Master thesis

Upper Echelons: The reflection of the CEO characteristics on the R&D spending at SMEs

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Abstract

In this study, the relationship between CEO characteristics and R&D spending at SMEs is investigated. The importance of innovation has been widely acknowledged by literature. Based upon the Upper Echelon Theory, which argues that the organizational outcomes are partially explained by the values and cognitive bases of their top managers, existing research found significant relationships between CEO characteristics and firm R&D spending. However, there is a clear lack of scientific evidence when specifying SMEs. CEO characteristics are defined by the tenure, age, formal education, and gender of the firm its CEO. The firm's R&D spending is measured by the R&D spending per employee, the R&D spending to asset ratio, and the R&D spending to revenue ratio. Based on a sample of 162 SMEs located on all continents, a multiple linear regression analysis is conducted. The results show, contrary to previous literature, that there seems to be no significant relationship between CEO characteristics and R&D spending at SMEs. After control variables, the explained variability by the CEO characteristics is not significant in the main model. In the main model, the only CEO characteristic that has a significant positive relationship with R&D spending per employee is the CEO's formal education. Furthermore, different robustness tests are conducted to strengthen the results of the main model. The robustness tests show similar results to the main research model, in which there is only a significant relationship between a CEO's formal education and firm R&D spending. Further research is needed to assess the validity of these results. Nevertheless, this study contributes to the existing literature because of the scarcity of research on CEO characteristics and SMEs.

Keywords: R&D spending, CEO characteristics, CEO tenure, CEO age, CEO formal education, CEO gender, SMEs.

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1. Introduction

1.1 Situation

"To stand still is to fall behind" is one of many famous quotes by the American writer Mark Twain. While this can be interpreted in many ways, this paper is aimed at innovation (research and development) at companies. Innovation and the relationship with performance have been a high topic of interest for decades in the scientific literature. It can be seen as the engine of growth (Brown, 2010) and is important for the survival and growth of companies functioning in highly competitive industries (Wang, Yu, & Lui, 2013; Hong, 2017). Additionally, the impact of research and development (R&D) investments is higher in high-tech sectors than in the non-high-tech sectors (Ortega-Argilés, Piva, & Vivarelli, 2014) The literature does show various results on the impact of innovation, but it is no secret that it is one of the most important aspects for survival and growth.

There is a relationship between R&D and growth at SMEs. Research by Deschryvere (2014) analyzed the role of innovation persistence (R&D) on growth in Finnish SMEs and large firms. Results showed that the consistent innovator had a positive relationship, albeit small, between R&D growth and sales growth. Complementary, Nunes, Serrasqueiro, and Leitão (2012) analyzed the relationship between R&D intensity and growth for high-tech and non-high-tech SMEs. They found a distinct difference between these industry classes. Non-high-tech SMEs had a linear and negative relationship between R&D intensity and firm growth. Whereas the high-tech SMEs had a U-shaped, quadratic relationship. The literature shows that the relationship between R&D and growth is not easily generalizable and is heavily dependent on the situation. However, in some of those situations, R&D can be the decisive factor that allows for growth in SMEs.

Innovation is one of many factors that determine organizational outcomes. The Upper Echelon Theory (UET) argues that the organizational outcomes can be reflected by the CEO's values and cognitive bases (Hambrick & Mason, 1984). The CEO is vital in the day-to-day decision-making process which steers the firm. Additionally, the CEO is responsible for building and maintaining organizational culture, which shapes the firm's workforce and guides its decision-making process (Wang et al., 2016). Following the UET shows that the innovation direction a firm takes is also reflected by the CEO's values and cognitive bases. The study of Barker & Mueller (2002) assessed the relationship between CEO characteristics and firm R&D spending. They found that the CEO characteristics have a higher association with R&D spending than some firm-level variables that received considerable research attention in the past. Despite the extensive line of research on the

UET, little of the research has focussed on the association of CEO characteristics with R&D spending, especially for SMEs.

1.2 Contribution

There have been many studies that have examined the relationship between CEO characteristics on firm decision-making. However, this seems to be lacking when specifying for SMEs. One reason could be that there seems to be more data available when it comes to big and listed firms because they have higher auditing requirements (Ayu et al., 2019). Therefore, more of the firm's data is saved and presented which can be translated more easily into databases. Nevertheless, there has been one research by Yong-hai (2010) which assessed the impact of CEO characteristics on R&D expenditure using small and medium listed companies in China. However, past research has shown that the economy between China and the western world is vastly different. For example, the research by Boisot and Child (1996) found that the rapid economic development in China is being accomplished through a system of governance that is vastly different from the Western culture. Additionally, the study by Yong-hai (2010) does not mention if the sample size consists of private ownership or state-controlled. Although there is a clear presence of research on CEO characteristics and the impact on R&D spending, it seems to be lacking when specifying SMEs. The research on SMEs can be of high interest because CEOs might have more control over the decisions than at bigger firms.

Based on the above, there is a lack of research on the relationship between CEO characteristics and R&D spending when it comes to SMEs. Firstly, most of the studies focused on the UET are based on the firm's performance (e.g., return on sales) and not on investment decisions. Whereas the innovation of a company is also important for survival and growth (Brown, 2010). Furthermore, past research has mostly focussed on the effect the CEO characteristics have on firm performance at large and listed firms. The implication could be made that the same relationship exists in SMEs, but it has never been established in the literature. Therefore, this study intends to assess the relationship between CEO characteristics and R&D spending at SMEs. This leads to the following central research question:

What is the relationship between CEO characteristics and R&D spending at SMEs?

This study contributes for theoretical and practical reasons. This study has a theoretical contribution for two reasons. Firstly, as mentioned before, most of the existing studies are focussed on the relationship between CEO characteristics and firm performance, rather than innovation. Whereas this study specifies R&D spending as a form of innovation. Secondly, most of the existing literature is focused on large and listed firms. Whereas this study is focused on SMEs. The results of this study can give a path to more research on CEO characteristics and innovation at SMEs. For example, rather than the effect of CEO characteristics on R&D spending, one can examine the R&D efficiency. And combine these studies to see which characteristics could be most favourable in a CEO to maximize the use of R&D. This study also has practical contributions. The results from this study can show which characteristics of a CEO influence R&D spending. This can be used for executive succession. When shareholders are in search of a successor that has more focus on innovation, they can use the results of this study to determine which CEO might be favourable.

1.3 Outline

The rest of this study is divided into five sections. Firstly, the literature review consists of the explanation of theories on the influence of CEO characteristics. Furthermore, the most researched CEO characteristics and the relationship they have with firm strategic actions are discussed. Additionally, the importance of innovation in SMEs is substantiated by the Schumpeterian view and the Nobel prize-winning model for growth by Romer (1990) which is based on the Schumpeterian view. Based on this literature review and additional empirical evidence, four hypotheses are stated. Secondly, the research methodology is discussed in which the analysis method, research model, measurement level, control variables, and robustness tests are presented. Thirdly, the data is discussed in which the sample selection, data, and the transformation of variables are presented. Fourthly, the results of the descriptive statistics, correlation analysis, and regression analysis is presented and how they answer the hypotheses. Lastly, the conclusion is presented in which a summary of the study is given, limitations of the study are discussed, and recommendations are given for future research.

2. Literature review

This chapter contains the literature on which this study is based. Firstly, the theories on the influence of CEO characteristics on firm performance will be examined. The three theories discussed are the agency theory, resource dependence theory, and the upper echelons theory. Secondly, the literature that exists on CEO characteristics and firm strategic actions is discussed. Thirdly, based on the previous literature and further substantiation on CEO characteristics and the relationship with R&D spending, four hypotheses are formulated.

2.1 Theories on the influence of CEO characteristics on firm performance

The influence of CEOs on the firm's performance has repeatedly drawn the attention of researchers. To address such questions, different theories and perspectives have been formed. Firstly, the agency theory will be discussed. This theory focuses on how the interest can differ between the managers and shareholders and the impact on the organization (Jensen & Meckling, 1976). Secondly, the resource dependence theory (RDT) will be discussed. This theory focuses on how resources affect the behavior of the organization (Pfeffer & Salancik, 1978). Thirdly, the Upper Echelons Theory (UET) will be discussed. The core idea of this theory is that top executives' experiences, values, and personalities greatly influence their interpretations of the situation and thus influence their choices (Hambrick, 2007).

2.1.1 Agency theory

The agency theory concerns the relationship between the agent and the principal (Jensen & Meckling, 1976). In a company the shareholders (principals) contract the managers and directors (agents) to run the business on their behalf, which includes the power for decision making. With the implication that the agents run the business to fulfill the same interest as the principals have. However, this is not always the case. The situation often arises where the interest and risk preferences of the agents and principal differ and conflict with each other (Eisenhardt, 1989). This conflict of interest is not a problem if the principal can monitor the agent's actions. However, an agency problem arises when interests differ, and it is difficult or expensive for the principal to monitor the agent.

Agency problems can lead to high costs and need to be controlled. Agency problems only arise when the control and ownership of an organization are separated (Band, 1992). Fama & Jensen (1983) mention that agency costs include the structuring, monitoring, bonding of contracts across agents with conflicting interests, and the enforcement of these contracts. Adding that there are three main devices to control for the separation of ownership and control. Firstly, decision hierarchies where the decision initiatives are passed on to higher-level agents. Secondly, a board of directors that ratifies and monitors the organization's most important decisions including the right to hire, fire, and compensate top-level decision managers. Lastly, create incentive structures that encourage mutual monitoring among decision agents (Fama & Jensen, 1983). A situation where these control devices are not implemented properly can allow a CEO to use more power with less opposition.

The power of the CEO can increase the agency problem, as they have more strength to follow their self-interest. Research by Band (2005) on the relationship between CEO power and the impact on corporate performance shows that, as CEO power increases, the stock returns are more variable. They find that when a CEO has more power, it is easier to make relevant decisions. Thus, the likelihood of either very good or very bad decisions is higher in an organization in which the CEO's power to influence decisions is higher. Additionally, the CEO's power influence multiple aspects of the organization. Jiraporn, Chintrakarn, and Liu (2012) found that when a CEO plays a more dominant role among top executives, the firm evades debt financing. Additionally, the impact of changes in the capital structure on firm performance is more negative for firms with more powerful CEOs. Core, Holthausen, and Larcker (1999) argue that CEOs earn greater compensation when governance structures are less effective. Furthermore, adding that the compensation arising from the less effective governance structures has a significant negative relation with firm operating and stock return performance. Moreover, a CEO with a longer tenure has more power and tends to be opportunistic and prioritize their interest while making strategic financial decisions, thus creating agency costs (Naseem et al., 2020). Furthermore, CEO successors are motivated to improve corporate social responsibility as a tactic, to secure their leadership and increase their power (Liu, 2020).

2.1.2 Resource dependence theory

The resource dependence theory conceptualizes that the leadership effect is a product of the organizational environment (Lieberson & O'Connor, 1972). The view on leadership influence is that it is a product of two different factors. The internal organizational and external environmental constraints on a leader. Good examples of these factors are the state of the economy, which industry it functions and the position of the company in the industry. They argue that the emphasis in the literature on leadership may cause overlooking far more powerful environmental influences. Their research, based on longitudinal research of over twenty years on 167 large corporations, found that the industry and company account for far more of the variance in performance than leadership. When using the variables year, industry, and company, they could predict up to 97% of the performance measures, meaning that the added effect of leadership was almost nil. In short, the environmental influences are far greater than the influence of leadership on organizational performance.

This approach was further adopted in the literature. Salanick and Pfeffer (1977), two well-known business management theorists, used this approach in their study on the effect of mayors on city budgets. Following the research of Lieberson and O’Connor (1972), they argue that leadership in organizations operates within constraints deriving from internal factors and external demands on the organization. Therefore, people outside of the position as leaders tend to overestimate the power that they have. Following this publication, Pfeffer & Salanick (1978) published the book T*he External Control of Organizations: A Resource Dependence Perspective.* Since this publication, the resource dependence theory has become one of the most influential theories in organizational theory and strategic management.

The resource dependence theory has been applied broadly to explain how organizations are exposed to environmental interdependence and uncertainty. A review of thirty years of resource dependence theory shows that there are ways that CEOs can reduce uncertainty (Hillman, Withers & Collins, 2009). The review shows that (a) mergers/vertical integration, (b) joint ventures, (c) board of directors, (d) political action, and (e) executive succession can enact to minimize environmental dependence. Different kinds of directors may also bring the company different resources (Farrag & Mallin, 2016). Directors can link their company with external organizations which in turn brings information, expertise, and communication. Farrag & Mallin (2016) also argue that different CEO characteristics, including gender and education, bring different perspectives, experiences, and backgrounds. Which in turn can bring different benefits and resources to the company. Additionally, Wang et al. (2016) argue that an older and longer-tenured CEO may have a stronger professional network, which in turn leads to more resources for the company. However, the CEO's tenure is dependent on the internal and external environment (Hillman, Withers & Collins, 2009). The CEO tenure is generally shorter in uncertain environments compared to predictable environments.

2.1.3 Upper Echelons Theory

The Upper Echelons Theory (UET) theory argues that the strategic choices and performance levels are partially predicted by the CEO's background characteristics. (Hambrick & Mason, 1984). Previous literature viewed that organizations are swept along by events or somehow run themselves (e.g., Lieberson & O’Connor, 1972). Hambrick & Mason (1984) argue that it falls short of being a definitive test of the impact of different chief executives. They argue that the organizational outcomes are partially explained by the values and cognitive bases of their top managers. The UET is based on a sequential view that leads to managerial perceptions and strategic choices (Hambrick & Mason, 1984). Firstly, a CEO cannot scan every aspect of the organization and its environment. The manager's *field of vision* is restricted which brings limitations to the eventual perception. Secondly, the CEO is further limited because one *selectively perceives* only some of the phenomena which are in the field of vision. This brings further limitations to the eventual strategic choice. Lastly, the selectively perceived information that is left will be interpreted through the values and cognitive bases of the CEO. "This shows that 1) executives act based on their personalized interpretations of the strategic situations they face, and (2) these personalized construals are a function of the executives' experiences, values, and personalities." (Hambrick, 2007, p.334). In summary, the UET states that strategic decisions are influenced by managerial background characteristics.

The emphasis of the UET is on observable managerial characteristics. The UET allows for two aspects, psychological dimensions, and background characteristics. Top executives are probably reluctant to participate in psychological data collection methods which can take a lot of time, whereas observable managerial characteristics are easier to obtain (Hambrick & Mason, 1984). The literature considers four CEO characteristics to be important indicators for the firm strategic actions, which in turn shape the future firm performance. Firm strategic actions mean important, large-scale, and long-term undertakings that involve significant resource commitments (Wang et al., 2016). Examples are acquisitions, entering new markets, and investments in innovation (e.g., R&D spending). The first characteristic is age, for which they argue that firms that are led by younger CEOs take more risk, thus translating into more strategic actions. They hypothesize that as CEO age increases, firm strategic action decreases. The second characteristic is tenure, for which they hypothesize that as CEO tenure increases, firm strategic actions decrease. The third characteristic is formal education, for which they hypothesize that as CEO formal education increases, firm strategic actions increases. The last characteristic is prior career experience, for which they hypothesize that as a CEO's prior career experience increases, firm strategic action increases. Wang et al. (2016) summarized the last three decades of UET research and performed a meta-analysis to get a definitive answer on if CEOs do matter to firm strategic actions and firm performance. The meta-analysis results show significant support for the hypotheses.

2.2 CEO characteristics and firm strategic actions

In this section, the most researched CEO characteristics that have an impact on the firm strategic actions will be described, which is mostly based on the UET. As mentioned in the last section, the CEO characteristics are tenure, age, formal education, and prior career experience. Additionally, the characteristic gender will be described since this topic has had increased interest due to the increasing number of women in the CEO position. The firm strategic actions can be described as important, large-scale, and long-term undertakings that involve significant resource commitments (Wang et al., 2016).

2.2.1 CEO tenure

The literature seems to agree on the negative relationship between tenure and firm strategic actions. The UET suggests that longer-tenured CEOs undertake less firm strategic actions (Hambrick & Mason, 1984). Miller (1991) researched CEO tenure and the match between the organization and environment. Their results found that CEO's tenure does affect the adaptation and innovation to match the firm's strategy and structure with the environment. They argue that long-tenured CEOs create an internally cohesive organization that better withstand pressure from outside stakeholders. This increases the autonomy of the CEO, which in turn can result in lower initiation of strategic actions as they grow "stale in the saddle". This is supported by Lee and Moon (2016), based on their study on CEO risk-taking within the U.S. airline industry, which found a significant negative relationship between CEO tenure and strategic risk-taking. Matta and Beamishi (2008) researched CEOs approaching retirement and its implications on risk-taking, specifically in international acquisitions. They find that a longer CEO career horizon is associated with a higher likelihood of international acquisitions. Additionally, CEOs nearing retirement with high levels of equity holdings are less likely to engage in international acquisitions. This is supported by Wang et al. (2016) in their meta-analysis based on the last three decades of UET research. They found a significant negative relationship between tenure and firm strategic actions. In short, the literature seems united in the negative relationship between tenure and the number of firm strategic actions.

2.2.2 CEO Age

CEO Age seems to have a negative relationship with the amount of firm strategic actions. The UET argues that the younger CEO takes more risks, which results in more strategic actions (Hambrick & Mason, 1984). Sefling (2014) researched the impact of CEO age on risk-taking behavior. The results show that older CEOs invest less in research and development, make more diversifying acquisitions, manage firms with more diversified operations, and maintain lower operating leverage. This in turn results in a negative relationship between CEO age and stock return volatility. In support of these results, Chowdhury and Fink (2017) found that not only do older CEOs invest in less R&D, but they do so sub-optimally. Belenzon, Shamshur, and Zarutskie (2019) also found that as the CEO ages, the growth in the number of investments declines compared to younger CEOs. Yim (2013) researched the impact of CEO age on acquisition behavior. The results show that acquisitions are accompanied by large and permanent compensation increases for the CEO, which further incentivizes the CEO to pursue acquisitions earlier in their career. Additionally, a firm with a CEO who is 20 years older is 30% less likely to announce an acquisition. In support of these results, Zhang et al. (2016) found that younger CEOs are more likely to acquire another firm and spend more on large capital expenditures. Nevertheless, Wang et. Al. (2016) found that they did not find a significant negative relationship between age and firm strategic actions when performing a meta-analysis on the last three decades of

UET research. In short, most of the literature shows, albeit, with some mixed results, that age has a negative relationship with the number of firm strategic actions.

2.2.3 CEO formal education

CEO's formal education level seems to be positively related to the number of strategic actions of a firm. The UET suggests that the amount of formal education will be positively associated with firm strategic actions (Hambrick & Mason, 1984). Wally and Baum (1994) developed a model of determinants for strategic decision-making. They argue that the level of formal education represents the cognitive abilities of a CEO. Which helps the CEO acquire and process more complex information for decision making. A study by Kimberly and Evanisko (1981) supports this argument. They found a positive relationship between formal education and the individual's receptivity to innovation and change. This is further supported by Lee and Moon (2016) in their research on risk-taking in the airline industry. Their results show that more educated CEOs of airlines take more strategic risks. The meta-analysis of Wang et al. (2016) on the last three decades of UET research found a positive relationship between the amount of formal education and firm strategic actions. To summarize, the literature seems to unanimously agree on the positive relationship between formal education and the number of firm strategic actions.

2.2.4 CEO's prior career experience

CEO's prior career experience seems to have a positive relationship with the amount of firm strategic actions. The UET does not argue that CEO's prior career experience has a positive relationship with the amount of firm strategic actions (Hambrick & Mason, 1984). Rather, the theory distinguishes the prior career experience between inside and outside succession. And argue that prior career experience inside the organization has a negative relationship with the amount of firm strategic actions. However, other literature has researched the previous career functions and the relationship with firm strategic actions. This line of research was started by Dearborn and Simon (1958) who argue that an executive is influenced by the activities and goals of his department. When confronted with a business case that contains company-wide situations the executives of various departments mostly cited problems in their area. For example, the production manager mostly cited problems in the production. Whereas the sales manager mostly cited problems including sales. Barker and Mueller (2002) mention two categories to test the effect of the career experience on R&D spending. Output functions (marketing, sales, and R&D) emphasize growth and new opportunities. Throughput functions (production, process engineering, accounting, finance, and law) emphasize improving the efficiency of the process. They hypothesize that the CEOs with output functions invest more in R&D and the throughput functions invest less in R&D. Their results show significant support for the output functions having increased R&D spending. Additionally, the results show a decrease in R&D spending for throughput functions but are not significant. More recent research also supports the relationship between financial expert CEOs and the lesser investment in R&D (e.g., Custódio & Metzger, 2014; Liu, Zhou, Chan, & Chen 2020). Nevertheless, Wang et al. (2016) argue that, although CEOs obtain prior career experiences in different areas, the accumulation of career experience may increase the CEOs' willingness to engage in strategic actions. They support this statement by mentioning that the knowledge and skills that CEOs develop through their accumulated prior career experience are likely increasing their confidence. Therefore, they can understand and competently handle the situation they are confronted with. In short, rather the kind of CEO's prior career experience is studied in literature than the amount of CEO's prior career experience. Results show that throughput functions decrease firm strategic actions and output functions increase firm strategic actions. Nevertheless, the argument can be made that by gaining more experience, the CEO has a better understanding of situations and therefore increases his willingness to engage in firm strategic actions.

2.2.5 CEO gender

The CEO characteristic gender has not been discussed in the original development of the UET (Hambrick & Mason, 1984) and the update on the UET (Hambrick, 2007). Gender has been increasingly getting more attention because the gender gap has been decreasing and more women are getting into positions such as CEO of a company. This is due to the legislated quotas for female representation but more so significant voluntary increases in the number and proportion of female directors (Srinidhi, Gul & Tsui, 2011). Nevertheless, female CEOs remain an exception rather than a rule. Based on data from 2014 on the fortune 500, only 4,8% of the firms are led by a female CEO (Faccio, Marchica & Mura, 2016). They added that only 3% of the largest 145 Scandinavian companies have a female CEO. Still, while there is a very clear gender gap, it is important to assess the relationship between gender and firm strategic actions.

CEO gender seems to have a relationship with firm strategic actions. Faccio et al. (2016) researched the relationship between CEO gender on corporate risk-taking and the efficiency of capital allocation. In this study, they found a significant negative relationship between female CEO and corporate risk-taking. Furthermore, Huang and Kisgen (2013) researched the relationship between gender and financial and investment decisions to see if male executives are overconfident. Their results show that male executives undertake more acquisitions and issue more debt than their female counterparts. This is supported by Levi and Zhang (2014) in their study on the relationship between director gender and acquisitions. Their results show that female directors are less likely to make acquisitions and if they do, pay lower bid premia. Additionally, Peltomaki et al. (2021) researched the effect of age and gender on market-based measures of firm risk. Their study shows that female-led firms are associated with lower levels of total and idiosyncratic risks. In short, the literature on CEO gender seems to be in accordance that female CEOs take less risk, and therefore have a negative relationship with the number of firm strategic actions.

2.3 The importance and determinants of innovation at SME

Innovation is necessary for every organization to survive and thrive. This view first started with Joseph Schumpeter in his famous book "The Theory of Economic Development" in which he tries to develop a new economic theory based on change (Schumpeter, 1911). In this theory, he puts forward the entrepreneur as a creative force driving economic development. The entrepreneur comes up with new ideas, implements those ideas, and replaces the older economic order. This process of continuously revolutionizing the economic structure from within, and destroying the old one, is more widely known by the term "creative destruction" (Schumpeter, 1942). The theory described by Schumpeter (1942) is applicable in many scenarios (e.g. knowledge, education, basic scientific research, process innovations, and product innovations). It has been the basis for multiple models which try to quantify economic growth for these scenarios (e.g. Aghion and Howiti 1992; Romer, 1990; Grossman & Helpman, 1991) and many studies that show empirical evidence in support of Schumpeter's view (e.g. King and Levine, 1993; Wang, Yu, & Liu, 2013; Hong, 2017)

The Schumpeterian view has been the basis of Romer's (1990) Nobel Prize-winning model for growth. Romer (1990) created a model based on endogenous growth in which R&D is the driving force. This model distinguishes three sectors of the economy, the final goods sector, the intermediate goods sector, and the research and development (R&D) sector. At the end of the economy is the household that consumes the final goods. The model distinguishes the workforce into two categories, unskilled labor, and skilled labor (human capital). The economy is presented that the final goods sector is where the goods are sold to the household. The intermediate goods sector is the firms that buy the patents and the monopoly rights to produce the wanted goods. This innovation that leads to patents and product improvements is created by the R&D sector which sells them to the intermediate goods sector. The R&D sector is fuelled by human capital which comes from households. The presentation of the model is very simplified as it is not the focus of this paper. However, the model does put a value on the R&D sector as the driving force for endogenous growth. There are multiple models for growth (e.g. Aghion and Howiti 1992; Grossman & Helpman, 1991) that use R&D as the key variable. This further strengthens the importance of innovation for economic growth. The literature shows, as presented by the Nobel Prize-winning model by Romer (1990), that the emphasis is on R&D to attain long-term economic growth. Furthermore, there is empirical research that shows a positive relationship between R&D spending and profitability, sustainability, and growth (Artz et al., 2010; Fernandez et al., 2018; Garcia-Manjon & Romero-Merino, 2012).

The literature gives mixed results on the relationship between R&D and growth when specifying SMEs. Research by Deschryvere (2014) analyzed the role of innovation persistence (R&D) on growth in Finnish SMEs and large firms. Results showed that the consistent innovator had a positive relationship between R&D growth and sales growth. Furthermore, this relationship is stronger for continuous innovators than for occasional innovators. Complementary, Nunes, Serrasqueiro, and Leitão (2012) analyzed the relationship between R&D intensity and growth for high-tech and non-high-tech SMEs. They found a distinct difference between these industry classes. Non-high-tech SMEs had a linear and negative relationship between R&D intensity and firm growth. Whereas the high-tech SMEs had a U-shaped relationship between R&D intensity and firm growth. R&D intensity was a restricting factor for medium levels of R&D investments and a positive factor for growth for high- and low levels of R&D investments. Jung, Hwang, and Kim (2018) researched the relationship between R&D investments and SME survival during a recession. Their results show that R&D investment is a poor choice for general firms to survive. However, it is an effective strategy for firms that are innovative and capable of producing intellectual properties during recessionary periods. Nunes, Viveiros, and Serrasqueiro (2012) researched the difference between young and old SMEs on the determinants of profitability. Their results show that R&D spending is of greater importance for increased profitability in old SMEs. The literature shows that the relationship between R&D and growth is not easily generalizable and is heavily dependent on the situation. However, in some of those situations, R&D can be the decisive factor that allows for growth in SMEs.

Previous research used multiple determinants for testing the relationship between R&D spending and growth. The R&D spending to total sales, used in the previously discussed studies (Garcia-Manjon & Romero, 2012; Nunes, Serrasqueiro, & Leitao, 2012; Deschyvere, 2014), seems to be the most used variable for tracking R&D spending. While this might be the most common determinant, there have been critiques from previous researchers. Baysinger et. al. (1991) argue that the R&D spending to sales ratio is less stable and more sensitive to the spurious effects of business cycles, accounting manipulations, and asset sales compared to the R&D spending per employee (supported by Scherer, 1984; Hill and Snell, 1989; Barker & Mueller, 2002). Additionally, the previously discussed studies also used other determinants for R&D. Artz et al. (2010) used the number of new patents and product announcements to measure the relationship between innovation and firm performance. Furthermore, Nunes, Viveiros, and Serrasqueiro (2012) used R&D to total assets to determine the relationship between innovation and profitability at different ages of SMEs. There does not seem to be one clear favorite determinant for R&D spending.

2.4 R&D spending and the relationship with CEO characteristics

In this section, the focus will shift from firm strategic actions to R&D spending and assess the relationship with CEO characteristics. Firstly, the literature on multiple CEO characteristics (that follow the UET) and R&D spending will be discussed. Secondly, the literature on CEO characteristics and R&D spending will be discussed. Lastly, based on all the literature on the relationship between CEO characteristics and R&D spending, the hypothesis will be developed.

2.4.1 The Upper Echelon Theory and R&D spending.

One of the firm strategic actions is the investment in innovation (e.g. R&D spending). Barker and Mueller (2002) analyzed the impact of CEO characteristics on R&D spending. Following the UET (Hambrick & Mason, 1984) they argue that organizational outcomes, strategies, and effectiveness, reflect the values and cognitive bases of top managers in the organization. They propose that a firm's R&D spending (as compared to industry competitors) will vary significantly with the CEO characteristics after controlling for the firm- and industry-level variables. To test this assumption, they examined the most used CEO characteristics from the UET of the most valuable companies in America. These CEO characteristics are tenure, age, career experience in various functions, and education (Barker & Mueller, 2002). These four characteristics are the same as in the meta-analysis of Wang et al. (2016), which showed to be the most used CEO characteristics when using the UET. Barker & Mueller (2002) did control for certain variables. These determinants are institutional ownership, diversification, past performance, leverage, and firm size. After controlling these variables, CEO characteristics predict between 11% and 14% of the explained variance in R&D spending.

The literature on the relationship between CEO characteristics and R&D spending is limited when specifying SMEs. The only research on this subject that contains three of the characteristics explained in the UET is done by Yong-hai (2010). This research contained the characteristics of tenure, age, and education. Their results show that CEO tenure and R&D spending are negatively correlated, CEO age is negatively correlated with R&D spending, and CEO education level is positively correlated with R&D spending. These results are the same as the ones hypothesized in the UET. However, this research is based on listed SMEs in China. As mentioned in the introduction, past research has shown that the economy between China and the western world is vastly different. For example, the research by Boisot and Child (1996) found that the rapid economic development in China is being accomplished through a system of governance that is vastly different from the Western culture.

2.4.2 Hypothesis development on CEO characteristics and R&D spending

The 5 CEO characteristics of tenure, age, career experience, education, and gender are substantiated further in the literature. Firstly, due to limitations in data the CEO characteristic career experience hypothesis cannot be tested. Nevertheless, the literature substantiating this hypothesis will be discussed as this can be of use in further research.

Firstly, the CEO's career experience in various functions is also shown to have an impact on the strategic actions a firm takes. This line of research was started by Dearborn and Simon (1958) who argue that an executive is influenced by the activities and goals of his department. When confronted with a business case that contains company-wide situations the executives of various departments mostly cited problems in their area. For example, the production manager mostly cited problems in the production. Whereas the sales manager mostly cited problems including sales. Barker and Mueller (2002) mention two categories to test the effect of the career experience on R&D spending. Output functions (marketing, sales, and R&D) emphasize growth and new opportunities. Throughput functions (production, process engineering, accounting, finance, and law) emphasize improving the efficiency of the process. They hypothesize that the CEOs with output functions invest more in R&D and the throughput functions invest less in R&D. Their results show significant support for the output functions having increased R&D spending. Additionally, the results show a decrease in R&D spending for throughput functions but are not significant. More recent research also supports the relationship between financial expert CEOs and the lesser investment in R&D (e.g., Custódio & Metzger, 2014; Liu, Zhou, Chan, & Chen 2020). As mentioned previously, due to the limitation of data it is impossible to test a hypothesis containing the CEO's career experience in various functions. However, based on the existing literature on the relationship between CEO career experience and R&D spending the following hypothesis could be formulated:

There is a positive relationship between the career experience in output functions of the CEO and the firm's R&D spending.

There is a negative relationship between the career experience in throughput functions of the CEO and the firm's R&D spending.

The tenure of a CEO and the impact on innovation is a well-studied subject. At first, researchers thought that this was a linear negative relationship (Grimm & Smith, 1991). The reasoning is that when top managers have spent a long time of their careers in the organization, they will have a limited knowledge base to conduct a strategic search for new opportunities and would not be likely to pursue them. Whereas younger managers with shorter tenure are more flexible and willing to sustain the risk of change. This is supported by Miller (1991) in the research on CEO tenure and the match between organization and environment. They suggest that CEO tenure affects the adaptation and innovation to match the firm's strategy and structure with the environment. They argue that long-tenured CEOs create an internally cohesive organization that better withstands pressure. This autonomy of the CEO results in lower initiation of innovation as they grow "stale in the saddle". Additionally, Barker & Mueller (2002) found a negative association between CEO tenure and R&D spending but not significant at the 5% level. More recent research has found an inverted U-relationship between tenure and the impact on innovation (Chen, 2013). The research by Chen (2013) is based on the five 'seasons' presented by Hambrick and Fukotomi (1991). Where the first season (e.g., the start of the CEO at an organization) is more about adaptation and expanding their skills. Whereas the last season (e.g. just before retiring at an organization) is more about leaving a stable organization behind. By testing this theory empirically Chen (2013) indeed found that inverted U-relationship between CEO tenure and R&D spending. Based on the existing literature on the relationship between CEO tenure and R&D spending the following hypothesis is formulated:

H1. There is a negative relationship between the tenure of the CEO and the firm's R&D spending.

The relationship between age and the impact on innovation shows mixed results. The UET hypothesizes that as the CEOs' age increases the firms' strategic actions decreases (Hambrick & Mason, 1984). The theory argues that (1) the older executives may have less physical and mental stamina, (2) older executives have a greater psychological commitment to the organizational status quo, and (3) older executives may be at a point in their lives at which financial and career security are important. This is supported by the literature that as CEO age increases, the relative R&D spending decreases. (Belenzon, Shamshur, & Zarutskie 2019; Chowdhury & Fink 2017; Barker & Mueller, 2002). However, Cazier (2011) finds that tracking R&D spending over time by the same CEO produces no evidence of R&D curtailment. Following the CEOs did not show a decrease in R&D investment. However, it might be that younger CEOs invest more in R&D than their older counterparts. Therefore, the relationship between age and decreased R&D investment has not been refuted by Cazier (2011). Nevertheless, this could show that younger appointed CEOs place higher importance on R&D spending. Based on the existing literature on the relationship between CEO age and R&D spending the following hypothesis is formulated:

H2. There is a negative relationship between the age of the CEO and the firm's R&D spending.

A CEO's education level impacts the strategic actions of a firm. Wally and Baum (1994) developed a model of determinants for strategic decision-making. They argue that the level of formal education represents the cognitive abilities of a CEO. Which helps the CEO acquire and process more complex information for decision making. A study by Kimberly and Evanisko (1981) supports this argument. They found a positive relationship between formal education and the individual's receptivity to innovation and change. On the contrary, Barker and Mueller (2002) did not find a significant positive relationship between the level of education and R&D spending. The reasoning might be because of the education specialties. CEOs with science or engineering degrees have a significant positive relationship with R&D spending, which is called an output degree. Additionally, CEOs with business degrees did have a negative but not significant relationship with R&D spending. Furthermore, CEOs with legal degrees had a significant negative relationship with R&D spending. Business degrees and legal degrees are both called throughput degrees. Based on the existing literature on the relationship between CEO education and R&D spending the following hypothesis is formulated:

H3. There is a relationship between the kind of degree a CEO has and the firm's R&D spending.

H3a. The CEO with a science or engineering (output) degree has a positive relationship with the firm's R&D spending.

H3b. The CEO with a business or legal (throughput) degree has a negative relationship with the firm's R&D spending.

CEO gender seems to have a relationship with R&D spending. The gender of the CEO on R&D has not been a widely studied topic, as the interest in CEO gender on the impact on firms' strategic actions has only recently gained traction. In these studies, there seems to be a consensus that a female CEO decreases corporate risk-taking (Facio et al., 2016; Huang and Kisgen, 2013; Peltomaki, 2021). Therefore, one could argue that a female CEO decreases R&D spending. However, there has been a study that assessed the relationship between CEO gender on R&D spending (Loukil, Yousfi & Cheikh, 2020). Their results show no significant relationship between CEO gender and R&D spending. One explanation that is given in the study is the small number of women as CEO in the study (1,3% of the total CEO positions). Therefore, it is hard to conclude the small sample of female CEO in the study. Therefore, the decision is made to follow the literature on the relationship between CEO gender and firm strategic actions to hypothesize. Based on the existing literature on the relationship between CEO gender and firm strategic actions the following hypothesis is formulated:

H4. There is a positive relationship between CEO that are male and firms' R&D spending.

3. Research methodology

3.1 Regression analysis

The relationship between CEO characteristics and firm performance has mostly made use of one form of research method. Namely, the use of data and analysis using regression analysis (e.g., Barker & Mueller, 2002; Custódio & Metzger, 2014; Chen, 2013). There has only been one study specifying the relationship between CEO characteristics and R&D spending at SMEs (Yong-hai, 2010). This research also made use of regression analysis for its results. The reason for this is that examining the relationship between R&D spending (one dependent variable) and CEO characteristics (multiple independent variables) is easiest done using regression analysis. Therefore, based on the previous studies, this study will also use regression analysis for the analysis of the relationship between CEO characteristics and R&D spending at SMEs.

Multiple forms of regression analysis have been used in the past. Regression analysis is the most used technique for testing hypotheses on one or multiple independent variables and one dependent variable (De Veaux, Velleman, and Bock, 2015). Testing a hypothesis for one independent variable and one dependent variable is called simple regression analysis. Testing one hypothesis for two or more independent variables and one dependent variable is called multiple regression analysis (De Veaux, Velleman, and Bock, 2015). The CEO characteristics used in this research contain more than one variable, thus the multiple regression analysis is chosen for this research. However, there are different types of multiple regression (e.g. linear regression, logistic regression, polynomial regression, quantile regression, PSL regression) that can be chosen (Hair et. Al., 2010)

The form of regression analysis that fits this research the best is multiple linear regression. As mentioned before, there are multiple forms of regression analysis. This study uses different measurement levels of the independent variables. For example, the independent variable gender will be a nominal variable. These independent variables are used to determine a metric dependent variable. Some of the regression analysis techniques can't be used in this scenario because the dependent variable is metric and not categorical (e.g., logistic regression, see Sperandei, 2014; Hair et. Al. 2010). Furthermore, this study contains data from one moment in time and is not collected over longer periods (time-series data or panel data). Additionally, this study aims to find a linear relationship between the variables and not a quantile relationship (e.g., quantile regression). After these criteria, the most used and best fitting form of analysis is the multiple linear regression (also known as OLS regression, see Duleba & Olive, 1996).

There are assumptions and criteria which must be met to use linear regression analysis. DeVeaux, Velleman, and Bock (2015) mention four assumptions that must be met to use linear regression analysis. Firstly, the independent and dependent variables must be quantitative, as it makes no sense to perform a regression on categorical variables. To meet this assumption, some of the independent variables will be made into dummy variables (e.g. gender). Secondly, the results must show a somewhat linear model, as it makes no sense to perform a linear regression on a non-linear relationship. The results do not have to be perfectly linear, but they must be straight enough for the linear model to make sense. Thirdly, the standard deviation of the residuals must share the same spread (homoscedasticity). The most common violation of this assumption is when the residuals spread out more for larger values of the dependent variable (heteroscedasticity). Hair et. al. (2010) mention that a heteroscedastic dataset is not a problem per se. Because there are ways to transform the data from heteroscedastic to homoscedastic. For example, skewed distributions can be transformed by taking the square root, logarithms, squared, cubed terms, or even the inverse of the variable. Lastly, outlying points can dramatically change the results of a regression model. For this, it is important to check the outlier condition and make sure there are no outliers. These outliers are likely interesting and informative. However, they can cause a very different impression of the relationship between variables. The steps mentioned for transforming the data to be more homoscedastic also help with this normality problem (Hair et. al., 2010). For example, taking the logarithm will drastically reduce the effect of an outlier on a research model. Furthermore, another way to take care of this problem is to Winsorize the data (Tukey, 1962). Winsorizing means values that are below a certain percentile are set to that percentile, and values that are above a certain percentile are set to that percentile. DeVeaux, Velleman, and Bock (2015) also mention that there is a sample size criterion. Depending on the margin of error, it is possible to calculate this sample size. Furthermore, there is a risk of overfitting the model based on the amount of data that is available (Babyak, 2004 [What You See May Not Be What You Get: A Brief, Nontechnical Introduction to Overfitting in Regression-Type Models]). Given the sample size, there is a limit to the complexity of the research model. The complexity of the model is given by the number of predictor variables that are used (independent variables and control variables in this study). Babyak (2004) mentions that there are a variety of rules of thumb for the sample sizes required for modeling. Adding that these rules are only approximations, and most often need more observations than the rules suggest. The most common rule of thumb or multiple regression is a minimum of 10 to 15 observations per predictor variable. However, Green (1991) argues that a somewhat better rule might be to have a minimum sample size of 50 observations and roughly 8 additional observations per predictor. These assumptions will all be further discussed in the empirical part of this paper.

3.2 Research model

There are four hypotheses on different CEO characteristics stated in the literature review. These are, (H1) tenure, (H2) age, (H3) degree, and (H4) gender of the CEO. Previous research also accounted for certain control variables (Barker & Mueller, 2002; Yong-hai 2010), as they could influence the firm's R&D spending. The control variables used in this study are (C1) past performance, (C2) leverage, and (C3) firm size. Furthermore, the (C4) industry effect will be controlled by classifying the samples into industry dummies based upon the NACE Rev. 2 classifications.

The model of Yong-hai (2010) is used as a basis for the model. To test the relationship between CEO characteristics and firm R&D spending at SMEs, the variables are put in the following research model:

$$R\&D_{it} = \beta_0 + \beta_1 (TEN)_{it} + \beta_2 (AGE)_{it} + \beta_3 (EDU)_{it} + \beta_4 (GEN)_{it} + \beta_5 (PER)_{i,t-1} + \beta_6 (LEV)_{i,t-1} + \beta_7 (SIZ)_{it} + \beta_8 (IND)_{it} + \varepsilon_{it}$$

$R\&D_{it}$ = R&D spending of firm i in year t;

TEN_{it} = CEO tenure of firm i in year t;

AGE_{it} = CEO age of firm i in year t;

EDU_{it} = CEO education dummy of firm i in year t;

GEN_{it} = CEO gender dummy of firm i in year t;

$PER_{i,t-1}$ = Control variable past performance of firm i in year t-1;

$LEV_{i,t-1}$ = Control variable leverage of firm i in year t-1;

SIZ_{it} = Control variable firm size of firm i in year t;

IND_{it} = Control variable industry dummy of firm i in year t;

ε_{it} = Error term of firm i in year t.

3.3 Measurement level

The dependent variable in this study is R&D spending. In this paper, the R&D spending is measured by the R&D spending per employee, R&D spending to asset ratio, and R&D spending to revenue ratio. The R&D spending per employee follows the research by Barker & Mueller (2002) in their research on the relationship between CEO characteristics and the firm's R&D spending. Furthermore, the research by Yong-hai (2010) on the relationship between CEO characteristics and firm R&D spending at SMEs used the R&D spending to asset ratio. Therefore, the measurement of R&D spending to asset ratio will be used as well. Previous literature has also used other measurements of R&D spending when testing a relationship with certain CEO characteristics. Research by Belenzon, Shamshur, and Zarutskie (2019) on the relationship between CEO age and R&D spending used the amount of employment devoted to R&D as a measurement. Chen (2013) on the relationship between CEO tenure and R&D spending used the ratio of R&D spending to total sales as measurement. Research by Hirshey, Skiba, and Wintoki (2012) on the evolution of corporate R&D spending used the ratio of R&D spending relative to the revenue as a measurement. Of these variables, the R&D spending to revenue ratio will also be used as a determinant for R&D spending.

The independent variables in this study are CEO characteristics age, tenure, formal education, prior career experience, and gender. The UET development by Hambrick and Mason (1984) and the following literature based on this theory have shown multiple measurement levels. Firstly, due to not having the necessary data to test the hypotheses. The measurement of a CEO's prior career experience will be described, as it can be of use for future research. CEO's prior career experience could be measured following Barker & Mueller (2002). All forms of career experience (R&D, sales, marketing for output functions, production, process engineering, accounting, finance, and law for throughput functions) would have an exclusive dummy variable (1 = CEO had career experience in that area, 0 = CEO did not have career experience in that area). For the first hypothesis, CEO tenure is measured in the years appointed as CEO which follows the research previously used in this study (Barker & Mueller, 2002; Chen, 2013; Grimm & Smith, 1991; Miller, 1991). Second, CEO age was mostly measured in years (Hambrick & Mason, 1984; Barker & Mueller, 2002; Chowdhury & Fink, 2017). However, Belenzon, Shamshur, and Zarutskie (2019) put age in dummy variables to capture more years in one dummy variable. Nevertheless, in this study, the most used measurement level for age is followed, which is in years. CEO formal education is measured following the research by Barker & Mueller (2002). The degree of the CEO will be changed into a dummy variable. The degree that falls under an output degree will be classified as 1. Whereas the degree that falls under a throughput degree will be classified as 0. Therefore, a positive relationship between CEO education and the firm's spending will follow the hypothesis. Lastly, CEO gender is measured in a dummy variable (1 = male, 0 = female) which follows the research previously used in this study (Faccio et. al. 2016; Loukil, Yousfi & Cheikh, 2020; Huang and Kisgen, 2013). The variables used in the research model are presented in table 1.

3.4 Control variables

There are also control variables that need to be included. Since Barker & Mueller (2002) is a well-developed study with the same independent and dependent variable, the decision is made to follow the control variables mentioned in their study. The control variables that they used are (a) institutional stock holdings, (b) related and unrelated diversification, (c) past performance, (d) leverage, and (e) firm size. However, two of these control variables are not presented in the data and thus must be excluded. These are the (a) institutional stock holdings, and (b) related and unrelated diversification. Nevertheless, in the next paragraphs, an overview of these control variables will be given. Because this can be of use for further research.

Institutional stock ownership and the relationship with R&D spending is a well-researched topic in the literature. However, the literature shows mixed results. Le, Walters, and Kroll (2006) examined the effect of external monitoring on the relationship between R&D and performance. Their results show significant support for the moderating effect of institutional investors on the form of the R&D spending-performance relationship. That is, they appear to involve themselves directly in the R&D spending process. On the contrary, there is also literature that does not find a significant relationship between institutional stock ownership and R&D spending (David, Hitt, & Gimeno, 2001; Lee, 2012). However, the research by David, Hitt, and Gimeno (2001) does find support between Institutional activism and R&D spending. In summary, it seems to be that institutional ownership alone might not be enough to impact R&D spending. However, it might be the activism that the institutional ownership takes which can influence the R&D spending.

Corporate strategy has been a widely studied influence on R&D spending. The use of diversification leads to divisions in which division managers are responsible. Most of the time these division managers are evaluated based on financial key performance indicators (KPI). And these KPIs are often focused on short-term performance (e.g., the profit of a month). Which in turn, can lead to underinvestment in long-term projects (Bebchuk & Stole, 1993). However, there is a difference between related and unrelated diversification. The study by Baysinger and Hoskisson (1989) examined the effect of diversification strategy on R&D intensity. The related diversification did not reduce R&D spending because the firms place less emphasis on financial controls. Therefore, there is less incentive to underinvest. Whereas unrelated diversification did reduce R&D spending because the firm places more emphasis on financial control. Therefore, there is more incentive to underinvest.

Past performance and the relationship with strategic decision-making is a thoroughly researched topic in business. With the scope of R&D spending, research shows mixed results for the correlation between the past performance of a firm and its R&D spending. Scherer (2001) analyzed the link between gross profits and R&D spending in the pharmaceutical market. The results show no support for past profitability to explain R&D spending. However, it did show support that it follows a virtuous rent-seeking model. This means that if profit opportunities grow, firms compete to exploit them by increasing their R&D spending. Additionally, Hirschey, Skiba, and Wintoki (2012) found that past profitability did not have a significant relationship with R&D spending. On the contrary, a more recent study on the pharmaceutical market in India shows a significant relationship between last year's profitability on R&D intensity (Tyagi, Nauriyal, & Gulati, 2018).

Higher debt-equity (or debt-assets) seems to restrict R&D spending. Cummings and MacIntosh (2000) found that firms with a high debt-equity ratio spend a lower proportion of their expenses on R&D. They argue that these firms are more financially constrained and therefore spend relatively less on R&D. This is supported by the research of Ogawa (2007). Based on a data set of Japanese manufacturing firms in research-intensive industries, they found that having a massive amount of outstanding debt has a negative relationship with R&D activities. They found that a ten-percentage-point increase in the debt-asset ratio lowered the factor productivity growth by a 0,26 percentage point because it reduced R&D spending.

The literature gives mixed results when it comes to the effect of firm size on R&D spending. Fishman and Rob (1999) created a model in which they make certain propositions when it comes to firm size and R&D spending. One of which is that the larger firms spend relatively more on R&D. However, Hirschey, Skiba, and Wintoki (2012) examined the size, concentration, and evolution of corporate R&D spending in U.S. firms. In their study, they did not find a significant relationship between firm size and R&D spending. Additionally, they mention that most of the variation in R&D spending can be explained using industry effects (industry it operates in). The control variables and definitions are presented in table 1.

3.5 Robustness tests

As will be shown in the data and result chapter, there are certain limitations for which the validity needs to be checked. Firstly, due to a weakened industry dummy, there is a robustness test on the sub-sample of the manufacturing industry. Secondly, there is a potentially overfit model due to the number of predictor variables relative to the sample size. Therefore, a robustness test is performed where some of the control variables are left out. Lastly, some of the variables are not normally distributed following the Shapiro-Wilk test. Therefore, a robustness test is performed where the variables which cause the most concern are excluded from the research model.

Variable	Name	Definition	References
Dependent	R&D spending per employee (RDE)	Natural log of R&D spending / Employees	Barker & Mueller, 2002
	R&D spending to asset ratio (RDA)	R&D spending / Total assets	Yong-hai, 2010
	R&D spending to revenue ratio (RDR)	R&D spending / Total operating revenue	Hirshey, Skiba, & Wintoki, 2012
Independent	CEO tenure (TEN)	Natural log of the CEO tenure in years	Grimm & Smith, 1991; Barker & Mueller, 2002; Chen, 2013
	CEO age (AGE)	Natural log of the CEO age in years	Hambrick & Mason, 1984; Barker & Mueller, 2002; Chowdhury & Fink, 2017
	CEO education (EDU)	1 for output education, 0 for throughput education	Barker & Mueller, 2002
	CEO gender (GEN)	1 for male, 0 for female	Huang & Kisgen, 2013; Faccio et. Al., 2016; Loukil, Yousfi, & Cheikh, 2020
Control	Performance (PER)	Gross profit / Total assets	Barker & Mueller, 2002; Tyagi, Nauriyal, & Gulati, 2018
	Leverage (LEV)	Equity / Total assets	Barker & Mueller, 2002; Ogawa, 2007
	Employees (EMP)	Natural log of employees	Fishman & Rob, 1999; Barker & Mueller, 2002; Hirschey, Skiba, & Wintoki 2012
	Assets (ASS)	Natural log of total assets	Yong-hai, 2010
	Industry (IND)	1 for specific industry, otherwise 0	Barker & Mueller, 2002; Yong-hai, 2010

Table 1: Variable measurements

4. Data

In this chapter, the sample selection, data, and transformation of variables will be described.

4.1 Sample selection

This quantitative study is based on secondary data, which is data collected by others that is retrieved from a database. The data is retrieved from the website ORBIS, which contains comprehensive information on companies worldwide. ORBIS allows for extensive filtering, and there are 7 selection steps used in ORBIS to gather the data. First, all active companies are selected to filter out any inactive companies. Second, all companies that have reported research and development expenses are selected. The next 3 steps will contain the selection of companies that fulfill the criteria of an SME. As presented by the European Commission (2003), an SME is short for Small and Medium Enterprises, which can be appointed to an enterprise if the number of employees is 250 or lower (third), the balance sheet total is 43 million or lower (fourth), and the turnover is 50 million euro or lower (fifth). Sixth, all companies that have reported directors' or managers' information are selected. Last, all companies that have reported their solvency ratio are selected. A short overview of the sample selection in ORBIS is shown in table 1.

Sample selection ORBIS	
Search Step	**Result**
1. Status of company	2,609,369
2. Research & Development expenses	29,435
3. Number of employees	10,891
4. Total assets	8,444
5. Operating revenue	8,005
6. Directors / Managers information	7,971
7. Solvency ratio	7,837
Total sample selection ORBIS	**7,837**

Table 2 - Sample selection in ORBIS

The selected samples from ORBIS do not all contain the variables needed in the research model and robustness test. The manual filtering of missing data is done in 6 steps in Excel. First, the missing data from the appointment date for which the CEO tenure is determined are filtered out. Second, the missing data from the CEO age is filtered out. Third, the missing data from the CEO education is filtered out. Fourth, the missing data from the CEO's gender is filtered out. Fifth, the missing data of past performance is filtered out. Last, the missing data on the solvency ratio is filtered out. A short overview of the manual filtering in Excel is shown in table 2.

Manual filtering	
Filter step	**Result**
Total sample selection ORBIS	7,837
1. CEO Tenure	2,345
2. CEO Age	2,307
3. CEO Education	208
4. CEO Gender	179
5. Past performance	168
6. Solvency ratio	162
Final sample size	**162**

Table 3 - Manual filtering steps in Excel

The steps that reduced the sample size the most are the reporting of research and development expenses and the filtering of the major of the CEO for the education variable. This might be because the SMEs have fewer obligations on their annual reports on which ORBIS partially relies on their data. An attempt was made to manually gather the data online on CEO education. However, after attempting this for 20 different CEOs, for which no education information was found, it became clear that this information is not easily gatherable online. After the selection in ORBIS and manual filtering in Excel, the final sample size consists of 162 samples.

4.2 Data

The goal of this thesis is to find out what the relationship is between CEO characteristics and R&D spending at SMEs. A standard procedure is to select data from a certain region, market, or country to control for cross-region differences. However, due to the small sample size relative to an extensive research model, the decision is made to take all available data. Furthermore, the data consist of different years, which are 2018 to 2021. The lagged control variables (past performance and leverage) consist of data from 2017 to 2020, as they are lagged by one year. The selection of data from multiple years could have a small inflation impact on the results, as this is not a time series analysis. However, limiting the sample size further would increase the chance of an overfit model (Babyak, 2004). The impact of the data selection will be further discussed at the end of this paper.

4.3 Transforming variables

The research model only contains quantitative variables to fulfill the assumption for regression analysis, whereas the results from ORBIS also contain categorical variables. These categorical variables need to be transformed into quantitative dummy variables. This applies to CEO education, CEO gender, and the industry it operates in. Furthermore, to achieve a homoscedastic and a better fit model, the logarithm of certain variables will be used. The logarithm is used for the research and development expenses per employee, CEO age, the number of employees, and the total assets.

This study controls for the potential effect of the industry the firm operates. The sample shows, based on the NACE Rev. 2 classification, that there are 10 different industries the companies operate in. Furthermore, there are industries in which only 1 or 2 companies operate. It is impossible to control the industry when it has only 1 or 2 samples in the dataset. Therefore, the industry code is reclassified to have more significant numbers. The 10 different industries are reclassified into 4 new ones, as presented in table 3. These 4 new industry classifications are the (1) administration and communication industry, (2) professional, scientific, and technical activities industry, (3) the manufacturing industry, and all (4) other industries. After the reclassification, the industry with the lowest number of companies contains 15 samples, which is a big enough sample to control for. However, the power of the control variable is lower due to combining multiple industries into one.

Industry reclassification			
NACE Rev. 2 main section	**Number of firms**	**Reclassification**	**Number of firms**
J - Information and communication	18	J / N = Administration and communication industry	26
N - Administrative and support service activities	8		
M - Professional, scientific and technical activities	22	M = Professional, scientific, and technical activities industry	22
C - Manufacturing	99	C = Manufacturing industry	99
B - Mining and quarrying	1	B / F / G / K / Q / S = Other industries	15
F - Construction	1		
G - Wholesale and retail trade; repair of motor vehicles and motorcycles	8		
K - Financial and insurance activities	1		
Q - Human health and social work activities	2		
S - Other service activities	2		
Total	**162**		**162**

Table 4 Reclassification of industry variable

5. Results

This chapter describes the steps that are performed to deal with potential outlier problems, presents the descriptive statistics, and presents the results of the correlation, regression analysis for the main research model, and robustness tests.

5.1 Outliers

Outliers might have a big impact on the outcome of the model. The natural logarithm of some of the variables is used to counter this effect, as this brings outliers closer to the model fit. However, this is not done for every variable as they are not all only positive. Another popular procedure to address the effect of outliers is to Winsorize the data (Tukey, 1962). Winsorization is the procedure of transforming the outliers to the nearest acceptable value, to limit extreme values. Finding extreme outliers to Winsorize is commonly done by taking the inter quartile range (IQR) of the variable and multiplying this by 3. All values above or below will be transformed to that threshold. In this study, the only variables with outliers that need to be Winsorized are the R&D spending to asset ratio, the R&D spending to revenue ratio, and CEO tenure. The R&D spending to revenue ratio shows highly problematic results on the outliers. A total of 30 extreme outliers need to be Winszorised, which accounts for almost 19% of the sample size. This might have an impact on the statistical outcomes using this variable due to the number of variables that are Winsorized. The R&D spending to asset ratio and CEO tenure both contain 3 extreme outliers that are Winsorized.

5.2 Descriptive statistics

Table 4 gives a summary of the descriptive statistics for all variables in the main research model, before taking the logarithm of the variables R&D per employee, CEO age, and Size. This section will shortly cover the dependent and independent variables in their results. As mentioned before, the data consist of a sample of 162 companies. The mean R&D spending per employee is €131,108, with a standard deviation of €280,439 and a median of €31,273. The mean and median differ a lot, which is due to some cases of very high R&D spending per employee. As seen in the maximum, at least one sample spends €1,989,040 on R&D per employee. This contrasts with Barker & Mueller (2002), whose results show a mean of $803.07 with a standard deviation of $4633.49 in their sample. There is no clear cause for this big difference. However, the number of SMEs that report R&D spending might be significantly lower than that of big companies, which have more obligations on their annual report. Therefore, only SMEs with significant R&D spending tend to report it. Furthermore, small impacts on this difference could be inflation and regional differences. The mean R&D spending to asset ratio is 0.181, with a standard deviation of 0.221 and a median of 0.114. This contrasts with Yong-hai (2010), who reported a mean R&D spending to asset ratio of 0.015 with a standard deviation of 0.0211. As with the R&D spending per employee, there is no clear cause for this difference. However, this might be because the research by Yong-hai (2010) only contains data from listed companies on the Shenzhen equity exchanges. Whereas this sample is not selected on only listed companies. As mentioned before, the R&D spending to revenue ratio shows very extreme results. Before Winsorization, the mean R&D spending to revenue is 9.269 with a standard deviation of 39.509. So, the mean company in the dataset spends more than 9 times its revenue on R&D. This is mostly due to extreme cases. After the Winsorization of these extreme cases, the mean R&D spending to revenue lowers to 0.755 with a standard deviation of 1.112.

The CEO tenure in this sample has a mean of 5.220 years and a 5.719 years standard deviation. In contrast to Yong-Hai (2010), for which they reported 3.194 years mean and 1.577 standard deviations. This might be due to differences in the Asian culture, where CEOs might switch positions more often. Barker & Mueller (2002) reports a mean tenure of 8.29 years with an 8.04 standard deviation. Once again, this difference could be impacted due to the difference in company size, where CEOs tend to stay longer. Another potential difference that can cause a small impact is the American culture. The CEO age in this sample has a mean of 61.37 years and a 10.163 standard deviation. In contrast with Yong-hai (2010) with a mean of 46.507 and a standard deviation of 6.97, and in contrast with Barker & Mueller (2002) with a mean of 57.42 and a standard deviation of 6.77. This might be explained by the same factors mentioned for CEO tenure, being the difference in company size and cultural differences. The variables EDU and GEN do not have comparable studies on CEO characteristics and R&D spending that used the same variables. The CEO education dummy shows a mean of 0.537. The number of studies that have a hypothesized positive effect on R&D spending is 87, and the number of studies with a hypothesized negative effect is 75. This small difference might be explained by the favor of CEOs with output-oriented education, rather than throughput-oriented education. The CEO Gender has a mean of 0.932. The sample has 151 male CEOs and 11 female CEOs. This is most likely due to the traditional view on the role of males and females, which is in line with other studies on the male-to-female CEO ratio (Faccio, Marchica & Mura, 2016; Srinidhi, Gul & Tsui, 2011).

5.3 Correlation analysis

In this section, some of the significant correlations at the 0.01 level are discussed. The correlation, based on Pearson's correlation coefficient, of the variables used in the main research model is presented in table 5. There is some correlation between variables, even at the 0.01 level. However, there do not seem to be troublesome correlations between these variables. As expected, there is a significant positive correlation between R&D spending per employee, R&D spending to asset ratio, and R&D spending to revenue ratio. Furthermore, all three dependent variables are also negatively correlated with past performance and the number of employees. There are also significant correlations between the independent and control variables. There is a significant positive correlation between age and tenure. This means that CEOs with longer tenure are also older. There is a significant negative relationship between performance and leverage. Therefore, there is a relationship between high performance and lower leverage. Furthermore, there is also a significant positive relationship between performance and employees. This means that the bigger companies had a higher performance last year. As expected, there is also a positive correlation between the two control variables for size, which are employees and assets.

The variance inflation factor (VIF) score is also presented in table 5 to check for multicollinearity. The VIF score shows the ratio of the variance of the predictor variables to the dependent variable in the research model. A common threshold is a VIF score of 2.5, 5, or 10. As presented in table 5, the highest VIF score is 1.572 for the employees, which is not surpassing one of the thresholds. Therefore, we can conclude that multicollinearity is not a problem.

Variables	Valid	Mean	Median	Std. Deviation	Minimum	Maximum	Q1	Q3
Panel A: Dependent variables								
RDE (x €1000)	162	131.108	31.273	280.439	0.164	1989.040	10.358	83.790
RDA	162	0.174	0.114	0.188	0.001	0.845	0.035	0.247
RDR	162	0.755	0.175	1.112	0	3	0.052	0.790
Panel B: Independent variables								
AGE	162	61.370	62	10.163	35	86	54	68
TEN	162	5.220	3	5.719	0	24	1	7.25
EDU	162	0.537	1	0.500	0	1	0	1
GEN	162	0.932	1	0.252	0	1	1	1
Panel C: Control variables								
PER	162	0.305	0.291	0.282	-0.493	1.516	0.085	0.448
LEV	162	0.528	0.576	0.258	0.001	0.958	0.337	0.726
EMP	162	68.303	56.5	50.582	2	219	27.75	96.25
ASS (x €1 mln)	162	20.705	19.336	10.355	1.184	41.582	12.443	30.584
This table reports the descriptive statistics after Winsorizing the outliers using the IQR * 3 method and before the natural logarithm change.								

Table 6 - Descriptive statistics

Correlations											
	Ln RDE	RDA	RDR	TEN	Ln AGE	EDU	GEN	PER	LEV	Ln EMP	Ln ASS	VIF
Ln RDE	1											
RDA	0.747**	1										
RDR	0.753**	0.749**	1									
TEN	-0.041	-0.02	-0.045	1								1.167
Ln AGE	0.096	0.093	0.077	0.292**	1							1.12
EDU	0.199*	0.151	0.113	0.089	0.115	1						1.034
GEN	0.1	0.02	0.016	0.062	0.032	-0.054	1					1.04
PER	-0.350**	-0.251**	-0.503**	-0.066	-0.104	-0.061	0.008	1				1.36
LEV	0.007	-0.067	0.113	0.179*	0.017	-0.047	-0.069	-0.216**	1			1.107
Ln EMP	-0.504**	-0.301**	-0.518**	0.066	-0.077	-0.044	-0.124	0.381**	-0.12	1		1.572
Ln ASS	0.124	-0.095	0.059	0.017	-0.038	0.039	-0.104	-0.128	0.047	0.388**	1	1.329
This table reports the correlation between variables based on the Pearson correlation coefficient, **, * shows significance at 1% and 5% respectively.												

Table 5 - Correlation matrix

5.4 Regression analysis

Multiple linear regression analysis is performed to test the four hypotheses with the main research model. However, the assumption stated in the research methodology chapter needs to be fulfilled first.

5.4.1 Assumptions

As mentioned in the research methodology chapter, some assumptions need to be met to start any form of linear regression. In short, (1) all variables must be quantitative, (2) the results must show a somewhat linear regression, (3) the data must be somewhat homoscedastic, (4) the variables are not multicollinear, and (5) the residuals must be somewhat normally distributed. Furthermore, there is a sample size criterion that must be met to avoid overfitting the model. Most of these assumptions are met due to adaptations made to the data by Winsorizing and making logarithm changes to the variables. (1) All categorical variables are transformed into dummy variables. Therefore, all variables are now quantitative. (2) The P-P plot is the most used graph to test the linearity assumption. The plot shows a somewhat linear regression, with small deviations, for all three dependent variables. (3) The scatterplot is most used to test the homoscedasticity assumption. The plot shows that the data is somewhat homoscedastic for the R&D spending per employee and R&D spending to asset ratio. However, the scatterplot for R&D spending to revenue ratio does show highly heteroscedastic results, even after Winsorizing. (4) The multicollinearity assumption is most tested with Pearson's correlation factor between variables and the VIF score. the Pearson's correlation factor and VIF factor shown in table 5 are not above any threshold for multicollinearity. (5) The normality of the residuals criteria is most tested using the Shapiro-Wilk test. The results of the Shapiro-Wilk test are troublesome, as most of the variables give a significant result on the Shapiro-Wilk hypothesis. A significant result on the hypothesis means that the data is not normally distributed. All variables, except for R&D spending per employee and the CEO age, show a significant result. However, some of the variables cannot be normally distributed due to being dummy variables. The histogram of the other variables does somewhat follow a normal distribution, except for R&D spending to asset ratio and CEO tenure. The analysis is continued. However, the heteroscedastic variables and the not normally distributed variables can harm further analysis. The plots and tables to test for these assumptions are presented in appendix A.

5.4.2 Research model

The hypothesis is tested using multiple linear regression analyses. The regression analyses are performed in a stepwise manner as reported in table 6. Firstly, the main models will be presented on the relationship of all CEO characteristics with R&D spending variables. The first model contains all the control variables that are mentioned in the main research model on the relationship with R&D spending per employee. The second model contains all the control variables and the independent variables that are described in the hypotheses, on the R&D spending per employee. The same two models are presented on the other dependent variables, the R&D spending to asset ratio and the R&D spending to revenue ratio.

The first regression analysis supports the evidence that the control variables do significantly influence the R&D spending per employee at the 1% level. The adjusted R^2 explains 41,3% of the variance in the sample's R&D spending per employee. However, the second model fails to support the hypothesized argument that CEO characteristics have a significant relationship with R&D spending per employee. which is the main proposition of this study. The CEO characteristics adjusted R^2, after the control variables, only accounts for 1.4% of the variance in the sample R&D spending per employee. In contrast, Barker & Mueller (2002) found a significant relationship between CEO characteristics and R&D spending per employee at the 1% level. Their results show that, after the control variables, the models including CEO characteristics explained between 11% to 14% of the variance in R&D spending per employee.

The second regression analysis also supports the evidence that the control variables do significantly influence the R&D spending to asset ratio at the 1% level. The adjusted R^2 explains 16.5% of the variance in the sample's R&D spending to asset ratio, which is significantly lower than the adjusted R^2 for the R&D spending per employee variable. The second model also fails to support the hypothesized argument that CEO characteristics have a significant relationship with the R&D spending to asset ratio. The CEO characteristics adjusted R^2, after the control variables, drops by 0,6% compared to the first model. Thus, the fit of the model worsens when adding in the CEO characteristics. In contrast, Yong-Hai (2010) found a significant relationship between CEO characteristics and R&D spending to asset ratio at the 1% level. After the control variables, the model including CEO characteristics explained 11.25% of the variance in the R&D spending to asset ratio.

The third model also supports the evidence that the control variables significantly influence the R&D spending to asset ratio at the 1% level. The adjusted R^2 explains 43.6% of the variance in the sample's R&D spending to revenue ratio, which is a higher result than the adjusted R^2 on the other two dependent variables. However, the second model also fails to support the hypothesized argument that CEO characteristics have a significant relationship with the R&D spending to revenue ratio. The CEO characteristics adjusted R^2, after the control variables, drops by 0.9% compared to the first model. Thus, the fit of the model worsens when adding in the CEO characteristics.

5.4.3 Hypothesis 1: CEO tenure

The first hypothesis states that an increase in CEO tenure decreases the amount of R&D spending. Table 6 reports the results of the multiple linear regression analysis for the R&D spending per employee, the R&D spending to asset ratio, and the R&D spending to revenue ratio. All models have a slight negative relationship between CEO tenure and R&D spending, as is hypothesized. However, these relationships are not significant. Therefore, hypothesis 1 can be rejected which means that there is no significant negative relationship between CEO tenure and R&D spending. The results do show a negative relationship, but it is not significant. This result is not consistent with the upper echelon's theory, which argues that as a CEO's tenure increases, the amount of firm strategic actions decreases. Therefore, the CEO with a longer tenure has lower R&D spending. This result is not in line with Yong-Hai (2010) who found a negative and significant relationship between CEO tenure and R&D spending at the 5% level. However, this result is in line with Barker & Mueller (2002) who found a negative but not significant relationship between CEO tenure and R&D spending.

5.4.4 Hypothesis 2: CEO age

The second hypothesis states that an increase in CEO age decreases the amount of R&D spending. The results show a positive or a small negative relationship between CEO age and R&D spending and the results are not significant. Based on these results, hypothesis 2 is rejected which means that there is no significant positive relationship between CEO age and R&D spending. This result is not consistent with the upper echelon's theory, which argues that younger CEOs tend to take more risks as they are at the beginning of their career and have less to lose. Therefore, the older CEO has lower R&D spending compared to their younger counterpart. Furthermore, this is not in line with empirical studies on the relationship between CEO age and R&D spending on samples of bigger companies (Sefling, 2014; Chowdhury & Fink 2017; Belenzon, Shamshur, and Zarutskie, 2019; Barker & Mueller, 2002). However, it is in line with Yong-hai (2010), which also researched the relationship between CEO age and R&D spending at SMEs. The results of the study show a negative non-significant relationship between CEO age and R&D spending.

5.4.5 Hypothesis 3: CEO education

The third hypothesis states that a CEO with an education that focuses on the output has a positive relationship with R&D spending. The results show that there is a significant positive relationship between CEO with an output education and R&D spending per employee at the 5% level and a nonsignificant positive relationship for R&D spending to asset ratio and R&D spending to revenue ratio. This implies that, when keeping all other variables stable, a change in CEO with a throughput education to a CEO with an output education increases the natural logarithm of R&D spending per employee by 25,2%. The result on the standardized coefficient for the natural logarithm of R&D spending per employee is also in line with Barker & Mueller (2002) as both results have a beta coefficient of 0,16. There is also a positive relationship between CEO with an output education and the other dependent variables, but not significant. Therefore, hypothesis 3 can be supported which means that there is a significant positive relationship between CEO education focussed on output and R&D spending. However, this is weak support as only one of the three models is statistically significant and only at the 5% level. This result is in line with Barker & Mueller (2002), which found a significant positive relationship between CEOs with an output focussed degree and R&D spending.

5.4.6 Hypothesis 4: CEO gender

The fourth hypothesis states that a male CEO has a positive relationship with R&D spending. The first regression shows a non-significant positive relationship between male CEO and the natural logarithm of R&D spending per employee. Whereas the second and third regression shows a non-significant negative relationship between male CEO and R&D spending to asset ratio. These results are not in line with empirical studies on the relationship between CEO gender and investment decisions (Huang and Kisgen, 2013; Faccio et al., 2016; Peltomaki et al.,2021). These studies all argue that male CEOs are more often overconfident. Whereas female CEOs take a more passive approach to investment decisions.

	Ln RDE		RDA		RDR	
Variables	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
TEN		-0.029		-0.013		-0.041
		(-0.447)		(-0.171)		(-0.631)
Ln AGE		0.031		0.022		-0.001
		(0.485)		(0.283)		(-0.004)
EDU		0.16**		0.119		0.06
		(2.576)		(1.58)		(0.961)
GEN		0.059		-0.026		-0.027
		(0.964)		(-0.353)		(-0.443)
PER	-0.065	-0.06	-0.17**	-0.164*	-0.275***	-0.275***
	(-0.919)	(-0.858)	(-2.023)	(-1.935)	(-3.97)	(-3.925)
LEV	-0.119*	-0.097	-0.146*	-0.135*	-0.025	-0.014
	(-1.886)	(-1.52)	(-1.941)	(-1.75)	(-0.398)	(-0.22)
Ln EMP	-0.586***	-0.571***	-0.17*	-0.168*	-0.433***	-0.428***
	(-7.607)	(-7.42)	(-1.85)	(-1.8)	(-5.735)	(-5.558)
Ln ASS	0.352***	0.349***	-0.034	-0.039	0.204***	0.198***
	(-5.059)	(5.057)	(-0.407)	(-0.462)	(2.981)	(2.867)
N	154	150	154	150	154	150
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R square	0.413	0.427	0.165	0.159	0.436	0.427
F-statistic change	17.196***	1.945	5.55***	0.718	18.764***	0.388
This table reports the standardized coefficients. The past performance and leverage are analyzed at t - 1. The numbers between parenthesis represent the t-statistics. ***, **, * shows significance at 1%, 5%, and 10% respectively.						

Table 7 - Regression analysis on the main research model

5.5 Robustness tests

The robustness tests will be performed to see if the results of the regression analysis are reliable. Furthermore, this allows for a good opportunity to test if there are any changes in the results which would comply with the formulated hypothesis. Three different robustness tests will be performed on the data. First, the adaptation of the industry dummy into bigger groups causes the strength of the control variable to drop. Therefore, a robustness check will be performed on the manufacturing industry, as it has 99 firms. Second, the research model contains a high amount of independent and control variables relative to the sample size. This causes concern about the potential overfitting of the research model (Babyak, 2003). Therefore, a robustness check will be performed with models containing only the size and performance control variables, as these are the only two variables with a significant relationship to the R&D spending variables. Furthermore, another robustness test is performed by using the independent variables individually and keeping all the control variables in the regression. This also limits the number of predictor variables to prevent overfitting. Furthermore, the relationship between the individual CEO characteristic and the relationship with R&D spending can be assessed without the influence of multiple characteristics at a time.

5.5.1 Manufacturing industry

The first robustness test is on the subsample of the manufacturing industry. As mentioned before, the control variable for the industry is weakened due to the reclassification. Therefore, the industry with the biggest sample is chosen to do the robustness test. The results of this robustness test can be found in table 9 in appendix B. The adjusted r square of the control variables for the R&D spending per employee is 0.342, the R&D spending to asset ratio is 0.226, and for R&D spending to revenue ratio is 0.400. These results are very similar to the main research model. When including the CEO characteristics, the adjusted r square increases for R&D spending per employee to 0.349, decreases for R&D spending to asset ratio to 0.223, and decreases for R&D spending to revenue ratio to 0.379. Thus, by adding the CEO characteristics to the model, the explained variance is increased by 0.7% for R&D spending per employee, decreased by 0.3% for R&D spending to asset ratio, and decreased by 2.1% for R&D spending to revenue ratio. The explained variance of CEO characteristics in the main research model has more explaining power. Therefore, the conclusion can be made that the robustness test on the manufacturing industry only weakens the explained variance. This is another indicator that the research model might be overfitting with predictor variables. The robustness test does show support at the 10% level for hypothesis 3. There is a significant positive relationship between CEO education on an output degree and R&D spending per employee. However, the other hypotheses on CEO characteristics still show no significant relationship to the other R&D measures.

5.5.2 Overfit

The main research model contains a high amount of independent and control variables relative to the sample size. This causes concern about the potential overfitting of the research model (Babyak, 2003). Therefore, the second robustness test is on a lower amount of control variables. The control variables with the strongest relationship to the R&D spending variables are past performance, the natural logarithm of employees, and the natural logarithm of total assets. Therefore, the control variable for leverage and the industry dummy variables will be excluded. As the correlation matrix presents, there is a significant correlation between the employees and assets variable because they both measure size. Therefore, the natural logarithm of total assets will also be excluded in this robustness test. The results of this robustness test can be found in table 10 in appendix B. The adjusted r square of the control variables for R&D spending per employee is 0.274, for R&D spending to asset ratio is 0.101, and for R&D spending to revenue ratio is 0.369. These results are lower than the main research model, which indicates that the control variables' size and performance do have an impact on the research model. When including the CEO characteristics, the adjusted r square increases for R&D spending per employee to 0.292, decreases for R&D spending to asset ratio to 0.100 and decreases for R&D spending to revenue ratio to 0.362. Furthermore, the F-statistic change of the adjusted r square is significant at the 10% level for R&D spending per employee. Thus, this robustness test does find support that there is a significant relationship between CEO characteristics and firm R&D spending. The robustness test also supports hypothesis 3 at the 5% and 10% levels. There is a significant positive relationship between CEO education with an output degree with R&D spending per employee and R&D spending to asset ratio. Nevertheless, the other hypotheses on CEO characteristics still show no significant relationship to both R&D measures.

Another robustness test is performed by using the independent variables individually and keeping all the control variables in the regression. This also limits the number of predictor variables by 3 which should limit the potential of an overfit model. Furthermore, the relationship between the individual CEO characteristic and the relationship with R&D spending can be assessed without the influence of multiple characteristics at a time. The results of this robustness test can be found in table 10 in appendix B. The results of this robustness test do not differ significantly from the main model. The only significant relationship is between CEO education and the firm's R&D spending per employee at the 5% level. This implies that, when keeping all other variables stable, a change in CEO with a throughput education to a CEO with an output education increases the natural logarithm of R&D spending per employee by 24.8%. This result is very similar to the results of the regression analysis containing all the independent variables. Furthermore, this robustness test strengthens the results of the main research model.

6. Conclusion

This chapter describes the conclusion of the study. Firstly, the results of the regression analysis including the robustness test are described and how it answers the hypothesis and main proposition of this study. Secondly, the limitations and recommendations for future research are discussed.

6.1 Summary and conclusion

The purpose of this study is to investigate the relationship between CEO characteristics and firm R&D spending at SMEs, which are measured by the firm's R&D spending per employee, the firm's R&D spending to asset ratio, and the firm's R&D spending to revenue ratio. The CEO characteristics with a hypothesized relationship to R&D spending are tenure, age, education, and gender. Furthermore, certain variables have shown to be of influence on the firm's R&D spending which needed to be controlled for. These are past performance, leverage, size, and the industry the firm operates in. The main research model found no significant relationship between CEO characteristics and the firm's R&D spending after accounting for all control variables. The explained variance by the CEO characteristics on R&D spending per employee was only 1.4% and not significant. Whereas the explained variance in R&D spending to asset ratio and R&D spending to revenue ratio decreased by 0.7% and 0.9% respectively. However, a robustness test on a lower set of predictor variables does show support between CEO characteristics and the firm's R&D spending at the 10% level. Therefore, it can be concluded that there is no significant relationship between CEO characteristics and the firm's R&D spending at SMEs. The CEO tenure does have a negative relationship with R&D spending but is not significant. As such, hypothesis 1 is rejected. The CEO age seems to have a positive relationship with firms' R&D spending and is not significant. Whereas it is hypothesized that the age of a CEO has a negative relationship with R&D spending. Therefore, hypothesis 2 is also rejected. The CEO with a degree in the output of the business rather than the throughput has a significant positive relationship with the firm's R&D spending per employee. However, there is no significant relationship with the other R&D spending variables. Nevertheless, there is empirical evidence to support hypothesis 3. Last, hypothesis 4 states that male CEO tends to spend more on firms' R&D spending than their female counterparts. However, the regression analysis finds non-significant mixed results. The relationship between male CEO and firms' R&D spending per employee is slightly positive. Whereas the relationship between the male CEO and the other two variables, the firm's R&D spending to asset ratio and the firm's R&D spending to revenue ratio, is slightly negative. Therefore, hypothesis 4 can also be rejected.

Different robustness tests have been performed to test for the validity of the result from the regression analysis on the main research model. The conducted robustness tests are on a subsample of the manufacturing industry, and a lower amount of predictor variables to account for a potential overfit model. The results of the robustness tests for the manufacturing industry subsample gave similar results as the main regression analysis. Additionally, there is support for hypothesis 3 as there is a significant relationship between CEO education and R&D spending per employee. However, the significance is lower than in the main regression analysis. Nevertheless, the explained variance of the CEO characteristics on R&D spending was only lowered. The results of the robustness tests on fewer predictor variables also showed similar results to the main model. However, this robustness test reports a significant relationship between CEO education and R&D spending. The relationship with R&D spending to asset ratio is significant at the 10% level. Whereas the R&D spending per employee is at the 5% level. Furthermore, the explained variance of the CEO characteristics is significant at the 10% level. The last robustness test is on the relationship of individual CEO characteristics to the firm's R&D spending. The results of the robustness test show a significant relationship between CEO education and a firm's R&D spending per employee at the 5% level. However, the relationship is still insignificant between the other CEO characteristics and the firm's R&D spending.

The main research question of this study "*What is the relationship between CEO characteristics and R&D spending at SMEs?"* can be answered. The main research model does not find a significant relationship between any of the CEO characteristics for both forms of R&D spending at SMEs. However, the robustness test with the lower predictor variables does show a small significant relationship for the CEO characteristics explained variance in R&D spending per employee. Furthermore, multiple robustness tests are performed and do show a significant result for the relationship between CEO education and the firm's R&D spending at the 10% and 5% level. Nevertheless, these results are weak and do not remain for every robustness test. Therefore, there seems to be no statistically significant relationship between CEO characteristics and firms' R&D spending at SMEs.

6.2 Limitations and recommendations for future research

The study found little to no support for the relationship between CEO characteristics and a firm's R&D spending at SMEs. As has been conceptualized in the literature review, previous studies did find a significant relationship for most hypotheses stated. However, there are some limitations to this study. Firstly, the conceptualization of CEO education is limited compared to previous literature. The dataset only allowed for the kind of degree the CEO has chosen, which is conceptualized in output and throughput dummies. However, previous literature focussed more on the level of education the CEO has. Secondly, previous literature also stated that the former career experience has a significant relationship with the firm's R&D spending. However, the dataset did not contain such information, as this is specific information that is often lacking for CEOs of smaller companies. Thirdly, the control dummy for the industry was reclassified due to a low number of results. This reclassification weakens the effect of the control variable. A robustness test was performed on the manufacturing industry to counter this weakened control variable. However, due to the smaller manufacturing sample, the overfitting problem grew stronger. Fourthly, previous literature shows that more control variables need to be accounted for to test the relationship between CEO characteristics and a firm's R&D spending. However, the required variables are not available in the dataset and were impossible to manually collect. Fifthly, the number of predictor variables might be too much compared to the relative sample size, which causes concern for an overfit model. An overfit model gives results that are not replicate able for other datasets and causes concern for nugatory results. Lastly, most of the variables were not normally distributed. The variables did not cause great concern to the correlation matrix. Nevertheless, the Shapiro-Wilk test only found normality for two variables. These normality problems cause concern as this leads to inconsistency of the standard errors.

Next to the limitations of this study, there are also recommendations for future research. As mentioned previously, the conceptualization of CEO education is limited to the kind of degree and put into a dummy variable for output and throughput degree. However, the degree can be split up into more outcomes. As some degrees focus more on efficiency, whereas others focus more on the development of the product. Therefore, it might be feasible to split up the education into more groups to get a better insight. Furthermore, the sample used in this study uses companies that are located worldwide. This brings potential cross-region differences in the results. Therefore, gathering data from one region or country might give different results, and can compare these results to this study. Another recommendation is to collect qualitative data with CEOs of SMEs through interviews. To collect the own perception of the CEOs on why and when they tend to spend on R&D. And to find out which traits cause the reaction to spend on R&D. This can give a much deeper insight into what motivates a CEO to spend on R&D.

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Appendix

Appendix A: Assumptions for regression analysis.

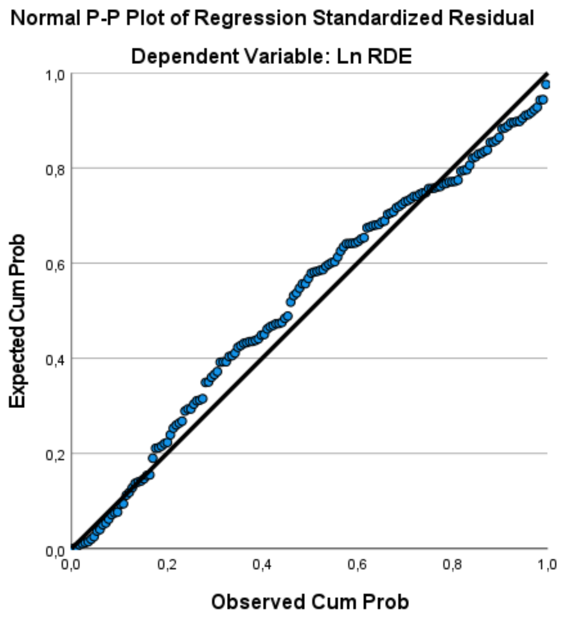

Figure 1 P-P plot for linearity assumption Ln RDE

Shapiro-Wilk			
Variable	Statistic	df	Sig.
Ln RDE	0.99	162	0.323
RDA	0.799	162	<.001
RDR	0.642	162	<.001
TEN	0.82	162	<.001
Ln AGE	0.986	162	0.101
EDU	0.634	162	<.001
GEN	0.272	162	<.001
PER	0.942	162	<.001
LEV	0.96	162	<.001
Ln EMP	0.96	162	<.001
Ln ASS	0.881	162	<.001

Table 8 - Shapiro-Wilk test for normality

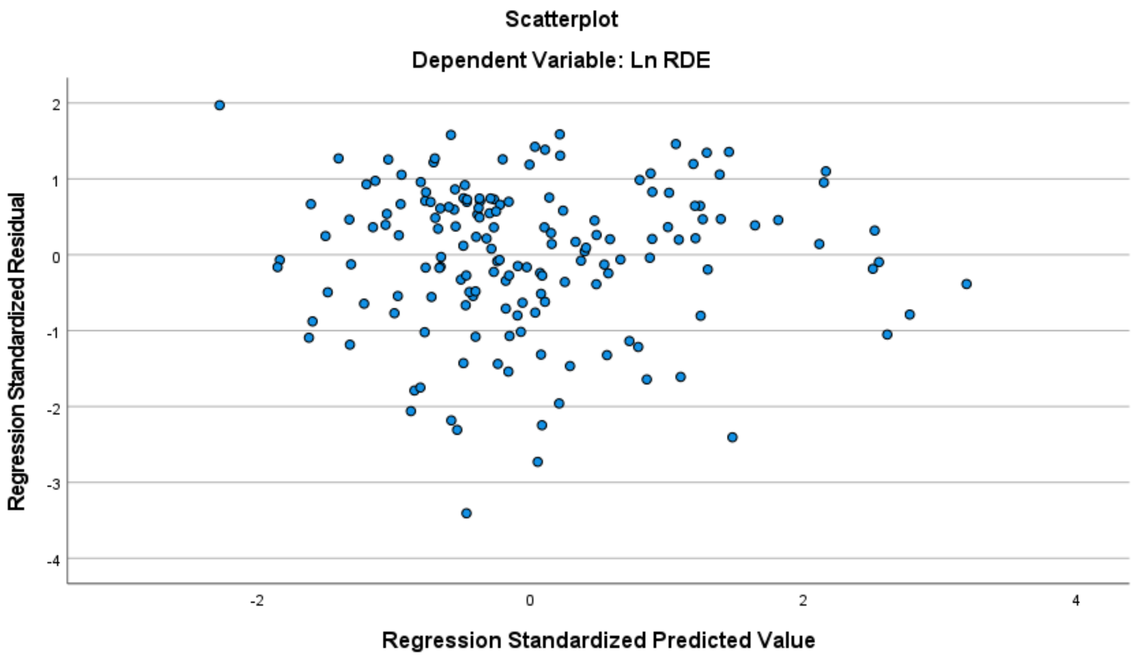

Figure 2 Scatterplot for homoscedacity assumption Ln RDE

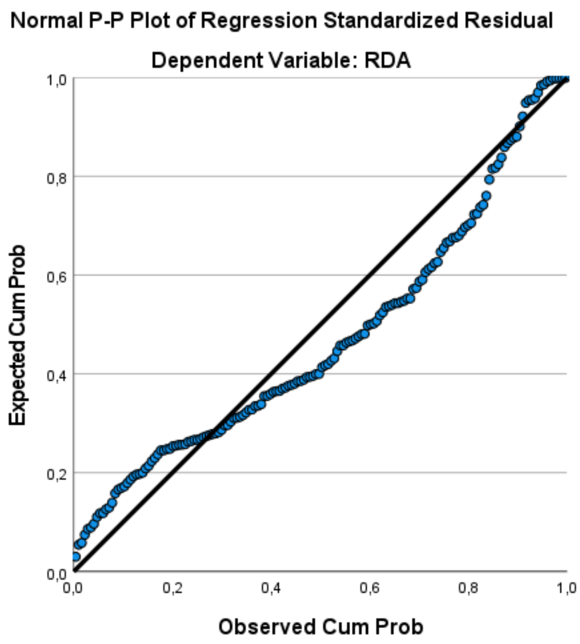

Figure 3 P-P plot for linearity assumption RDA

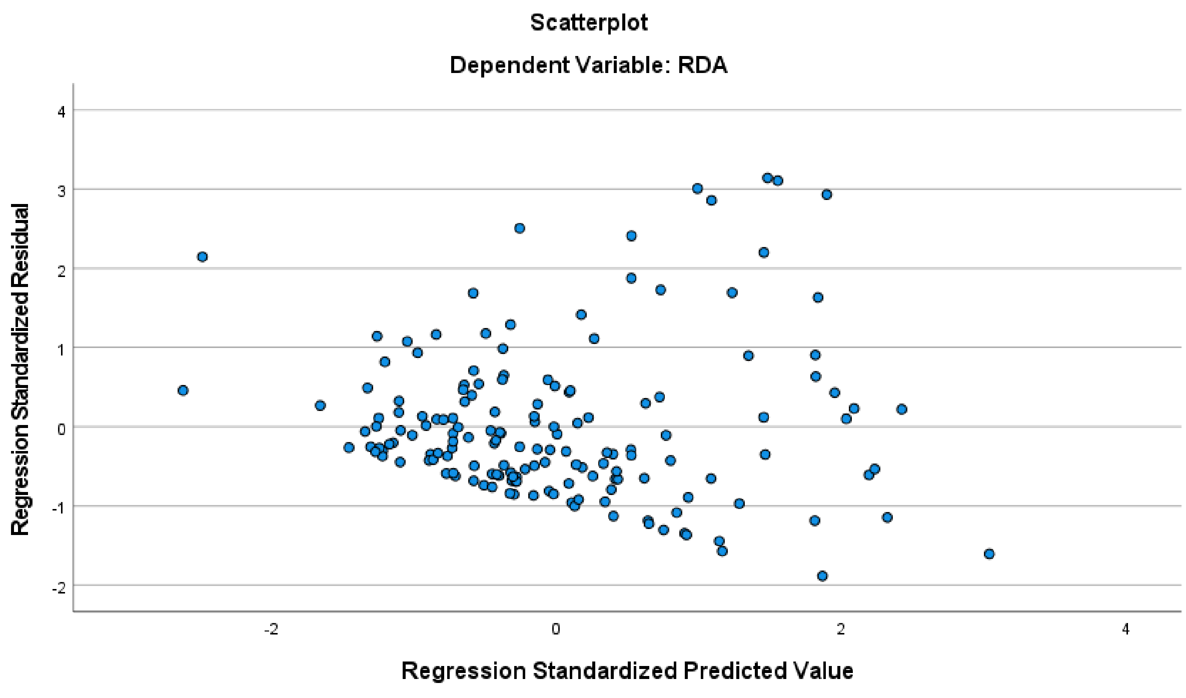

Figure 4 Scatterplot for homoscedasticity assumption RDA

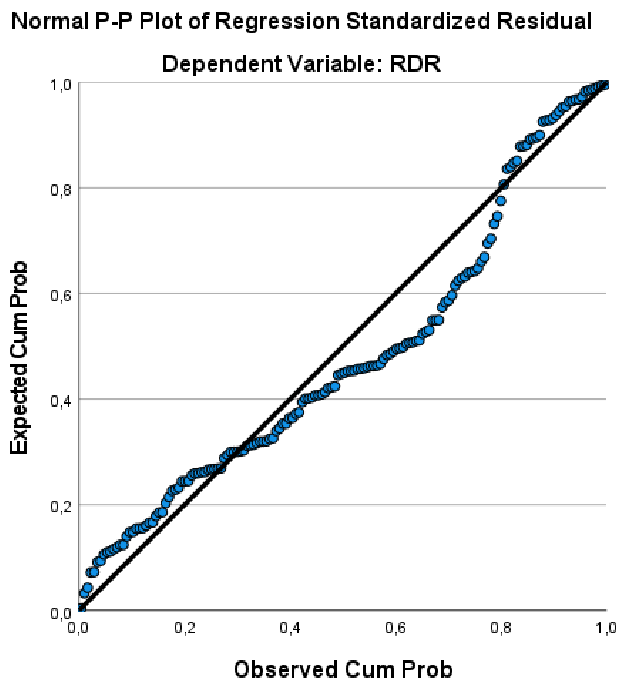

Figure 5 P-P plot for linearity assumption RDA

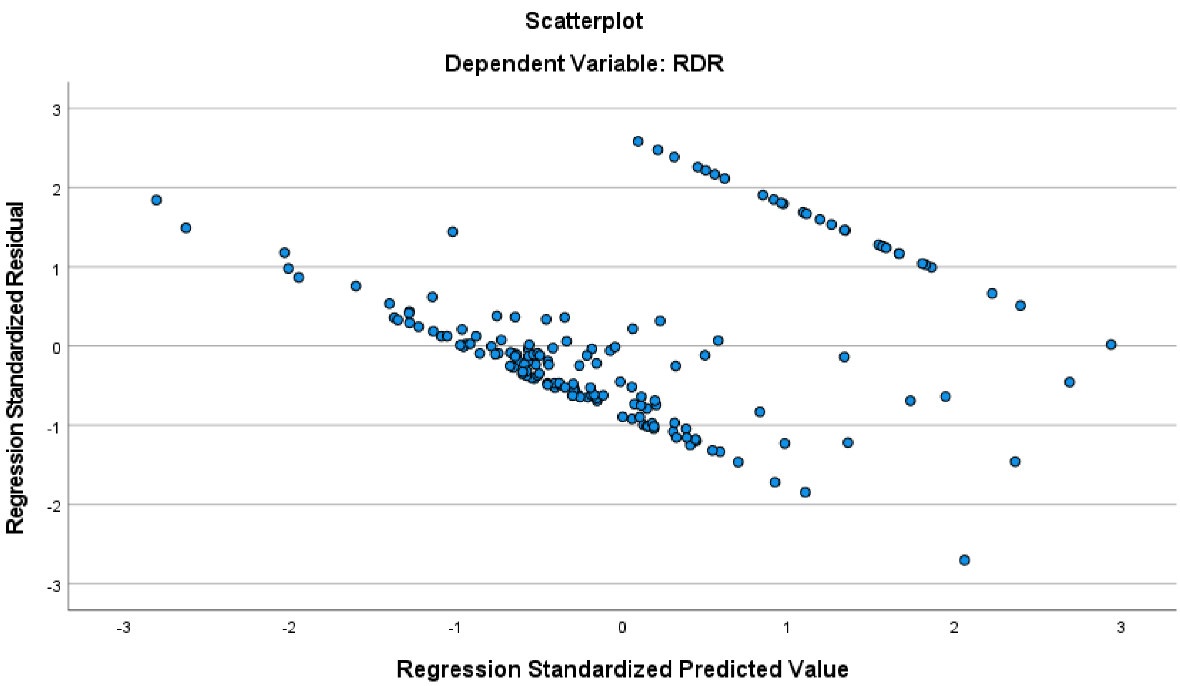

Figure 6 Scatterplot for homoscedasticity assumption RDR

Appendix B: Robustness tests

	Ln RDE		RDA		RDR	
Variables	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
TEN		0.046		0.042		-0.002
		(0.509)		(0.422)		(-0.02)
Ln AGE		0		-0.016		-0.029
		(0.001)		(-0.166)		(-0.326)
EDU		0.17*		0.128		0.059
		(1.979)		(1.363)		(0.707)
GEN		0.003		-0.106		-0.043
		(0.04)		(-1.153)		(-0.526)
PER	-0.112	-0.091	-0.306***	-0.282***	-0.343***	-0.337***
	(-1.237)	(-0.997)	(-3.119)	(-2.836)	(-3.969)	(-3.781)
LEV	-0.025	-0.013	-0.002	0.002	0.078	0.083
	(-0.305)	(-0.152)	(-0.023)	(0.02)	(0.982)	(1.01)
Ln EMP	-0.598***	-0.596***	-0.193*	-0.204*	-0.465***	-0.464***
	(-6.228)	(-6.062)	(-1.852)	(-1.897)	(-5.073)	(-4.836)
Ln ASS	0.195**	0.201**	-0.285***	-0.294***	0.07	0.062
	(2.057)	(2.106)	(-2.773)	(-2.826)	(0.778)	(0.669)
N	94	90	94	90	94	90
Adjusted R square	0.342	0.349	0.226	0.223	0.4	0.379
F-statistic change	13.725***	1.24	8.138***	0.926	17.327***	0.214
This table reports the standardized coefficients. The performance and leverage are analyzed at t - 1. The numbers between parenthesis represent the t-statistics. ***, **, * shows significance at 1%, 5%, and 10% respectively.						

Table 9 – Regression analysis on robustness test for sub-sample of manufacturing industry

	Ln RDE		RDA		RDR	
Variables	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
TEN		-0.056		-0.043		-0.055
		(-0.803)		(-0.544)		(-0.821)
Ln AGE		0.039		0.057		0.019
		(0.562)		(0.721)		(0.288)
EDU		0.174**		0.129*		0.076
		(2.587)		(1.699)		(1.193)
GEN		0.062		0.001		-0.021
		(0.921)		(0.003)		(-0.331)
PER	-0.185**	-0.183**	-0.159*	-0.152*	-0.357***	-0.356***
	(-2.549)	(-2.525)	(-1.969)	(-1.864)	(-5.277)	(-5.184)
Ln EMP	-0.434***	-0.413***	-0.241***	-0.231***	-0.382***	-0.376***
	(-5.974)	(-5.648)	(-2.98)	(-2.799)	(-5.637)	(-5.424)
N	159	155	159	155	159	155
Adjusted R square	0.274	0.292	0.101	0.1	0.369	0.362
F-statistic change	31.457***	2.008**	10.079***	0.925	48.128***	0.557
This table reports the standardized coefficients. The performance and leverage are analyzed at t - 1. The numbers between parenthesis represent the t-statistics. ***, **, * shows significance at 1%, 5%, and 10% respectively.						

Table 10 - Regression analysis on Robustness test for potential overfit model

	Ln RDE				RDA				RDR			
Variables	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
TEN	0				0				-0.03			
	(0.04)				(0.04)				(-0.61)			
Ln AGE		0.04				0.03				-0.01		
		(0.66)				(0.41)				(-0.11)		
EDU			0.16**				0.12				0.06	
			(2.58)				(1.64)				(0.93)	
GEN				0.05				-0.03				-0.03
				(0.80)				(-0.45)				(-0.56)
PER	-0.07	-0.06	-0.06	-0.07	-0.17**	-0.17*	-0.17**	-0.17**	-0.3***	-0.28***	-0.27***	-0.27***
	(-0.91)	(-0.85)	(-0.86)	(-0.95)	(-2.01)	(-1.97)	(-1.98)	(-2.01)	(-3.99)	(-3.95)	(-3.94)	(-3.95)
LEV	-0.12*	-0.12*	-0.11*	-0.12*	-0.15*	-0.15*	-0.14*	-0.15*	-0.02	-0.02	-0.02	-0.03
	(-1.86)	(-1.89)	(-1.70)	(-1.84)	(-1.91)	(-1.94)	(-1.81)	(-1.96)	(-0.29)	(-0.40)	(-0.32)	(-0.43)
Ln EMP	-0.59***	-0.59***	-0.58***	-0.58***	-0.17*	-0.17*	-0.17*	-0.17*	-0.4***	-0.43***	-0.431***	(-0.44***)
	(-7.54)	(-7.60)	(-7.69)	(-7.50)	(-1.84)	(-1.85)	(-1.82)	(-1.88)	(-5.61)	(-5.71)	-5.71	-5.75
Ln ASS	0.35***	0.35***	0.35***	0.35***	-0.03	-0.03	-0.04	-0.04	0.20***	0.20***	0.20***	0.20***
	(5.04)	(5.07)	(5.07)	(5.08)	(-0.40)	(-0.39)	(-0.46)	(-0.42)	(2.94)	(2.97)	(2.95)	(2.95)
N	153	153	153	153	153	153	153	153	153	153	153	153
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R square	0.41	0.41	0.43	0.41	0.16	0.16	0.17	0.16	0.43	0.43	0.44	0.43
F-statistic change	17.2	17.63	23.85	17.83	5.55	5.72	8.25	5.75	19.14	18.87	19.63	19.08

This table reports the standardized coefficients. The performance and leverage are analyzed at t - 1.
The numbers between parenthesis represent the t-statistics. ***, **, * shows significance at 1%, 5%, and 10% respectively.

Table 11 - Regression analysis on robustness test for individual independent variables