of their revenues in R&D. At that point the company's market value is maximized and after that point the relationship between R&D and market value of the firm is negative. A positive relationship was found by Ehie and Olibe (2010) who researched a sample of 26429 US companies from 1990 through 2007 and found a positive relationship between R&D intensity and market capitalization. This positive relationship of R&D intensity with market performance is also found in several countries as Ravšelj and Aristovnik (2020) found that R&D expenditures improve market performance and found that this effect fades after a year both within the Slovenian sample and within the sample including the world's major economies (Ravšelj and Aristovnik, 2020). A positive effect from lagged RDI intensity was also seen as Leung and Sharma's (2021) research found a positive relationship between the market performance and the lagged R&D intensity.

TABLE 1: LITERATURE SUMMARY ORGANIZED BY YEAR

Authors	Sample scope	Sample period	Findings
Sougiannis (1994)	Companies listed on the New York Stock Exchange	1975-1985	• R&D expenditure is positively related with profit • R&D expenditure is positively related with market value
Andras and Srinivasan (2003)	Consumer product companies & Manufacturing product companies	2000	• R&D is positively related with the profit margin
Eberthart et al. (2004)	US Companies	1951-2001	• R&D expenditure increases are positively related with long term financial performance

			• R&D expenditure increases are positively related with market returns
Lantz and Sahut (2005)	Listed technological firms	2004	• Companies investing intensively in R&D is negatively related with financial performance • Companies investing intensively in R&D is negatively related with market performance
Ehie and Olibe (2010)	US firms	1990-2007	• R&D intensity is positively related with market capitalization
Yang, Chiao, and Kuo (2010)	Taiwanese listed high-tech and non high-tech firms	2000-2007	• S-curve model, R&D negatively related with the financial performance at first but positively related after a certain threshold and then negative again after a certain point
Pantagakis, Terzakis and Arvanitis (2012)	Publicly traded EU high-tech companies	2006-2010	• R&D expenditure is negatively related with financial performance • R&D intensity is negatively related with market performance up to 41%, a further increase is negatively related
Rao,Yu and Cao (2013)	Companies publicly listed in Japan and China	2007-2011	• R&D expenditure is negatively related with financial performance • Lagged R&D expenditure is positively related with financial performance
Chen et al. (2019)	Companies in Taiwan's semiconductor industry	2005-2016	• R&D intensity is negatively related with financial performance • Lagged R&D intensity is positively related with financial performance
Ravšelj and Aristovnik (2020)	Slovenian-specific listed companies as well as the world's major economies' companies	2015-2017	• R&D expenditure is negatively related with financial performance • Lagged R&D expenditure is positively related with financial performance • R&D intensity improve market performance

Leung and Sharma (2021)	Firms listed on the Shanghai and Shenzhen stock exchanges.	2010-2013	• Lagged R&D intensity is negatively related with financial performance • Lagged R&D intensity is positively related with market performance
Haque, Siddique and Kumar (2024)	US manufacturing sector	1992-2019	• R&D intensity is negatively related with operational performance

From the empirical evidence and the theoretical support the following hypotheses are formed:

H1a: There is a negative relationship between R&D intensity and firm performance

H1b: There is a positive relationship between lagged R&D intensity and firm performance

b. Technology investment

Technological innovation can create new industries and transform or destroy existing ones(Cooper & Schendel, 1976). It is clear that innovation plays a big part in the technology industry, there is practically no getting around it.

In this era where companies compete globally and especially technological competitiveness is seen as key to the economic well-being of a company and technology and innovation seem to be synergistic (Ehie and Olibe, 2010) the importance of investment in technological innovation can clearly be seen.

The paper by Andrade et al. (2019) shows the value of specifically investing in R&D within companies that are at the technological edge within their industry as it did research on a sample of 2012's 2000 biggest R&D spending companies within 46 countries and 40 industries. They found that the companies around the technological frontier of their industry had a better relationship between profits and investment in R&D than companies that were at a greater distance from that frontier. As the firms investing in emerging technologies are inherently on the edge of the technological frontier and are thus said to only be able to upgrade their performance by moving the technological frontier by innovating (Andrade et al., 2019), it can be concluded that investing in these emerging technologies is valuable.

The study by Aristovnik et al. (2023) also points out certain types of companies that are impacted heavily by high research and development. The paper examines industrial R&D performance from 2016 to 2020 by comparing the productivity of the top R&D enterprises across world-leading economies and industries. Results reveal that R&D productivity has improved over time, particularly in the last year observed. Despite Consumer Goods & Services presenting the best average R&D performance, the highest improvements are observed more recently, especially in Healthcare & Pharmaceuticals and ICT Goods & Services.

c. Key Technologies

Key technologies are technological areas in which the Netherlands is positioned strongly within the scientific community and from which a big societal and economic impact is expected in the near future. These key technologies consist of both the Key Enabling Technologies and the Future and Emerging Technologies found in the European Union's program Horizon Europe (Holland High Tech, 2024).

The Key Emerging Technologies are said to drive innovation throughout the economy and cut across industries with a trend toward full convergence and integration. At the same time, their growing complexity is expected to make it more difficult for industry and SMEs to fully capture their innovation potential (NWO, 2019).

The Future and Emerging Technologies as laid out in the Horizon 2020 program will be supported by actions that are supposed to make a path for game-changing future technologies. This will be done by enabling far-reaching collaborations between advanced multidisciplinary science and cutting-edge engineering requiring cooperation among a range of disciplines, communities, and programs in both academia and industry (European Commission, 2018). This is said to help Europe gain a leading position in those promising novel technologies that are expected to support the continent's growth and competitiveness.

The key technologies that were identified to be uniquely positioned in the Netherlands to deliver a positive economic and scientific impact are as follows (Ministerie van EZK, 2023):

• Optical systems and integrated photonics;

• Quantum technologies;

• Process technology, including process intensification;

• Biomolecular and cell technologies;

• Imaging technologies;

• Mechatronics and Opto mechatronics;

• Artificial intelligence and data science;

• Energy materials;

• Semiconductor technologies;

• Cybersecurity technologies.

These key technologies are said to be a great asset to the economy by enabling the creation of new business ventures and new markets (TNO, 2023).

The literature that could be linked to these technologies in a complete one-to-one manner is sparse. This is true as these technologies are inherently new and thus not researched as much and changes are a constant within these technologies. The future technology companies do have some characteristics that are present in all of the companies as can be read in the preceding info on them. The companies engage in several novel technologies, are present in new markets and the companies themselves are usually new and younger companies. The technology they engage in is also said to be complex as advanced science and cutting-edge engineering are used to make these technologies ready to be applied.

Madhok (2002) finds that in a situation of technological complexity uncertainty, and competitive intensity more resources are required as aligned to the model that was formed. R&D would be one of the resources that could be required to be at a high level to financially perform well, especially when working with these key technologies which were mentioned to be uncertain and increasingly complex.

This complexity being inducive to good use of R&D spending is further supported by the paper written by Goossen and Brandonjic (2014). They mention that technological diversity is a major determinant of the ability of the firm to combine existing technologies or ideas in new and creative ways and an organization's ability to learn from the research that was done with the R&D spending. This technological diversity would be fulfilled by engaging in many of the key technologies as they are stated to have started from multidisciplinary science ventures and engaging in the development of several of these technologies at once inherently makes for high technological diversity.

In the paper by Lee, Wu & Pao (2014) it is also mentioned that the presence of technological opportunity triggers the explorativeness-enhancing effect of R&D intensity, this explorativeness is deemed important for a firm's strategic renewal and survival in environments that are uncertain and invariably subject to changes. This state of explorativeness is noted to be hard to achieve for many firms, making the enhancing effect interesting to businesses. Engaging in Key technologies provides a clear technological opportunity.

The paper by Piétro Moncada-Paternò-Castello (2016) also noted that several studies back up the notion that strong sectoral dynamics, distinct patterns of specialization as can be found in many of the companies engaging in key technologies, and excellent product quality and/or high R&D intensity are necessary conditions for business growth and increased economic competitiveness.

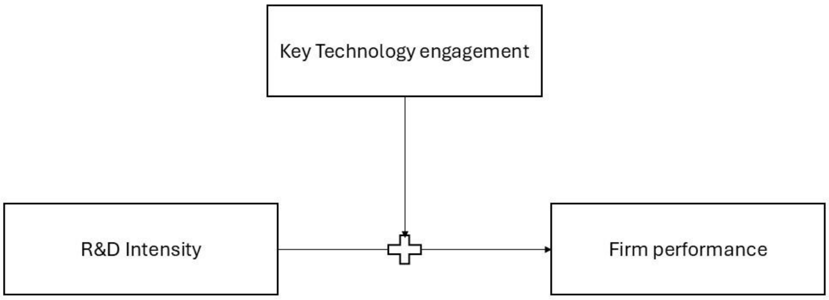
Chao and Kavadias (2013) go against many of the aforementioned theories posed in their paper. They find that for companies earlier in the industry lifecycle that are in these new industries with low stability a higher profitability results from the company having a lower R&D intensity and adopting a more incremental portfolio. At this stage, incremental implies exploitation of a firm's current position and thus less technological complexity rather than radical, long-term initiatives which are expected to be more complex technologically. They pose that companies that find themselves in industries later in the industry lifecycle, with a higher sense of stability are the companies that perform best with a higher R&D intensity and a more complex new product development portfolio.

As the literature mostly finds positive results related to the characteristics described regarding the key technologies the relationship between the R&D intensity and the financial performance is expected to be more positive if the companies engage in the Key Technologies. This makes for the following hypothesis:

H2: Engaging in Key Technologies has a positive effect on the relationship between firms' R&D intensity and their performance

From these hypotheses, the conceptual framework that is shown in Figure 1 follows.

Figure 1: Conceptual framework



3. Methodology

a. Regression method

As the data that will be collected consists of the same variables on the same 45 firms over several years, this data can be said to be panel data.

The panel data analysis methods that were taken into account for this research and were tested against this sample will be described below. These methods are noted to be the methods used most frequently in research. The methods are: The Fixed effects method, the Random effects method, and the pooled OLS method.

The first and most basic method is the pooled OLS method where the data will simply be pooled together and the Ordinary Least Squares method will be used on this pooled data. Ordinary Least Squares regressions are one of the most common forms of linear regression. As the amount of observations is not grouped but all counted individually more observations can be used in the regression which produces more significant estimates through the regression. With Ordinary Least Squares, the sum of the squared distance between the actual values and the values predicted by the model is minimized.

There are several assumptions that the methods rely on as the OLS approach relies on the relationship's assumed linearity, there is an assumed absence of multicollinearity, the residuals are assumed to be constant and thus there is a supposed homoscedasticity and the residuals are assumed to be normally distributed.

As the companies and the time units will not be differed in the pooled OLS method the variables being from the same company over multiple years may be influenced by underlying company-specific omitted variables which may cause the constant residuals assumption to be violated.

The fixed effects model is often used when it is valuable to control for omitted variables that are constant over the multiple periods of time found in the data and differ between the companies from which the variables are observed over time. This is called unobserved heterogeneity or fixed effects. It is assumed that the unobserved heterogeneity between companies' errors is correlated with the explanatory variable (RDI). Another important assumption is that the error specific to a single observation is independent of the explanatory variable. By eliminating the company-specific effect, thereby controlling for omitted company-specific variables, the estimates are expected to be more robust (Xu, Lee, Aeom; 2007).

Another model that could help in controlling for company-specific effects within this research is the random effects model. These company-specific effects are constant over time as well. The difference is that under the random effects model, a common intercept and a random variable measure the random deviation from this intercept (Brooks, 2014) per company which is assumed to be random. This variable measures the random deviation of each company's intercept from the global intercept, the per-company deviation is thus not encapsulated in the intercept but in this random variable.

These assumptions and the assumption of the fixed and the random effects method, the company-specific effects being correlated with the explanatory variables will be tested as was done using the same methods in other research (Ravšelj and Aristovnik, 2020).

The objective of this regression analysis, for which the results will be described is to explain the firms' financial performance in the sample, in terms of return with the independent variable of the research and development intensity next to reviewing the influence of the moderator variable, being whether the companies engage in the development of Key Technologies and to what extent the companies engage in the development of these technologies.

The dependent variables of Return On Assets (ROA) and Earnings Per Share (EPS) are regressed against the main independent variable, the R&D intensity (RDI) for which the lagged values are also tested in different models. The moderator variable of engagement in key technologies (KEY) is also added as well as the control variables. The control variables are Size, Net Sales Growth (NSG), and Leverage (Lvg).

This will be done in multiple regressions as has been done in multiple papers (Yang et al., 2010; Lantz & Sahut, 2005; Ravšelj & Aristovnik, 2020).

The panel regression models predicting both the Earnings per Share and the Return on Assets are presented in the Equations below. The 2 lagged R&D intensity variables are considered in separate models as done in the paper by Ravšelj & Aristovnik (2020). There are different models for the different sets of hypotheses, for the first set the engagement in key technology variables are excluded and the models are as shown below:

$$ROA_{i,t} = \alpha_0 + \beta_1 RDI_{i,t} + \beta_2 SIZE_{i,t} + \beta_3 NSG_{i,t} + \beta_4 LEV_{i,t} + \varepsilon_{i,t}$$

$$ROA_{i,t} = \alpha_0 + \beta_1 RDI_{i,t-1} + \beta_2 SIZE_{i,t} + \beta_3 NSG_{i,t} + \beta_4 LEV_{i,t} + \varepsilon_{i,t}$$

$$ROA_{i,t} = \alpha_0 + \beta_1 RDI_{i,t-2} + \beta_2 SIZE_{i,t} + \beta_3 NSG_{i,t} + \beta_4 LEV_{i,t} + \varepsilon_{i,t}$$

$$EPS_{i,t} = \alpha_0 + \beta_1 RDI_{i,t} + \beta_2 SIZE_{i,t} + \beta_3 NSG_{i,t} + \beta_4 LEV_{i,t} + \varepsilon_{i,t}$$

$$EPS_{i,t} = \alpha_0 + \beta_1 RDI_{i,t-1} + \beta_2 SIZE_{i,t} + \beta_3 NSG_{i,t} + \beta_4 LEV_{i,t} + \varepsilon_{i,t}$$

$$EPS_{i,t} = \alpha_0 + \beta_1 RDI_{i,t-2} + \beta_2 SIZE_{i,t} + \beta_3 NSG_{i,t} + \beta_4 LEV_{i,t} + \varepsilon_{i,t}$$

In these equations, the error term is denoted by ε. The subscript i indicates the company and t denotes the current year. The subscripts t-1 and t-2 are used to denote the current year lagged by 1 and 2 years, respectively.

For the second set of hypotheses, the Key technology variable, as well as an interaction variable, were added to test the moderating effect of the engagement in Key technology on the relationship between the RDI and the ROA or EPS. The interaction variable as well as the correlated independent and moderator variables were included in the model as this is essential as without it the regression equation is said to be incomplete and it would not be possible to interpret the results as described by Dawson (2014).

Besides these separate models for the different hypotheses, a further distinction will be made through different models within these formulated models as the moderator variable KEY is operationalized in two ways, as a dummy, and as an ordinal variable. As these variables would be highly correlated separate models need to be used.

$$ROA_{i,t} = \alpha_0 + \beta_1 RDI_{i,t} + \beta_2 KEY_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 NSG_{i,t} + \beta_5 LEV_{i,t} + \beta_6 RDI_{i,t} * KEY_{i,t} + \varepsilon_{i,t}$$

$$ROA_{i,t} = \alpha_0 + \beta_1 RDI_{i,t-1} + \beta_2 KEY_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 NSG_{i,t} + \beta_5 LEV_{i,t} + \beta_6 RDI_{i,t-1} * KEY_{i,t} + \varepsilon_{i,t}$$

$$ROA_{i,t} = \alpha_0 + \beta_1 RDI_{i,t-2} + \beta_2 KEY_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 NSG_{i,t} + \beta_5 LEV_{i,t} + \beta_6 RDI_{i,t-2} * KEY_{i,t} + \varepsilon_{i,t}$$

$$EPS_{i,t} = \alpha_0 + \beta_1 RDI_{i,t} + \beta_2 KEY_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 NSG_{i,t} + \beta_5 LEV_{i,t} + \beta_6 RDI_{i,t} * KEY_{i,t} + \varepsilon_{i,t}$$

$$EPS_{i,t} = \alpha_0 + \beta_1 RDI_{i,t-1} + \beta_2 KEY_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 NSG_{i,t} + \beta_5 LEV_{i,t} + \beta_6 RDI_{i,t-1} * KEY_{i,t} + \varepsilon_{i,t}$$

$$EPS_{i,t} = \alpha_0 + \beta_1 RDI_{i,t-2} + \beta_2 KEY_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 NSG_{i,t} + \beta_5 LEV_{i,t} + \beta_6 RDI_{i,t-2} * KEY_{i,t} + \varepsilon_{i,t}$$

To show the effect the moderating variables have more clearly margins-plots of the effect the variables have on the relationship are created. The predicted values of the ROA and the EPS were calculated for several different levels of the RDI, keeping the control variables constant. The levels of RDI were kept equal and from there the predicted values of the dependent variables were calculated under different levels of the moderator variables. This shows the slopes of the relationship between the dependent and the independent variable between the different levels of the Key Technology variables. The levels that were chosen for the continuous variables in the calculations are one standard deviation below the mean, the mean itself, and one standard deviation above the mean as this is commonly done as described in the paper written by Dawson (2014).

b. Variables explained

1. Dependent variables

The dependent variable is firm performance. This firm performance is operationalized by two variables. Two operational measures were used as these measures measure the actual realized performance as reported in the annual reports of firms (Thanos and Papadakis, 2012). Using these two measures also provides a more clear picture as ROA is very operational and EPS incorporates financial decisions that are based on market sentiment to an extent.

The first way the firm performance is operationalized is the return on assets (ROA). This variable is often used in the literature (Artz et al., 2010; Chen et al.,2019; Rao et al.,2013; Pantagakis et al., 2012; Yang et al., 2010), it is one of the most common ratios for measuring operating performance. This accounting-based performance measure indicates whether companies are effectively using their assets, equity, and sales to generate profits (Ravšelj & Aristovnik, 2020). ROA can be calculated as follows:

$$ROA = \frac{Net\ Income}{Total\ Assets}$$

The firm performance is also operationalized by the Earnings Per Share (EPS) which is also said to explain financial performance commonly and is considered an important ratio to review the accounting performance. It is specifically mentioned to be relevant for shareholders (Yang et al., 2010). It is often mentioned to be used in literature (Yang et al., 2010; Ravšelj & Aristovnik, 2020). This is how it is calculated (Jordan, Westerfield & Ross, 2012):

$$EPS = \frac{Net\ Income}{Total\ Shares\ Outstanding}$$

2. Independent variable

R&D intensity is the main independent variable of this paper, the variable has often been used in research, and as noted, conclusive evidence has not been given over time as to whether it increases business performance. Due to the differences in the amount of assets and resources available to companies R&D investment tends to differ by company, therefore the intensity is calculated (Chen et al., 2019). This R&D intensity is defined as the ratio of R&D expenditure to Net Sales within that same year as was done in several papers (Pantagakis et al.,2012; Yang et al.,2010; Ravšelj & Aristovnik, 2020), the formula for this calculation is shown underneath.

$$R\&D\ Intensity = \frac{R\&D\ Expenditure}{Net\ Sales}$$

Not only the current values will be used, lagged values will be taken into account as well as the investment in R&D is an immediate cost that could have an effect on the ROA while the positive influence of the R&D spending on the operating performance might only come across in one of the next two years as posed in the paper by Chen, Guo & Wei (2019) and Rao et al. as in their paper they found a lag period of 1 year for Japan and 2 years for China (2013). These values are occasionally referred to as RDI1 for the R&D Intensity of one year before the recording of the performance and RDI 2 for the R&D Intensity 2 years before.

3. Moderator variables

Key Technology engagement is the moderator variable that is used in this research, this variable is operationalized in two ways.

Firstly the companies listed on the Dutch stock exchanges will be looked over to see whether these companies engage in the Key Technologies. For this variable news articles and company / financial announcements will be looked through reviewing the possible engagement in the development of the Key Technologies.

From this check a dichotomous variable is created which is coded as 0 if the companies do not engage in any of the key technologies and 1 if they do engage in any of the key technologies.

If this company is found to engage in one of the Key Technologies this will be noted as 1, after this, it will be checked and noted if the company engages in any of the other Key Technologies and it will be noted in how many they are engaged.

This extent of engagement is a way in which Key technology engagement is also operationalized. It is operationalized through an ordinal variable that can be between 1 and 10, as there are 10 key technologies. It is valuable to know how many Key Technologies the companies actually have a vested interest in to gauge the extent to which companies are working on the Key Technologies.

4. Control variables

In the literature, three control variables are used across the papers nearly universally. These variables will be laid out here.

The first control variable that has been used in Literature extensively (Chen et al.,2019; Pantagakis et al.,2012; Yang et al.,2010; Rao et al.,2013) is Size. It is controlled for as Chen et al. (2019) noted that earnings performance and variations in R&D investment were affected by firm size. It will be defined as the logarithm of total assets as done in the paper by Rao et al. (2013), shown in the formula below.

$$Size = \log_{10} Total\ Assets$$

Leverage, which will be shortened to Lvg is defined as the ratio of total liabilities to total assets. It reflects the company's capital structure (Rao et al.,2013). There is one clear operationalization used across the literature (Chen et al.,2019; Pantagakis et al.,2012; Yang et al.,2010; Rao et al.,2013) which can be seen in the formula below:

$$Leverage = \frac{Total\ Liabilities}{Total\ Assets}$$

The firm growth is another control variable, it is used in several papers (Chen et al., 2019; Rao et al., 2013; Pantagakis et al.,2012; Ravšelj & Aristovnik, 2020) it shows the growth trend of a company and as it is operationalized as Net Sales Growth as done in the paper by Ravšelj and Aristovnik (2020) it is expected to have a positive impact on the financial performance due to the extra income generated and increasing profitability (Ravšelj & Aristovnik, 2020). The following formula shows how Net Sales Growth (which may be referred to as NSG) is calculated:

$$Net\ Sales\ Growth = \frac{Current\ Net\ Sales - Net\ Sales\ previous\ year}{Net\ Sales\ previous\ year}$$

4. Data

The data will be structured as a dynamic panel, having each company be its group within the panel to be observed over time. The data from the companies and the companies themselves that are deemed fit will be taken from Refinitiv Eikon as well as their annual reports.

To be deemed fit the companies first need to have been listed on the Dutch Stock exchange. Secondly, data should be available and they should thus have been listed for at least 3 years between 2016 to 2023 as that is the sample period that was taken for this research and the R&D intensity is lagged for 2 years making 3 years the requirement. Finally, companies within the financial industry are excluded as these companies are expected to have invested in all of the key technologies indirectly as they have most technologies which would thus cloud the results.

The companies on the Dutch Stock Exchange were chosen as the Key Technologies were chosen specifically for the companies within the Netherlands and it would be a relevant scope for this research. Even though the research is thus limited to companies within the Netherlands it should not entirely be written off for other countries. The reason for this is that both the Key Technologies and the R&D research can be argued to be useable for other countries as the key technologies consist of technologies that are listed in the European Union's program Horizon Europe (Holland High Tech,

2024) and past research on R&D has shown consistent cross-country results (Rao, Yu & Cao;2013, Ravšelj and Aristovnik; 2020).

The time period from 2018 to 2023 was taken as this firstly is research using new industries found in the Horizon Europe program which started in 2018 (European Commission, 2018). Using the newest data is key to the research as well and the period being from 2018 to 2023 is a feasible time period to do research on as the amount of data will be reasonable.

The Key Technology engagement check was done in NexisUni. The news and the company files and financials as listed by NexisUni were checked. The following search terms were used to check for news and company files and financials regarding the engagement: "The company" AND "The key technology" + "The company" AND The key technology. In cases where the key technology as named in the key technology strategy is not broad enough to find any results it was shortened as optical systems is not broad enough to find any results in NexisUni, the search term was shortened to optical to be able to find results.

To be able to exclude the effect of potential outliers the variables in the study were winsorised by each year as done by Ravšelj and Aristovnik (2020). The variables were winsorized at the 1% level and the 99% level. This winsorization excludes the moderator variables as it can only be 0 and 1 and cannot include a spurious outlier which leaves no need to winsorized them.

5. Results

a. Descriptive statistics

Table 2 shows the descriptive statistics of the independent, dependent, and moderator variables that are used in this research. As mentioned in the section on the data used in this paper the data was winsorized to exclude the effect of outliers. To show both the impact and the need for the winsorization the sample is shown before winsorization and after winsorization.

The effect of the winsorization can be seen most clearly in the research and development intensity as the difference between the base and the winsorized maximum of the variable is more than 10 times its standard deviation, this difference being more than 8 times its respective standard deviation for the variable lagged by 1 year and being more than 13 times its respective standard deviation for the variable lagged by 2 years.

TABLE 2: DESCRIPTIVE STATISTICS

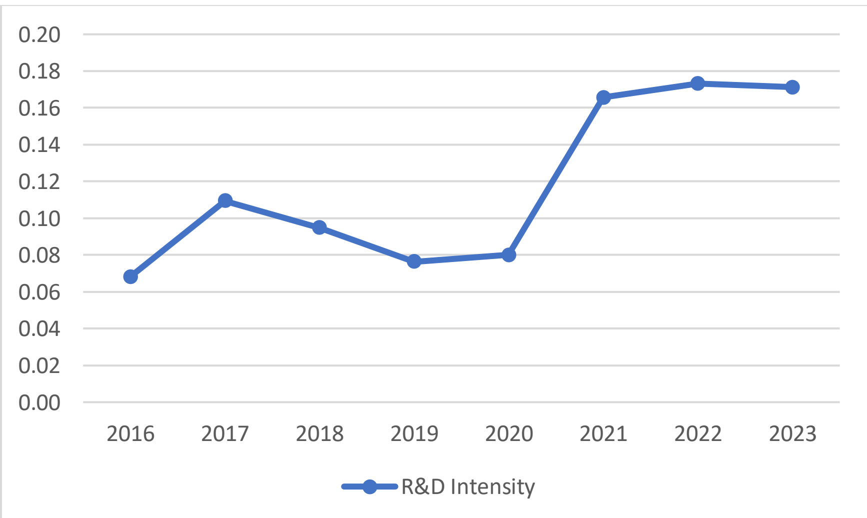
Descriptive Statistics of Base Sample					
Variable	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
ROA	235	-2.402	0.266	0.016	0.206
EPS	235	-4.669	20.627	2.520	3.956
RDI	235	0.000	10.002	0.154	0.799
RDI(-1)	235	0.000	5.453	0.124	0.446
RDI(-2)	235	0.000	24.300	0.237	1.690
KEYD	235	0.000	1.000	0.804	0.398
KEY	235	0.000	7.000	2.115	1.667
Total Assets	235	$1.731*10^{6}$	$4.140*10^{11}$	$1.921*10^{10}$	$5.856*10^{10}$

Size	235	6.238	11.617	9.253	1.077
Leverage	235	0.112	1.163	0.564	0.181
Net Sales Growth	235	-0.773	8.554	0.128	0.607
Descriptive Statistics of Winsorized Sample					
ROA	235	-0.570	0.225	0.025	0.131
EPS	235	-2.995	15.952	2.508	3.856
RDI	235	0.000	1.318	0.094	0.224
RDI(-1)	235	0.000	1.797	0.105	0.277
RDI(-2)	235	0.000	1.975	0.114	0.313
KEYD	235	0.000	1.000	0.804	0.398
KEY	235	0.000	7.000	2.115	1.667
Total Assets	235	$4.731*10^6$	$3.590*10^{11}$	$1.894*10^{10}$	$5.679*10^{10}$
Size	235	6.560	11.555	9.256	1.067
Leverage	235	0.159	0.975	0.563	0.177
Net Sales Growth	235	-0.495	0.959	0.093	0.235

NOTE: THIS TABLE REPORTS THE DESCRIPTIVE STATISTICS FOR THE SAMPLE. IT IS SPLIT INTO A TABLE REPORTING THE WINSORIZED STATISTICS AND THE BASE STATISTICS. THE TOTAL ASSETS ARE REPORTED AS WELL AS THEIR LOG TRANSFORMATION IN SIZE. FURTHER INFO ON THE VARIABLES CAN BE FOUND IN SECTION 3B.

The development of the R&D Intensity within the companies of the sample is shown in Figure 2 which is displayed below. This figure does not show a linear trajectory as there are periods of decline and periods where the R&D intensity is constant over multiple years. It does show a gradual positive trend over a longer horizon, which suggests that firms have placed a higher value on R&D investment.

FIGURE 2: TIME SERIES PLOT OF AVERAGE R&D INTENSITY



NOTE: THIS FIGURE GRAPHS THE LEVEL OF R&D INTENSITY DURING 2016-2023

Table 3 shows the frequency distribution of the key technology engagement variable. The table shows that 10 out of 45 or 22.2% of the companies were not seen to engage in investment in the research and development of key technologies. It can also be said that companies that are seen to engage in this investment tend to engage in more investment of more than one technology as only 20% of the companies that invest in key technologies engage in a single key technology. This can be explained by the key technologies that are most engaged in, namely Artificial Intelligence and data and Imaging technologies have significant overlap as the visualization of data within the imaging technologies is part of data science and the imaging technologies themselves can be improved by the use of artificial intelligence.

TABLE 3: KEY TECHNOLOGY ENGAGEMENT FREQUENCY DISTRIBUTION

Key Technology Engagement	**Frequency**
0	10
1	7
2	16
3	6
4	2
5	2
6	1
7	1
Total	**45**

NOTE: THIS TABLE REPORTS THE NUMBER OF BUSINESSES ENGAGED IN A SPECIFIC NUMBER OF KEY TECHNOLOGIES.

b. Correlation table

Table 4 shows the Pearson correlations of the independent, dependent, and moderator variables that are used in this research. The values displayed for these correlations show an insight into the relationship between two variables. The values are between -1 and +1, the negative values suggest a negative relationship and the positive values suggest a positive relationship. The strength of the relationship is expected to be larger, the further the value deviates from 0.

TABLE 4: PEARSON CORRELATIONS

Basic correlation table									
	ROA	**EPS**	**RDI**	**RDI1**	**RDI2**	**KEY**	**Size**	**Lvg**	**NSG**
ROA	1								
EPS	,453**	1							
RDI	-,452**	-,343**	1						

RDI1	-,526**	-,206**	,936**	1					
RDI2	-,556**	-,226**	,855**	,932**	1				
KEY	,197**	,011	,010	-,030	-,067	1			
Size	,374**	,165*	-,208**	-,256**	-,301**	,464**	1		
Lvg	,025	-,143*	-,146*	-,166*	-,137*	,015	,155*	1	
NSG	,109	,216**	-,077	,077	,132*	-,001	-,100	-,099	1

Correlation table of Companies not engaged in Key Technologies

	ROA	EPS	RDI	RDI1	RDI2	Size	Lvg	NSG
ROA	1.000							
EPS	.624**	1.000						
RDI	-.694**	-.238	1.000					
RDI1	-.777**	-.271	.967**	1.000				
RDI2	-.850**	-.313*	.927**	.972**	1.000			
Size	.531**	.327*	-.444**	-.479**	-.517**	1.000		
Lvg	-.082	-.528**	-.078	-.088	-.108	.102	1.000	
NSG	-.446**	-.039	.300*	.455**	.487**	-.235	-.173	1.000

Correlation table of Companies engaged in Key Technologies

	ROA	EPS	RDI	RDI1	RDI2	KEY	Size	Lvg	NSG
ROA	1								
EPS	.462**	1							
RDI	-.373**	-.368**	1						
RDI1	-.414**	-.207*	.931**	1					
RDI2	-.391**	-.243**	.855**	.920**	1				
KEY	.199**	.109	-.018	-.029	-.037	1			
Size	.302**	.215**	-.177*	-.193**	-.200**	.353**	1		
Lvg	.075	-.067	-.175*	-.204**	-.155*	.017	.192**	1	

NSG	.304**	.329**	-.186*	-.058	-.023	.019	-.059	-.073	1

NOTE: THIS TABLE REPORTS THE PEARSON CORRELATION COEFFICIENTS. THE LEVEL OF STATISTICAL SIGNIFICANCE IS DENOTED AS FOLLOWS: **=P<0.01 *=P<0.05.

The two dependent variables, namely the ROA and the EPS show similar correlations which makes sense as they both are significantly correlated with one another. Other than this correlation both of these variables show significant negative relationships with both the current and the lagged R&D Intensities and a significant positive relationship with the size of the companies.

There are differences in the correlations for the dependent variables as the ROA is significantly positively correlated with the KEY and the EPS is not. Besides this difference, there is the difference that the EPS does find a significant negative relationship with the leverage of the company and a significant positive relationship with the NSG of the company whereas a significant relationship with the ROA was not found.

The independent variable of the RDI and its lagged variants are significantly positively correlated showing that the intensity stays relatively consistent over the years. As mentioned there is a correlation with the dependent variables but other than this correlation a significant positive correlation with the size of companies can also be found in the table as well as a less significant relationship with leverage. The two-year lagged variable also shows a significant positive correlation with the Net Sales Growth.

The moderator variable of the Key Technology Engagement is positively correlated with the dependent variable ROA as mentioned above. Besides this correlation, a significant correlation with size is found which shows that larger companies are more likely to invest in key technologies and in more technologies which was to be expected.

The control variables differ in their correlations as size seems to have many correlations as the only variable it shows no correlation with is the Net Sales Growth. The Leverage and NSG being significantly correlated with the EPS the first negatively and the second positively is relevant as it shows that there is some validity in controlling for these variables. The variables being correlated with for the Leverage all variants of the R&D intensity and for the NSG only the 2-year lagged variant does not necessarily detract from this validity.

After splitting the correlation tables into a table for the sample that engages in Key Technologies and a table that does not engage in key technologies the differences most relevant to the research are that the correlation between all forms of the RDI and the ROA shows a significant relationship that is less negative for the table with the companies that engage in key technologies and the negative relationship between the RDI and EPS shows more significance the table with the companies that engage in key technologies. The differences in these correlations provide reasoning to test the moderation effect of these variables.

c. Regression assumptions

As previously described four key assumptions need to be tested for the regression to be considered as a valid method. Testing these key assumptions is an important step towards this regression analysis, as these assumptions not being fulfilled could lead to results that are inaccurate and even lead to a misinterpretation of the findings from the regression.

The first key assumption that will be gone over is the assumption of linearity. Most of the relationships found in the literature were linear as noted in the literature review. The studies that have investigated the relationship between R&D Intensity and firm performance specifically also mainly described linear relationships (Lantz & Sahut,2005; Chen et al.,2019; Andras & Srinivasan, 2003; Rao, Yu & Cao, 2013; Haque et al, 2024). It is specifically mentioned that linear modeling is commonly used to test the relationship between R&D and firm performance (Yang, Chiao, and Kuo; 2021). From the literature, it can thus be seen that the assumption of linearity is not refuted.

The second check that has to be done as was described in the methodology is the check for the existence of a correlation between the predictor variables or multicollinearity. The correlation was checked through a Pearson correlation table as can be viewed in Table 4. In this table, multiple significant correlations were found which resulted in having to use a further check, namely looking at the Variance Inflation Factor scores. The standard threshold that is set for this test is that the scores should all be lower than 10 for the multicollinearity assumption not to be violated. These scores are shown in Table 5 and are all below 10 as the highest score is that of the key technology engagement dummy which is 1,691. The absence of multicollinearity is thus fulfilled.

TABLE 5: VARIATION INFLATION FACTOR SCORES

Variable	VIF
RDI	1.095
KEYD	1.691
KEY	1.837
Size	1.431
Leverage	1.052
NSG	1.034

The third assumption that was checked is whether there is the assumption of constant variance of the residuals. This assumption was checked by looking at the residual plot shown beneath in Figure 3 for the Return on Assets or operational performance model and in Figure 4 for the Earnings per Share or market performance model. Whereas the variance seems constant in the first plot, in the second plot a slight pattern can be seen as the residuals are shown to be further from 0 the further they are from the point where the results are clustered, and there seems to be a negative relationship between the residuals and the predicted value for the earnings per share model. This perceived plot for the EPS does not make it seem very plausible for the errors to be independent due to the perceived relationship.

FIGURE 3: RESIDUALS ROA MODEL

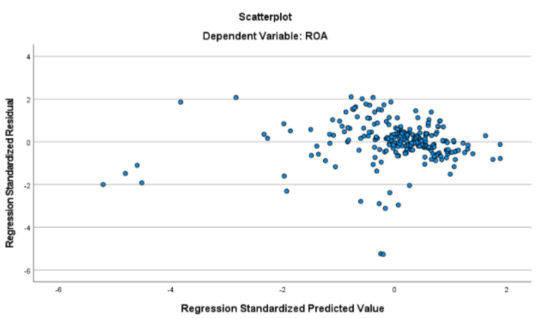
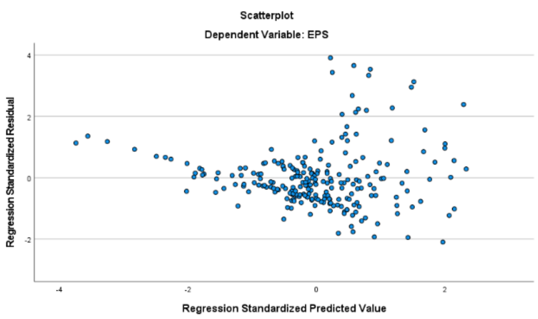


FIGURE 4: RESIDUALS EPS MODEL

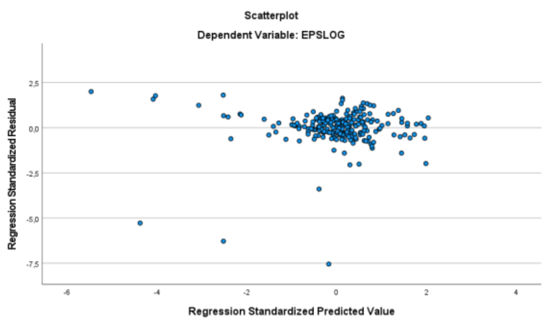


To control for the problem of the variance not being constant for the EPS model, the EPS variable was log-transformed as was done in other research (Lantz & Sahut, 2005). Taking the log of economic variables is said to substantially improve forecasting if the log transformation were to stabilize the variables (Lütkepohl & Xu,2009).

This log-transformed model can be seen to have improved constant variance as in Figure 5 no relationship in the variances can be seen and they seem constant. As this improvement was found it was determined that the logged EPS model was to be used for the regressions.

The fourth assumption is the assumption of normality. To verify that the data is approximately normally distributed the P-P plots that can be found in Appendix 1 as well as the histograms that can be found in Appendix 2 have been made. In these plots, it can be seen that the data is not completely normally distributed as the histogram has a skewness. This skewness is less significant in the case where ROA is used. This can also be seen in the P-P plot as the line deviates more from the normally distributed distribution when using the logged EPS. The normality is not very clear. This unclear normality does not have to be considered to be too significant of a violation to continue as the normality assumption becomes less important as the sample size grows (Sharpe, De Veaux, Velleman; 2021) and the fact that the sample size here is larger than 200 may allow this slight violation to be neglected due to the Central Limit Theorem.

FIGURE 5: RESIDUALS LOGGED EPSMODEL



As the assumptions are not significantly violated the pooled regression the pooled regression will be used as the main method in this research. A pooled regression was used to do these regressions as firstly it allowed the use of all models. The KEY and KEYD variables do not change over time for a single unit. This violates the assumption of variance over time that needs to be fulfilled when using the fixed effect model. Secondly, the underlying OLS method is used frequently both in the literature (Ravšelj & Aristovnik, 2020; Yang et al., 2010) and in general in statistical research.

Even though the main method that is used is pooled regression, the possibility of using other models will be taken into account. The slight violation of the assumption of normality could have been taken as a reason not to use the pooled regression which provides a reason to look at this possibility. To look at this possibility of using other models another check was done by doing a Lagrange Multiplier test. This test as designed by Breusch and Pagan (1980) is used to test the existence of random effects. The null hypothesis of the one-way random group effect model is that variances of groups (in this case the between the firms) are zero (Xu, Lee, Aeom; 2007). As this hypothesis is rejected here for both regressions as confirmed by the significant Lagrange multiplier test results as seen in Table 6, the variances are expected to be different per group and the random effect model is deemed better than the pooled regression method.

Other than the result for this method this result also shows heteroskedasticity even after logging the EPS. This is why robust standard errors were used in the regressions as was done in the paper by Ravšelj and Aristovnik (2020). A modified version of White's (1980) heteroskedasticity-consistent covariance matrix estimator was used as is standard in Stata.

TABLE 6: LAGRANGE MULTIPLIER

Regression model	RDI	RDI1	RDI2
ROA multiplier	218.08**	220.39**	209.69**
EPS multiplier	26.33**	30.84**	38.18**

NOTE: THIS TABLE REPORTS THE LAGRANGE MULTIPLIERS FOR THE MODELS EXCLUDING THE MODERATOR VARIABLE. THE LEVEL OF STATISTICAL SIGNIFICANCE IS DENOTED AS FOLLOWS: **=P<0.01 *=P<0.05.

As it has now been decided that models other than the pooled regression method could be used a further test is done to see whether the fixed or random effects model should be used. This test is the Hausman test which tests for endogeneity, the null hypothesis there not being endogeneity and the parameter estimates being unbiased. To see how the bias could arise, suppose that we have only one explanatory variable, x_{2it}, that varies positively with y_{it} and also with the error term, ω_{it}. The estimator will ascribe all of any increase in y to x when in reality some of it arises from the error term, resulting in biased coefficients (Brooks, 2014). As 5 out of 6 of the tests were significant as seen in Table 7(with an alpha of 5%) the null hypothesis of the error term not being correlated with the independent variables and the parameters being biased is refused. To correct for these findings the Fixed effects regression will be tested on the applicable models.

TABLE 7: HAUSMAN STATISTIC

Regression model	RDI	RDI1	RDI2
ROA statistic	15.98**	11.14*	8.69
EPS statistic	23.49**	22.00**	13.44**

NOTE: THIS TABLE REPORTS THE HAUSMAN STATISTICS FOR THE MODELS EXCLUDING THE MODERATOR VARIABLE. THE LEVEL OF STATISTICAL SIGNIFICANCE IS DENOTED AS FOLLOWS: **=P<0.01 *=P<0.05.

d. Regression results

The results of the multiple least square regressions done to test the hypotheses will be presented here. These regressions were done as they were deemed valid as explained in the section on the methodology of this thesis. The regressions are presented under the hypotheses which they are intended to test for.

Hypothesis 1

The results for the regression on the relationship between R&D intensity and firm performance as measured by the ROA and EPS are displayed beneath in Table 8. The R&D intensity of the year the firm performance was recorded and each lagged R&D intensity variable was regressed in a separate model to test the differences in the explanation of the variance they show.

A negative relationship between the unlagged R&D Intensity and both of the performance measures was found. The relationship between RDI and ROA that was found (-0.226) is significant with an alpha of 1% and the relationship between RDI and EPS (-0.486) is significant with an alpha of 5%.

These findings confirm hypothesis 1a. The literature provides support for these results as Chen et al. (2019), Ravšelj and Aristovnik (2020), Pantagakis et al. (2012), and Haque et al. (2024) found similar relationships between the R&D Intensity and the firm performance as measured by the ROA or similar return based performance measures. A moderate economic significance was found for the relationship with the ROA as this performance measure was used in most of the papers and the relationship found here (-0.226) is stronger than the relationship found in the paper by Chen (-0.0283) and weaker than the relationship (-1.297) found in the paper by Haque et al. (2024).

These results could be explained by the high costs incurred for the R&D spending turning into poor short-term financial performance (Leung & Sharma, 2021). As R&D spending can be seen as a cost, the higher the R&D spending, the higher the cost and thus the greater the decrease in profits for the current year (Chen et al., 2019). It is also not possible for every R&D investment to be a success for every company and the costs incurred may not lead to any increased returns at all (Rao, Yu & Cao; 2013). Leung and Sharma (2021) also hypothesized that investing in R&D has a negative effect on short-term performance due to the time lag between the R&D investments and the return on those investments.

The relationship between lagged R&D investments and the firm performance can be found in Table 8. The RDI1 has a negative relationship with ROA (-0.226) significant at the 1% level and a negative relationship with the EPS (-0.371) significant at the 5% level. The RDI2 also finds a relationship with the ROA (-0.216) significant at the 1% level and with the EPS (-0.342) significant at the 5% level. This result is not in line with hypothesis 1b nor with the literature as there is only one relationship with lagged R&D intensity that was found to be linearly negative. In the paper by Leung and Sharma (2021), this negative relationship between R&D intensity and short-term financial performance was found.

This result could be due to the same reasons described earlier for the relationship with the unlagged RDI as the timeframe may not make a significant difference and R&D projects could fail years into the project. The results going against the hypothesis could also be due to peculiarities in the Dutch market acting as Ravšelj and Aristovnik (2020) deemed it valuable to look into specific markets as in the paper the Slovenian market was isolated to be looked into. In the paper by Rao, Yu & Cao (2013) it was shown that Japan had a positive relationship between R&D Intensity and company performance after lagging the RDI for one year, and for China this was only the case after one year, whereafter the relationship was negative. The results could thus also be due to the Dutch companies having a longer lag period and thus a longer period of uncertainty regarding the return than companies in other countries. The investment in R&D to develop new knowledge and abilities may benefit the firm performance over a longer period but hurt the performance in the short term (Leung & Sharma, 2021). Other than the investment being too high it could also be too low as an S-Curve relationship was proposed (Yang, Chiao, and Kuo; 2010) where R&D investments do not lead to profits before a certain threshold and then reach a peak after which further investments again lead to losses, it could be the case that the companies are on the wrong side of this curve.

Besides these main results, some significant relationships were found between the performance measures and the control variables as expected from the correlation table. A significant positive relationship between size and ROA was found in all models and a significant negative relationship was found between the Leverage and the EPS in all models. These relationships are significant at the 1% level. A significant positive relationship was found between the Net Sales Growth and the ROA in the models with the lagged R&D Intensity variable. This relationship is significant at the 5% level.

TABLE 8: POOLED REGRESSION FIRM PERFORMANCE

	Dependent variable:					
	ROA			**EPS**		
RDI Model	**RDI**	**RDI1**	**RDI2**	**RDI**	**RDI1**	**RDI2**
Constant	-0.287	-0.244	-0.216	0.530	0.534	0.568
RDI	-0.226 (-4.35)**	-0.226 (-7.22)**	-0.216 (-7.80)**	-0.486 (-2.50)*	-0.371 (-2.21)*	-0.342 (-2.02)*
Size	0.039 (4.76)**	0.034 (4.63)**	0.030 (4.45)**	0.045 (1.56)	0.043 (1.42)	0.037 (1.16)
Lvg	-0.052 (-1.02)	-0.060 (-1.28)	-0.047 (-1.02)	-0.445 (-3.68)**	-0.440 (-3.60)**	-0.418 (-3.35)**
NSG	0.058 (1.13)	0.092 (1.97)*	0.109 (2.59)*	-0.276 (-1.26)	-0.207 (-1.02)	-0.182 (-1.01)
Observations	235	235	235	235	235	235
Companies	45	45	45	45	45	45
Adj. R^2	0.291	0.363	0.389	0.010	0.092	0.094

NOTE: THIS TABLE REPORTS THE POOLED LEAST SQUARES REGRESSION FOR BOTH DEPENDENT VARIABLES AND ALL VERSIONS OF THE RDI. THE MODELS TESTED HERE EXCLUDE THE MODERATOR VARIABLES. T-VALUES ARE REPORTED IN PARENTHESES. THE LEVEL OF STATISTICAL SIGNIFICANCE IS DENOTED AS FOLLOWS: **=P<0.01 *=P<0.05.

Hypothesis 2

Pooled regressions will be done to test the second hypothesis. The results of the regression show the moderation the Key Technology variable operationalized as a dummy and a continuous variable has on the relationship between the RDI and the ROA and EPS. These results are shown in Table 9.

To mitigate some of the multicollinearity found as can be seen in the VIF table in Appendix 3 the interaction variable being mean-centered was looked into as this was done in other research. As Dawson (2014) suggested in the paper on moderation in management research, binary variables should not be mean-centered and neither should other variables for which the value 0 denotes a state that is intended to be researched. As both the standard KEY variable and the dummy hold importance for the value 0 it was thus chosen not to mean center the variables.

The relationship between the R&D Intensity and the ROA stayed significantly negative at the 1% level while moderated by the Key Technology dummy. This significance is found for the RDI (-0.409) the RDI1 (-0.345) and the RDI2 (-0.296). Firms that engage in Key Technologies have a less negative relationship between RDI and ROA as the interaction variable between Key Technologies and the RDI (or KEYRDI) is significantly positive for both RDI (0.240) and RDI1(0.171) at the 1% level and significant for RDI2(0.137) at the 5% level.

The relationship between RDI is significantly negative in the regressions using the variable measuring the extent of Key Technology engagement for the RDI (-0.426), the RDI1 (-0.348), and the RDI2(-0.295). This relationship is also positively moderated by the extent of Key Technology engagement as the interaction is significantly positive at the 1% level when using the RDI (0.113), the RDI1 (0.081), and the RDI2 (0.064).

These results provide evidence for hypothesis 2 as can be seen in figures 6 and 7 which are graphing the relationships. Figure 6 graphs the moderation of the Key Technology dummy on the relationship between the RDI and ROA, engaging in key technology can be seen to positively affect the relationship between RDI and ROA as not engaging in key technology (or KEYD = 0) engagement showed a stronger negative relationship between these values. From Figure 7 it can be seen that the greater extent of key technology engagement (or a higher level of KEY) lowered the negativity or had a positive effect on the relationship between RDI and ROA. The RDI of the current year was taken as for this moderator variable the t-value was the highest in all cases. The graphs of the RDI1 and RDI2 can be found in Appendix 4 for the dummy KEY variable and Appendix 5 for the continuous KEY variable.

The engagement in Key Technologies and the level to which they are engaged having a positive effect on the relationship between RDI and ROA could be explained by the presence of technological opportunity of firms engaging in Key Technologies. Firms engaged in Key Technologies can be assumed to be present in sectors with a high level of technological opportunity which is said to enhance the effectiveness of R&D intensity (Lee, Wu & Pao, 2014). Besides high technological opportunity, firms engaged in Key Technologies are also assumed to be in sectors with a high level of technological complexity. These firms require a higher amount of resources to perform well financially (Madhok, 2002) and for these firms, higher levels of R&D could thus be required and have less of a negative effect. As this could extend to R&D it could explain why a relatively high level of R&D would have a less negative effect on the financial performance of these firms.

The results of the regression on the EPS showed different results. Besides the control variables, the only variable that showed significance was the Key Technology engagement dummy variable which is significant at the 1% level for the RDI (-0.163), RDI1 (-0.168), and RDI2 (-0.164). For the regression models using the extent of Key Technology engagement, no significant results supporting the hypothesis have been found.

The moderation from the KEY dummy was even found to be negative for RDI (-0.407), RDI1 (-0.377), and RDI2 (-0.407). This is the same for the moderation from the continuous KEY variable for the RDI (-0.201), RDI1 (-0.220), and RDI2 (-0.288). Neither of these relationships is significant even as the negative effect of the engagement and the extent of the engagement in Key technologies can be seen in Figures 8 and 9 respectively.

From these results that were found from the regression against the EPS, no clear support for hypothesis 2 has been found. This could be due to the dependent variables differing in what they encapsulate in their measurement as ROA is a more operational variable. For the ROA the R&D costs are expected to have more of an impact than for the EPS as the EPS is more related to financial decisions and market sentiment through share repurchases and new shares being sold. As these effects of R&D on EPS are less significant, the moderating effect of Key Technology also lost its significance. Other than this difference in the performance part of the literature can explain this result as well. Besides the earlier mentioned positive effects, it was also found that companies in new industries in which the Key Technologies are regularly found firm performance improves with lower R&D intensity. Within companies in these new industries, no radical long-term initiatives should be undertaken (Chao and Kavadias, 2013) which investments in Key Technologies could fall under, this points out a negative effect of Key Technology engagement. This could explain the negative sign and the conflicting consults could be explained by the conflicting literature.

TABLE 9: REGRESSION MODERATION ON FIRM PERFORMANCE **= P<0.01 *=P<0.05

Dependent variable:		
	ROA	**EPS**
	Regression using Key Technology dummy	

RDI Model	RDI	RDI1	RDI2	RDI	RDI1	RDI2
Constant	-0.258	-0.221	-0.199	-0.364	-0.361	-0.388
RDI	-0.409 (-8.81)**	-0.345 (-8.13)**	-0.296 (-5.97)**	-0.136 (-1.59)	-0.087 (-1.24)	-0.090 (-1.79)
KEY	-0.015 (-0.71)	-0.018 (-0.96)	-0.024 (-1.40)	-0.163 (-2.88)**	-0.168 (-2.87)**	-0.164 (-2.64)**
KEYRDI	0.240 (3.12)**	0.171 (2.92)**	0.137 (2.12)*	-0.407 (-1.53)	-0.377 (-1.37)	-0.407 (-1.38)
Size	0.036 (4.19)**	0.032 (4.10)**	0.030 (3.83)**	0.079 (2.61)*	0.079 (2.58)*	0.075 (2.41)*
Lvg	-0.043 (-0.86)	-0.050 (-1.07)	-0.041 (-0.88)	-0.476 (-3.88)**	-0.483 (-3.84)**	-0.463 (-3.57)**
NSG	0.077 (1.47)	0.112 (2.54)**	0.126 (3.25)**	-0.301 (-1.31)	-0.247 (-1.11)	-0.229 (-1.16)
Adj. R^2	0.314	0.385	0.410	0.125	0.126	0.140
	Regression using continuous Key Technology					
Constant	-0.206	-0.174	-0.158	-0.377	0.348	0.340
RDI	-0.426 (-8.33)**	-0.348 (-8.89)**	-0.295 (-6.75)**	-0.129 (-0.98)	-0.039 (-0.38)	0.009 (0.11)
KEY	-0.002 (-0.52)	-0.000 (-0.08)	0.000 (0.01)	0.002 (0.07)	0.002 (0.06)	0.066 (0.26)
KEYRDI	0.113 (5.69)**	0.081 (4.10)**	0.064 (2.90)**	-0.201 (-1.25)	-0.220 (-1.32)	-0.288 (-1.84)
Size	0.028 (3.54)**	0.025 (3.48)**	0.023 (3.18)**	0.064 (1.91)	0.068 (2.04)*	0.067 (2.03)
Lvg	-0.029 (-0.58)	-0.036 (-0.77)	-0.031 (-0.65)	-0.485 (-3.96)**	-0.505 (-3.89)**	-0.490 (-3.65)**
NSG	0.066 (1.32)	0.095 (2.20)*	0.111 (2.97)**	-0.291 (-1.29)	-0.214 (-1.05)	-0.193 (-1.18)
Adj. R^2	0.339	0.403	0.419	0.107	0.114	0.147

Note: This table reports the pooled least squares regression for both dependent variables and all versions of the RDI. The models tested here include the dummy moderator variable in the top half and the continuous moderator variable in the bottom half. T-values are reported in parentheses. The level of statistical significance is denoted as follows: **=p<0.01 *=p<0.05.

Figure 6: Moderation graph KEYD on ROA

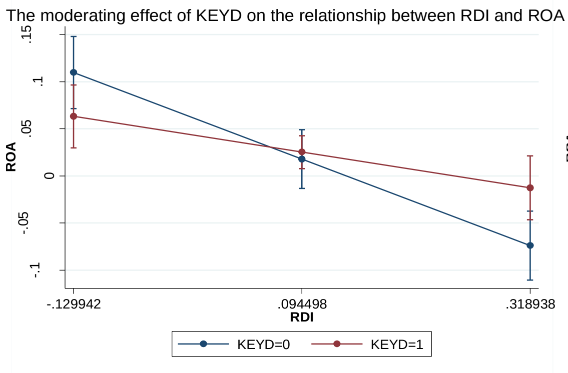


Figure 7: Moderation graph KEY on ROA

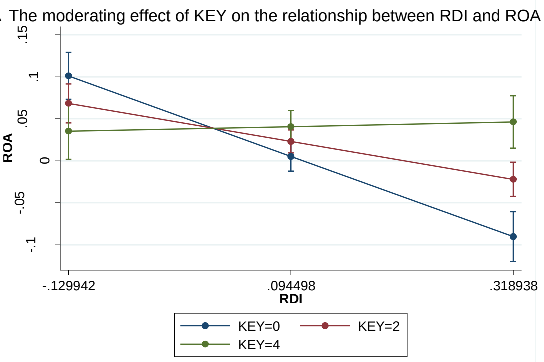


FIGURE 8: MODERATION GRAPH KEYD ON EPS

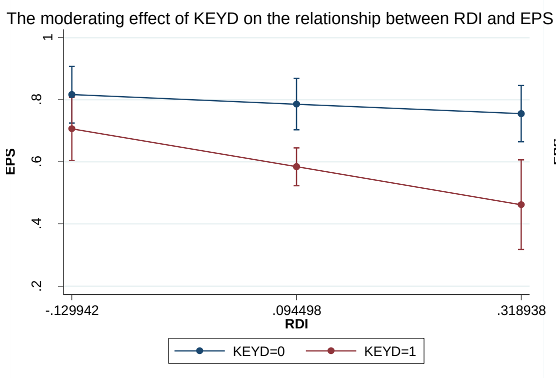
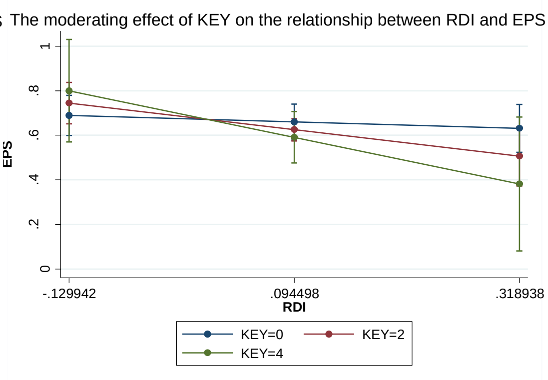


FIGURE 9: MODERATION GRAPH KEY ON EPS



e. Robustness test

As was laid out in the regression assumptions the tests for panel data indicated the use of the fixed effects model to be valid for this data.

The relationships between the RDI(0.631) and EPS, as well as the RDI (-0.037) and the ROA, were different as both of these relationships showed no significance within this fixed regression.

The lagged RDI also differs as the relationship between both RDI1(0.315) and RDI2(-0.130) and the EPS show no significance with the relationship with the RDI1 being positive and with the RDI2 being negative with a more significant t-value (-1.70) compared to the t-value (0.78) found for the RDI1. For the relationship with the ROA, only the RDI1 shows significance (-0.084) at the 5% level, the RDI2(-0.072) does not.

This difference in results could be due to the different methods having a difference in the variables as only the influences of variables that vary over time can be investigated(Brooks, 2014) possibly leading to omitted variables. This is especially relevant here as there is a small sample of 45 companies over which the time variance could be tested. This small sample is also expected to have played a part in the diminished significance that was found. This small sample and small variance through limited variables leads to a lower statistical power. This lower statistical power can be explained in part as the sufficient variability over time required for the predictor variables (Hill et al., 2020) is not clearly seen in the R&D Intensity as it does not fluctuate significantly as seen in Figure 2.

The signs of the relationships between the lagged RDI Models and the performance measures that show the highest t-values in Table 10 do show a negative relationship which is in line with the results found in the pooled regressions which could be used to strengthen this conclusion.

TABLE 10: FIXED REGRESSION FIRM PERFORMANCE

Dependent Variable:						
	ROA			**EPS**		
RDI Model	**RDI**	**RDI1**	**RDI2**	**RDI**	**RDI1**	**RDI2**
Constant	-0.644	-0.344	-0.498	5.073	4.930	6.733
RDI	-0.037 (-0.85)	-0.084(-2.01)	-0.072 (-1.44)	0.631 (0.75)	0.315 (0.78)	-0.130 (-1.70)
Size	0.072	0.041	0.056	-0.460	-0.446	-0.640

	(1.70)	(0.82)	(1.24)	(-1.95)	(-1.76)	(-1.71)
Lvg	-0.008 (-0.09)	-0.008 (-0.08)	0.015 (0.15)	-0.401 (-0.69)	-0.330 (-0.65)	-0.260 (-0.51)
NSG	0.056 (1.59)	0.070 (2.18)*	0.071 (2.60)*	-0.232 (-2.64)*	-0.318 (-1.79)	-0.254 (-1.94)
Observations	235	235	235	235	235	235
Companies	45	45	45	45	45	45
Adj. R^2	0.069	0.090	0.083	0.090	0.071	0.063
Hausman	15.98**	11.14*	8.69	23.49**	22.00**	13.44**
LM	218.08**	220.39**	209.69**	26.33**	30.84**	38.18**

NOTE: THIS TABLE REPORTS THE FIXED EFFECTS REGRESSION FOR BOTH DEPENDENT VARIABLES AND ALL VERSIONS OF THE RDI. THE MODELS TESTED HERE EXCLUDE THE MODERATOR VARIABLES. T-VALUES ARE REPORTED IN PARENTHESES. THE LEVEL OF STATISTICAL SIGNIFICANCE IS DENOTED AS FOLLOWS: **=P<0.01 *=P<0.05.

6. Conclusion

This thesis looked at the relationship between R&D intensity and firm performance and the moderating role of engagement in key technologies. This relationship was looked into using several panel regressions. This was done using a sample of 45 companies and 235 observations taken from the annual reports of the years 2018 to 2023.

The results provide evidence for the hypothesis that the unlagged R&D intensity has a negative impact on the firm performance as measured by the ROA and the EPS. This is in line with the literature that notes that R&D expenditures are seen as costs leading to immediate financial stress on the company and an uncertainty of whether the expenditure will lead to improved firm results.

The hypothesis that the lagged R&D intensity has a positive relationship with the firm performance was not supported. This is possibly due to the aforementioned reasons still having effects on the performance, which could play a part in a nonlinear relationship. It could also be due to specifics of the Dutch market as in literature different terms have been found over which the positive returns on R&D expenditures come in.

These relationships were not significant when checking the results over time between companies. As the sample is small and the difference between the variables in the companies over the different years is not stark this was to be expected.

There was some evidence found for the positive moderation effect that was hypothesized as both the extent to which firms engaged in key technologies and the fact that companies engaged in the development of key technologies positively influenced the relationship between all instances of RDI and the ROA. This was reasoned to be due to aspects related to the environment, the industry and the position these firms are in that are conducive to effective use of R&D expenditure. This positive moderation was not found for the relationship with the EPS as no significance was found. This could be due to the EPS being a broader measure compared to the operational focus of ROA as it incorporates market sentiment to a small extent.

7. Implications

Firstly it contributes further evidence of the R&D performance relationship being complex as evidenced by the variety of results found in the literature. This is now described for this recent period. In this thesis the results differed over separate methods and even though hypothesis 1a was confirmed 1b was not. Secondly, it provides further evidence that the position the company is in is a relevant factor. The position being the environment, the industry the company is in and the position the company is in within its industry are factors in the firm performance of companies engaging in R&D. Specifically the moderation by several different KEY technology industries is new as studies tend to focus on one key industry (Chen et al., 2019) or whether or not the companies are in tech industries (Lantz and Sahut, 2005; Rao, Yu and Cao,2013; Pantagakis et al., 2012).

Some managerial implications follow from this research. The results suggest that firms having a relatively high level of R&D expenditure could hurt short-term financial performance. Managers should choose the right moment to invest in R&D and make sure that this burden can be carried before heavily investing in R&D. Managers of companies that engage in the development of key technologies should look at the possibility of heavily investing in R&D. As their companies are posed to be hurt less by heavily investing in R&D and are better suited to engage in these higher levels of R&D which they could possibly use to have an edge over other companies in the long term especially when the firm is preparing to engage in many of the Key technologies.

8. Limitations and future research

While this thesis provides contributions, there are also limitations to this study and its generalizability which will be explained in this section.

Firstly the sample could limit the generalizability of this study as it consists of 235 observations over 45 different companies. This sample is relatively small. This dataset is this small as the data collection process was done by reading through all the different annual reports which limited the scope as this is a time-intensive process and because of the limited availability of firms actually producing their R&D expenditure which was needed for this research to keep the independent variable in line with the variables used in other studies on this topic.

A second limitation related to the sample is that the sample only includes companies listed on the Amsterdam Stock Exchanges and thus in the Netherlands. This may affect the generalizability of the results to other exchanges or countries as differences have been made and found in other studies on the relationship between R&D and firm performance (Rao, Yu & Cao,2003; Ravšelj and Aristovnik, 2020). The KEY Technology sectors are also centered around the Netherlands as they are found specifically strategic for this country even though they are also deemed strategic within the European Union, separate strategic technologies may thus be needed to be used to relate the results of the moderation towards other countries.

A third limitation lies in the Size variable being log-transformed using a common logarithm. In most literature on the topic of R&D the natural logarithm of the size was taken. This could limit the ability to compare the results of this paper to the literature. As the common logarithm could be multiplied by a constant to get the natural logarithm the underlying relationships are not expected to be affected under this different scaling of the variable.

Finally, only accounting metrics were used to measure the firm performance. Even though the Earnings per Share is said to be relevant to shareholders (Yang et al., 2010) it is also said not to be able to reflect shareholder value creation (Wet, 2013), it is not a market performance measure after all. While accounting-based and market-based measures are seen as valid indicators for the level of firm performance, their relationship is debated (Gentry & Shen, 2010). This makes it more clear that it might be valuable to use both types of variables to capture the entire concept of firm performance. The inclusion of market metrics might have led to different conclusions that were not captured in this research.

Future research could fill in the gaps these limitations leave by researching a bigger sample size which would then likely already be on multiple exchanges. Researching the moderation effect over multiple countries would be another way future research could be done. The natural logarithm of size could be used to be able to better compare the results of future research to other research. The final limitation of only using accounting metrics could also be taken as a guideline for new research as market-based metrics could be used in future research. Another avenue of future research that is relevant is expanding the timeline and taking longer lag periods to be able to capture long-term performance. Other than expanding the research the moderation could be further looked into by taking the different moderation effects in multiple countries and seeing what policies that the countries have in place influence this moderation effect.

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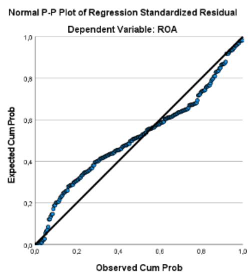
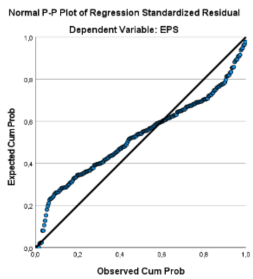
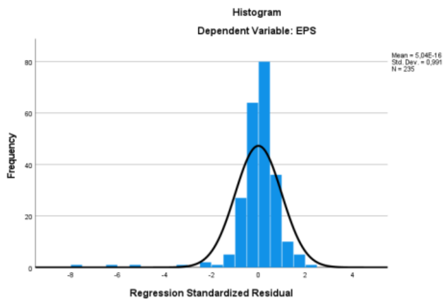
Appendix

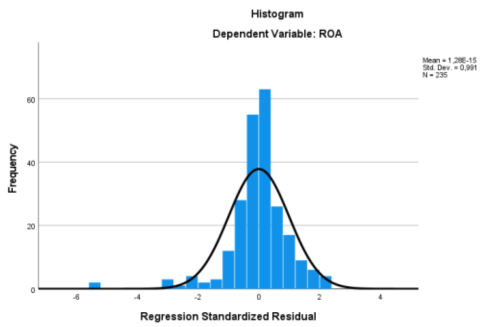
APPENDIX 1: P-P PLOTS





APPENDIX 2: HISTOGRAMS OF THE STANDARDIZED RESIDUALS

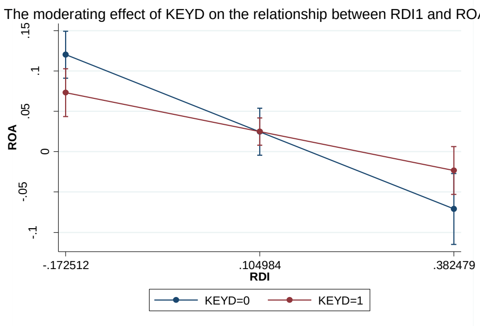


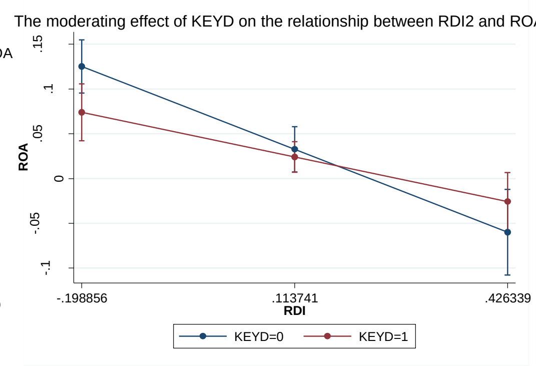


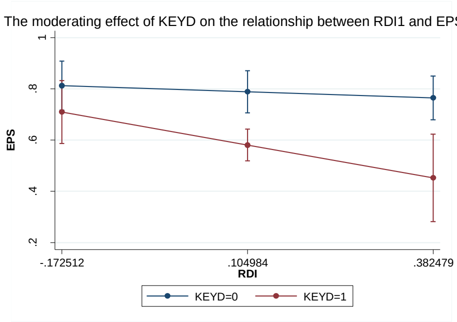
APPENDIX 3: VARIATION INFLATION FACTOR SCORES OF THE REGRESSION INCLUDING THE INTERACTION VARIABLE

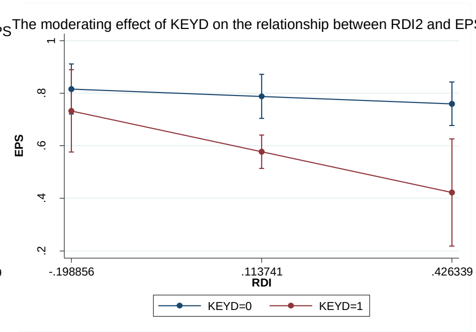
Variable	VIF	VIF CENTERED
RDI	3.364	1.200
KEY	1.492	1.332
KEYRDI	3.565	1.183
Size	1.444	1.444
Leverage	1.066	1.066
NSG	1.041	1.041

APPENDIX 4: KEY DUMMY MODERATION GRAPHS









APPENDIX 5: KEY MODERATION GRAPHS