The effect of R&D investments on firm performance

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Abstract

Growth and development of business firms is mainly a consequence of innovation. Innovation is a broad concept that applies to all companies on different aspects of the organization, like products, markets, internal processes and employees. One of the most important goals of innovation is to improve the performance of the company, either on the short term or on the long term. Because it is an important topic in business, a lot of research is already done about innovation. However, there is no unanimous conclusion about the relationship between R&D investments and firm performance. Some studies find positive relationships, some find negative relationships and others find no significance, all with their own remarks and footnotes. The goal of this study is twofold: The first goal is to assess the relationship between R&D, measured by R&D intensity, and firm performance, which is measured by return on assets. Secondly, this research aims to study the differences between Service firms and Non-service firms in terms of strength and/or direction of this relationship.

This study uses a quantitative approach with a sample of 100 firms with annual data about their R&D investments and their performance. Several statistical methods are used to test the relationship between R&D intensity and firm performance and the differences between Service and Non-service firms. The most important technique is linear regression, but ANOVA and its non-parametric alternative, the Kruskal-Wallis test, are also used.

In line with existing research, it is found that there is no straightforward linear relationship between R&D intensity and firm performance. However, there is empirical evidence for a relationship between the two variables, but this relationship is not linear. It is found that the effect of R&D intensity on firm performance is more prominent when R&D intensity is low. Studying the differences between Service and Non-service firms makes clear that the effect of R&D intensity on firm performance is different between the two types of firms. The relationship is negative and significant for Non-service firms, while it shows positive signs for Service firms. However, the positive relationship for Service firms is not significant.

This study has several theoretical and practical contributions. Besides that it tests the direct relationship between R&D intensity and firm performance, it also shows that the relationship is probably not linear. This has implications for practice, because firms should take their current state of innovativeness into account when evaluating their R&D activities. Another contribution of this study is that the effects of R&D intensity are different between Service and Non-service firms.

1. Introduction

Innovation is one of the most prominent topics in business literature. According to Dess and Lumpkin (2005), innovation is about creative behavior and experimentation. Innovation creates new opportunities for firms to grow and to develop new products or services (Christensen & Raynor, 2013). Innovation can for example lead to competitive advantage over competitors and improvement of productivity (Feder, 2018; Wang et al., 2023) and is therefore crucial to the long-term success of firms (Goel & Nelson, 2022).

An indispensable part of a firm's long-term innovation strategy are the investments in research and development (also known as R&D) (Baik et al., 2022). These investments are necessary for firms to remain competitive. There may be several motivations for firms to invest in research and development, but in the end the goal will always be for firms to improve their performance, either on short term or long term (Vecchiato, 2017).

Based on the literature, there is already a lot of existing research about the topics R&D and firm performance. However, the results of several studies are somewhat contradicting, so there is no unanimous answer. Some researchers find a significant relationship, like Gharbi et al. (2014) and Mezghanni (2011), but some do not, like Lin (2017). Moreover, there seems to be a research gap in the literature about the possible moderating role of firm typology or industry (Kamath et al., 2016; Han et al., 1998; Atuahene-Gima, 1996). The moderating effect of firm typology means that the effect of R&D on firm performance is different for different firm types. For example: It might be the case that R&D investments have more effect on firm performance for a steel producer (manufacturing company) compared to a IT company (service company). Based on the paper by Atuahene-Gima (1996) and the typology model by Starreveld (Griffioen et al., 2000), this study will investigate whether the effect of R&D on firm performance is different between Service and Non-service firms[1], which will be explained more extensively in the literature review. It is useful for executives and managers to know this, because it might affect their decision-making regarding innovation of the company. However, as already mentioned, there is a lack of empirical evidence on this topic. The goal of this study is twofold: Firstly, the goal is to empirically assess the relationship between R&D intensity and firm performance. Secondly, the aim is to study whether the effect is different between Service firms and Non-service firms. The research question is formulated as follows:

"What is the effect of R&D intensity on firm performance and is this effect moderated by firm typology?"

Annual reports of companies are used for data collection. These annual reports are available via the database 'company.info'. The annual reports contain all the data about the variables in this research (these variables will be explained in Section 3). Data is collected for a sample of 100 firms, of which 50 are Service firms and 50 are Non-service firms. Data is collected for the period 2014-2021. This research will be conducted in the Netherlands. The reason for this is because the researcher has easy access to data about R&D investments and firm performance for companies in the Netherlands. Several statistical techniques are used to test the hypotheses. Linear regression modelling is the most important one, but ANOVA and the non-parametric Kruskal-Wallis test are also used.

[1] Firms 'with dominant flow of goods' are called 'Non-service firms' in this paper and firms 'without dominant flow of goods' are called 'Service firms'

Because there is some ambiguity about the effect of R&D intensity on firm performance, this study contributes to the existing literature by statistically assessing whether there is an effect of R&D intensity on firm performance or not. It also contributes to the literature by finding evidence that the relationship between R&D intensity and firm performance is not linear. This theoretical contribution has also value for business practitioners, because they should be aware about which stage of innovativeness their firm is in. That is because the effect of R&D investments on firm performance is different for firms who are unexperienced in the area of R&D than for firms who have established R&D departments. Lastly, this study enters a relatively new field of research by investigating whether the effect of R&D intensity on firm performance is different between Service firms and Non-service firms.

This research paper is structured as follows: First, existing literature about the topic will be discussed in the second chapter. This literature review elaborates on both R&D and firm performance as single concepts, but it will also dive into existing research about the relationship and the effect of R&D intensity on firm performance, as well as the potential moderating effect of firm typology. Section 3 will describe the research method that will be applied to answer this research question. This chapter elaborates on the data sources, sampling criteria, measurement of variables and the process of analysing the data. The results of the analysis are described in section 4, including some explanation about the models and techniques that are used. The results will be discussed and interpreted in section 5, which will also mention the limitations of this study and some entry points for future research. Finally, the main conclusions are mentioned in section 6, including the theoretical and practical contributions.

2. Literature review

There is already a lot of existing literature about the topic of R&D and firm performance. Moreover, a lot of research is also done about similar topics, like the impact of innovative behavior of managers on firm performance for example (Deshpandé et al., 1993; Kamath et al., 2016). However, the results are somewhat contradicting. Some researchers show a significant relationship between innovation and firm performance, but some do not. This section will elaborate on the large amount of literature on this topic. First, there will be a section on the topic of Research and Development. Secondly, literature about firm performance is reviewed. The last part of this section is about the literature about the relationship between R&D intensity and firm performance. This literature is also used to formulate hypotheses.

2.1 Research & Development

According to Han et al. (2015), R&D investments are an important aspect of firm innovation. Research and development are important regarding a firm's development and competitiveness (Kor, 2006; Chen et al., 2013). Three characteristics of R&D investments are specified by existing literature. First, R&D investments are regarded as risky (Honoré et al., 2015). That is, because there is no guarantee that the investment will result in better performance or in higher profitability. Secondly, R&D investments are not necessarily beneficial on the short term, but they are more focused on the long-term performance of a company (Zona, 2016). And thirdly, R&D investments are complex and difficult to communicate. This is partly due to the fact that innovative ideas often have to remain anonymous until they are executed. Because new ideas need some protection (for example against imitation by competitors), communication about it can be difficult (Lucas et al., 2018; Entwistle, 1999).

There are different possibilities regarding the reporting of research and development. For R&D investments, it is possible to capitalize or to treat is as an expense. Capitalizing R&D investments means that the investment is taken as an asset on the balance sheet. The yearly depreciation of this investments leads to costs. When an R&D investment is treated as an expense, it is deducted from profit in the year that the money is spent (Corporate Finance Institute, 2019). The International Financial Reporting Standards (abbreviated as IFRS, which also apply to all listed companies in the Netherlands) distinguish between research expenses and development expenses. According to Govers (n.d.), research expenses can be defined as expenses to generate new knowledge and insights about potential products, markets or customers for example. Development expenses occur in the next phase, because these expenses are made to develop new products, prototypes or models. The main difference between research expenses and development expenses is that research expenses have a higher level of uncertainty about the future benefits of the expenses (Han et al., 2004). In later stages, when the development phase starts, the uncertainty about future benefits is lower (because if the investments are not expected to be beneficial, companies would not make these investments at all) (Landry & Callimaci, 2003)

Koetzier and Brouwers (2018) mention that, according to the IFRS, research expenses should not be included on the balance sheet of a company. These expenses should be treated as costs. The reason for this is that research expenses do not lead to a clear expectation of future benefits, as already mentioned. The expectation of future benefits is an important condition for an asset to be included on the balance sheet. This expectation is not present for research expenses. However, for most of the development costs, it can be expected that there is a future economic benefit. Therefore, development costs can be capitalized according to the IFRS.

It is important to take into account these different ways of reporting investments in research and development. When looking at the annual reports of companies, it is important to collect data about both the regular expenses, as well as the depreciations on capitalized investments. Within this research, the general relationship between R&D intensity and firm performance is investigated. Therefore, both research expenses and development expenses will be included in the study, regardless of how they are reported in the annual report. Moreover, not all companies make an explicit distinction between research expenses and development expenses in their annual report. Therefore, it would be very hard to collect data to investigate the effects of research and development separately. As already said, both types of R&D investments will be included in the measurement of R&D intensity. Section 3.1 will elaborate on the measurement of this variable (Dai et al., 2020).

2.2 Firm performance

Firm performance is quite a broad construct in the way that it can be measured in a lot of different ways. Firm performance can be measured by looking at internal financial numbers like sales (Atuahene-Gima, 1996), profit (Zandi et al., 2019) or return on assets (Balagobei, 2018). It is also possible to look at external financial numbers like stock price (Sukesti et al., 2021), stock volatility (Rahman et al., 2023) or the ratio between market value and book value of equity, also called Tobin's Q (Bharadwaj et al., 1999). Although firm performance is usually measured via financial numbers, it is also possible to look at non-financial performance measures. The Balanced Scorecard by Kaplan and Norton for example is a tool to measure non-financial performance, because it looks at four different perspectives of a company (financial perspective, customer perspective, internal business process perspective and learning and growth perspective) (Wang et al., 2013; Kaplan, 2009). Similar measures were used by Omran et al. (2021) to investigate the relationship between internal performance evaluation and the extent to which external market participants are able to assess the effectivity of management quality.

The paper by Peloza (2009) provides an extensive framework about measuring firm performance with four different hierarchical types of metrics. His theoretical framework starts with metrics of corporate performance. These are the most overarching 'values' that an organization wants to pursue. It focuses on the firm's impacts and outcomes for society, stakeholders and the firm itself (Wood, 1991). Examples of these values are social values, environmental values or cultural values (Waddock & Graves, 1997).

Out of the corporate performance metrics, the organization can define mediating metrics. Mediating metrics are closely related to the corporate social performance metrics, because the mediating metrics are the link between the overarching 'values' and the generation of business value. However, mediating metrics are not necessarily quantitative already. A mediating metric that is related to environmental value can be reduction of pollution for example, or reducing the consumption of polluting fuels. The treatment of minority groups is an example of a mediating metric for social value (Peloza, 2009).

The next type of metrics are called intermediate metrics or intermediate outcomes. These metrics are already focused on measuring outcomes that precede the generation of business value. Intermediate metrics have a quantitative nature and are therefore easier to measure than corporate social performance metrics and mediating metrics. Examples of intermediate metrics can be cost reduction, operational efficiency or the entry to new markets (Carter, 2005; Sharma & Vredenburg, 1998).

The final type of metric that is mentioned by Peloza (2009) is the end state outcome metric. End state outcome metrics are the final (often financial) results. In existing research, this type of metrics is most commonly used to measure firm performance. The financial performance measures that were mentioned earlier in this section (profit, return on assets, stock price) are well-known examples of end state outcome metrics. Because end state outcome metrics are most directly related to firm performance, this type of metric will be used in this study to measure firm performance. The other types of metrics are more focused on the process of how to align the performance of the organization with its corporate values, but that is not the focus of this study.

Looking at the end state outcome metrics, a further distinction can be made. Peloza (2009) acknowledges market metrics, accounting metrics and perceptual metrics. The most important characteristic of market metrics is that the metric (or the underlying values of the metric) are determined by external stakeholders, and not directly by the company itself. Therefore, market metrics are influenced by a lot of different factors like macroeconomic factors (Basher et al., 2012; Hsing, 2011), political factors (Benlagha, 2020; Batrancea, 2021), and cultural or social factors (Singh et al., 2017; Sun et al., 2020). Examples of market metrics are share prices and stock returns (Schnietz & Epstein, 2005; Barnett & Salomon, 2006).

Accounting metrics are, in contrast to market metrics, internally oriented. These metrics are derived from the financial statements of an organization. Well-known examples of accounting metrics are return on equity (McWilliams & Siegel, 2000), return on assets (Turban & Greening, 1997) and return on sales (Griffin & Mahon, 1997). Accounting metrics are very concrete measures of financial performance and how the firm uses its assets. Moreover, they are quite comprehensible and easy to interpret. A disadvantage of accounting metrics is that the interpretation to a certain extent depends on the accounting policies of firms. There might be differences in how companies report costs like depreciation for example (Huselid et al., 1997; Hirschey & Wichern, 1984).

Perceptual metrics can both be from insiders of the company as from outsiders of the company, but the difference between perceptual metrics and the other two types is that perceptual metrics are qualitative measures. Examples of perceptual metrics are magazine ratings (Verschoor, 1999) or management surveys (Husted & Allen, 2007). Qualitative measures have the advantage that it enables to retrieve more in-depth information (Murphy et al., 1998), but Peloza (2009) mentions that they are often correlated with quantitative (market or accounting) metrics, which makes perceptual metrics sometimes superfluous.

Within this quantitative research, the goal is to collect sufficient financial data to assess the relationship between R&D intensity and firm performance. Therefore, market metrics and accounting metrics are most suitable. These metrics are easily accessible via internet and it is also possible to collect large amounts of data. Perceptual metrics are more qualitative in nature and it is therefore hardly possible to collect large amounts of data.

Both market metrics and accounting metrics are easily accessible via databases on the internet. However, if market metrics will be used, the population would be quite limited. Information about share prices and stock returns are only available for limited companies (in the Netherlands called: 'Naamloze Vennootschappen'). The population would be quite small if only limited companies are included. Therefore, private companies (in Dutch: 'Besloten Vennootschappen') will also be included in the sample, but these companies do not share information about stock returns for example. Therefore, it is concluded that market metrics for firm performance are not suitable for this study. This means this study will only use accounting metrics to measure firm performance.

2.3 Relationship between R&D intensity and firm performance

A lot of existing literature is already written on the topic of innovation and/or research and development on the performance of companies. Gharbi et al. (2014) investigated the relationship between R&D investments, firm performance and the associated risk profile of a company. The most important result of this study is that investments in R&D are positively related to the stock volatility of a company (which is used as a measure of the risk profile of a company). Companies with a higher risk profile also have higher expected rates of return (Won et al., 2019), which implies better (expected) firm performance. Of course it is impossible to say that a high level of R&D intensity guarantees better firm performance, but it can at least be expected. The main goal of R&D is actually to improve firm performance, as already mentioned in section 2.1. Furthermore, Mezghanni (2011) conducted a study of the moderating role of board of directors' characteristics on the relationship between R&D investments and firm performance. This study also shows a significant positive relationship between R&D investments and firm performance.

Besides that, there is also literature which uses the more general concept of innovation. Le et al. (2020) study the role of management's value orientation towards innovation and innovative capability on firm performance. This study contributes to the literature by finding that the higher the value perception towards innovation by the management, the higher the firm performance. However, it is concluded that this relationship is not direct: It is mediated by the use of management accounting systems. That is because sophisticated management accounting systems helps managers to make better decisions, which in result lead to better firm performance. However, this is again an example of a study that shows a positive relationship between innovation (value orientation towards innovation in this case) and firm performance.

An interesting study that is in line with this expectation is the study by Chan et al. (1990). In their study, they find that announcements of R&D investments result in positive responses in the share price of that particular firm. Moreover, the positive effect is present even for firms that were facing a decline in earnings. These results indicate that investors expect a positive effect of R&D investments on firm performance, because they are willing to pay a higher amount for the shares. Higher firm performance is of course not guaranteed, but at least expected by investors.

Another study (Lin, 2017) also assessed the relationship between R&D investments and firm performance. This study investigated whether this relationship is different for firms that engage in corporate social responsibility and firms that do not. Lin only finds a significant, positive relationship between R&D investments and firm performance for firms that engage in corporate social responsibility. The relationship is not significant for firms that do not engage in corporate social responsibility. This suggests that R&D investments indeed have a positive effect on firm performance, but only for firms that align its investment strategies with its corporate social responsibility objectives.

The first hypothesis is focused on the main effect of R&D intensity on firm performance. There are some studies that show a significant effect (Mezghanni, 2011; Gharbi et al., 2014), but some are also a bit more cautious (Lin, 2017). All in all, a positive effect of R&D intensity is expected. This leads to the following hypothesis:

H1: R&D intensity is positively related to firm performance.

The second part of this study focuses on the moderating role of firm typology on the relationship between R&D intensity and firm performance. This means that it will be investigated whether the relationship between R&D intensity and firm performance is different for different types of firms. In this study, the typology model by Starreveld will be used to classify firms into two different types ('Firms with a dominant flow of goods' and 'Firms without a dominant flow of goods', also called 'Non-service firms' and 'Service firms' respectively). More information about firm typology will be provided later in this section, but also in section 3.1 about the measurement of the variable 'Firm typology'. Another possibility would have been to divide firms in different categories according to the industry in which it operates. However, this approach requires a bigger sample size than 100, because the number of firms per category would be smaller in that case. Because the data collection process is quite time-intensive, categorizing firms by their industry is not feasible. Therefore, this study investigates whether the effect of R&D on firm performance is different between Service firms and Non-service firms. This may not be the most sophisticated approach, but because there is a lack of research on this topic, it can already provide new empirical evidence which might be impetus for more in-depth research.

An interesting study related to this topic is the study by Atuahene-Gima (1996). Within his study, he studies the effect of market orientation on innovation performance. The results of this study show that market orientation has a partially significant effect on innovation. However, Atuahene-Gima also studies whether this effect is different for service innovation than for product innovation. His assumption is that service firms are more market-oriented than manufacturing firms. Therefore, the effect of market orientation on innovation is expected to be stronger for service firms. Ultimately, there was no empirical evidence for the significance of this effect.

Existing literature about innovation effectiveness for service companies and manufacturing companies state that innovation at service companies depends more on good relationships with customers (Tufano, 1989). Because service companies have higher levels of interaction between its employees and its customers, it is easier for service companies to discover the needs of the customers and to come up with suitable ideas for development. Innovations regarding service are also easier and less time-consuming to develop than product developments (De Brentani, 1989; Zeithaml, 1981). Moreover, regarding service companies, it is harder for customers to evaluate quality. Therefore, service firms are facing a higher level of competitor uncertainty and, as a result, more resistance against the implementation of developments (Easingwood, 1986).

The moderating role of firm typology is even more interesting because it is often mentioned as a limitation of existing research on the relationship between R&D investments and firm performance. Kamath et al. (2016) investigate the effect of knowledge management on innovation and firm performance. The researchers found significant effects for both relationships, but as a limitation it is mentioned that they only focused on a certain type of company (manufacturing company). They mention that their external validity could be better if the scope of organizations in the sample had been broader. Similarly, Han et al. (1998) study the relationship between market orientation, innovativeness and firm performance within the banking industry. In their future research section, they suggest to study similar effects of innovation for different sectors.
Based on the literature that is described above, it is expected that the relationship between R&D intensity and firm performance is different between 'Non-service firms' (Firms with a dominant flow of goods) and 'Service firms' (Firms without a dominant flow of goods). In line with Atuahene-Gima (1996), it is expected that the effect of R&D intensity on firm performance is stronger for Service firms than for Non-service firms. The literature provides several reasons for this expectation: Firstly, it is easier for Service firms than Non-service firms to discover the needs of the customers and to come up with suitable ideas for development (Tufano, 1989) and, secondly, service innovations are less time-consuming (De Brentani, 1989) and often less complicated compared to product developments (Zeithaml, 1981).

For the investigation of the moderating role of firm typology on the relationship between R&D intensity and firm performance, the second hypothesis is stated as follows:

H2: The positive relationship between R&D intensity and firm performance is stronger for Service firms than for Non-service firms.

There are multiple ways to classify companies. For example, the typology model by Miles and Snow classify companies based on their type of competitive strategy. They identify three types: Defender, analyzer and prospector (Blackmore & Nesbitt, 2013; Jayashree & Yang, 2015). Besides that there is a fourth category, the non-strategic type of company. Another typology model that connects better with the already mentioned study by Atuahene-Gima (1996) is the typology model by Starreveld. The typology model by Starreveld classifies companies based on their primary processes (Griffioen et al., 2000). The most important distinction within the model of Starreveld is the distinction between organizations with a dominant flow of goods and organizations without a dominant flow of goods. The organizations with a dominant flow of goods are then classified in three categories: Trading organizations, industrial organizations and agrarian/extractive organizations. The organizations without a dominant flow of goods can be divided in two subcategories: Service organizations and financial institutions (Paur et al., 2014).

The theoretical model of this study can be displayed as follows:

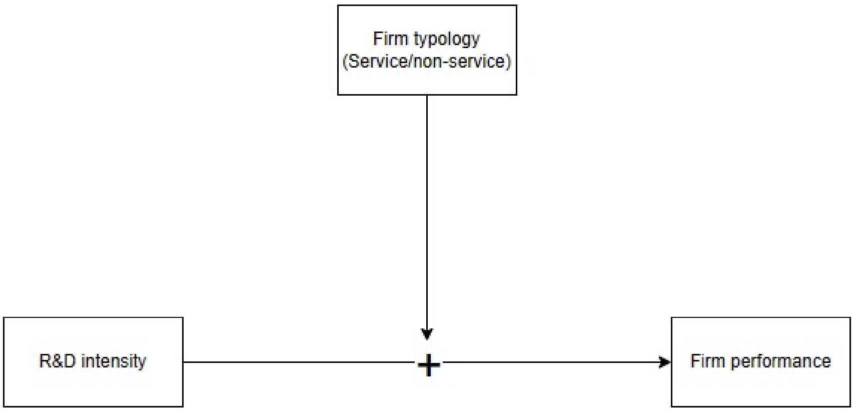

Figure 1: Theoretical framework

3. Research method

A quantitative research approach is used in this study. All data about R&D intensity and firm performance can be found in the annual reports of companies. The data is collected in yearly format for the period of 2014-2021. For the annual reports of companies, company.info is used as a database. This chapter will provide information about the sample and about the measurement of variables.

3.1 Sample

This section briefly discusses the data sources that will be used during this study and the sampling criteria that will be applied.

Data sources

Annual reports of companies are the main data source for this study. Information about investments and expenses for Research and Development can be found here, but also data on the financial performance. The website company.info is a database where a lot of information about companies can be found, including their annual reports. Company.info is used as a database, but it also has a search engine with a filtering function. This made it a useful tool to get a good sampling frame for the study, because companies can be filtered on legal form, size and also on industry, which is important for the 'Service'-variable. More information about the filtering will be provided in the next paragraph.

Sampling criteria

The sample consists of 100 companies from the Netherlands with data about their investments in R&D, the most important information about their financial performance and some additional information like size and industry. An important condition for the sample is that it contains both companies with a dominant flow of goods and companies without a dominant flow of goods. This is a dichotomous variable ('Service') that is recorded during the data collection phase.

The database company.info contains a filtering function which allows to search for companies within a certain industry. Some filters were applied during the data collection phase. First, 'micro companies' had to be excluded, because according to the Dutch regulations, these companies don't have to publish a profit- and loss account. Including micro companies would have resulted in incomplete data. In the Netherlands, micro companies are classified as 'micro' when the value of total assets is below €350,000 and the total revenue is below €700,000. These filters will be applied in company.info (Epe, 2017). The second filter that has been applied is about the legal form. Only 'Besloten vennootschappen' (Private companies) and 'Naamloze vennootschappen' (Public companies) are included. Other legal forms like foundations or associations are often non-profit companies. This will result in biased estimations of financial performance.

Lastly, companies are filtered on 'industry' to make a distinction between firm typology. The following industries are used to get a sampling frame of companies with a dominant flow of goods (Non-service companies): 'Industrial' and 'Wholesale and retail'. To get a sampling frame of companies without a dominant flow of goods (Service companies), the database was filtered on the following industries: 'Information and communication' and 'Administrative and support services'. From these sampling frames, companies will be selected randomly.

As already mentioned, the data is collected for the period between 2014 and 2021. This is a period of eight years. Looking at existing research, this period is long enough to get representative averages of R&D intensity, firm performance and the potential control variables. These averages are then used to assess the relationship between these two variables.

The sampling frame of this study consists of all companies that meet the aforementioned criteria. The data collection phase included random selection of companies from this sampling frame. However, sometimes it occurred that a selected company was not suitable for data collection. These companies were then not included in the data. Reasons why companies were not suitable for data collection are:
- Not all annual reports for the sampling period were available
- The company ceased to exist during the sampling period (due to bankruptcy or mergers/acquisitions)
- When a company reports that it is engaged in R&D activities but it does not mention numbers about the investments[2]

3.2 Measurement of variables

This section is about how the different variables in the model will be measured. The measurement of variables will be based on existing literature.

R&D intensity

Regarding the measurement of R&D, there are roughly two possibilities: The first option is to measure R&D in absolute numbers. In this case, the 'real' amount of investments would be the data for the analysis. The other option is to measure R&D on the basis of one or multiple ratios. In that case, the amount of R&D investment is expressed as a ratio with another variable (for example sales, next paragraph will elaborate on this). When a ratio is used to measure the 'level' of R&D expenditure, it is called R&D intensity (Chan et al., 2001). The advantage of using relative numbers instead of absolute numbers is that ratios are more suitable for comparison. It is quite likely that large companies invest a larger amount of money in R&D than smaller companies, but that does not say anything about their level of innovativeness, because it is an absolute number. Using ratios (R&D intensity) is a better reflection of the innovativeness of a company than absolute numbers. Moreover, it allows for a less distorted comparison across companies and industries. Another advantage of ratios is that they are easier to interpret.

Existing research show a lot of different possibilities to measure R&D intensity. The paper by Chan et al. (2001) mentions four different measurements of R&D intensity: R&D expenses relative to sales, earnings, dividends and book value of equity. However, in the paper it is already mentioned that relating R&D expenses to earnings or dividends might not be the best way to go. That is because earnings might be quite volatile (Raman & Shahrur, 2008), but managers also have some influence in how the accounting numbers are reported. This is also called 'earnings management' (Kothari et al.,

[2] Including these observations would result in a R&D intensity of 0, whereas that is not true in practice. The real level of R&D intensity is unknown, so that is the reason why these companies do not provide suitable data. However, this does not mean that the sample only includes companies that invest in R&D. If a company explicitly mentions that it does not invest in R&D, then a R&D intensity of 0 is a true value (and is therefore included in the data).

2005). Graham et al. (2005) conclude that managers care a lot about smooth earnings paths. Volatility also occurs regarding dividends. That is firstly because earnings are volatile (and dividends are paid out of earnings), but also because there are large differences between different dividend policies of companies (La Porta et al., 2000; Brav et al., 2005).

The ratios of R&D investments to sales and R&D investments to book value of equity seem to be more stable. Sales and book value of equity are at least less influenced by accounting procedures of a company. However, when looking at existing research, the ratio of R&D investments to book value of equity does not seem very common. Besides the paper by Chan et al. (2001), there is not much literature to find where this ratio is also used. It might be because of the interpretability of the ratio between R&D investments and book value of equity. On the other hand, there is a considerable amount of existing research that measure R&D intensity as a ratio with (net) sales, like Gharbi et al. (2014), Lin (2017), Cantwell and Mudambi (2005) and Tsao et al. (2015).

All in all, the ratios of R&D expenses to earnings and R&D expenses to dividends are not preferable due to volatility of earnings, earnings management and the differences between companies regarding their dividend policies. The ratio between R&D expenses and book value of equity seems more suitable, but it is actually not a common approach in existing research. Therefore, the ratio of R&D expenses to sales is applied to measure R&D intensity. The value of R&D intensity is recorded in percentage points, meaning that a value of '5' in the dataset is equal to a R&D intensity of 5% (following the approach of Lee (2002)).

Because R&D investments are regarded as long-term investments (Kor, 2006; Zona, 2016), data on R&D investments is collected for a time period of eight years (2014-2021). For every year, the amount of R&D expenditure and the level of net sales are recorded, so that the ratio of R&D investments with net sales could be calculated.

The literature review already referred to the distinction between capitalizing R&D investments (include it on the balance sheet) or expensing R&D investments (include it on the profit and loss account). It is possible to follow both approaches simultaneously (Ahmed & Falk, 2009). Which approach to use depends on the probability that the investment will lead to future benefits for the company. If future benefits of a certain investment are expected, then the IFRS allows companies to capitalize the investment and to amortize it over a longer period. If future benefits are not expected, the expenses will be treated as costs. This means that if a company has multiple R&D projects, it can use both approaches simultaneously (Dekkers, 2009; Dargenidou et al., 2021).

In this research, the ratio between R&D expenses and sales is calculated, so capitalized R&D investments is not taken into account (at least not the investment as a whole in the year that the money is invested). However, a company that capitalizes its R&D investments includes depreciations for these investments in its profit and loss account. These depreciations are taken into account when measuring R&D expenses. This approach is also followed by the already mentioned existing research of Gharbi et al. (2014), Lin (2017), Cantwell and Mudambi (2005) and Tsao et al. (2015). The approach is also followed by Han and Manry (2004), who mention the difference between capitalized R&D and expensed R&D a bit more explicit.

So, in short, R&D expenses (in year *t*) is measured as follows:
R&D expenses $_t$ = Expensed R&D $_t$ + Depreciation on capitalized R&D $_t$
R&D intensity for year *t* is then calculated as follows:
R&D intensity $_t$ = R&D expenses $_t$ / Net sales $_t$

Firm typology
To investigate the moderating role of firm typology, a dichotomous variable 'Service' is created. The definition of 'Service' is close to the definition given by Fuchs (1965). He defines service as 'not being involved in the production of food, clothing, houses, automobiles, and other tangible goods'. The latter part ('tangible goods') gives a good idea what this distinction is about (Drejer, 2004). Another description of the distinction between Service and Non-service is already given by Griffioen et al. (2000), as mentioned in the literature review (Paur et al., 2014). In their paper about the typology model by Starreveld (Starreveld, De Mare & Joels, 1997), which will also be used in this study, they distinguish between companies with a dominant flow of goods (like trading or manufacturing companies) and companies without a dominant flow of goods (like companies focused on communication, information or financial services).

To distinguish between companies with a dominant flow of goods and companies without a dominant flow of goods, the filtering function on company.info is used. Company.info is the database that is used for the collection of all financial data in this study. To get a sampling frame of companies with a dominant flow of goods, the 'Sector'-filter was set on 'Industrial' AND 'Wholesail and retail'. To get a sampling frame of companies without a dominant flow of goods, the 'Sector'-filter was set on 'Information and communication' AND 'Administrative and support services'.

To create the dichotomous moderation variable 'Service', all companies with a dominant flow of goods (the Non-service companies) are coded as '0', whereas the companies without a dominant flow (the Service companies) are coded as '1'.

Firm performance
There are several ratios that could be used to measure firm performance. Examples are net profit margin (Zulfiatf & Wijaya, 2015; Miller 2018), return on assets (Balagobei, 2018; Fukuda, 2020) and return on equity (Mughal et al., 2021). These are all examples of accounting metrics (Peloza, 2009). Other metrics besides accounting metrics could be market metrics or perceptual metrics (see also the literature in the previous chapter). Examples of market metrics are share price (Schnietz & Epstein, 2005) or stock returns (Barnett & Salomon, 2006), while magazine rankings (Verschoor, 1999) and management surveys (Husted & Allen, 2007) can be regarded as examples of perceptual metrics.

Referring to the literature review in chapter 2, it is concluded that accounting metrics are the most suitable metrics for this study. Due to the availability and the objectivity of the information, an accounting metric is used to measure firm performance. As mentioned earlier, the most important examples of accounting measures are net profit margin (Zulfiatf & Wijaya, 2015; Miller, 2018), return on assets (Balagobei, 2018; Fukuda, 2020) and return on equity (Mughal et al., 2021). This is confirmed by Delen et al. (2013), who conducted an exploratory factor analysis to identify the most important financial ratios. However, because firms from different industries are compared with each other, net profit margin does not seem the best way to go. This is based on Brealey et al. (2020), where it is said that profit margins might differ between different industries. Brealey et al. talk about the (negative) relationship between turnover (as an indication of size) and profit margins. Companies or industries with a high turnover often have a lower profit margin and vice versa. There are several explanations for the relationship between size and profit margins, like economies of scale, market power and access to capital markets (Amato & Wilder, 1985).

Return on assets and return on equity both look at the ratio between income and invested capital. Comparing these two ratios, return on equity is focused on the profitability for the shareholders, while return on assets takes the company as a whole into account. It is found that return on equity is more volatile (Kizildag, 2015). That is because return on equity depends on the capital structure of the company, also called financial leverage (Christie, 1982). When a company is largely financed with debt, shareholders expect a higher return on their investments. This phenomenon is also called 'equity premium' by Abel (1999). To mitigate the risk of capital structure acting as a third variable in the relationship between R&D intensity and firm performance, return on assets is used as a measure of firm performance. This is the most objective measure of these two (Brealey et al., 2020).

Return on assets is measured according to the approach of Fukuda (2020) and the literature by Brealey et al. (2020), namely the ratio of after-tax operating income to average total assets (which is defined as the average of the value of total assets at the start of the year and at the end of the year). The values of return on assets are recorded in the same way as R&D intensity, namely as percentage points (return on asset of 10% is recorded as '10' in the data). The data for firm performance is collected for the same period as the R&D investments (2014-2021). On one hand, one might say that the first few years of the sample period might not be very relevant, because R&D investments are mainly long-term oriented (Kor, 2006; Zona, 2016). It is known that there is a time lag between the R&D investment and the effect on firm performance (Minasian, 1969; Teirlinck, 2017).

It depends on the type of research whether it is necessary to include the time lag as a factor in the analysis or not. There are some studies that investigate the time lag of certain investments. Horst (2001) for example investigates how and when company performance changes (in his case measured by sales level) after a patent application. Kondo (1999) focuses on a step earlier in the process, namely the duration between R&D input (investments in research and development) and R&D output (patent applications). However, this research does not focus on the effect or the duration of specific R&D investments, but more on the general relationship between R&D intensity and firm performance. This type of study is in line with other studies like Griliches (1985), Lichtenberg & Siegel (1991), Gharbi et al. (2014) and Tsao et al. (2015). All these studies use a certain sampling period and they average the values across that period. Although it is not possible to investigate the time it takes for an R&D investment to become effective, this approach has the advantage that it is less affected by influential outliers of both the input and the output variable, according to Griliches (1980). Firm performance may fluctuate substantially across individual years, which makes it difficult to relate it to input variables (in this case R&D investments) in a certain year. Therefore, it is not problematic to use the same sample period for both variables. This is also confirmed by Mansfield (1980). Although his study uses a certain type of time lags, he also mentions that the assumption of no lags is a useful approach in research.

3.3 Control variables

Firm performance is determined by a large number of different factors. According to a study by Lin, Horng and Chou (2016), working capital management is quite an important one. This study follows the approach of Lin (2017), who includes 'leverage' and 'liquidity' as control variables in his model to measure firm performance. Moreover, existing literature (Mishra, 2023; Mansour et al., 2023; Hadjaat, 2019) often include company 'size' and 'age' as control variables. This study will also include these variables as controls.

Data on the control variables is collected for the same sampling period as the main variables (2014-2021). During data analysis, it is checked if there are correlations with the main variables. If that was the case, then the variable(s) is included as a control variable in the linear regression. If there is no correlation between a (potential) control variable and one of the main variables, then including the control variable(s) is not necessary.

Leverage

(Financial) leverage is about the capital structure of the company. It is about the ratio between debt and equity (Abu-Abbas et al., 2019). There is a lot of existing research about the relationship between leverage and firm performance. Some find a positive relationship (Brander & Lewis, 1986; Jensen, 1986), but some also find a negative relationship (Salawu, 2007; Tian & Zeitun, 2007). Because this study focuses on the relationship between R&D intensity and firm performance, it is important to control for other variables that could disturb the investigated relationship. Therefore, 'leverage' is included as a control variable. Moreover, according to Brealey et al. (2020), the level of leverage also varies from industry to industry. There is no empirical evidence that leverage differs significantly between Service and Non-service firms, but the fact that debt ratios differ per industry is another reason to include leverage as a control variable.

Leverage is measured following the approach of Brealey et al. (2011). It is calculated as the ratio between debt and the sum of debt and equity (which is equal to total assets).

Liquidity

Next to leverage, liquidity is also included as a control variable, following the approach of Lin (2017) and Yameen et al. (2019). Liquidity is about the ability of a firm to pay back their short term liabilities (Farooq & Bouaich, 2012). It is found that liquidity has a positive effect on firm performance (Yameen et al., 2019; Farooq & Bouaich, 2012; Wang, 2002). Wang (2002) found that good liquidity management improves operating performance, resulting in higher firm value. It also reduces financing costs, because the risk of not being able to meet short term obligations decreases, which results in lower risk for investors and therefore lower interest rates (Priya & Nimalathasan, 2013). Because this study wants to investigate the relationship between R&D intensity and firm performance, the effect of liquidity should be controlled for.

The two most common measures for liquidity are the current ratio and the quick ratio. The current ratio is the ratio between total current assets and current liabilities. Quick ratio is almost the same, but it excludes inventories from the current assets. That is because inventories cannot be sold immediately at every moment, so these are not as liquid as regular cash or other receivables (Brealey et al., 2020). In this case, the quick ratio is used to measure liquidity. That is, because both service- and non-service firms are analysed. Non-service firms usually have higher levels of inventory than service firms, so to make these two types of firms more comparable, the quick ratio is used (Folger, 2023).

Firm size

Another control variable that is often used in research regarding firm performance is firm size (Mishra, 2023; Mansour et al., 2023). Ghozali et al. (2018) find a positive relationship between firm size and firm performance. One of the possible explanations that they mention and that is relevant for this study is that investment behavior differs between small firms and large firms. On the other hand, Kalkan et al. (2011) study the relationship between firm size and firm performance but they found an insignificant relationship.

Different measures for firm size exist. The most common ones are sales, often measured as the natural logarithm of sales (like Mishra (2023) and Ghozali et al. (2018)), or (the natural logarithm of) total assets (like Mansour et al. (2023)). Kalkan et al. (2011) measure firm size via employment numbers. In this study, the natural logarithm of sales during the sampling period is used as a measure for firm size. Just like the other variables, the value of this measure for a specific firm is equal to the natural logarithm of the average sales level during the sampling period. Data about assets is also available in the database, but because of the difference in capital intensity between Service and Non-service firms, sales level seems to be a more suitable measure in this case.

Age

The final control variable is age. Although Legesse (2018) failed to find a relationship between firm age and firm performance, it is still possible that it affects the relationship between R&D intensity and firm performance (Mabenge et al., 2022). Moreover, studies usually incorporate firm age as a control variable when studying firm performance (Mishra, 2023; Mansour et al., 2023; Hadjaat, 2019; Marashdeh et al., 2021).

Firm age is calculated using the same approach as Mishra (2023), namely as the year of study (2023) minus the year of establishment of the firm.

Table 1: Main variables

Variable	Measurement	Definition	Type
R&D Intensity	R&D expenses / sales	Measures the level of R&D investments relative to sales	Independent variable
Firm typology	0 = Non-service firm 1 = Service firm	Indicates whether the firm is a Service firm or not	Independent variable (moderation)
Firm performance	Return on assets	Profitability of a firm	Dependent variable

Table 2: Control variables

Variable	Measurement	Definition	Type
Leverage	Debt ratio	Extent to which a firm is financed by external debt	Control variable
Liquidity	Quick ratio	Ability to pay back short-term liabilities	Control variable
Firm size	Natural logarithm of sales	Indication of how big a firm is	Control variable
Age	Year of study (2023) minus year of establishment	Indication of how old a firm is	Control variable

4. Results

This section describes the different models that are used to test the hypotheses including the results and their interpretation. The first part of this section provides some descriptive statistics about the data. After that, the results of the two hypotheses will be described and interpreted.

4.1 Descriptive statistics

Descriptive Statistics ▼

	intensitypct	roapct	Avg_Leverage	Avg_Liquidity	lnsales	Age
Valid	100	100	100	100	100	100
Mean	2.148	4.769	0.712	1.137	12.384	40.330
Std. Deviation	4.730	12.496	0.289	0.744	1.792	28.211
Minimum	0.000	−40.316	0.105	0.177	9.201	8.000
Maximum	34.368	75.444	2.377	4.071	17.763	187.000

Figure 2: Descriptive statistics whole sample (N = 100)

Figure 2 shows the descriptive statistics of the independent variable R&D intensity (intensitypct), the dependent variable ROA (roapct) and the control variables leverage (Avg_Leverage), liquidity (Avg_Liquidity), size (lnsales) and age (Age) for the whole sample of 100 firms. The mean R&D intensity in the whole sample is 2.1% with a standard deviation of 4.7%. The mean ROA in the sample is 4.8% with a standard deviation of 12.5%. The average debt ratio in the sample is 0.712, whereas the average quick ratio is 1.137. The average size, measured as the natural logarithm of sales, is 12.384. Age ranges between 8 (TBAuctions B.V. which is established in 2015) and 187 (Wolters Kluwer N.V. which is established in 1836), with an average value of 40.33.

Descriptive Statistics ▼

	intensitypct		roapct		Avg_Leverage		Avg_Liquidity		lnsales		Age	
	0	1	0	1	0	1	0	1	0	1	0	1
Valid	50	50	50	50	50	50	50	50	50	50	50	50
Mean	1.383	2.914	4.594	4.945	0.640	0.784	1.003	1.271	12.652	12.115	46.780	33.880
Std. Deviation	2.996	5.919	7.290	16.195	0.227	0.326	0.748	0.722	1.927	1.620	27.205	27.982
Minimum	0.000	0.000	−24.945	−40.316	0.105	0.296	0.177	0.278	9.374	9.201	11.000	8.000
Maximum	15.815	34.368	24.243	75.444	1.549	2.377	3.775	4.071	17.763	15.619	113.000	187.000

Figure 3: Descriptive statistics, broken down into Non-service and Service firms

Figure 3 shows the descriptive statistics for the same variables, but this table is broken down into Non-service firms (value of '0') and Service firms (value of 1). As shown in the first row of the table, the sample of 100 firms consist of 50 Non-service firms and 50 Service firms. The average level of R&D intensity is higher for Service firms compared to Non-service firms, whereas there does not seem to be a big difference between the ROA of both types. However, the range of values of ROA is larger for Service firms, where the lowest value is -40.3% and the highest value is 75.4%.

Table 3: Type of R&D expenditure

Type of R&D expenditure	*Non-service*	*Service*	*Total*
Expense only	7	6	***13***
Capitalize only	28	27	***55***
Both expensing and capitalizing	11	12	***23***
No R&D investments	4	5	***9***

As already mentioned in the theoretical section, there are roughly two ways of recording R&D expenditure in the company reports. Companies can incur R&D expenditure in the profit- and loss statement or they can include these investments on the balance sheet (capitalization) and amortize these investments over several years, based on expected future benefits of the investment.

Table 3 shows the distribution of the different ways how firms record their R&D expenditure. It shows that more than half of the firms capitalize their R&D investments, whereas a quarter of the firms apply both methods of recording R&D expenditure. The fact that 78% of the companies in the sample capitalize R&D is quite plausible, because investments in R&D are almost always focused on the long-term (Baik et al., 2022; Goel & Nelson, 2022). Expected future benefits is one of the criteria to allow an investment for capitalization, according to the International Financial Reporting Standards (Koetzier & Brouwers, 2018). Firms incur R&D expenditure in the profit- and loss statement when there is no clear expectation about future benefits. This occurs often in the case of research costs (Govers, n.d.; Landry & Callimaci, 2003). Therefore, the way how firms deal with R&D expenditure in their annual reports can possibly say something about their R&D activity. Table 3 shows also that there are almost no differences between Non-service and Service firms regarding the way how they report R&D expenditure.

Pearson's Correlations

Variable		intensitypct	roapct	Avg_Leverage	Avg_Liquidity	lnsales	Age
1. intensitypct	Pearson's r	—					
	p-value	—					
2. roapct	Pearson's r	0.096	—				
	p-value	0.341	—				
3. Avg_Leverage	Pearson's r	−0.144	−0.380	—			
	p-value	0.154	< .001	—			
4. Avg_Liquidity	Pearson's r	0.240	0.351	−0.383	—		
	p-value	0.016	< .001	< .001	—		
5. lnsales	Pearson's r	−0.025	0.016	0.020	−0.155	—	
	p-value	0.804	0.871	0.843	0.123	—	
6. Age	Pearson's r	0.210	0.074	−0.184	−0.018	0.342	—
	p-value	0.036	0.463	0.067	0.857	< .001	—

Figure 4: Correlation matrix

Figure 4 shows all correlations between the several variables. What stands out is that the correlation between R&D intensity and ROA is small and insignificant. However, this is not necessarily problematic. There is a possibility that intensitypct is a 'suppressor variable'. A suppressor variable can be described as a variable that is not correlated to the dependent variable, but nevertheless contributes to the predictive validity of a test (Krus & Wilkinson, 1986; Conger, 1974). Therefore, testing the effect of R&D intensity on firm performance is still possible.

As already mentioned in the Method-section, the control variables are included in the linear regression when they are correlated with at least one of the main variables (intensitypct and/or roapct). Leverage is significantly correlated to ROA and is therefore included as a control variable. Liquidity is significantly correlated to both independent and dependent variable, so Avg_Liquidity is also included as a control variable. Size (lnsales) is not correlated to either intensitypct or roapct and is therefore not included as control variable. Age is included as control variable because it has a positive and significant correlation with intensitypct.

However, when variables are significantly correlated, it is important to watch for multicollinearity. Multicollinearity occurs when at least two highly correlated predictor variables are included in a linear regression model (Mason et al., 1991). The main problem with multicollinearity is that it leads to biased standard errors, which in result lead to an unstable assessment of statistical significance (Mela & Kopalle, 2002). There are multiple ways to detect multicollinearity, but one option is to look at the correlation coefficients between variables, as shown in figure 4. If the correlation coefficient between two variables is higher than a certain threshold, then there is a possibility of multicollinearity. Berry and Feldman (1985) use a threshold of 0.8, but some researchers also use a lower threshold of, for example, 0.5 (Donath et al., 2012). Even when using the lowest threshold of 0.5, it looks like there is no multicollinearity among the independent and control variables.

Another way to detect multicollinearity is by using the Variance Inflation Factor (VIF). Vatcheva et al. (2016, p. 2) define the VIF as the measure of 'inflation in the variances of the parameter estimates due to multicollinearity potentially caused by the correlated predictors'. A high value of VIF indicates a potential multicollinearity problem. However, the disadvantage of VIF is that it does not show which variables cause multicollinearity (Kim, 2019). The common threshold for VIF is that it should not be higher than 5 (Kutner et al., 1996). The Variance Inflation Factors are shown in table 4.

Table 4: Variance Inflation Factors

Variable	VIF
R&D Intensity	1.121
Leverage	1.225
Liquidity	1.264
Firm size	1.169
Age	1.246

In line with the correlation coefficients shown in figure 4, it does not seem that there is a potential problem of multicollinearity.

4.2 Hypothesis 1: R&D intensity is positively related to firm performance.

This section describes and evaluates the different models that are used to test the first hypothesis. The first hypothesis focuses on the general effect of innovation, measured by R&D intensity, on firm performance.

The models described in table 5 are organised in terms of the independent variable. Each model will have multiple specifications due to the addition of control variables. These specifications will be explained when discussing a specific model. Model 1 is the most basic linear regression. The other models are derived from model 1. How a model is established will be explained separately for every model.

Table 5: Models/tests for hypothesis 1

Model	Description
Model 1	$ROA = ß_0 + ß_1 \times R\&D\ Intensity$
Model 2	$ROA = ß_0 + ß_1 \times \log(R\&D\ Intensity)$
Model 3	Analysis of Variance (ANOVA) with portfolios based on R&D intensity
Model 4	Kruskal-Wallis test with portfolios based on R&D intensity

Model 1: ROA = $ß_0 + ß_1$ × R&D Intensity

The first model that is tested is the most straightforward one. It tests the effect of the independent variable intensitypct on the dependent variable roapct.

Model 1: Dependent variable = roapct						
	Coefficients (p-values)					
Independent variable	**Model 1.1**	**Model 1.2**	**Model 1.3**	**Model 1.4**	**Model 1.5**	**Model 1.6**
intensitypct	0.086 (0.641)	0.203 (0.340)	-0.182 (0.613)	0.004 (0.983)	-0.180 (0.467)	-0.244 (0.393)
Avg_Leverage		-15.062 (0.000)***			-13.351 (0.000)***	-12.914 (0.001)***
Avg_Liquidity			3.926 (0.006)***		1.476 (0.168)	1.562 (0.153)
Age				0.024 (0.412)		0.011 (0.649)
Number of observations	95	91	94	96	90	90
Adjusted R^2	*0.00%*	*19.38%*	*6.02%*	*0.00%*	*19.96%*	*19.22%*
Note: After deleting influential cases						

Figure 5: Coefficients for model 1

As already mentioned, a model has multiple specifications. In this case, the columns of the variables that are filled are the variables that are included in a specific model. So for example, model 1.1 only includes intensitypct as predictor variable, whereas Avg_Leverage is added for model 1.2. This approach provides the possibility to test whether the effect of R&D intensity on firm performance changes when another (control) variable is added. This approach is also used for other models later in this paper.

Model 1 shows different coefficients for intensitypct, both positive and negative. However, all coefficients are insignificant, meaning that there is no significant effect of R&D intensity on firm performance. Even after adding several control variables, intensitypct does not become significant. R&D intensity is not a variable that can explain the variance in the dependent variable, firm performance.

Although it is not regarded as a main variable, it can also be observed that leverage is the only variable that has significance at the 1% level in all different model specifications. The impact on firm performance appears to be negative.

All models are tested twice, namely with and without influential cases. To detect if an individual observation is influential, Cook's distance is used. Cook's distance is a measure that can be used for identifying influential outliers in regression models (Diaz-Garcia & Gonzalez-Farias, 2004; Cook, 1977). According to Bollen & Jackman (1985) and Jayakumar & Sulthan (2015), an observation is influential if the value of Cook's distance is higher than the threshold of 4 / (n-p), where:
n = number of observations
p = number of predictors (independent variables)
This approach is used for identifying and disregarding influential outliers.

Even after deleting influential outliers, the effect of R&D intensity on firm performance is insignificant.

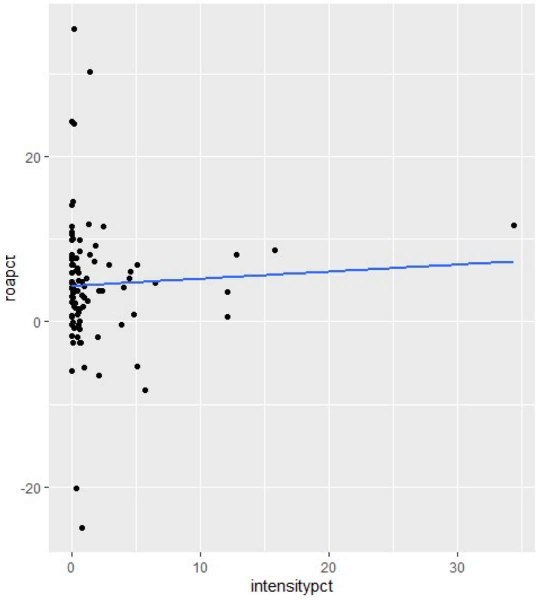

Figure 6: Model 1 (ß0 + ß1 × R&D Intensity) after deleting influential outliers

Looking at the linear model, the values of intensitypct do not seem to follow a normal distribution. This is also shown in figure 7.

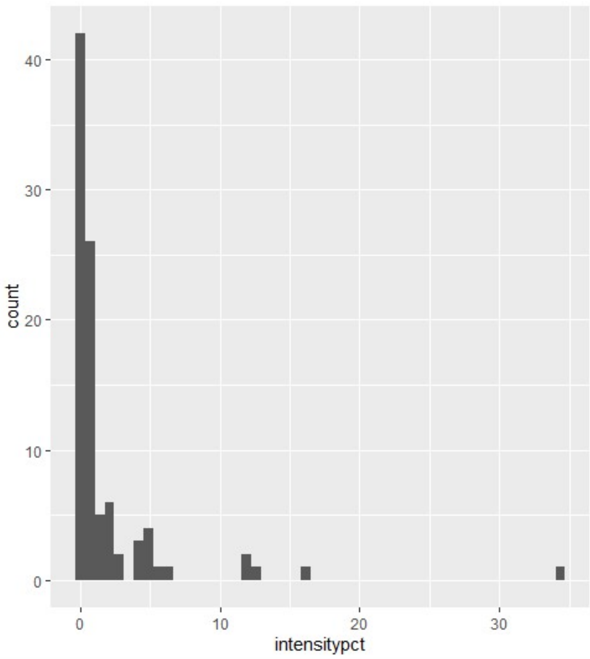

Figure 7: Distribution of R&D intensity

Looking at existing research, it is found that the distribution of R&D intensity is usually not normal. Research papers by Cohen and Klepper (1992), Lee (2002) and Lee & Noh (2009) show that the distribution of R&D intensity is a lognormal distribution, which means that the distribution is skewed towards larger values. The findings of these papers are in line with figure 7, which also indicates a lognormal distribution.

The non-normal distribution of R&D intensity may cause problems with linear regression. One of the main approaches to address this problem is a logarithmic transformation, as suggested by Changyong et al. (2014) and applied by Lee & Sung (2005). Therefore, the next model that is tested uses the logarithm of intensitypct as independent variable.

Model 2: ROA = $ß_0 + ß_1 \times \log(\text{R\&D intensity})$

This model is quite similar to model 1, but it uses the logarithm of R&D intensity as independent variable.

Model 2: Dependent variable = roapct (Return on Assets)						
	Coefficients (p-values)					
Independent variable	**Model 2.1**	**Model 2.2**	**Model 2.3**	**Model 2.4**	**Model 2.5**	**Model 2.6**
log(intensity)	-0.322 (0.489)	-0.538 (0.119)	-0.898 (0.077)*	-0.572 (0.271)	-0.637 (0.121)	-0.642 (0.130)
Avg_Leverage		-17.008 (0.000)***			-12.180 (0.005)***	-11.039 (0.012)**
Avg_Liquidity			4.159 (0.003)***		2.233 (0.083)*	1.885 (0.138)
Age				0.035 (0.238)		0.013 (0.579)
Number of observations	85	83	86	86	83	84
Adjusted R^2	*0.00%*	*27.18%*	*10.22%*	*0.00%*	*17.13%*	*14.43%*

Note: After deleting influential cases

Figure 8: Coefficients for model 2

The model specifications for model 2 are similar to model 1, which is explained already.

The results are somewhat similar to model 1, with the main finding that R&D intensity is not related to firm performance. However, model 2 shows exclusively negative coefficients, which are also closer to significance compared to model 1. Model 2.3, which includes log(intensity) and Avg_Liquidity as independent variables, even shows a coefficient for log(intensity) that is significant at the 10% level. Moreover, the relationship between leverage and firm performance is again negative and significant for all model specifications.

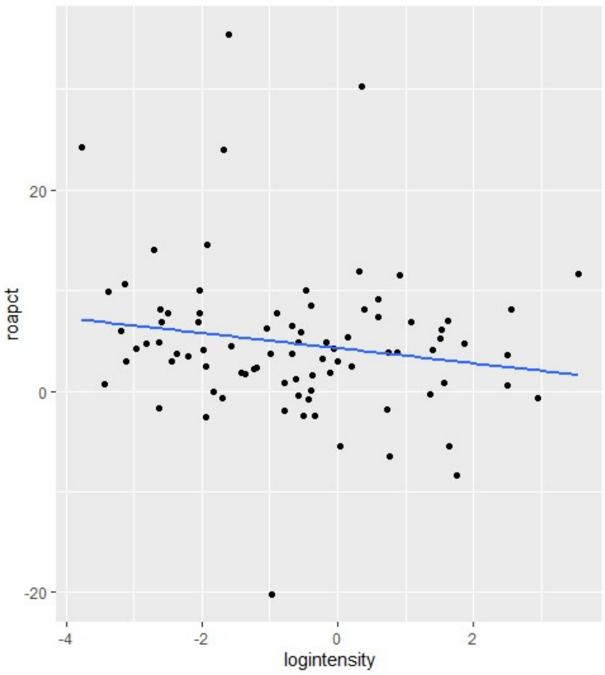

Figure 9: Model 2 (ß0 + ß1 × log(R&D Intensity)) after deleting influential outliers

Figure 9 shows the relationship between log(intensity) and ROA. Compared to figure 6, the data seems more suitable for linear regression after the logarithmic transformation. The relationship is negative, but also insignificant.

Because the independent variable R&D intensity is log-transformed in model 2, the interpretation of the effect changes compared to model 1. Model 1 assumes a linear relationship between R&D intensity and ROA (which does not seem to exist), but model 2 assumes a linear relationship between the logarithm of R&D intensity and the real value of ROA. This relationship seems to be negative, although there is no statistical significance. Figure 10 illustrates how to interpret the relationship from model 2 between R&D intensity (not as a log-transformed variable) and ROA.

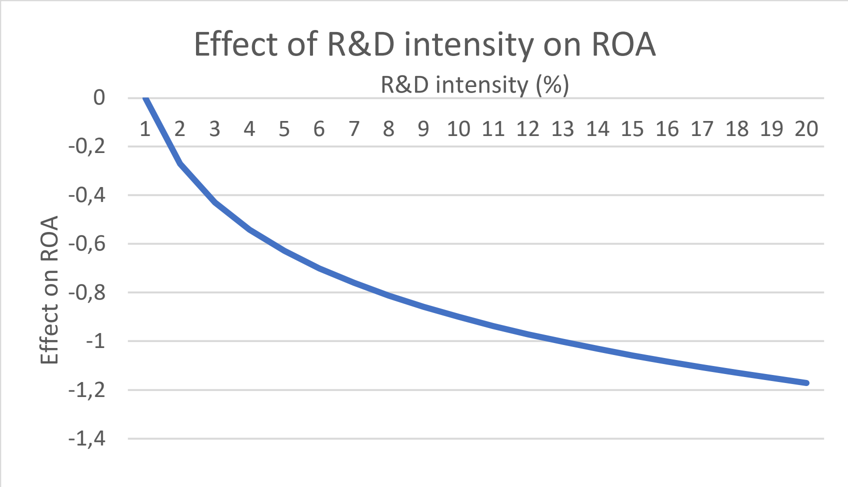

Figure 10: Interpretation of model 2, with R&D intensity as a percentage (no log-transformation)

Figure 10 shows that the effect of R&D intensity on firm performance is negative, but that it is not linear. The interpretation of the marginal effect of R&D intensity on firm performance changes. The marginal effect 'measures the effect on the mean of *y* of a change in one of the regressors *x*' (Williams, 2012). In model 1, where ROA is a linear function of R&D intensity, the marginal effect is equal to the regression coefficient of the variable intensitypct. However, this is no longer the case for model 2, where the marginal effect of R&D intensity on ROA decreases as R&D intensity becomes higher. In other words: An increase of R&D intensity from 1% to 2% has a more detrimental effect on ROA than an increase from 19% to 20% (Cameron & Trivedi, 2010).

The fact that log(intensity) becomes (partially) significant when Avg_Liquidity is added to the model indicates that log(intensity) is a suppressor variable, as mentioned earlier. The paper by Krus & Wilkinson (1986) mentions three types of suppression: Classical suppression, net suppression and cooperative suppression. This case is an example of classical suppression, where the independent variable has no correlation with the dependent variable, but becomes significant when another independent variable (in this case liquidity) is added (Gaylord-Harden et al., 2010).

Looking at the plots of model 1 (figure 6) and model 2 (figure 9), it seems that the regression may be influenced by some anomalous observations, although they are not identified as influential outliers by Cook's distance. In their paper, Fama & French (1992) apply an approach that is more robust and which cancels out specific observations. Their approach is to form portfolios based on the independent variable (in their case 'Size' and 'Beta') and to observe whether there is a relationship between the independent and the dependent variable (Chan & Chen, 1988). Model 3 uses a similar approach by forming portfolios based on R&D intensity.

Model 3: Analysis of Variance with portfolios based on R&D intensity

By applying the approach of Fama & French (1992), the firms are divided in four equal-sized portfolios based on their R&D intensity, where Portfolio 1 consist of the 25 firms with the lowest level of R&D intensity and Portfolio 4 of the 25 firms with the highest level of R&D intensity.

Table 6: Average values of R&D intensity and ROA

	Portfolio 1	Portfolio 2	Portfolio 3	Portfolio 4
Average of R&D intensity	0.04%	0.23%	0.81%	5.35%
Average of roapct	6.05%	4.92%	3.04%	2.19%

Looking at table 6, a negative relationship is observed between R&D intensity and ROA. However, it is not possible to say anything about statistical significance based on this table. Analysis of Variance (ANOVA) is a method for comparing the means of different groups and to test for statistical significant differences between groups. The statistical test that corresponds with ANOVA is called the F-test. The null-hypothesis of the F-test is that the means of all groups are equal. If the F-statistic is significant, then at least one of the group means is statistically different (Kim, 2014; Moore et al., 1995).

Usually, ANOVA is mainly used to test for significance in differences in the dependent variable between groups. The dependent variable is often a interval or a ratio variable (continuous), whereas the independent variable is nominal. Nominal variables are variables whose values cannot be ranked (for example: Countries). In this case, the independent variable is the categorized version of R&D Intensity. Therefore, the independent variable is ranked in this case. This is also called an ordinal variable. According to Kitchenham et al. (2016), ANOVA can also be used for ordinal variables.

ANOVA provides the possibility to test for significant differences between groups. It can provide statistical significance for the pattern that is already observed in table 6. If the F-statistic is significant, it is interesting to further investigate which of the portfolios have statistically significant different means of ROA. Testing which groups are different can be done with the Mann-Whitney-Wilcoxon test (De Winter & Dodou, 2010). For example, if the mean ROA of portfolio 1 is significantly different from portfolio 2, then there is some empirical evidence for the negative effect of R&D intensity on firm performance, which is in line with model 2 (see also figure 10).

Before conducting ANOVA, it is necessary to assess the equality of variances between the portfolios. Levene’s test is used to test the equality of variances. The null-hypothesis of this test is that the variances between the groups is equal. Performing Levene’s test on this data resulted in an insignificant result, with a p-value of 0.91. Therefore, it can be concluded that the variances between the groups are equal (Zimmermann, 2004).

Performing the ANOVA resulted in an insignificant result, with a p-value of 0.39. That means that there is no evidence that at least one of the group means of ROA is different from another group mean. Therefore, the observation of the negative relationship between R&D intensity and ROA in figure 10 cannot be empirically confirmed based on ANOVA. Looking at figure 11, it seems unlikely that there are significant differences in ROA between the groups, which is in line with the result of the ANOVA. Based on the ANOVA results, it is concluded that there is no significant difference in ROA between the different portfolios based on R&D intensity.

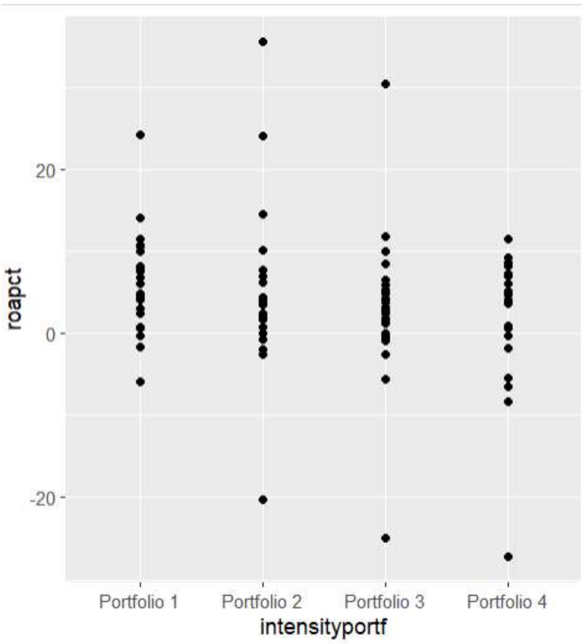

Figure 11: ROA by portfolio (portfolios formed based on R&D intensity)

ANOVA is a parametric method of analysis. A disadvantage of parametric statistical procedures is that they rely on assumptions about the distribution and certain parameters of the data (Hoskin, 2012). As mentioned earlier, it might be the case that these data are not suitable for parametric tests, because the distribution of R&D intensity follows a lognormal distribution. In their literature review, Pek et al. (2018) mention the alternative option: Non-parametric tests. These tests transform the data into ranks, which has as a consequence that extreme values have less influence. The non-parametric alternative for one-way ANOVA is the Kruskal-Wallis test (Siegel, 1957).

Model 4: Kruskal-Wallis test with portfolios based on R&D intensity

The Kruskal-Wallis test uses ranks instead of original raw data (smallest value is replaced by 1, next-to-smallest by 2 and so on). According to Kruskal & Wallis (1952), the main advantages of this test is that calculations are simplified and the number and complexity of assumptions about the distributions is very limited. The null-hypothesis of the Kruskal-Wallis test is similar to the null-hypothesis of one-way ANOVA, namely that at least one of the group means is significantly different.

The goal of this test is to find statistical support for the observed pattern in table 6, namely that firm performances seems to be negatively related to R&D intensity. If the Kruskal-Wallis test is significant, the next step is to investigate which of the groups differ significantly from each other, to see whether there is empirical evidence for the suspected negative relationship.

Performing the Kruskal-Wallis test leads to an insignificant test result. The p-value of the test statistic H is 0.35, which means that the null-hypothesis cannot be rejected.

The general conclusion about hypothesis 1 is that there is no empirical evidence that supports the effect of R&D intensity on firm performance. Model 2 and model 3 show some results that can indicate a negative relationship, but both findings are insignificant. These findings make it somewhat difficult to test the second hypothesis, because it assumes a significant effect of R&D intensity on firm performance. However, it is still possible to test whether the effect may be present for one of both groups. The results of hypothesis 2 are described next.

Hypothesis 2: The positive relationship between R&D intensity and firm performance is stronger for Service firms than for Non-service firms.

The second hypothesis is about the question whether the effect of R&D intensity on firm performance is different between Non-service and Service firms. Based on the literature review (Section 2), it is expected that the effect of R&D intensity on firm performance is positive and that it is stronger for Service firms (Atuahene-Gima, 1996; Tufano, 1989; De Brentani, 1989; Zeithaml, 1981). However, according to the analysis regarding hypothesis 1 it is found that this relationship seems to be negative and, more importantly, insignificant.

To investigate whether there are differences between Non-service and Service firms, two types of models are tested. Models 5 and 6 are similar to model 1, but with the difference that the sample is split in Non-service and Service firms. The same holds for models 7 and 8, but these models use the logarithm of R&D intensity instead of the original variable. Model 9 includes the variable 'Service' (Value of 0 for Non-service firms and 1 for Service firms) as a moderation variable.

Table 7: Models for hypothesis 2

Model	Description
Models 5 & 6	$ROA = ß_0 + ß_1 \times R\&D\ Intensity$
Models 7 & 8	$ROA = ß_0 + ß_1 \times \log(R\&D\ Intensity)$
Model 9	$ROA = ß_0 + ß_1 \times \log(R\&D\ Intensity) + ß_2 \times Service + ß_3 \times \log(R\&D\ Intensity) \times Service$

<u>Models 5 & 6: $ROA = ß_0 + ß_1 \times R\&D\ Intensity$</u>

These models are similar to model 1. R&D intensity is the independent variable and ROA is the dependent variable. Model 5 is about the Non-service firms, model 6 about the Service firms.

Model 5: Dependent variable = roapct (Return on Assets) --> Only Non-service firms						
	Coefficients (p-values)					
Independent variable	**Model 5.1**	**Model 5.2**	**Model 5.3**	**Model 5.4**	**Model 5.5**	**Model 5.6**
intensitypct	-0.069 (0.844)	-0.420 (0.135)	-0.472 (0.182)	-0.140 (0.713)	-0.445 (0.136)	-0.475 (0.139)
Avg_Leverage		-21.403 (0.000)***			-20.638 (0.000)***	-20.490 (0.000)***
Avg_Liquidity			4.320 (0.003)***		0.411 (0.779)	0.449 (0.763)
Age				0.022 (0.601)		0.009 (0.786)
Number of observations	50	50	50	50	50	50
Adjusted R^2	*0.00%*	*39.91%*	*13.48%*	*0.00%*	*38.71%*	*37.45%*

Figure 12: Coefficients for model 5 (Non-service firms)

The effect of R&D intensity on firm performance is insignificant for Non-service firms in all models, whereas the significance of the control variables is also similar to model 1.

Model 6: Dependent variable = roapct (Return on Assets) --> Only Service firms						
	Coefficients (p-values)					
Independent variable	**Model 6.1**	**Model 6.2**	**Model 6.3**	**Model 6.4**	**Model 6.5**	**Model 6.6**
intensitypct	0.0338 (0.392)	0.174 (0.652)	0.178 (0.634)	0.294 (0.472)	0.095 (0.798)	0.045 (0.907)
Avg_Leverage		-15.900 (0.026)**			-10.974 (0.127)	-10.421 (0.153)
Avg_Liquidity			8.439 (0.008)***		6.843 (0.036)**	7.099 (0.033)**
Age				0.041 (0.637)		0.048 (0.557)
Number of observations	50	50	50	50	50	50
Adjusted R^2	*0.00%*	*7.66%*	*11.73%*	*0.00%*	*14.31%*	*13.09%*

Figure 13: Coefficients for model 6 (Service firms)

The same can be concluded about the Service firms, which show no significance between R&D intensity and firm performance. However, these findings are not surprising, because the effect of R&D intensity on firm performance is also insignificant for the whole sample. Nevertheless, it also turns out that all coefficients for intensitypct are negative for Non-service firms, whereas all coefficients are positive for Service firms. Although the coefficients for Service firms are not statistically significant, it seems that the relationship between R&D intensity and firm performance is positive for Service firms.

Models 7 & 8: ROA = $ß_0 + ß_1 \times$ log(R&D Intensity)

The logarithmic transformation of R&D intensity seems to suit the data better, because this variable follows a lognormal distribution. Therefore, models 7 and 8 are tested, where a logarithmic transformation is applied to R&D intensity. These models are similar to model 2.

Model 7: Dependent variable = roapct (Return on Assets) --> Only Non-service firms						
	Coefficients (p-values)					
Independent variable	**Model 7.1**	**Model 7.2**	**Model 7.3**	**Model 7.4**	**Model 7.5**	**Model 7.6**
log(intensitypct)	-1.142 (0.077)*	-1.183 (0.021)**	-1.493 (0.014)**	-1.367 (0.045)**	-1.229 (0.020)**	-1.326 (0.019)**
Avg_Leverage		-20.617 (0.000)***			-19.395 (0.000)***	-18.879 (0.001)***
Avg_Liquidity			4.720 (0.003)***		0.651 (0.695)	0.737 (0.662)
Age				0.044 (0.281)		0.018 (0.590)
Number of observations	46	46	46	46	46	46
Adjusted R^2	*4.83%*	*42.11%*	*21.15%*	*5.24%*	*40.95%*	*39.94%*

Figure 14: Coefficients for model 7 (Non-service firms)

The results for model 7 show negative and significant coefficients for all models. Even after controlling for leverage, liquidity, and age, the effect of R&D intensity on firm performance is significant. This is an interesting finding, because it is the first model that shows significant coefficients for all models.Especially the fact that the sign of the relationship is negative is interesting, because that is contrary to some existing studies (like Gharbi et al. (2014), Mezghanni (2011), and Lin (2017)). Possible explanations might be that R&D expenses reduce profits (Arif Khan et al., 2023) or that R&D investments have an above average probability of failure (Finkelstein & Boyd, 1998). Moreover, an intriguing question is whether firms are aware of this negative relationship and, if yes, what the reasons are that they still invest in R&D while it reduces firm performance.

Model 8: Dependent variable = roapct (Return on Assets) --> Only Service firms						
	Coefficients (p-values)					
Independent variable	**Model 8.1**	**Model 8.2**	**Model 8.3**	**Model 8.4**	**Model 8.5**	**Model 8.6**
log(intensitypct)	1.523 (0.368)	0.666 (0.683)	0.988 (0.537)	1.359 (0.437)	0.538 (0.736)	0.417 (0.780)
Avg_Leverage		-26.845 (0.017)**			-18.685 (0.114)	-17.768 (0.144)
Avg_Liquidity			8.353 (0.014)**		6.077 (0.089)*	6.297 (0.085)*
Age				0.040 (0.667)		0.033 (0.705)
Number of observations	45	45	45	45	45	45
Adjusted R^2	*0.00%*	*10.34%*	*11.22%*	*0.00%*	*14.50%*	*12.68%*

Figure 15: Coefficients for model 8 (Service firms)

The results for the Service firms are quite different compared to the Non-service firms. Model 8 shows no significance for the effect of R&D intensity on firm performance. Moreover, all coefficients for log(intensitypct) are positive, which is also different compared to the negative coefficients for Non-service firms. This finding corresponds with the findings of models 5 and 6. However, it has to be taken into account that the positive coefficients for Service firms are also insignificant.

These findings might also (partly) explain the results for the whole sample. The negative and significant coefficients for Non-service firms and the positive but insignificant coefficients for Service firms together may cancel each other out, which results in an insignificant effect over the whole sample.

Models 5-8 test the effect of R&D intensity on firm performance for the individual samples, split by firm typology. Another option is to include firm typology (variable 'Service') as a moderation term in the formula. This will be done in model 9.

Model 9: ROA = ß0 + ß1 × log(R&D Intensity) + ß2 × Service + ß3 × log(R&D Intensity) × Service

Model 9 uses the logarithm of R&D intensity as the independent variable. The goal of the model is to test whether the effect of R&D intensity on firm performance is different between Non-service firms and Service firms. To do this, the dichotomous variable 'Service' is included in the model as a representation of the construct 'Firm typology'. This is a similar approach as used by Troilo et al. (2014), but they use a nominal variable (with multiple categories) as a moderator variable. However the idea is the same, namely to choose one of the values as the reference category (in this case: Non-service firms) and subsequently compute interactions between the independent variable and the remaining firm typology (in this case: Service firms). This approach is based on the literature by Cohen et al. (2003). Furthermore, when testing for moderation, it is important to include the independent variable also as a single variable in the model (Cohen, 1978).

Model 9: Dependent variable = roapct (Return on Assets)	
	Coefficients (p-values)
Independent variable	**Model 9**
log(intensitypct)	-1.142 (0.076)*
Service	0.811 (0.638)
log(intensitypct)*Service	1.356 (0.180)
Number of observations	86
Adjusted R^2	*0.00%*

Note: After deleting influential cases

Figure 16: Coefficients for model 9

The data in figure 16 show a negative and partially significant relationship between R&D intensity and firm performance, which is found earlier for Non-service firms. The coefficient for the variable 'Service' is insignificant, which indicates that there is no significant difference in ROA between Non-service and Service firms. The coefficient of the moderation variable is also insignificant. This means that there is no empirical evidence that the effect of R&D intensity on firm performance is different between Non-service and Service firms. This model seems to have no explanatory power, because it has an R^2 of 0%.

However, the results of model 9 correspond with the earlier findings in the way that the effect of R&D intensity on firm performance seems to be present for Non-service firms. When predicting the ROA for Non-service firms, the model only uses the coefficient of log(intensitypct), which is negative and significant. When the ROA for a Service firm is predicted based on this model, the insignificant coefficients of Service and log(intensitypct)*Service are added.

The main finding of the analysis of hypothesis 2 is that there is empirical evidence for the effect of R&D intensity on firm performance for Non-service firms, whereas there is no significance for Service firms.

5. Discussion

The results and the findings of the previous section are discussed in this section. The findings will be related to the literature that is dealt with in the literature review and it is discussed whether these findings are in line with existing research or not. Moreover, this section will also elaborate on some limitations of this research and some suggestions for future research.

Discussion of findings

The first part of this section contains a discussion of the findings. This discussion will be separated for both hypotheses.

H1: R&D intensity is positively related to firm performance.

The first linear regression model is a model where ROA is a function of R&D Intensity. The coefficients of this model are all insignificant and there is also no clarity about whether the sign of the relationship is positive or negative, because the different model specifications show mixed results. This is in contrast to existing studies that show significant relationships. Some studies that were already mentioned in the literature review, like Gharbi et al. (2014), Mezghanni (2011), and Lin (2017) all show positive relationships between R&D intensity and firm performance. However, although these studies find significant relationships, the researchers also mention some footnotes. Mezghanni (2011) states that the positive effect of R&D investments on firm performance depends on the role of the board of directors. Mezghanni says that guiding managers' decisions and ensuring effective deployment of resources is essential for achieving firm performance. Lin (2017) finds that R&D investments are positively related to firm performance, only for firms that are engaged in corporate social responsibility. These footnotes indicate that there is some uncertainty about the plain relationship between R&D and firm performance. The results of this study are also in line with this.

There are several explanations why there might be no relationship between R&D intensity and firm performance. In the first place, the research approach that is used in this study tests the relationship between current level of innovativeness and current level of firm performance. It is said that investments in Research and Development are mainly focused on the long term (Kor, 2006; Zona, 2016). This might be a reason that comparing current level of innovativeness and current firm performance result in an insignificant relationship.

However, a counterargument for this is that the level of innovativeness of a firm (in this study measured as R&D intensity) is mainly determined by long-term factors. Martinez-Roman & Romero (2017) divide the determinants of innovativeness into three categories: Personal characteristics of the entrepreneur like level of education (Koellinger, 2008), creativity (Nonaka & Takeuchi, 1995) and risk-taking behavior (Baron & Tang, 2011); internal organisational factors like culture (Bukowski & Rudnicki, 2019) and continuous learning ability (Caloghirou et al., 2004); and external knowledge sources like formal networks (Bessant et al., 2012) and cooperation in the value chain (Patterson et al., 2003). These factors seem to be related more to the long term than to short-term time-specific events. Based on this, it is reasonable to expect that the level of innovativeness of a firm does not change drastically over time. In other words: If a firm invested a lot in R&D during the sampling period of 2014-2021, it is plausible to expect that this firm has been engaged in R&D to a similar degree in the time before.

A second explanation for the insignificant relationship between R&D intensity and firm performance might be that R&D investments are considered as risky (Honoré et al., 2015) with a high probability of failure (Finkelstein & Boyd, 1998). When a firm starts with a certain R&D-project, it is still uncertain whether this project will lead to future benefits or not (Han et al., 2004; Landry & Callimaci, 2003).

Balachandra & Friar (1997) mention that 90% of 16,000 new products that were introduced in 1991 did not meet their business objectives. The high level of failing R&D investments might be another reason why there is no significant relationship between R&D intensity and firm performance. It might, for example, be the case that firms that invest more in R&D also have higher rates of failing R&D-projects. It can be that these firms are less risk-averse or that they have the (financial) capacity to incur unexpected losses. Therefore, the firm performance of a firm with a relatively high level of R&D intensity does not necessarily improve, because the degree of failing investments can be high. It would be interesting to study the relationship between R&D intensity and the rate of success of the R&D investments, and the consequential effect on firm performance.

However, as already mentioned, using the raw value of R&D intensity as an independent variable can be problematic in the way that this variable follows a lognormal distribution (Cohen and Klepper, 1992; Lee, 2002; Lee & Noh, 2009). Therefore, the second linear regression model uses the logarithm of R&D intensity as the independent variable. Although the main model with the logarithm of R&D intensity as independent variable and ROA as dependent variable is not significant, all different model specifications (inclusion of different combinations of control variables) show a consistent negative relationship between R&D intensity and firm performance. This is in contrast with the earlier mentioned studies that expect a positive relationship.

Because the independent variable is transformed, the interpretation of the negative relationship also changes. Due to the logarithmic transformation, the relationship is not linear anymore. Figure 10 in the Results-section gives a good illustration of how the effect of R&D investments on firm performance should be interpreted. It shows that when R&D intensity of a firm is low, an increase in R&D intensity of 1% has more impact on firm performance than a 1% increase in R&D intensity for firms that already invest a lot in R&D.

Although some studies suggest (Christensen & Raynor, 2013; Wang et al., 2023; Goel & Nelson, 2022) or find (Gharbi et al., 2014; Mezghanni, 2011; Lin, 2017) a positive relationship between R&D intensity and firm performance, there is also a line of literature that finds negative relationships. For example, Arif Khan et al. (2023) find that firm performance reduces as R&D expenses rise, similar to Chen et al. (2019). These researchers say that the negative relationship might be caused by the fact that R&D expenses reduce operating profit, and therefore (financial) firm performance. Another study by Kim et al. (2018) finds that the negative effect of R&D intensity on firm performance might arise due to information asymmetry, which is in line with Lucas et al. (2018) and Entwistle (1999). However, Kim et al. (2018) measure firm performance via shareholder value, which is more affected by information asymmetry than operating profit. An explanation of the negative effect of R&D investments on firm performance that is in line with the results of this study is provided by Yang et al. (2009), who say that firm performance may diminish during the initial stages of R&D investments due to lack of experience with R&D and the small scale of R&D departments and their investments. This reasoning is supported by the results of this study, because it is found that the negative effect of R&D investments on firm performance is most prominent when innovation levels are rather low.

Another possibility is that the relationship is bi-directional, which means that firm performance is not just explained by R&D intensity, but that it can also be the other way around. For example, Hundley et al. (1995) find that decreasing profitability leads to increased R&D investments in Japan. That is because decreasing profitability might make companies aware of the need to develop new technologies and products. On the other hand, it could also be that more profitable firms feel less need to invest in innovation, because their performance is already successful. However, one could also theorize that profitable firms have more surplus resources, which gives them the possibility to invest in R&D activities. This is also an interesting point for future research.

H2: *The positive relationship between R&D intensity and firm performance is stronger for Service firms than for Non-service firms.*

When formulating hypotheses 2 after the literature review, it was assumed that the general relationship between R&D intensity and firm performance is positive. It turned out that this is not the case. However, studying and analysing the data can still result in theoretical and practical contributions on this topic.

Studying this hypothesis started with a similar linear regression model as for the first hypothesis, namely with R&D intensity as independent variable and ROA as dependent variable. The difference is that the model in this case was run on the separate subsamples of Non-service firms and Service firms. The coefficients of R&D intensity are insignificant for both types of firms. However, although the coefficients are insignificant, it is interesting to observe that the coefficients of the different model specifications are consistently negative for Non-service firms and consistently positive for Service firms. This is different compared to the model running on the whole sample, because the coefficients for the whole sample were both positive and negative for different model specifications.

When doing the same logarithmic transformation of the independent variable, the negative relationship between R&D intensity and firm performance even becomes significant for Non-service firms. Negative significant coefficients are found for all model specifications. The relationship for Service-firms seems to be positive, but there is no statistical significance. These findings are confirmed by another type of model which includes the variable 'Service' (0 = Non-service firm, 1 = Service-firm) as moderation variable. The resulting coefficients show that R&D intensity has a significant negative relationship with ROA for Non-service firms, while the effect on ROA becomes positive, but not significant, for Service firms.

The literature review already referred to a study by Tufano (1989), who says that service companies have higher levels of interaction with its customers compared to Non-service firms. Because of that, it is easier for service companies to discover the needs of the customers and to come up with suitable ideas for development. This will probably lead to more successful R&D investments which improve firm performance. Moreover, according to De Brentani (1989) and Zeithaml (1981), innovations regarding service are also easier and less time-consuming to develop than product developments, and therefore less costly. As a consequence, their negative impact on firm performance is also less strong compared to Non-service firms (Arif Khan et al., 2023; Vithessonthi & Racela, 2016).

There is no clear pattern in existing research about the differences between Service firms and Non-service firms. Ehie and Olibe (2010) conclude that the positive effect of R&D investments on firm value is stronger for service firms, whereas Ho et al. (2005) find that this is the other way around, namely that manufacturing firms benefit more from R&D investments compared to non-manufacturing firms. Chauvin and Hirschey (1993) on the other hand do not find significant differences between the two types of firms.

Ehie and Olibe (2010) study whether the effect of R&D investments on firm value is different between manufacturing and non-manufacturing companies. The main difference is that they use market metrics (share value) instead of accounting metrics like ROA. However, Ehie and Olibe also find that R&D investments contribute more positively to firm value for non-manufacturing firms compared to manufacturing firms.

This is in contrast with the findings of Ho et al. (2005), who find that manufacturing firms benefit more from R&D investments than non-manufacturing firms. Their argument for this is that they expect that product innovation is more crucial for manufacturing firms to distinguish themselves from competitors. Ho et al. think that service firms benefit more from investments in marketing and advertising, instead of R&D investments.

Limitations

Although the study provides several contributions, which will be elaborated on in the next section, this research also has some limitations. The first limitation is about the sample. A total sample of 100 firms with two subsamples of 50 Non-service firms and 50 Service firms is quite small. As a consequence, one can put some question marks about the generalizability of this study. The reason that this study does not use a bigger sample is because of the time-consuming data collection process, where all data had to be collected by hand.

Another limitation about the sample is that it only contains Dutch firms. Interpretation to other countries should be done with some care, because there might be differences regarding both R&D intensity and firm performance. For example, it is already found that R&D intensity is affected by cultural factors (Lorca & De Andres, 2019; Bukowski & Rudnicki, 2019) or economy size (Sandven & Smith, 1998).

The main limitation regarding the research approach of this study is that it did not allow for investigating the effect of time. A sampling period of eight consecutive years is actually too short to split the data in two or more periods. Another possibility would have been to compare individual years with each other, for example by studying whether R&D intensity in 2014 is related to firm performance in 2016. However, this approach also has its disadvantages. According to Griliches (1980), using data of individual years is associated with more influential outliers in both the input and the output variable. That is a plausible argument: If a firm has good performance ratios but it had one year with an impactful unexpected loss, then this observation might disturb the results of data analysis. Or if a firm wants to reduce the tax obligation in a certain year, it might choose to expense a high amount of R&D instead of capitalizing the investment. Therefore, averaging values across a longer period is a good way to make the analysis more stable and reliable (Mansfield, 1980).

Using an accounting metric as a measure for firm performance has both advantages and disadvantages. The advantage is that these data are comprehensible, easy to interpret and that these ratios give a concrete indication of firm performance, while they are also comparable among different type of firms. However, the return on assets of a firm depends on many other factors, which might make it somewhat tricky to predict firm performance based on R&D intensity. If market metrics, like share price for example, would have been used, then different type of conclusions could have been drawn (Schnietz & Epstein, 2005). Then it would have been possible to say something about how investors perceive the attitude towards innovation of a certain firm for example. Using perceptual metrics on the other hand could have resulted in more in-depth information about why R&D intensity is related in a certain way to firm performance (Murphy et al., 1998).

Future research

The relationship between R&D intensity and firm performance is an interesting topic that still allows for several future research topics. This study finds that this relationship seems to be negative. Some other studies also find a negative relationship (Arif Khan et al., 2023; Chen et al., 2019), but some do also find a positive relationship (Gharbi et al., 2014; Mezghanni, 2011; Lin, 2017). So, there is still ambiguity in existing research about the direction of this relationship and what exactly causes the relationship. If it indeed turns out to be negative, a follow up research question would be what the reasoning is for firms to invest in R&D, if it deteriorates firm performance in the end. This type of research could also be qualitative, to get more in-depth arguments from directors why and how firms choose to invest in R&D.

Next to that, it is also possible that the relationship is bi-directional. This means that there is also a possibility that the level of R&D intensity can be (partially) explained by firm performance. Hundley et al. (1995) for example find that decreasing profitability might lead to an increase in R&D spending, because companies feel more necessity to innovate. On the other hand, profitable firms may have more resources to invest in R&D. Profitable firms also have more financial buffer to overcome a failing R&D project. Future research could further study the bi-directional nature of this relationship.

Besides the sign of the relationship, another point for future research would be to investigate the relationship itself. Existing research, including this study, shows that it is probably not a linear effect. But there is still a gap to fill about this. Some studies find an inverted U-shaped relationship (Kim et al., 2018) or a sigmoid function (Yang et al., 2009), whereas this study finds a negative exponential function. This is an interesting topic of research, because it says something about the effect on firm performance for different stages of R&D investment.

Another topic that is closely related to this is the success rate of R&D investments. This topic already came along in the discussion section, but it might be worth studying. Although R&D intensity is a common measure for the level of innovativeness, it does not say much about the effectiveness of the R&D investments of a firm. If a firm has very strict criteria for R&D investments before these investments are carried out, it might result in lower levels of R&D expenditure. However, because of the fact that this firm takes a critical stance on R&D investments, the probability of success of these investments is probably higher. Therefore, it is interesting to study whether firm performance can be related to the success rate of R&D investments (Balachandra & Friar, 1997).

As already mentioned as a limitation, the effect of time is an area of research that can be studied more extensively in the future. That is because an investment in R&D is not immediately effective. This study looks more at the general relationship between the level of innovativeness of a firm and its performance (like Griliches (1985) and Lichtenberg & Siegel (1991)), but it does not look at the effect of specific investments. However, this is a difficult topic to measure. That is because R&D investments often comprise multiple years. Oftentimes, these investments can be divided in a research phase and a development phase, so future research should take this into account (Han et al., 2004; Landry & Callimaci, 2003). A future research question could be to study the time it takes for an R&D investment to have effect on a certain outcome variable, like firm performance. Horst (2001) already applied a certain approach on patent applications. Another point of future research on the role of time of R&D investments can be derived from this research. The results show that the effect of R&D intensity on firm performance is negative, especially for Non-service firms. Studying the long term in this case might contribute to this topic, because it can provide clarity about why this type of firms still invest in R&D while it has a negative on firm performance, at least on the short term.

This study also finds that there seems to be a difference in the effect of R&D investments on firm performance between Service firms and Non-service firms. However, looking at current literature, it is difficult to find concrete arguments about why this effect is different. Ehie & Olibe (2010) and Ho et al. (2005) also studied this topic and found differences, but there seems to be a gap in the literature about the interpretation and explanation of this phenomenon. One point of attention is the difference in nature of the investments between the two types of firms. It is reasonable to expect that R&D investments for Service firms are mainly focused on software for example, whereas R&D investments for Non-service firms could be more about product development. Studying the similarities and differences between these two types of firms will contribute to the existing knowledge on this topic.

6. Conclusion

This sixth and final section will conclude this research. In this section, the findings of the data analysis are used to provide an answer to the research question. After that, both the theoretical contributions and the practical contributions of this study will be considered.

Research question and hypotheses

The goal of this study has been to statistically assess whether there is a relationship between R&D intensity and firm performance and if yes, how this relationship looks like. Next to that, this study enters a relatively unexplored area of research by studying whether this relationship is different for two different types of firm: Service firms and Non-service firms. The aim of this study is to provide an answer to the following research question:

"What is the effect of R&D intensity on firm performance and is this effect moderated by firm typology?"

This research question is twofold. To study this research question, two hypotheses are formulated which will be discussed separately.

H1: *R&D intensity is positively related to firm performance.*

This study finds that there is actually no significant relationship between R&D intensity and firm performance. The linear regression models, ANOVA and the non-parametric Kruskal-Wallis test all showed insignificant results, concluding that there is no significant relationship between R&D intensity and firm performance.

Performing a logarithmic transformation on the independent variable in the linear regression model did also not result in significant findings. However, regression coefficients for this variable are consistently negative for different model specifications, which indicate a negative relationship. The fact that the independent variable has been transformed into a logarithmic function also changes the interpretation. The marginal effect (the effect of a change) of R&D intensity on firm performance is bigger when R&D intensity is relatively small. When the level of R&D intensity is already high, an increase in expenditure has less effect on firm performance.

H2: The positive relationship between R&D intensity and firm performance is stronger for Service firms than for Non-service firms.

Although the relationship between R&D intensity and firm performance not turned out to be positive, the difference between Service firms and Non-service firms is still studied. The main finding here is that the effect indeed seems to be different between the two types of firm. Testing the effect of R&D intensity on firm performance resulted in consistently negative coefficients for Non-service firms and positive coefficients for Service firms, although both effects are not significant. When transforming the independent variable into a logarithmic function, the negative effect of R&D intensity on firm performance becomes significant for Non-service firms.

These findings should be interpreted with caution, because the positive effect for Service firms is insignificant. However, it seems like there is a difference in effect of R&D intensity between Service firms and Non-service firms. The effect is not just stronger or weaker for a certain type, but the direction itself is different.

Theoretical contributions
This study provides several theoretical contributions. Firstly, it investigates the relationship between R&D intensity and firm performance. Although this relationship is studied earlier, the findings are not straightforward. There are researchers who find positive relationships (Gharbi et al., 2014; Mezghanni, 2011), negative relationships (Arif Khan et al., 2023; Chen et al., 2019) or positive relationships with certain remarks (Lin, 2017). This study finds a negative relationship, but there is no significance, making it a topic that has to be studied further in the future. Especially the effect of time seems to be an important topic to keep into account.

A second theoretical contribution of this study is about the marginal effect of R&D intensity on firm performance. This study finds significance for the relationship when a logarithmic transformation is performed on the independent variable. As a consequence, the effect of R&D intensity on firm performance is not linear. Some researchers already found an inverted U-shaped relationship (Kim et al., 2018) or a sigmoid function (Yang et al., 2009), but this research shows that it might also be the case that the relationship is a negative exponential function. The theoretical contribution that this relationship is probably not linear is an interesting entry point for future research.

The analysis of the difference of the effect between Service firms and Non-service firms also provides an interesting contribution to theory. Firstly, it is found that the effect of R&D intensity on firm performance is negative and significant for manufacturing firms. Next to that, the effect seems to be positive for Service firms. In other words: Service firms seem to benefit from investments in innovation, whereas the performance of Non-service firms deteriorates when it invests in Research and Development. It can be concluded that firm typology should be considered as a factor when considering the relationship between R&D intensity and firm performance. The fact that the sign of the relationship is different for the two types is an important theoretical contribution. Other studies like Ehie & Olibe (2010) and Ho et al. (2005) also studied the differences between Service firms and Non-service firms (they call it 'Manufacturing firms' and 'Non-manufacturing firms'), but they only find a difference in the strength of the relationship. This study contributes to the theory in the way that it finds a difference in the direction of the relationship.

Practical contributions
Besides the theoretical contributions mentioned above, this study also provide some implications for business directors, management teams and managers of Research and Development-departments. Firstly, the fact that there is no straightforward significance for the relationship between R&D intensity and firm performance indicates that managers should not simply assume that investing in innovations and developments automatically leads to improved performance. R&D investments are risky and have a higher probability of failure than other types of investment on average, because these investments always have some uncertainty about future benefits (Balachandra & Friar, 1997). Just like with other investments, managers should make a detailed trade-off between the costs and the expected benefits of R&D investments, despite the fact that the expected benefits are difficult to estimate.

Next to that, it seems to be the case that the stage of innovation and the experience of a firm with investments in R&D is a determinant for the effectivity of R&D investments. In case of Non-service firms for example, it is found that the marginal (negative) effect of an increase in R&D expenditure has a more detrimental impact on firm performance when the current level of R&D intensity is low. This has probably to do with a lack of experience and with the fact that firms with small R&D departments (or with no R&D department at all) can not benefit from economies of scale. The latter means that small R&D departments have less ability to divide certain fixed costs (licenses, testing equipment for example) across multiple development projects (Yang et al., 2009). Managers should realize that experience and existing knowledge is important for successful R&D. When a company has a small R&D department or it does not have a R&D department and it wants to set up one, management could consider to use external resources like research agencies, consultants, or partners with experience in the field of R&D. This increases the probability of a successful R&D department.

Finally, the observed differences between Service firms and Non-service firms can also be impactful for business practitioners. The observed negative effect for Non-service firms implicate that managers should think critically about the nature of the R&D investments they execute. Vithessonthi & Racela (2016) for example think that Non-service firms invest more in product development compared to Service firms. Although it is not studied empirically yet, it might be that this type of investments do not contribute much to firm performance.

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