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Corporate Bankruptcy and the Knowledge-Based View

A quantitative analysis of the patent portfolio strength's impact on bankruptcy

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Abstract

Little is known about the underlying causes of corporate bankruptcy from a strategic management position. Most research on bankruptcies stems from the field of accounting, while scholars in strategic management have so far mostly studied the determinants of superior rather than inferior performance. This thesis fills that research gap by deploying the knowledge-based view (an extension of the resource-based view) as established theory in order to explain bankruptcy. More specifically, it is argued that patents represent a technology firm's most important (knowledge) resources. Firms with weak or no patent portfolios face, therefore, a competitive disadvantage in technology industries. Hence, it is hypothesized that firms with inferior patent portfolios are more likely to file for bankruptcies than firms with superior patent portfolios. Further, it is argued that this effect is moderated by the firm's belonging to a high-technology industry, by the firm's age and by the firm's size. Additionally, a negative relationship between growth of patent strength and bankruptcy likelihood is expected. These hypotheses were tests, applying logistic regression analysis to a sample of 220 publicly listed US firms that filed for bankruptcy between 2006 and 2013 and a control group of 220 comparable firms. As expected, the results show a statistically highly significant relationship between patent strength and bankruptcy probability. Further a significant moderator effect was found for firm age and size. No statistically significant impact was found for growth of patent strength and for industry belonging as moderator. These finding contribute to the theory development on causes of bankruptcy and offer relevant implications for scholars and practitioners in regards to the role of patent resources for corporate bankruptcy.

Keywords: *Knowledge-based view, bankruptcy, patents*

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List of Abbreviations

BvD – Bureau van Dijk

Etc. – Et cetera

IPC – International Patent Classification

LR – Likelihood Ratio

SEC – Security Exchange Commission

SIC – Standard Industry Classification

US – United States (of America)

Knowledge has become the key economic resource and the dominant–and perhaps even the only–source of competitive advantage. – Peter Drucker (1995)

1. Introduction

Knowledge is the *sine qua non* of today's business organizations. The concepts of knowledge society and knowledge economy have considerably shaped economic and business research in the last (two) decades. Trends such as "[…] a shift towards high-value-added, knowledge-intensive products and services […]" (Reich, 1991 in Hislop, 2013, p. 68) , an increase in knowledge-intensive work and the use of knowledge as such has promoted the importance of knowledge as the key resource of competitive advantage (cf. Hislop, 2013; Bosch-Sijtsema et al., 2010; Carleton, 2011; Kogut & Zander, 1992 , 1996; Liebeskind, 1996). One of the most important pillars of competitive strength can be seen in a firm's ability to constantly improve and exploit its resource base (Barney, 1986; Wernerfelt, 1984; Rumelt, 1984). Valuable knowledge is thereby often protected by intellectual property rights such as patents (cf. Liebeskind, 1996; Munari & Oriani, 2011). The aim to create intellectual property rights is not an end in itself, but a means to help a particular company to differentiate itself on a market and to ultimately convert patent resources into profits to the firm (Liebeskind, 1996). This notion appears to be even more relevant in technology industries in which revenue stems to a considerable amount from the application of patents (cf. Munari & Oriani, 2011). Companies active in these industries seem to have an increased necessity to improve, increase and protect their knowledge resources in order to stay competitive (Cf. Munari & Oriani, 2011). Hence, it comes as no surprise that especially the importance of patents has grown considerably in the last years, not only in terms of increased patenting activity (cf. Munari & Oriani, 2011) but also regarding patent competition (Petruzzi, Del Valle & Judlowe, 1988; Hall, 2004; Bessen and Meurer, 2005).

Acknowledging the importance of knowledge resources, strategic management researchers have made substantial efforts to explain why some organizations perform consistently better than others, thereby coining concepts such as knowledge management, organizational learning and the knowledge-based view (cf. Alvesson & Kärreman, 2001; Hansen, Nohria & Tierney, 2000; Earl, 2001; Kogut & Zander, 1992; Liebeskind, 1996; Grant, 1996; Spender, 1996; Barney & Arikan, 2001). However, what has so far been widely neglected in the debate relates to the "dark side" of performance, i.e. reasons for persistently inferior performance.

The potential relationship between weak resources, competitive disadvantage and ultimately corporate bankruptcy has therefore remained rather unknown. By excluding corporate bankruptcy from the research focus, strategic management research might have suffered from a systematic bias due to “undersampling of failure” (Denrell, 2003, p. 227) .Thereby, this field of research disregards a topic that has been virulent for decades, not only in the light of the rather recent dot-com and Global Financial Crises. Only very few companies are successful in continuing the business in the long run. Looking for example at S&P 500, only 74 companies survived between 1957 and 1997 (Schenkel, 2012). This evokes the question for the underlying causes of failure. Bankruptcy can be the result of many reasons that are either company inherent or due to external factors such as technology change (cf. Greenwood & Jovanovic, 1999; Hobijn & Jovanovic, 2000) or distress of the (financial) industry. In any case, companies failing to constantly improve or are unable to change may ultimately file for bankruptcy (cf. Beer & Nohria, 2000). However, the prospect of bankruptcy is mostly no coincidence hitting a company unexpectedly. Performance indicators, liquidity and leverage ratios can provide good evidence of a company’s state and its prospects. Hence, this evidence can also predict bankruptcy to some extent and investors as well as analysts heavily rely on these indicators to anticipate the expected future performance (Sueyoshi & Goto, 2009). Despite this relationship, financial indicators are only the result of managerial activity. For managers to take meaningful action and for analysts to have a good understanding of the firm’s strength – especially when highly reliant on intangible resources like knowledge – an “early indicator”, closer to a company’s resources and technology base, would be beneficial (cf. Griliches, 1998). Patent data thereby brings about useful insights regarding a firm’s underlying knowledge and technological progress (cf. Griliches, 1998; Ernst, 2001; Liebeskind, 1996; Kogut & Zander, 1993). Hence, in the light of the knowledge economy, patent data might be helpful in explaining not only firm success but also bankruptcy.

1.1. Research gap

Despite considerable interest in the research world regarding general performance differences conditional on knowledge resources (cf. Hansen et al., 2000; Griliches, 1998; Munari & Oriani, 2011), little attention has been paid to the notion of patent resources and their relationship to company failure (cf. Denrell, 2003) as the predominant focus on considers why some companies perform better than Most contributions to the bankruptcy research/literature focus on financial management aspects and prediction models using financial indicators such as the Altman’s Z-Score (Altman, 1968) or the Ohlson O-Score (Ohlson, 1980). These indicators give rather little explanation about the underlying resource drivers of negative performance. Deploying a management perspective on the explanation of firm failure can therefore be a substantial value-add both for researchers and practitioners. Moreover, the currently available research body is not older than a decade evaluating and can therefore be considered to be in its infant stage. The studies applied different patent indicators as well as other, more established, firm variables such as age or size in order to analyze their relationship with corporate bankruptcy or survival respectively (Levitas, McFadyen & Loree, 2006; Cockburn & Wagner, 2007; Buddelmeyer, Jensen & Webster, 2010; Eisdorfer & Hsu; 2011). The results are however sometimes ambiguous and vary according to the particular research focus, despite some support for a negative relationship between patent resources and bankruptcy (cf. Cockburn & Wagner, 2007; Eisdorfer & Hsu, 2011). Additionally, one can argue that the specific patent indicators chosen vary substantially regarding their inherent information characteristics (cf. Buddelmeyer et al., 2010) such that the real importance of patent resources regarding corporate bankruptcy remains to be determined.

Therefore, considering the outlined research gap for the study of corporate bankruptcy in the light of the knowledge-based view, we deem the analysis of patent resources’ impact on company failure an understudied area meriting further study.

1.2. Research question

In order to close the aforementioned research gap, we propose the following research question:

> *Does the level of patent portfolio strength explain corporate bankruptcy in technology industries and can it be justified by the KBV?*

1.3. Contribution

The aim of this thesis is to contribute to the current body of bankruptcy research through applying a company internal perspective. In particular, we want to shed light on the current research gap outlined above by analyzing the relationship between knowledge resources and the occurrence of firm failure of U.S. public listed technology firms by using patent data as an expression of a the company’s knowledge.

In doing so, we contribute to the validation or challenging of the knowledge-based view for the "dark side" of performance, i.e. reasons for persistently inferior performance. Furthermore, we challenge the existing literature for the relationship between patent data and organizational performance.

Practical contributions relate to importance of patent resource management for business and the potential insights for institutional investors with regards to patents. Lastly, we provide insights for policy makers with respect to the importance of patent protection in general and providing particular stimuli for technology firms to invest in intellectual property for certain technology fields.

1.4. Disposition

In the following, we will provide a brief summary of the thesis structure:

Chapter 2 provides the theoretical foundation of this study by contrasting two classical schools of firm performance, the Industrial Organization theory and the Resource-based View (RBV). Furthermore the Knowledge-based view (KBV) is introduced as an extension of the RBV. In *chapter 3*, the theoretical contribution of this study is presented by looking at the "dark side" of firm performance in conjunction with the KBV. Additionally, according hypotheses are derived. *Chapter 4* presents the specificities of patent portfolio strength evaluation as well as empirics regarding the research focus. Thereafter, in *chapter 5* the chosen methodology following from the research question will be introduced. In *Chapter 6* the obtained statistical results are presented and related to the proposed hypotheses. This is followed by interpretation and discussion of the result in *chapter 7* including identified limitations. Lastly, in *chapter 8* the major findings are summarized and theoretical as well as practical implications provided. The thesis is concluded with further research suggestions.

2. Theoretical Background

Corporate bankruptcy is an expression of weak firm performance. Therefore, it seems natural to turn to the research on determinants of firm performance to explore the causes of this phenomenon. In the following, the resource-based view and the knowledge-based view are deployed to analyze the causes of corporate bankruptcy. Knowledge is identified as one of the strategically most important resources. Subsequently, it is argued that knowledge disadvantages help explaining corporate bankruptcy – especially within technology-intense industries.

This chapter sets the theoretical framework for this study and is structured into two sections. The first section contrasts external and internal schools within strategy research. It presents the Industrial Organization theory as an external view on firm performance and the resource-based view as an internal perspective. The second section discusses the importance of knowledge and introduces the knowledge-based view as extension of the research-based view. In particular it discusses the role of patents as resources that can lead to (sustained) competitive advantages.

2.1. Classical school of strategy: Explaining superior firm performance

The "classical" school of strategy has its origins in the 1970s and attempts to explain the creation of competitive advantages and the observation of persistent performance differences between firms (Cashian, 2007). Two different lines of research are differentiated within this field. One the one hand, external theories explain performance differences between firms by external factors in the firm's environment and particularly industry structure. The most prominent theory within this area is the *Industrial Organization* (or *market-based view*) theory. On the other hand, internal theories, like the *Resource-Based View* (RBV) theory, place the determents of firm success within the firm itself. While the RBV theory is applied in the course of this study, first the industrial organization theory is briefly presented to provide a comprehensive picture and contrast their differences.

2.1.1. The Industrial Organization theory and superior performance

Industrial organization theory (IO) explains differences in economic performance between firms by analyzing the industry structures they operate in (Porter, 1980). This theory has its roots in oligopoly theory and assumes that firms can only generate economic profit by appropriating oligopolistic or monopolistic rents[1] (Rumelt, 1984; Barney & Arikan, 2001; Church & Ware, 1999; Caves, 1980). It is argued that these rents stem from imperfect competitive markets and the obtainment of market power (Kraaijenbrink, Spender, Groen, 2010; Rumelt, 1984; Church and Ware, 1999; Porter, 1979). The underlying assumptions are that all firms within one industry are identical and only differ in size (Rumelt, 1984). All strategic resources are homogeneously distributed and any heterogeneity exists only short-term (Barney, 1991).

Porter (1979, 1980) was one of the first authors to highlight the importance of industry structures in diagnosing industry profit potential. He argues that the degree of competition determines the possibility to earn monopolistic rents and is shaped by five underlying forces[2] (commonly referred to as "Porter's five forces"). Similarly, Caves (1980, p. 64) views "[…] the number and size distribution of sellers and buyers, height of barriers to entry and exit, extent and character of product differentiation, extent and character of international competition […), and certain parameters of demand (elasticity, growth rate) […]" as market characteristics that explain profitability differences between industries. These features are inherent and stable for each market and firm behavior can only partly influence these (Caves, 1980; Rumelt, 1984).

IO theory has normative implications for firms, their positioning and their strategy development. Porter (1980) suggests that firms analyze their industry's basic forces and formulate a competitive strategy relative to them. The strategy needs to address the strongest force(s) in order to defend the firm against its adverse effects and ensure survival and growth. Firms can do so, for example, by positioning themselves where these forces are the weakest

[1] Rumelt (1984) and Peteraf (1993) define economic rents as profits that do not cause new competition. Monopoly (or oligopoly) rents are earned as a consequence of (purposely) restricted output (Peteraf, 1993).

[2] These five forces are: (1) The threat of new entrants, (2) the threat of substitute products or services, (3) the bargaining power of buyers, (4) the bargaining power of suppliers and (5) the rivalry among existing firms (Porter, 1980, p. 4).

or can be influenced favorably (Porter, 1979, 1980). Emphasizing the importance of competitive positioning, IO is also referred to as the “school of positioning” (Mintzberg, Ahlstrand and Lampel, 2001).

2.1.2. The Resource-Based View on the firm and superior performance

The antecedents of the RBV date back to 1959 when Penrose highlighted that firms display high heterogeneity in terms of their resources and proposed that firm growth depends, for example, on the available resources. Despite Penrose’s early contribution, the RBV is mainly rooted in the studies of Wernerfelt (1984), Rumelt (1984) and Barney (1986) but complemented and extended by various scholars.

Promoting the RBV in contrast to the IO theory, Gort and Singamsetti for example showed already in 1976 that industry belonging has little explanatory value for variance in profit rates compared to organizational characteristics. Later scholars like Hansen and Wernerfelt (1989) or Rumelt (1991), who found that variance in return on assets is better explained by differences between firms than by industry effects as proposed by the IO theory, supported this view.

The main aspect that distinguishes the RBV and the IO theory can be seen in the fact that the RBV does not focus on a firm’s positioning and ability to earn monopolistic rents within imperfectly competitive product markets. Rather, it considers the resources required to achieve such an aspired positioning and the costs associated with acquiring them. By competing for these positions, firms ultimately compete for resources (Wernerfelt, 1984; Rumelt, 1984; Barney, 1986). Wernerfelt (1984, p. 172) thereby defines resources as “[…] anything which could be thought of as a strength or weakness of a given firm”. This includes all tangible and intangible assets (and skills), which are “semipermanently tied to the firm” (Caves, 1980, p. 65; Wernerfelt, 1984). Similarly, Draft (1983, in Barney, 1991, p. 101) defines firm resources as “all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc. controlled by a firm that enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness”. Amit and Schoemaker (1993) highlight that resources can also take the form of tradable knowhow, such as patents or licenses.

The positioning based on a firm's resources aims at achieving a (sustained) competitive advantage (Rumelt, 1984; Barney, 1986; Barney & Arikan, 2001). Barney (1991, p.102): "[…] a firm is said to have a competitive advantage when it is implementing a value creating strategy not simultaneously being implemented by any current or potential competitors". A competitive advantage is *sustained* if the strategy cannot be imitated by any current or future competitor (Barney, 1991). Therefore, it is not the duration that defines a sustained competitive advantage but it's inherent enduring uniqueness. In turn, this does not mean that a sustained competitive advantage is of unlimited durability. It may vanish, though not due to imitation. "Unanticipated changes in the economic structure of an industry may make […] sustained competitive advantage, no longer valuable for a firm […]." (Barney, 1991, p. 103) Finally, in order to understand whether or not a resource can be a source of sustained competitive advantage four criteria need to be analyzed. Resources need to be (1) valuable, (2) rare, (3) inimitable and (4) non-substitutable. These criteria are also referred to as the "VRIN framework". (Barney, 1991)

According to the RBV, firms generate economic profit from a (sustained) competitive advantage by earning either monopolistic or Ricardian rents[3]. Furthermore, the RBV has two main assumptions. Firstly, resources of strategic importance can be heterogeneously distributed among firms of the same industry. Secondly, these resources may be of limited mobility and resource heterogeneity may, hence, be lasting (Barney, 1991). Consequently, the firm is viewed as an accumulation of resources which are to some extent bound to it (Wernerfelt, 1984, p. 172).

Barney (1986, 1991) analyzes how firms obtain these resources and introduces the concept of "strategic factor markets" as the arenas where resources can be acquired. He argues that if

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[3] Ricardian rents are profits which are earned due to superior and scarce resources that are controlled by some firms. These resources are often limited in the amount of output that can be obtained from deploying them. Therefore firms using these resources might not be able to fulfill the whole market demand for their products. Hence, firms with inferior resources remain in the market too. In market equilibrium, demand and supply is balanced and firms with inferior resources sell at marginal costs. Firms with superior resources are able to produce at lower costs and consequently generate profits. These profits do not cause further competition, as sellers without the superior resources cannot appropriate them. Contrarily to monopolistic rents, Ricardian rents are earned due to (unintended) restricted supply. (Peteraf, 1993)

strategic factor markets are perfectly competitive, it is impossible to acquire resources that can be deployed to earn above average economic rents. This is due to the fact that in perfectly competitive markets the potential seller of resources knows the value that can be appropriated with them. Consequently, the seller would not sell below this value, thereby diminishing the potential rents for the acquirer. There are however two market imperfections that can allow a market participant to earn economic profits from resources acquired on strategic factor markets:

(1) *Different expectations.* If a firm has more accurate expectations about the future benefits of certain resources, it is able to identify if these are underpriced and can acquire them for less than their true value. In order to have more accurate expectations about the value of certain resources, special insights are required. These insights might be obtained from (a) analyzing a firm's environment (external analysis) or (b) analyzing the set of resources, skills and capabilities already controlled by a firm (internal analysis). Barney (1986) shows that special insights are more likely to be obtained from internal analysis as the environmental analysis could be performed by any player in the market and should therefore not lead to an information advantage. (Barney, 1986)

(2) *Pure luck or fortune* can be another source of above average economic performance part from heterogeneous expectations. Firms might acquire resources at the supposedly "fair" value that does not enable them to achieve economic rents. If the value of these resources is changing over time and firms did not anticipate that (i.e. due to more accurate expectations than other market participants), pure luck or fortune is the source of economic profits earned. (Barney, 1986)

Since luck can by definition not be controlled (Barney, 1986), it follows that firms should aim at having more accurate expectations. In particular, firms should analyze their own resources, skills and capabilities in order to gain special insights about the value of these or any complementary resources. These insights might allow firms to act advantageous on strategic factor markets and prevent them from paying out all future benefits. Therefore, the internal analysis of resources already controlled by a company is used within this paper.

The resource-based view has received much attention from researchers and practitioners throughout the last two decades. Many scholars have extended, improved or modified the theory. Prahalad and Hamel (1990, p.4), for example, introduced the concept of "core competencies” to describe the firm’s “[…] collective learning […], especially how to coordinate diverse production skills and integrate multiple streams of technologies”.

Stalk, Evans, and Shulman (1992) coined the term “capabilities” and adapted the RBV theory accordingly. Amit and Schoemaker (1993) define capabilities as the firm’s capacity to combine resources with organizational processes and deploy them to achieve a certain purpose. Capabilities are “information-based, tangible or intangible processes” (p. 35) that have emerged over time and are specific to each firm. Building on the RBV, the knowledge-based view emphasizes the role of knowledge resources in acquiring a competitive advantage (Grant, 1996; Liebeskind, 1996; Spender, 1996). This extension will subsequently be discussed in more detail.

In summary, it is important to note how the RBV arose from the observation that variance in performance is better explained by company-specific factors than by industry factors. The RBV, therefore, explains superior performance by firm internal factors. More specifically, firms need to acquire relevant resources on strategic factor markets in order to implement competitive advantages in product markets. The resources already controlled by firms are most likely to provide special insights that allow firms to acquire further resources for less than their fair value and therefore obtain economic rents when deploying those resources. Therefore, we will assume the internal perspective in the remainder of this study to investigate causes of performance differences between firms.

2.2. The Knowledge-based view and the role of patents

The knowledge-based view (KBV) is an advancement of the RBV. Kogut and Zander (1992, 1993, and 1996) have been earlier contributors to this field of research. Other main proponents were Grant (1996), Liebeskind (1996) and Spender (1996). The KBV regards knowledge as the strategically most important resource that firms can control that determines to a large extent if firms are able to develop a competitive advantage (Grant, 1996; Liebeskind, 1996; Spender, 1996; Kogut & Zander, 1992). Firms that possess superior knowledge can gain efficiency advantages and earn Ricardian rents or, if applied to new product development, achieve monopolistic rents. This knowledge needs to be unique and not commonly available to all competitors to be a source of competitive advantages (Liebeskind, 1996). In other words it needs to exhibit characteristics of the VRIN principles. The term knowledge is thereby used in a very broad sense. Liebeskind (1996, p. 94) defines it as “information whose validity has been established through tests of proof“. Edvinsson and Malone (1997) view knowledge as part of a firm’s human and structural capital. Human capital encompasses for example employees’ skills, abilities and experience. Structural capital, on the other hand, comprises organizational structures, customer relationships, patents and trademarks. Both terms are summarized under the expression *intellectual capital*.

It is crucial for firms to protect their knowledge and develop “isolating mechanisms” in order to ensure that its intellectual capital remains exclusive (Rumelt, 1984, p. 141; Liebeskind, 1996; Kogut and Zander, 1992). Liebeskind (1996) proposes two ways to protect knowledge: through organizational mechanisms like employment of the possessors of knowledge or through intellectual property rights (cf. Kogut & Zander, 1992). Protected intellectual property comprises a range of legal rights including patents, copyright, trademarks, registered designs, and also trade secrets. All of them protect some form of knowledge, either from new technical inventions in the case of patents, from original creative or artistic forms for copyrights or from valuable information not known to the public in the case of trade secrets. Some of the rights (copyright) exist automatically or can be protected by the organization itself (trade secrets), whereas others have to be registered (registered designs; optional for trademarks) or even be applied for in the case of patents. One can therefore say that the latter bear the highest (direct) cost of protection due to comprehensive patent procedure. (EPO, 2013)

As a consequence of the complicated and costly protection of knowledge, firms have to act economically and set priorities when protecting their knowledge (Liebeskind, 1996). Accordingly, it we argue that the knowledge which firms choose to protect by patents represents their most valuable knowledge. Therefore, analyzing the quality and quantity of a firm’s patent portfolio appears suitable to understand the strength of its resource base and make assumptions about its performance. In the following, the quantity of patents controlled by a firm and the quality of that portfolio is referred to as the firm’s *patent portfolio strength*.

Having established that patents represent some of the most valuable knowledge and incorporating the fact that knowledge is a firm’s key resource according to the KBV, it can be concluded that patents resemble one of a firm’s most valuable resource. Also proponents of the more general RBV consider patents as an important firm resource (cf. Amit and Schoemaker, 1993). Whether or not patent can be source of sustained competitive advantage depends on its classification according to the VRIN model. First, patents are *valuable* since they can be used to either mitigate a threat or to exploit an opportunity (Barney, 1991). As intellectual property right, patents allow its holder to 1) block competitors from markets, (2) secure freedom of action, (3) license or sell the patent or (4) a combination of the three (cf. EPO, 2013; Munari & Sobrero, 2011). For example, a firm that fears a competitive market entry can neutralize this threat by patenting proprietary knowledge and raise the entry barrier for potential competitors. In this sense, patents can generally be considered valuable.

Second, a resource needs to be *rare* to be the source of a (sustained) competitive advantage. Patents are naturally rare as a consequence of the difficult and costly application process. However, a large number of firms within one industry can hold several patents. These cannot be identical but to some extent similar in technological coverage or content. Third, patents qualify as *inimitable* per definition as duplication would lead to an infringement claim by the original patent holder. Nevertheless, other patents can be partially based on previous patents if the latter are cited correctly. Last, patents are to a certain extent *non-substitutable*. According to Barney (1991, p.111), a resource is non-substitutable if there are "[…] no strategically equivalent valuable resources that are themselves either not rare or imitable." Since patents per definition require technical application, one can conclude that many technical products rely on patents and thus cannot be manufactured without legal access to them (EPO, 2013). Hence, patents are non-substitutable in most cases and, overall, satisfy all four VRIN criteria.

Nevertheless, there are industry differences with regard to the importance of patenting due differences in knowledge intensity levels. Firms in technology industries are often highly reliant on knowledge resources and exposed to fierce and fast-moving competition due to constant advancements (cf. Sueyoshi & Goto, 2009). These advancements lead to new products being developed, which are often secured by patents (Kleinknecht & Reinders, 2012). Therefore, technology industries on average exhibit higher patenting activity than, e.g., service industries (Eisdorfer & Hsu, 2011; Kleinknecht & Reinders, 2012). Hence, we will put a focus on technology industries.

In summary, the KBV presents a theory that proposes knowledge to be a fundamental resource of a firm to achieve competitive advantages. In line with that, it can be argued that patents as one form of knowledge classify as strategic resources according to the RBV and can potentially lead to sustained competitive advantages. Analyzing a firm's patent portfolio strength can thus help to understand its resource base in order to identify sources of future competitive advantage.

3. Theoretical contribution and hypothesis development

Having reviewed the relevant theory explaining performance differences between firms in the previous chapter, this chapter highlights an important research gap and attempts to close it. In the following, we will contribute to theory by deploying the KBV to investigate the causes of corporate bankruptcy. Based on these theoretical considerations, the second section of this chapter deducts five hypotheses in order to test the proposed theoretical conclusions.

3.1. Knowledge and the “dark” side of firm performance

Business strategy research – including theories such as the IO, RBV and KBV – has long focused on answering the question why some firms perform persistently better than others. Contrarily, the question why some firms perform worse than others and ultimately file bankruptcy has seldom been on the agenda of business strategy researchers. The phenomenon of corporate bankruptcy has mostly been the subject of research in the field of accounting with an emphasis on bankruptcy prediction (cf. Ohlson, 1980; Altman, 1968; Apergis, Sorros, Artikis, & Zisis, 2011; Dichev, 1998; Appiah & Abor, 2009; Eisdorfer & Hsu, 2011). Causes of bankruptcy and its prevention remain so far an understudied area in business strategy research (Crutzen & Caillie, 2008; Thornhill & Amit, 2003). Thornhill and Amit (2003, p. 506) comment: “Just as medical science would be unlikely to progress by studying only healthy individuals, organization science may be limited in the knowledge attainable only from the study of successful firms.” Hence, business strategy researchers need to acknowledge the importance to investigate the causes of performance differences on both sides of the coin, i.e. superior and inferior performance.

Assuming this perspective on the resource-based and knowledge-based view, it can be argued that research in this area has been so far potentially prone to a fundamental selection bias (cf. Denrell, 2003, 2005): Analyzing the differences in firm performance by comparing only successful firms to less successful firms has excluded a significant amount of (relevant) observations from the analysis – namely, those firms that performed the worst and filed for bankruptcy. Denrell (2003, 2005) has emphasized that business research is often systematically biased by an undersampling of failures. In order to understand the causes of superior firm performance, researchers frequently analyze those firms that perform particularly well. By doing so, all observations that might have undertaken similar measures but failed are excluded. In consequence, the returns of risky actions might be overestimated while risks are underestimated (Denrell, 2003). In order to avoid bias from an underrepresentation of failure sampling, it is necessary to test if the RBV and its extension, the KBV, also hold when investigating firm failure. This will not only shed light on the causes of bankruptcies but also contribute to the further validation of the RBV and KBV theory.

Thornhill and Amit (2003) and Crutzen and Caillie (2008) acknowledge this shortcoming of previous RBV research and deploy the theory in order to explain firm failure. Focusing on performance differences with regards to inferior performance, they argue that a firm's resource and capability configuration needs to be analyzed to understand the causes of weak performance and bankruptcy. They propose that firms with weak resources perform worse than others and are more prone to file bankruptcy. If the resources and capabilities of a firm are misaligned with its environmental requirements, it does not just face a position of competitive parity, but even find itself in a position of competitive disadvantage (Crutzen & Caillie, 2008). This reasoning is also in line with D'Aveni's (1989) early contribution that a firm's net asset (resource) stock impacts its likelihood to default. Consequently, it can be argued that firms that have not enough resources, resources of too low quality or resources not in line with their environment's demands are more likely to face a competitive disadvantage and ultimately go bankrupt.

In a similar way, we argue that this also holds for the knowledge-based view. Following the same rationale, we propose that firms with knowledge resources of less strength (quality or quantity), i.e. inferior strength, may face a competitive disadvantage. Compared to companies with strong knowledge resources, these firms are less likely to generate profits and maintain market shares. This ultimately leads to a diminishing set of assets and causes corporate bankruptcy. As noted before, patents are an important knowledge resource and are likely to represent the most important knowledge a firm possesses. Therefore, a firm's patent portfolio strength appears to be a suitable approximation of its knowledge resource strength. Consequently, this paper investigates the strength of patent portfolios in order to explain bankruptcy.

In the previous section (2.2) it was argued that controlling patents can be beneficial for firms in four different ways (cf. EPO, 2013; Munari & Sobrero, 2011). Likewise, not holding patents or holding a weak portfolio can have four implications leading to inferior performance. (1) Firms that do not control patents for relevant knowledge might find it harder to block competitors from using this resource. (2) Firms may be limited in their freedom to act as competitors holding relevant patents might block them. (3) Firms may have to pay royalties to patent owners when licensing these patents. And (4) firms may be affected by a combination of these factors. These four potential effects illustrate why weak patent portfolios can cause inferior performance.

However, painting this picture black and white does not reflect the complexity of reality. According to the RBV and KBV (cf. Rumelt, 1984; Wernerfelt, 1984; Barney, 1986, 1991; Liebeskind, 1996; Kogut & Zander, 1992, 1996) the possession of (knowledge) resources is important but not a sufficient condition to develop a competitive advantage and achieve superior performance. Firms need to develop and implement strategies that match their resource configurations (cf. Rumelt, 1984; Lockett, Thompson & Morgenstern, 2009; Cefis & Marsili, 2005). Focusing only on the possession of knowledge neglects this aspect. Weak patent portfolios do not necessarily lead firms to failure if firms control and secure knowledge in other forms or choose a strategy that fits to their weak patent portfolio strength. Neither should holding strong patents always imply superior performance. Firms need to, for example, also be able to commercialize their patents and pursue a strategy that makes use of their resources (cf. Barney, 1986, 1991; Wernerfelt, 1984). Therefore, we conceptually propose a matrix contrasting the *patent portfolio strength* (x-axis) with the *fit of strategy* to a firm's patent portfolio (y-axis) as illustrated in figure 1.

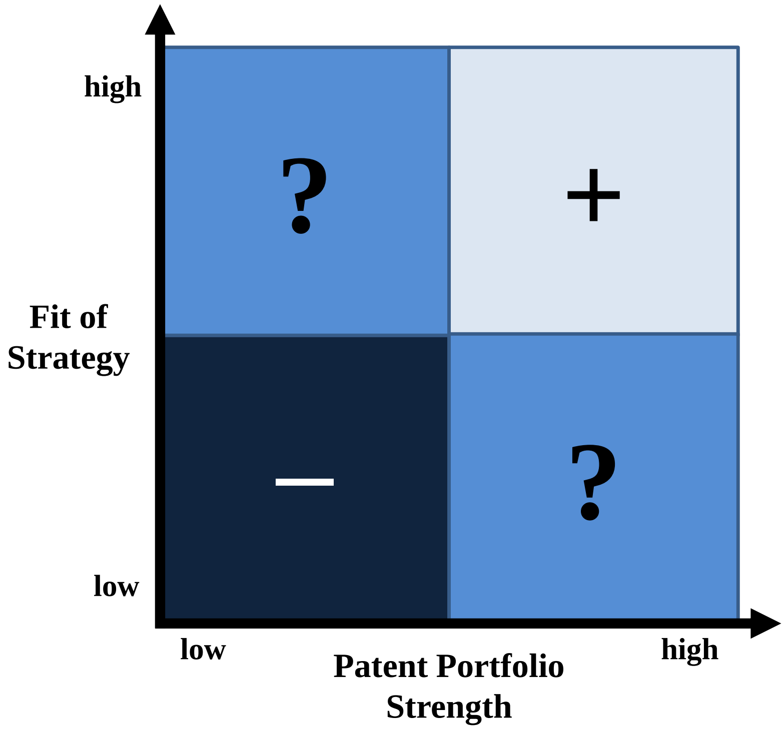

Figure 1 - Patent Resource-Strategy Fit

Firms in the upper right corner are those that control strong patent portfolios and pursue a strategy that fits to these resources. These firms are expected to be most likely to develop a sustained competitive advantage and display superior performance. In contrast, firms in the lower right corner also have strong patent portfolios but do not pursue a strategy that matches these resources, i.e. neither sufficiently exploiting their potential through commercialization nor gaining appropriate royalties from licensing or profits from selling them on strategic factor markets. Christensen and Bower (1996) have noted that firms that are particularly successful in one industry and assume a technology leadership position might find themselves confronted by disruptive innovations and forced to alter their strategies. Consequently, these firms control strong patent portfolios in the previously leading technology that do not fit to their strategy anymore or have become obsolete. This refers to what Christensen and Bower (1996) call an innovator's dilemma[4]. Looking only at patent portfolio strength, these firms

[4] This phenomenon is called "innovator's dilemma" because often the industry's previously leading firms are the first to develop a new, disruptive technology. However, these firms (the "innovators") rationally choose to

might appear strong while in fact they perform inferior due to the strategic misfit and therefore need to be placed in the lower right corner.

The upper left corner describes firms that hold weak patent assets but adapted their strategy to this position. These companies might possess knowledge not protected through patents. For example this could mean that they protect knowledge by other intellectual property rights or through organizational mechanisms. Moreover, it is also possible to benefit from other parties' patent-protected knowledge through licensing rather than owning it. Firms applying this strategy can still obtain a competitive advantage. This can be achieved through gaining exclusive access to the patents while paying less than the value one can derive from it,

Last but not least, firms in the lower left corner neither control strong patent portfolios nor adapted their strategy accordingly. These firms are most likely to face a disadvantage, especially in industries characterized through fierce competition. Consequently, the likelihood to go bankrupt is expected to be the highest for those firms.

In order to test the considerations underlying this matrix, ideally one would test the relationship between on the one hand likelihood of bankruptcy and on the other hand both patent portfolio strength and fit of strategy at the same time. However, the fit of a strategy is hard to assess and analyze in empirical research. Venkatraman (1989, p. 423) in his article "The Concept of Fit in Strategy Research: Toward Verbal and Statistical Correspondence" notes that "[…] a major problem is the lack of corresponding schemes by which fit has been tested." He further argues that this shortcoming might lead to inconsistent research results from theory testing. Therefore, we acknowledge the importance to consider the fit of strategy, but choose to limit the scope of this study to the analysis of patent portfolio strength as determinant of bankruptcy. As proposed in the later section 8.2, we suggest however that subsequent scholars challenge our findings considering also the second dimension.

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disregard these technologies as they are originally not competitive and do not serve the core customers' demands. However, as these technologies (sometimes rapidly) develop, new market entrants deploy them to alter ("disrupt") industries leading to incumbent market leaders becoming obsolete. Therefore, the innovators face the a-priori "dilemma" whether or not to pursue thee initially less appealing technologies. (Christensen & Bower, 1996)

To sum it up, we have argued in this chapter that RBV and KBV can be deployed to analyze the determinants for inferior performance. More specifically, we have theoretically shown how low patent portfolio strength can cause a competitive disadvantage and ultimately lead to bankruptcy. Further, we discussed the importance to also assess the fit of a firm's strategy to its given patent resources in order to determine bankruptcy probability. The focus of this study remains, however, on patent portfolio strength as determinant of bankruptcy.

3.2. Hypotheses development

In the following, we will deduce the hypotheses that will be tested empirically within this study. In order to do so, we will relate back to related theoretical discussions.

As outlined in the previous chapter, we expect weak knowledge resources to explain the occurrence of corporate bankruptcy. More specifically, we propose a negative relationship between patent portfolio strength and bankruptcy probability. This means that ceteris paribus a firm with lower patent strength should be more likely to go bankrupt. Accordingly, we hypothesize:

H 1: *The strength of a firm's patent portfolio is negatively related to its likelihood to go bankrupt.*

The resource-based view theory proposes that firms are an accumulation of resources which are collected throughout time (cf. Wernerfelt, 1984; Thornhill & Amit, 2003; Lockett, Thompson and Morgenstern, 2009). Also, knowledge resources are acquired throughout time (Kogut & Zander, 1992). We suggest that the pace with which these resources are accumulated or decreased influences the likelihood to go bankrupt. Stronger investments in resources generally display bigger growth plans and an overall better state of health. Consequently, we argue that firms that increase their resource strength slower, that are reducing their resource base rather than increasing it or that have a resource base which is diminishing in quality are more likely to go bankrupt than others. Applied to patents as knowledge resources this means that firms that exhibit low or negative growth rates of their patent portfolio strength are – ceteris paribus – more likely to file bankruptcy than others. Therefore, we propose the following hypothesis:

H 2: *The growth rate of a firm's patent portfolio strength is negatively related to its likelihood to go bankrupt.*

Knowledge is not equally often protected by patents when comparing different industries. Generally, high-tech industries such as biotechnology exhibit a much higher patent propensity than low-tech industries such as Oil & Gas extraction (Eisdorfer & Hsu, 2011; Kleinknecht & Reinders, 2012). On the one hand, high-tech industries exhibit substantially higher average returns. This comes in turn at an elevated risk (cf. Sueyoshi & Goto, 2009), which is why high-tech firms need to aim for a very effective and efficient resource management, including the protection of own intellectual capital. On the other hand, most high-tech industries are still exhibiting high growth rates and value-add (cf. Damodaran, 2013; OECD, 2013). Altogether, this implies that firms in high-tech industries need to have especially strong (knowledge) resources and capabilities to avoid competitive disadvantages. Moreover, high-tech firms might be more prone to innovate and compete in the technology race as suggested by the high patent propensity. Hence, one can conclude that a strong patent portfolio should reduce the likelihood to go bankrupt more in high-tech industries than a similarly strong patent portfolio reduces the likelihood to go bankrupt in low-tech industries. On the other hand, a firm holding a weak patent portfolio should – ceteris paribus – be more likely to go bankrupt in high-tech industries than in low-tech industries. Accordingly, the following hypothesis is proposed:

H 3: *For high-tech firms, the strength of the patent portfolio is stronger negatively related to its likelihood to go bankrupt than for low-tech firms.*

Resources in general and also knowledge resources in particular are accumulated over time (cf. Kogut & Zander, 1992; Wernerfelt, 1984; Thornhill and Amit, 2003; Lockett, Thompson and Morgenstern, 2009). This implies that older firms control more (knowledge) resources even if they do not take the form of patents. Furthermore, these firms have successfully passed their early development phase, established business relationships and proved themselves being able to survive in the market as well as increased overall efficiency (Dunne, Roberts & Samuelson, 1988; Mata & Portugal, 1994; Pakes & Ericson, 1998). Consequently, the fate of these firms depends less on the possession of strong patent portfolios. Therefore, a moderator effect of firm age on the impact of patent portfolio strength is expected.

H 4: *For older firms, patent portfolio strength is weaker (negatively) related to the likelihood to go bankrupt than for younger firms.*

Similarly, firm size represents the degree to which firms have established themselves in the market and acquired resources in any form (Audretsch & Mahmood, 1995; Hall B. H., 1988; Dunne, Roberts, & Samuelson, 1988). Moreover, company size can be seen as a proxy for firms' "[…] accumulation of basic competitive assets or skills […]" (Geroski, 1995, p. 435). Hence, a moderator effect of firm size on the relationship between patent portfolio strength and bankruptcy likelihood is expected. This leads to the following hypothesis:

H 5: *For larger firms, patent portfolio strength is weaker (negatively) related to the likelihood to go bankrupt than for smaller firms.*

4. Patent strength: Measures and empirics

4.1. Evaluation of patent portfolios

In order to assess the competitive advantage stemming from a company's patent stock or its implied disadvantage from possessing weak patents or no patents at all respectively, one has to understand the (future) benefits that can be appropriated by making use of patents. The benefits are thereby of both economic and strategic nature. As seen before, particular benefits can be obtained through (1) blocking competitors from markets, (2) securing freedom of action, (3) licensing or selling patents or (4) a combination of the three (cf. Munari & Sobrero, 2011). Furthermore, patent portfolio strength, i.e. the value of the individual patents and the number of patents within the portfolio determine the economic and strategic benefits obtainable.

Under perfect circumstances, the benefits from holding patents should equal the operating cash flow generated from their internal or external use. However, determining this is an almost impossible endeavor to undertake due to many reasons, mainly arising from the patents' "[…] intangible nature, the complex effects that they have on firm performance and the high uncertainty that typically affects their expected returns." (Munari & Oriani, 2011, p. 3)

The value distribution of patents is highly skewed (cf. Gambardella, Harhoff & Verspagen, 2008; Schankerman & Pakes, 1987; Scherer & Harhoff, 2000). This is due to the fact that patent value is industry and firm specific. For example, it is impacted by a firm's capabilities and commercialization strategy (cf. Bhatia & Carey, 2007; Ernst & Omland, 2003). Further, the value also depends on the valuing party's perception and its underlying valuation purpose (cf. Munari & Oriani, 2011; Kapoor, Karvonen & Kassi, 2013). The contexts in which patent valuation is applied vary from e.g. financial reporting requirements and stock market valuations to patent portfolio management. Accordingly, also the valuation techniques differ. An overview of the different qualitative and quantitative valuation methods is given in table 1.

Valuation context	Valuation methods
Patent portfolio management	- Patent rating/ranking - Patent indicators
Patent licensing	- Rules of the thumb - Market approach - Income approach - Real options
Patent damages	- Rules of the thumb - Market approach - Income approach
Financial reporting	- Cost approach - Income approach
IP-backed finance	- Patent rating/ranking - Patent indicators - Income approach
Stock market valuation	- Patent indicators

Table 1 - Main Contexts for Patent Valuation (Adapted from Munari & Oriani, 2011)

Given this study's aim to compare patent portfolios as knowledge resources between companies, a patent portfolio management valuation method is applied (see table 1). In particular, a quantitative patent indicator-based method will be used, since it "[…] contains various clues on [a patent's] current value" (Omland, 2011, p.170; cf. Hall, Jaffe & Trajtenberg, 2001). These indicators include for example the number of citations a patent received by other patents or the geographic region to which the protection applies. An overview of different patent indicators is provided in table 2.

One of the advantages of this method in comparison to other valuation approaches relates to the fact that it is a low-time needed, low-cost approach (cf. Omland, 2011). This facilitates the evaluation of a high number of patents as well as cross-company comparisons (cf. Brockhoff, 1992; Ernst, 1998; Omland, 2011). On the downside, not all inventions are actually patented[5], patent data is not always 100% accurate and it only becomes useful information if interpreted

[5] Some patent applications are not granted by the patent office or patenting might not be pursued for strategic reasons.

in context (cf. Arundel & Kabla, 1998; Ernst, 2001; Hall, 1988; Omland, 2011). Moreover, patent indicators only compare the strength of patent portfolios instead of quantifying their (monetary) value.

Nevertheless, patent indicators have often been used by scholars to determine a patent's underlying value. Furthermore, much effort has been made in order to identify ways to reduce potential biases and increase the wealth of information (Omland, 2011).

Similar to the patent data's wealth of information, many different patent indicators are available to be used to indicate value, most of which were used in the past. The contained information includes e.g. legal status, technological or international scope. An overview of major patent indicators and their empirical support is given in table 2.

Topic	Common indicators	Rationale	Empirical support
Legal status	Grant Y/N; Pending Y/N	Valid patents and pending applications discourage competitors to use the invention	Strong
International scope	Number of countries in which patents on the invention have been applied for; Triadic patent Y/N	Each patent is valid for a certain territory only. Covering all markets by patents thus requires significant investment. This investment indicates expected value	Strong
Forward citations	Number of citations received from later patents, corrected for time-dependency	Further investment into related developments made; invention contained useful aspects; relevance of invention in later technology space	Strong
Backward citations	Number of citations to earlier patents, corrected for time-dependency	Extent to which the patent makes use of the existing prior art	Strong
Opposition and Litigation	Survived opposition Y/N; Survived annulment Y/N; Infringement lawsuit Y/N	If competitors invest money in order to challenge the patent (or if they illegally use the technology), then this means the patent is valuable if it is upheld	Strong
Technological scope	Number of 4-digit IPC classes assigned to the patent	A broader technological scope could mean the protected market for the invention is larger	Limited (contradictory findings)
Claims	Number of claims	The breadth of the claims defines the scope and effectiveness of protection	Limited (few tests)
Patent filing strategy	Choice of PCT system Y/N (+ Misc.)	Choices in the application process may reveal patent value as perceived by the applicant	Weak (one indicator falsified, others essentially untested)
Renewals	Number of years a patent is renewed	Increasing cost of maintaining a patent	Limited (few tests)
Inventors	No. of inventors (+ Key inventor Y/N)	Number of inventors related to size of R&D investment. Patents of key inventors are more likely to be valuable	Limited (few tests)

Table 2 - Overview of Patent Data-based Indicators of Value (Adapted from Omland, 2011 and Kapoor et al., 2013)

All of the mentioned patent indicators in table 2 reflect some of a patent's inherent value. It can be argued however, that more simple patent indicators provide less information about a patent's value. The number of filings, for example, does not account for the value distribution in patents. Similarly, application does not necessarily translate into successful filings (Greenhalgh & Rogers, 2006; Haagedorn & Clod, 2003; Klepper, 1996). Hence, patent indicators that relate to a patent's particular value seem to be better suited (Traijtenberg, 1990; Albert, Avery, Narin & McAllister, 1991; Bierly and Chakrabarti, 1996; Levitas et al., 2006). These include for example international scope, forward/backward citations and opposition & litigation.[6] However, one can argue that these indicators only capture one particular aspect of what makes the value of a patent. The international scope for example does not cover to what extent the patent is important for the technology a firm is using.

In spite of its shortcomings, patent indicators have gained considerable empirical attention regarding their performance prediction usefulness. In the following, an overview of major research contributions – especially with the linkage to bankruptcy or company survival – will be given. The review also includes two non-patent indicators, i.e. R&D expenditures and new product development, since they have often been used to explain corporate bankruptcy and survival.

4.2. Previous research: Patents and Bankruptcy

The issue of bankruptcy and company survival has been on the research agenda for many years. Analyzing determinants of bankruptcy as well as general firm performance is a useful means for investors and managers of incumbent firms. Predicting bankruptcy through patent indicators has recently gained popularity.

Innovative activity expressed through R&D expenditures or patent indicators has often been found to reduce hazard rates (cf. Audretsch & Mahmood, 1995; Cockburn & Wagner, 2007; Cefis & Marsili, 2006), and increase firm performance in general (Hall & Bagchi-Sen, 2002; Sher & Yang, 2005). Despite, findings differ according to research focuses. Many scholars

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[6] In empirical research, new product development is also often taken as an early measure of firm performance. However, due to the focus on a firm's resources, this will only be taken into account when giving an overview of past research.

focus on industry-specific determinants such as technological level or industry cycle-time. However, some also analyze firm-specific determinants of bankruptcy – as is the focus of this thesis - such as age, size or patent indicators are very prominent, too.

Buddelmeyer et al. (2010, p. 278) for example put a particular focus on the “degree of uncertainty embodied in the innovation proxies” when examining innovation and company survival for Australian firms. The uncertainty pertains to three different levels: Technological, legal and market uncertainty. R&D expenditures underlie fundamental uncertainties of all three, whereas patent applications only ” […]embody legal and market uncertainty” (Buddelmeyer et al., 2010, p. 262) and granted patents have already passed the legal hurdle.[7]

As R&D expenditures, patent indicators and new product developments are most often used to investigate their effect on bankruptcy risk, we therefore focus on these in the review of the research body.

R&D

Researching and developing new technology, products, services or even processes can be considered as investment into company resources. Therefore, it is often seen as good indicator of technological advancement at the industry level but also as an indicator of technological (dis-)advantage at the corporate level, ultimately affecting financial performance. Additionally, data on R&D expenditure is well available due to separate disclosure in firms’ income statements. Hence, it is convenient to use this data to analyze its impact on financial performance in subsequent periods. Not surprisingly, various studies have investigated this relationship in a broad sense (cf. Buddelmeyer et al. 2010; Esteve-Perez & Manez-Castillejo, 2008; Greenhalgh & Rogers, 2006; Ortega-Argiles & Moreno, 2007; Segarra & Callejon, 2002). Various authors found R&D expenditures to be particularly important for firm survival (cf. Esteve-Perez & Manez-Castillejo, 2008; Sueyoshi & Goto, 2009) and positively related to a firm’s competitive position in general. This can be explained by R&D resulting in superior knowledge or better processes, products or services of a firm (cf. Ortega-Argiles & Moreno, 2007). These results are in line with the KBV / RBV as learning contributes to building necessary resources leading to competitive advantages and avoiding bankruptcy. However, from a management perspective, this insight falls short in providing meaningful guidelines as

[7] Cf. Audretsch (1995).

to which projects and which technologies a firm should invest in not to run the hazard of "betting on the wrong horse" potentially risking bankruptcy.

Furthermore, empirical findings are not all consistent as they seem to vary according to an industry's technology intensity or a firm's maturity level. Geroski (1995) and Ortega-Argiles and Moreno (2007) found that the likelihood of survival decreased with increasing R&D intensity in the industry. Segarra & Callejon (2002) as well as Audretsch & Mahmood (1995), however, find this relationship only for firms entering a market. The latter is in line with Audretsch (1995) and Audretsch, Houweling and Thurik, (2000) who found that there is a threshold time after which the likelihood of survival increased (again) for incumbent firms in a "[…] turbulent and innovative environment [...]" (Audretsch, 1995 in Segarra & Callejon, 2002, p. 11). This notion of "adolescence" (Esteve-Perez & Manez-Castillejo, 2008, p. 231) fits with the "liability of 'newness'" (Esteve-Perez & Manez-Castillejo, 2008, p. 233), implying that new firms are more prone to go bankrupt as they first have to undergo a period of learning and establishment of functioning business structures. Similarly, Ortega-Argiles & Moreno (2007, p. 19) claim that "R&D activities contribute to building a stock of knowledge that increases the market value of the firm and consequently its likelihood of survival."

Moreover, Greenhalgh & Rogers (2006) found that from a market value perspective, R&D valuation was rather low in highly competitive "science-based" sectors where R&D expenditure levels are high in general. Finally, the relationship of R&D and company knowledge and thus the filing for patents is not necessarily linear, as firms with smaller R&D budgets seem to be more efficient when it comes to patenting (cf. Bound, Cummins, Griliches, Hall & Jaffe, 1984).

Intellectual Property – Patent applications and granted patents

In comparison to R&D expenditures, intellectual property is considered one step closer to firm performance since it can be seen as the output of successful research and development provided that it reflects their economic results (Ernst 1995; Ernst 2001; Eisdorfer & Hsu, 2011; Griliches, 1990). Furthermore, it entails a lower degree of uncertainty. This is due to the fact that technological uncertainty (for patents and applications) and most legal uncertainty[8] (for patents and trademarks) are already overcome (cf. Buddelmeyer et al., 2010). However, "given the absence of proper accounting standards for intangible capital […]" (Buddelmeyer et al., 2010, p. 265), researchers often rely on patent indicators to study its relationship with business performance and failure. These include mainly patent applications, patent number, patent citations and/or trademarks[9]. The different focus of trademarks however makes it difficult to use for an analysis of technology industries despite its broad use in various industries, from manufacturing to services (cf. Buddelmeyer et al., 2010). Therefore, trademarks are not considered in the present. In the following, an overview of the main research contributions will be given.

Surprisingly, Buddelmeyer et al. (2010) find that investments in radical innovation, measured by *patent applications*, tend to increase the hazard rate of a company. They conclude that this is due to the fact that a company is substantially more vulnerable in the years after the deliberate R&D investment. Cockburn and Wagner (2007), however, find that companies lacking patent applications face a higher bankruptcy risk. However, the authors studied only internet-related firms that went public before the dotcom crisis. Complementing their own finding, Buddelmeyer et al. (2010) furthermore find that high *patent stock* in force does lower the bankruptcy rates for the analyzed firms.

Confirming the finding of Buddelmeyer et al. (2010) on patent stock, Eisdorfer & Hsu (2011) conclude in their study that firms active in a high-tech industry and with a low number of recently *granted patents* face higher bankruptcy risk than firms with a rather high number of active patents. Furthermore, they show that high "technology competition" – defined as "the ability of a firm to create patents, adjusted to its R&D effort [...] and the intensity of the technology competition in the industry the firm belongs to." – explains bankruptcy to some extent. They argue that this is due to the fact that patents can tell much more about a firm's status in the "technology race" (Eisdorfer & Hsu, 2011, S. 1089) than financial indicators

[8] Buddelmeyer et al. (2010) do not claim that R&D expenditures entail legal – only technological and market – uncertainty. However, since part of the R&D is likely to result in intellectual property we argue that it entails a certain degree of uncertainty before the potential application and filing as IP.

[9] In research, further proxies regarding for example patent opposition, technological scope, claims or inventors are used as indicators of value, too. In this literature review however, we focus on the predominant ones.

only (e.g. Altman Z-Score or credit ratings), especially in industries were patents and technology as such are vital.

Generally, most presented findings seem to be in line with the KBV in that patents represent important knowledge resources and also support our hypothesis that its absence can lead to a comparative disadvantage. It is noteworthy, that the size of the patent portfolio was found to decrease bankruptcy probability while patent applications seem increase it. However, these studies focused only on the quantity of patents, rather than a combination of both quality and quantity. As patent differ in value, the impact of patent portfolio *strength* on bankruptcy is still unknown.

Intellectual Property – Patent strength

Looking at the *strength of a patent*, little research has been done with regards to performance and bankruptcy although it is probably the most indicative technology measure available as seen before. Chen and Chang (2010) investigated the market value effect of US pharmaceutical firms' *revealed technology advantage*[10], their *relative patent position*[11]*, patent citations* (forward and backward, see table 2) and the *Herfindahl-Hirschmann Index*[12] applied to patents. Their findings suggest that these firms "should increase their leading positions in their most important technological fields, cultivate more diversity of technological capabilities, and raise innovative value of their patents" (Chen & Chang, 2010, p. 20). This confirms that the quality of patents is a factor influencing company performance, especially with regards to a company's most important technology fields. This notion is supported by a study of the German machine-tool industry (Ernst, 2001) which showed that increasing patent quality, reflected by high *market coverage* of a patent, leads to greater sales increases.

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[10] A firm's patent concentration implies a corporate advantage in one particular technological field compared to other firms, i.e. RTA for a given firm in a given field is the firm's share of patenting in one particular technological field divided by the firm's share of total patenting in all fields. Thus the higher the value the better. (cf. Granstrand, Patel & Pavitt, 1997)

[11] Relative patent position refers to a firm's the number of patents in its most important technological field divided by the number of patents of the leader in the technological field. Hence, the maximum value is equal to 1, when the firm itself represents the leader that is (cf. Ernst, 1998)

[12] The Herfindahl-Hirschmann Index is generally used to measure industrial concentration, giving clues about oligopolistic and monopolistic structures. Applied to patents, this index measures evenly patents are distributed among the market participants. (Hall & Bagchi-Sen, 2002)

Additionally, Levitas et al. (2006) found that the value of an innovation – in their case measured as an overall firm level average *number of forward citations* (see table 2) - is indeed an important determinant of a firm's probability to exit. However, the value alone seems not to be sufficient to explain the impact of new technology on survival (or bankruptcy likewise) but also the current turbulence[13] of the industry is important. Cockburn & Wagner (2007) on the other hand did not find evidence that patent portfolio strength or patent quality indicators (forward citations and market coverage) can explain bankruptcy. They only find it to be a quality signal for buyers of a firm.

Taking into account Cockburn & Wagner's (2007) insights, previous investigations of patent quality and financial performance seem somewhat ambiguous. However, since Cockburn & Wagner (2007) only studied internet-related IPOs, the importance of patent strength on bankruptcy might still hold for (other) technology industries.

New Product Development

While intellectual property is regarded a resource, *new product development* can be seen as the output of resources since most patents are applied in order to produce physical goods (Kleinknecht & Reinders, 2012). New product announcements are sometimes also referred to as an indicator of "[…] level of product innovation" (Hagedoorn & Cloodt, 2003, p. 1366). Major research contributions with regard to company performance are presented in the following.

According to Banbury & Mitchell (1995), successfully *developed products* seem have a positive effect on business survival. Similarly, a positive relationship with regards performance – in this case with regards to product sales, total revenue, export and pretax profit growth – was found by Hall & Bagchi-Sen (2002). In their study of the Canadian biotechnology industry, they did however not encounter a relationship between patents or patent applications on one side and firm performance on the other side. Their findings further point to the fact that success also entails the capability to *commercialize* a firm's patent

[13] Levitas et al. (2006, S. 183) define turbulence "[…] as the rate at which new knowledge is being introduced into the market and is a gauge of the external environment's willingness to accept technological change."

resources to positively impact performance (and avoidance of bankruptcy) (cf. (Ernst, 2001). This is not only contingent on the internal capabilities and the strategic fit but also on the clear need of the market (cf. Hall & Bagchi-Sen, 2002), no matter if it is already existing or created by the company itself. Ortega-Argiles & Moreno (2007) second the notion that a firm's capability to produce new products has a crucial effect on its survival. Interestingly though, this was not the case for product innovations of large firms. However they fall short in providing a theoretically grounded explanation for this.

The last findings confirm our argument above, that not only the patent portfolio strength per se, but also the strategic fit in relation to it are crucial for success and survival (see figure 1, section 3.1.). Firms need to have a strategy in place that allows them to most effectively exploit their resources, for example through the development of new products based on their technological know-how.

Table 3 presents an overview of the major research contributions with regard to patent indicators and bankruptcy or survival.

Authors	Sample	Dependent variable	Independent variables		Method	Main findings
Audretsch (2000)	2,017 Dutch manufacturing companies that started between 1978 and 1982 (tracked until 1992)	Survival	- Startup size - Scale economies (share of energy and depreciation cost) for industry and firm - Industry price–cost margin - R&D industry importance	- Industry sales growth rate - Industry entry rate - Firm debt structure - Startup year cohort dummy	Logit regression	Firm characteristics increasing survival likelihood: - firm age and firm size Industry characteristics decreasing survival likelihood: - R&D intensity - Capital intensity - High importance of scale economies
Segarra & Callejón (2002)	(All) 7.561 Spanish Manufacturing companies founded in 1994 (observed until 1998)	Firm exit	- Industry growth - Advertisement - R & D - Entrants Size	- Mobility - Percentage of small entrants - Entry rate	Cox regression hazard function	Hazard rate is negatively relatd to: - Initial firm size - Industry growth rate - Mobiliy of a firm (quick size adjustment capacity) - Industries characterized by market power and positively related to: - Innovative environments - Advertisement competition industry
Levitas et al. (2006)	295 American integrated circuit manufacturers (163 bankruptcies)	Survival	- Firm level average citation ratio - Firm level average technology cycle time ratio - Total number of applied and granted patents within time frame and industry (technologic al turbulence) - Firm age - Firm size	- Population density - Total market ($) - Left censored (founding time) - Patenting firms dummy - Diversification dummy	Logistic regression	- During periods of low technological turbulence, firms utilizing new technologies to create significant technological advances, face a higher probability of failure - During periods of high technological turbulence, firms using older technology to develop significant technological advancements face lower probabilities of failure
Cockburn & Wagner (2007)	356 internet-related firms that IPO'd (NASDAQ) Feb 1998-Aug 2001. (followed until 2005)	Survival	- Industrial classification - Cashburn rate - Sales - Operating income - Age at IPO - Total assets - Cash & short term investment rate - PPE rate - Average NASDAQ composite index before IPO - Number of patents - International scope of filings - Patent value proxies	- Patent stock or application (yes/no) - Number of USPTO patent applications and grants - Number of European and Japanes patent applications and grants - Average family size of a firm's USPTO patents - Average number of forward citations received per grant or application - Number of forward citations per claim	Adapted Cox's proportional hazard (PH) model	- Positive association of patenting and firm survival, excluding business method patents - Negative effect of patent applications on acquisition likelihood - though obtaining unusually highly cited patents increased acquisition attractiveness
Ortega-Argiles & Moreno (2007)	Spanish Manufacturing Firms (obtained from ESEE)	Survival	- Marginal price-cost ratio - Advertising investment (yes/no) - R&D investment (yes/no) - Product innovation/enhancement (yes/no) - Productin material (new/old) - Components/intermediary products (new/old) - Product function (new/old) - Number of process innovations - Machinery used (new/old)	- Production organisation (nwe/old) - Organisation AND production method improvement (yes/no) - Firm size (employees) - Firm age - Capital s ource (foreign/domestic) - Technology level (low/medium/high) - Year dummy	Duration analysis (Cox Model, lognormal and log-logistic model)	Positive relationship with firm survival: - R&D and price differentiation strategy on survival, but not for advertising - New product development or design - Use of new machinery or simultaneous changes of organization and machinery - Firm size and age, but non-linear - The level of technology Negative relationship with firm survival: - Presence of foreign capital

Table 3 - Overview of Major R&D and Patent related Bankruptcy Empirics

Authors	Sample	Dependent variable	Independent variables		Method	Main findings
Estevez-Perez & Manez-Cantillejo (2008)	2028 Spanish Manufacturing firms in 1990 (observed until 2000)	Survival	- Size - Advertising - R&D - Industry technological intensity - Productivity - Price-cost margin	- Price-cost margin - Exporting intensity - Limited liability (yes/no) - Foreign capital participation - Year dummy - Size (small/large)	Hazard regression models	- Advertising and R&D are crucial determinants of survival, the latter being positively affected by - industry technologicy intensity - Impact of age on survival in line with liablity of "adolescence" and "senescence" - Increased survival prospects of more productive international market-oriented firms
Sueyoshi & Goto (2009)	Listed Japanese machinery (171 non-default , 2002-2004, 9 default 1995-2003) and electric equipment firms (203 non-default 2002-2004, 11 default 1998-2006)	Bankruptcy	- Adjusted Altman Z-Score - R&D		Data envelopment analysis–discriminant analysis	- Positive impact of R&D expenditure on the financial performance of Japanese machinery industry, but negative on Japanese electric equipment industry
Buddelmeyer et al. (2010)	299,038 Australian employing companies (1997-2003)	Survival	- Capital stock - Industry conditions - Strength of Macro-economy - Company size - Company ownership - Company wage bill	- Trademark applications - Design applications - Patent applications - Rate of interest - Industry dummies (propensity to patent, patent effectivenss against imitation, regional concentration, export dependency, reliance on domestic demand)	Piecewise-constant exponential hazard rate model	- Pattern of company survival is shaped by degree of uncertainty embodied in different innovation proxies - Radical innovation investment leads to financial vulnerability in the short term - Companies that have patents which are worth renewing also possess the bundle of financial, management and economic capabilities that raise their chances of survival Positive effect on company survival of: - Macroeconomic conditions and interest rates - Trademark applications and stocks
Eisdorfer & Hsu (2011)	5.024 public high-tech US firms (1975-2005)	Bankruptcy	- Ability to patent adjusted for R&D - Industry technology competition intensity (# of patents) - Altman Z-score	- KMV - Credit rating	Logit regression	High importance of technology competition in corporate bankruptcy - Increase in patent activity, especially in technology-intensive industries, leads to more bankruptcies - Number of patent issues in a technology-intensive industry is positively associated with bankruptcy among the firms in the industry that did not receive patents recently

Table 31 - Overview of Major R&D and Patent related Bankruptcy Empirics (cont’d)

The finding that no single indicator appears to capture the value of a patent in its entirety and the partial ambiguity of previous research results, give reasons to believe that a combination of multiple indicators may be superior. Support for this theory is provided by various scholars (cf. Lanjouw & Schankerman, 2004; Hagedoorn & Clodt, 2003; Harhoff, Scherer & Vopel, 2003; Gambardella et al., 2008). Therefore, a combination of indicators will be used for the present study in order to measure a company's patent portfolio strength. In the following, the PatentSight measure to assess patent strength, the Patent Asset Index, will be introduced alongside the underlying individual indicators.

4.3. PatentSight and the Patent Asset Index

PatentSight[14] constructed an international database with different patent indicators. Global patent office data is thereby combined with company directory data[15] to assign patents, patent families[16] and applications to the respective holders. The patent inherent information is used to compute a standardized patent indicator to measure the strength of a company's patent portfolio by assessing the value of each individual patent family. The patent portfolio strength, measured by Patent Asset Index (PAI), is based on three pillars: (1) technology relevance, (2) market coverage and (3) portfolio size. All three pillars have empirically been verified as value indicators as seen before.

Technology Relevance is defined as "[…] the number of worldwide patent citations received by a patent family, corrected for patent age, patent office citation practices and citation differences between technology fields" (Ernst & Omland, 2011, p. 36). These adjustments are made to account for the time-dependence of citation counts, different patent office practices and citation differences between technology fields. (Ernst & Omland, 2011)

The second stand-alone patent indicator, Market Coverage, refers to the geographic scope of a patent family. It takes into account the "market size covered by valid patents and published pending patent applications" (Ernst & Omland, 2011, p. 36) adjusted for the average patenting

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[14] PatentSight (www.patentsight.com) is a German university spin-off.

[15] Here, the well-established database of Bureau van Dijk is used (http://www.bvdinfo.com/en-gb/home).

[16] A patent family is a group of individual patents that share major characteristics (same invention and same priority) or identical patents filed at different patent offices (cf. Ernst & Omland, 2011).

probability of applications (approx. 70%) and the country-specific GDP. (Ernst & Omland, 2011)

The combination of both Market Coverage and Technology Relevance results in the measure of Competitive Impact, which indicates the average patent strength of a particular company's patent portfolio. Finally, the Patent Asset Index represents the absolute patent strength of the portfolio, i.e. adjusted for the portfolio size including granted, active and patents under examination.

In summary, the PAI intends to balance several major single patent indicators: Patents filed, patent applications, forward citations and international scope. Despite the adjustments made to the individual indicators, some of the aforementioned fundamental issues pertaining to patent indicators in general and those used here in particular do still apply. For example, the potential inaccuracy of patent data cannot be eliminated and some of the adjustments, such as the patenting probability are only proxies and should be seen as such. Moreover, the indicator does not yield an absolute monetary value of patent portfolio which could then be compared for, e.g., the R&D expenditures incurred. The patent strength indicator rather suggests whether or not a portfolio is stronger or weaker than, for example, a competitor's portfolio. Last but not least, it is important to note that "[…] the choice of the benchmarking methodology has impact on the results" (Ernst & Omland, 2011, p. 40), implying that it might be advisable to deploy several methodologies or information sources in order to arrive at a meaningful value.

Nevertheless, the PAI shows advantages as it combines several individual quality indicators to demonstrate "[…] a firm's level of important intellectual assets that create competitive advantage and hence economic returns" (Ernst & Omland, 2011, p. 38). Hence, it used to approximate a company's patent portfolio strength for the purposes of this study.

5. Methodology

The present study comprises a detailed analysis of the proposed research question and tests the theoretically founded hypotheses derived in chapter 3. In order to achieve maximum meaningfulness of our study, a comprehensive data sample was constructed, as outlined in the following section. This data served as a basis for the statistical analyses. The second section explains the operationalization of the hypotheses by introducing the dependent, independent and control variables deployed in the analysis. The last section of this chapter discusses the statistical methodologies applied to test the hypothesis.

5.1. Sampling

As outlined in section 3.2., our analysis focusses on firms from technology intensive industries. Therefore, the focus industries will be defined first. Secondly, the analyzed time frame had to be defined before the analysis sample (section 3) and the control sample (section 4) were constructed.

5.1.1. Technology industries

Since the focus of this study is to investigate the relationship between patent strength and a firm's likelihood to go bankrupt, the analysis is limited to technology industries only, as reasoned in section 3.2. Technology industries are defined as all industries related to the originating, manufacturing or processing of physical goods. In this sense, all industries with Standard Industry Classification (SIC) codes starting with the digit 1, 2 or 3 are subsumed under this term. This definition excludes industries such as Transportation & Public Utilities, Wholesale Trade, Retail Trade, Finance, Insurance, Real Estate, Services and Public Administration.

5.1.2. Analysis horizon

This study's analysis is limited to corporate bankruptcies during the time from January 2006 to October 2013. Due to the fact that digitalized patent data has become reliable not until after the turn of the millennium, the sample was taken for bankruptcies occurring since 2006 in order to allow analysis of the years preceding the bankruptcy without causing distortions through incomplete or misleading data. Furthermore, this horizon includes observations before, during and after the recent financial crisis allows for a more holistic examination. As Denrell (2003) noted, the limitation of the analysis only to the time before or after a crisis can cause a systematic bias to the data. However, to avoid distorted results the temporal dimension is controlled for by partly matched sampling, as explained below.

5.1.3. Sample collection procedure and data sources

The sample collection was carried by using multiple established databases. Initially, following Greenhalgh & Rogers (2006), all at the beginning of 2006 publicly listed US companies were collected through Thomson One Banker. Subsequently, out of these all firms that filed bankruptcy under chapter 7 or 11 of the US Bankruptcy Code during the analysis time horizon were identified. Thomson One Banker *Screening* contained 2616 that changed status from "active" to "inactive" during this time. Since not all of these companies filed for bankruptcy, a cross-verification with three other sources was conducted. Firstly, 286 bankruptcy cases were retrieved from the Thomson One Banker *Deals database*. Secondly, in line with Begley, Ming and Watts (1996) and Franzen, Rodgers and Simin (2007), further bankruptcy cases were collected from and cross-checked with the LexisNexis *Bankruptcy Datasource*, which contains public notifications for US listed companies filing for bankruptcy. To ensure completeness, the LoPucki *Bankruptcy Research Database* from the UCLA School of Law was also used as cross-reference. After cross-checking all databases, duplicates were removed and a preliminary sample of bankruptcy cases was identified.

For all of these firms, patent data was collected from PatentSight's database. Financial data was obtained from Thomson One Banker. Additional company information such as age and date of the bankruptcy filing were retrieved from the Bureau van Dijk's database *Orbis* and LexisNexis respectively. Cases with missing or incomplete firm or financial information for the last 3 years before bankruptcy were excluded. This resulted in a final sample of 440 bankruptcy firms. The final sample consisted of 220 US public listed firms that filed for bankruptcy between 2006 and October 2013.

For the purpose of this analysis a control group of firms not going bankrupt was constructed. This was done by applying partly-matched random sampling. The population from which control frims were drawn contained all US firms within the focus industries that have been publicly listed at the beginning of 2006, have until the end of the analysis horizon not filed bankruptcy and for which data was available on Thomson One Banker. In order to account for industry factors that were not separately controlled for in the following analysis, the control sample was matched by industry belonging. That mean for each bankrupt company, one non-bankrupt company was randomly drawn from the same 3-digit SIC code. In the rare event that no matching case was available with the same 3-digit SIC, a substitute case was randomly picked from the universe of cases that belonged to one of the surrounding 3-digit SIC in order to assure maximum adherence to the industry matching principle. Furthermore, temporal distortions of the analysis, e.g. from macro-economic factors (see above), were avoided by temporal matching. This means, that for the industry-matched non-bankrupt case the reference year of analysis was set equal to its bankrupt counterpart, with which the industry was matched.

At the end of the sampling procedure, one analysis sample containing 220 former publicly listed US bankruptcy firms and one control sample containing 220 randomly drawn but temporal- and industry-matched non-bankrupt publicly listed US firm were defined. These in total 440 cases constitute the data set for the further analysis in this study.

5.2. Definition of variables

In the following, the variables applied in this study to test the hypotheses (chapter 3.2) and their data sources are presented. Some of these variables have been transformed in order to satisfy the underlying statistical assumptions of the analysis techniques (see section 5.3), to avoid distorted results or to enhance the quality and interpretation of results (cf. Pallant, 2007; Kohler & Kreuter, 2008). This is highlighted in the following where applicable.

An overview of all variables used, their underlying measures and their transformation is given in Table 4 at the end of this chapter.

5.2.1. Dependent Variable

Due to the purpose of this study, the dependent variable Bankruptcy is a dichotomous indicator variable. It takes the value zero (0) for non-bankrupt firms in the control sample and the value of one (1) for bankrupt firms in the analysis sample.

5.2.2. Explanatory Variables

In order to test our hypotheses, patent portfolio data and interaction terms including patent portfolio variables are deployed as explanatory variables.

5.2.2.1. Patent variables

Patent portfolio strength

A firm's patent portfolio strength is defined by the PatentSight Patent Asset Index (PAI; see above). PAI is the absolute measure of a company's patent portfolio strength and represents the synthesis of the indicators Market Coverage, Technology Relevance and Portfolio Size.

PAI values for the end of the year previous to the bankruptcy or reference year respectively were obtained from the PatentSight database by manual search for each firm. Firms without any patent portfolio have PAI value of zero. The PAI measure was log transformed in order to approximate normal distribution and mitigate its skewness. As the indicator can take the value of zero, for which the logarithm is not defined, we followed Whittaker, Whitehead and Somers (2005) and transformed the variable as follows: *log*(x+1). Moreover, to allow more convenient interpretation and reduce collinearity in combination with interaction terms (see below), the variable is centered by its mean Kohler & Kreuter (2008). The resulting variable is labelled *Portfolio strength*.

Patent portfolio strength growth

In order to measure the development of a company's patent portfolios strength, the growth rate of the PAI is deployed. It is calculated as the percentage change in PAI over three years preceding the bankruptcy or reference year respectively (i.e. change from year Y-4 to Y-1, with Y0 being the bankruptcy or reference year). This variable is labelled *Portfolio Strength Growth.*

5.2.2.2. Interaction terms

In order to analyze how the relationship between patent portfolio strength and bankruptcy probability is moderated by other factors, interaction terms are calculated. In line with Kohler & Kreuter (2008), the (centered) moderating variable is multiplied with the (centered) variable for patent portfolio strength.

Interaction effect of Industry technology focus

In order to analyze if the influence of the patent portfolio strength on the likelihood to go bankrupt is dependent on a company belonging to a high- or low-tech industry, the interaction variable *Portfolio strength x industry techn. focus* was introduced.

Interaction effect of Age

The interaction term *Portfolio strength x Age* measures if the influence of the patent portfolio strength on the likelihood to go bankrupt is contingent on the company's age.

Interaction effect of Size

The moderator effect of company size on the relationship between patent portfolio strength and bankruptcy likelihood is labelled *Portfolio strength x Total Assets*.

Table 4 gives an overview of the used variables and their definition

5.2.2.3. Control variables

As control variables, financial as well as non-financial firm specific indicators were applied. These are mostly in line with previous findings on bankruptcy causes or prediction. The specific variables used will be presented in the following. It noteworthy, that data for most financial control variables is taken from the second preceding year of the bankruptcy. This is done for reasons of better data availability.

Altman Z-Score

The Altman Z-score is one of the most commonly used indicators to predict corporate bankruptcy in research and practice (Apergis, Sorros, Artikis, & Zisis, 2011; Dichev, 1998). Altman (1968) derived this linear model applying multiple discriminant analysis. It consists of five weighted financial ratios resulting in an overall index ("Z-score"), which is an indicator of the firm's financial position and a measure of the company's risk of bankruptcy (Altman, 1968; Apergis, Sorros, Artikis, & Zisis, 2011). According to Altman (1968), Z-scores of $Z > 2.675$ distinguish companies that are unlikely to go bankrupt. The range of $2.675 \geq Z \geq 1.81$ is defined as "grey zone". Z-scores within this range do not allow clear distinction between bankrupt and non-bankrupt firms. Z-scores of $Z < 1.81$ indicate firms that are likely to go bankrupt. Altman (1968) finds his model's to be highly accurately predicting bankruptcy. The combined average error is found to be 5%, meaning that the model correctly classifies 95% of the sample's firms as either bankrupt or non-bankrupt.

The commonly applied formula for stock exchange listed manufacturing firms – which will also be used throughout this paper – is as follows:

$\mathrm{Z} = 1.2\,\mathrm{X}_1 + 1.4\,\mathrm{X}_2 + 3.3\,\mathrm{X}_3 + 0.6\,\mathrm{X}_4 + 0.999\,\mathrm{X}_5$, with

$X_1 = \frac{Working\ capital}{Total\ assets}$,

$X_2 = \frac{Retained\ earnings}{Total\ assets}$,

$X_3 = \frac{Earnings\ before\ interest\ and\ taxes}{Total\ assets}$,

$X_4 = \frac{Market\ valuee\ quity}{Book\ value\ of\ total\ debt}$'

$X_5 = \frac{Sales}{Total\ assets}$ and

$Z = \ Overall\ index$ (Altman, 2000).

Despite much criticism in the past (cf. Appiah & Abor 2009; Joy & Tollefson 1975; Moyer 1977; Wu, Gaunt and Gray 2010) the Altman Z-Score is still a recognized indicator of financial distress and widely applied among scholars and practitioners (Berger, Ofek, & Swary, 1996; Eisdorfer and Hsu, 2011; Francis, 1990; Pastena and Ruland, 1986; Subramanyam and Wild 1996); more than for example the Ohlson (1980) O-Score or other financial bankruptcy predictors.

The necessary data to calculate the Z-score was obtained from Thomson One Banker, as outlined above. The distribution of the Z-score was highly skewed and had several outliers. To reduce potential distortions, the variable was winsorized at 5% and 95% level (cf. Hastings, Mosteller, Tukey & Winsor, 1947) and transformed. Due to the possibly negative values of the Z-score, a cube root transformation ($x^{1/3}$) yielded the best results (Cox, 2007). The variable is labelled *Z-Score* in the model.

Firm Size

Many researchers have found company size to be positively related to firm survival (e.g. (Geroski, 1995; Audretsch & Mahmood, 1995; Mata & Portugal, 1994; Jovanovic, 1982; Hall B. H., 1988; Dunne, Roberts, & Samuelson, 1988; Dunne, Roberts, & Samuelson, 1989; Ohlson, 1980; Evans, 1987). Geroski (1995) explains these findings by arguing that firms' growth and survival are positively influenced by their ability to learn and adapt to their environment. Firm size can be seen as a proxy for firms' "[…] accumulation of basic competitive assets or skills […]" (Geroski, 1995, p. 435).

We follow Franzen et al. (2007) and Sorescu & Spanjol (2008) measuring firm size as total assets. Due to its skewed distribution we log transform the variable. As for *portfolio strength*, this variable is centered by its mean to ease interpretation and reduce collinearity. The variable is labeled *Size*.

Firm Age

Another factor that is used to explain the occurrence of bankruptcy is the age of a company (Geroski, 1995; Audretsch & Mahmood, 1995; Mata & Portugal, 1994; Jovanovic, 1982; Dunne, Roberts, & Samuelson, 1988). It is thought to be a proxy for a firm's accumulated learning (Geroski, 1995). Hence, the company's age in years at the time of bankruptcy or reference year is described by the variable *Age*. The data was obtained mainly from Thomson One Banker and Bureau van Dijk's Orbis database. As with other variables, log transformation was performed to compensate for a skewed distribution. Furthermore, the variable is centered by its mean, increasing ease of interpretation and reducing collinearity.

Growth: Sales Growth

Previous researchers have found firm growth to influence bankruptcy probabilities. The direction of relationship is however unclear. Some scholars associate positive firm growth with survival (cf. Evans, 1987). Others found high growth rates to explain bankruptcy (cf. Jovanovic, 1982) as high growth is often displayed by young companies which in turn are more likely to fail. Either way, it can be seen as relevant factor for bankruptcy occurrence and is thus included. Following Kannebley, Sekkel and Araujo (2010) and Platt & Platt (1990) it is measured in terms of compounded annual sales growth rate for the three preceding years before bankruptcy (year 5 to year 2 prior to the occurrence of bankruptcy). Sales data has been gathered from Thomson One Banker in order to compute the growth rate. The variable is labelled *Sales Growth*.

Industry Technology Focus: High- vs. Low-Tech

In order to be able to differentiate between high and low-tech firms and their relationship with the prediction of bankruptcy, a dummy variable was introduced to the model. In the light of previous research (cf. Sueyoshi & Goto, 2009; Levitas et al., 2006), it is expected that the belonging to a high-tech industry comes at a higher bankruptcy risk than for low-tech industries. The variable is dichotomous where a value of 1 indicates a high-tech and a value of 0 indicates a low-tech firm. It is labelled *Industry techn. focus.*

Variable	Definition	Point in Time[1]
Bankruptcy	1 = bankrupt 0 = not bankrupt	n/a
Age	Logarithm of company age	Occurrence of bankruptcy
Industry techn. focus	Technology intensity indicator 1 = high; 2 = low	n/a
Sales growth	Compound annual Sales growth	4 yrs. to 1 yr. prior to bankruptcy
Size	Logarithm of total assets (i.e. company size)	2 yrs. prior to bankruptcy
Altman Z-Score	Cubic root of winsorised Altman Z-Score	2 yrs. prior to bankruptcy
Portfolio Strength	Centered modified $\log^2$ of Patent Asset Index™	1 yr. prior to bankruptcy
Portfolio Strength Growth	Compound annual Patent Asset Index™ growth	4 yrs. to 1 yr. prior to bankruptcy
Portfolio strength x industry techn. Focus	Interaction term between centered modified $\log^2$ of Patent Asset Index™ and technology intensity	1 yr. prior to bankruptcy
Portfolio strength x Age	Interaction term between centered modified $\log^2$ of Patent Asset Index™ and centered logarithm of company age	1 yr. prior to bankruptcy
Portfolio strength x Total Assets	Interaction term between centered modified $\log^2$ of Patent Asset Index™ and centered logarithm of total assets	Y1 and Y2 prior to bankruptcy

[1] "prior to bankruptcy" always refers to the case in the sample. For non-bankrupt firms it refers to the time and industry-matched bankrupt counterpa

Table 4 - Variable Definition Overview

5.3. Statistical methods

In order to analyze the data set and test the hypotheses, different statistical techniques were used. These will be outlined in the following.

5.3.1. Descriptive statistics

To gain first insights about the sample's characteristics, frequencies, distribution measures and other descriptive statistics were analyzed first. More specific, an overview of the industry distribution of bankrupt firms is provided. Also, temporal distribution of bankruptcy cases is presented. Furthermore, key statistics on mean, median, standard deviation and binary correlation of the continuous variables are given to obtain a better understanding about their distribution and relationship. The section concludes with an overview of the patenting activity of the observed companies to get a first impression on the topic of major interest.

5.3.2. Univariate analysis

In this part, t-tests are performed for the variables in focus, comparing mean values between bankrupt and non-bankrupt firms. That is to understand if there are statistically significant differences between bankrupt and non-bankrupt firms. This will provide further understanding of the sample and give first indications about the proposed hypotheses.

5.3.3. Multivariate analysis

In order to test the proposed hypotheses logistic regression analysis is performed. This particular method was chosen due to the dichotomous nature of the dependent variable "bankruptcy", as explained in part 5.2.1. This approach is in line with previous studies of bankruptcy or survival prediction by means of patent data (Audretsch, 1995; Eisdorfer & Hsu, 2011; Levitas et al. 2006). Furthermore, logistic regression has less strict underlying assumptions than other statistical methods and allows inclusion of continuous and categorical independent variables as well as interaction terms. Furthermore, it facilitates convenient interpretation of results in terms of probabilities and odds.

In total, seven logistic regression models were calculated to test the hypothesis. Table 5 presents an overview of the different models. Comparison between different models is done by deploying likelihood ratio tests.

Variable	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**
Altman Z-Score	✓	✓	✓	✓	✓	✓	✓
Industry techn. focus		✓	✓	✓	✓	✓	✓
Age		✓	✓	✓	✓	✓	✓
Sales growth		✓	✓	✓	✓	✓	✓
Size		✓	✓	✓	✓	✓	✓
Portfolio strength			✓		✓	✓	✓
Portfolio strength growth				✓			
Portfolio strength x industry techn. focus					✓		
Portfolio strength x Age						✓	
Portfolio strength x Total Assets							✓
Hypothesis			*H1*	*H2*	*H3*	*H4*	*H5*

Table 5 - Overview of Logistic Regression Models

Model 1 is a simple model only including *Altman's Z-Score* in order to analyze how much of the bankruptcy probability can be explained by using this widely established predictor.

The benchmark model with all control variables selected (*Age*, *Sales growth*, *Size*, *Altman Z-Score* and *Industry technology focus*) is presented in *model 2*.

Model 3 includes the first patent indicator, the *Portfolio Strength*, in addition to the control variables in order to test the first hypothesis (*H1*).

Similarly, *model 4* incorporates *Portfolio strength growth* together with the set of control variables thereby testing *H2*. Finally, *Models 5-7* contain the different interaction terms based on the combination of *portfolio strength* and *industry technology focus*, *age* or *size* respectively in order to test hypotheses *H3-H5*.

5.4. A critical reflection on methodological limitations

In order to assess the credibility of the statistical research performed, it is important to analyze three major aspects of the study: reliability, validity and generalizability (cf. Saunders, Lewis & Thornhill, 2009). These will be discussed in the following.

Reliability

The concept of "reliability refers to the extent to which your data collection techniques or analysis procedures will yield consistent findings" (Saunders et al., 2009, p. 156). It furthermore questions the repeatability by oneself, the duplicability by others with similar outputs as well as the transparency of the sense-making process from the raw data (cf. Easterby-Smith, Thorpe, Jackson & Lowe, 2008). Applying this concept to the present study, one can say that overall the study is reliable. The data gathering and analysis was described in particular detail and according to statistical standards such that the results could be reproduced either by us or a third person with access to the same financial and patent data. Since mostly "hard data" such as financial and patent data were used, subject and observer bias for the data are minimal. However, since patents can be traded and the patent strength indicator contains time-dependent (weight) factors e.g. in the Technology Relevance, the indicators change with time and patent ownership.

Validity

Saunders et al. (2009) propose to test validity of the conducted research in order to assess if the study does measure what it aims to measure and if the relationship between observed variables is causal or not. The review of theory and previous research revealed a gap that this study is contributing to close. Hypotheses about causal relationships were formulated based on the current state of research. The methodology chosen to test these hypotheses is suitable and has been described above. Moreover, distortions by the factor time were minimized by obtaining all data at one point in time and as reported to the SEC. Patent data was obtained in between two database updates in order to avoid distortions through time or ownership dependent patent strength changes.

However, while the inclusion of three distinct economic periods – before, during and after a financial crisis – in the observation avoids a time related selection bias, the companies might have changed behavior or their strategy in the aftermath of the crisis.

Secondly, on a related note, potential interdependence of companies within one industry may have caused one firm to benefit from the bankruptcy of the other thereby improving its performance. This could bring distortions as some companies might have performed worse otherwise. These effects cannot be observed in the data.

Generalizability

Sometimes also referred to as *external validity,* the concept of generalizability questions to what extent obtained results are "equally applicable to other research settings" (Saunders et al., 2009, p. 158). Generalizability for the present study is rather limited due to the following reasons.

First, our study comprises only public listed US firms from a technology industry. This implies that the findings cannot be generalized for example for service firms as the business models of these firms are built on entirely distinct assumptions with different industry drivers. Furthermore, knowledge might be less codified through patents in non-technology industries.

Second, looking only at public listed firms probably limits the generalizability of the findings to firms of the same legal form, even within the same industry. This is because firms that are public might display distinctive characteristics due to the legal form, e.g. they might on average be more successful than non-public firms as they achieved to obtain external equity financing or they might exhibit higher patent propensities in order to signal their quality to investors.

Third, the results might not hold for different countries as firms might act differently in other markets or if they come from other markets. For example, the patent propensity varies greatly between different countries. Hence, the findings are rather restricted to make conclusions for the US market.

Fourth, the findings are only indicative of the observed period and should be seen as a current 'snapshot'. The same study in a different decade would have probably yielded somewhat different results. As seen before, the importance of knowledge for firms and thus patent resources has increased substantially in the last years which could explain different outcomes for a distinct research setting.

A positive aspect of the study relates to the sample size which is with a total of 440 cases rather representative. Furthermore, it includes all bankruptcies within the chosen industries and time-frame except the ones that had to be excluded due to restricted data availability. Concluding, the findings can be generalized only to companies exhibiting similar characteristics regarding industry, legal form, financing and location but can hardly be applied to other companies with differences regarding these characteristics.

Summarizing, several study inherent limitations could be identified. These apply partially to the validity but mostly to the generalizability of the results. The reliability of the study is considered rather high. Hence, the study can give valuable insights with respect to its particular research setting.

6. Research Results

The following chapter presents our findings from the analysis outlined in chapter 5. It firstly reports findings from the descriptive statistics. Thereafter, insights from t-tests are presented. The third section describes the results of the hypothesis testing through regression analysis. Lastly, the fourth chapter summarizes all findings.

6.1. Descriptive statistics

In order to get a first overview of the data set deployed in this study, distributions with regard to type of industry, technology intensity and time will be described. Furthermore, other descriptive statistics (mean, minimum, maximum, standard deviations) and correlations are reported.

Industry Distribution of Bankruptcies

Table 6 provides an overview of the industry classification of all 220 sampled low- and high-tech bankruptcies according to their SIC code and shows the distribution of bankruptcies. Nearly half of the bankruptcies occurred in Manufacturing (SIC 20XX-39XX). Generally, the bankruptcy cases seem to be distributed rather evenly among the different industry classes. Three SIC codes, however, stand out exhibiting the most bankruptcy cases: *Oil and Gas Extraction* (SIC 13XX), *Chemicals and Allied Products* (SIC 28XX), and *Electronic and other Electrical Equipment and Components, except Computer Equipment* (SIC 36XX). Oil and Gas Extraction is classified as a low-tech industry whereas the two latter ones are classified as high-tech industries. Within SIC 13XX, more than two thirds of the cases belong to Crude Petroleum and Natural Gas (131X). A similar distribution is observed within SIC 28XX, where this holds true for Drugs (283X). The distribution of bankruptcy cases within SIC 36XX is somewhat more balanced with Communication equipment (366X) accounting for more than 40% of the bankruptcy cases and Electronic Components and Accessories (367X) as well as Miscellaneous Electrical Machinery, Equipment, and Supplies accounting for about 25% each.

Industry	SIC Code	Bankruptcy Frequency (absolute)	Percent
Agricultural Services	07XX	1	0,5%
Metal Mining	10XX	2	0,9%
Bituminous Coal and Lignite Mining	12XX	4	1,8%
Oil and Gas Extraction	13XX	30	13,6%
Building Construction General Contractors and Operative Builders	15XX	5	2,3%
Construction Special Trade Contractors	17XX	1	0,5%
Food and Kindred Products	20XX	10	4,5%
Textile Mill Products	22XX	3	1,4%
Apparel and other Finished Products Made from Fabrics and Similar Materials	23XX	3	1,4%
Lumber and Wood Products, except Furniture	24XX	3	1,4%
Furniture and Fixtures	25XX	4	1,8%
Paper and Allied Products	26XX	9	4,1%
Printing, Publishing, and Allied Industries	27XX	6	2,7%
Chemicals and Allied Products	28XX	39	17,7%
Petroleum Refining and Related Industries	29XX	1	0,5%
Rubber and Miscellaneous Plastics Products	30XX	2	0,9%
Leather and Leather Products	31XX	1	0,5%
Stone, Clay, Glass, and Concrete Products	32XX	2	0,9%
Primary Metal Industries	33XX	4	1,8%
Fabricated Metal Products, except Machinery and Transportation Equipment	34XX	7	3,2%
Industrial and Commercial Machinery and Computer Equipment	35XX	16	7,3%
Electronic and other Electrical Equipment and Components, except Computer Equipment	36XX	29	13,2%
Transportation Equipment	37XX	15	6,8%
Measuring, Analyzing, and Controlling Instruments; Photographic, Medical and Optical Goods; Watches and Clocks	38XX	18	8,2%
Miscellaneous Manufacturing Industries	39XX	5	2,3%
	Total	***220***	***100,0%***

Table 6 - Industry Distribution of Bankruptcies (2006-Oct.2013)

Time distribution

Figure 2 depicts the distribution of bankruptcy cases over time during the observed period. Most bankruptcies occurred in 2009 which seems reasonable in light of the financial crisis that commenced with major financial institutions collapsing in the end of 2008. On average, there were more bankruptcies for high-tech firms than for low-tech ones, however this is dependent on the definition of the categories (see part 5.1.1 Technology Industries) which resulted in 142 sampled high-tech and 78 sampled low-tech firms. Therefore, preliminary conclusions cannot be drawn. However, it is interesting to note that after the shakeout in 2009, the number of bankruptcies dropped sharply. The caption of a sampling period before, during and after a financial crisis thereby helps avoid sampling bias since numerous firms exit an industry during a crisis like the one in 2009 (cf. Denrell, 2003).

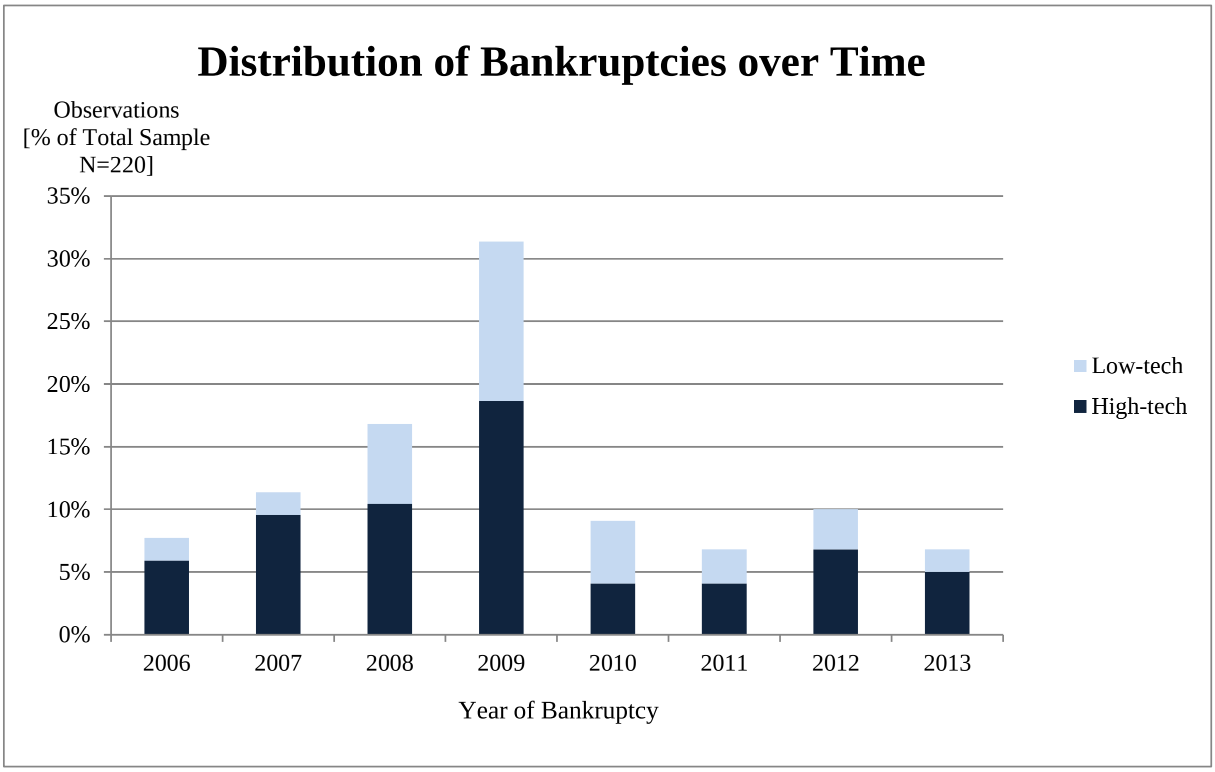

Figure 2 - Low- and High-tech Bankruptcies over Time

Variable distribution

In table 7 descriptive statistics such as mean, median, and standard deviation of all continuous variables[17] deployed are given for all bankrupt as well as all non-bankrupt cases. A first observation is that the mean of non-bankrupt firms in the control sample are characterized by higher average age, size and portfolio strength. The contrary is the case for sales growth. The portfolio strength growth of bankrupt firms in the sample does not differ much from that of non-bankrupt firms in the control sample in term of median, mean and standard deviation. Surprisingly, though, the Altman Z-Score displays a much lower mean but higher median for non-bankrupt cases in the control sample than for bankrupt cases analyzed. In summary, the descriptive statistics indicate that some variables have skewed distributions or outliers. Histograms were examined to analyze the distribution in more detail and transform the variables accordingly (as t-tests assume normal distribution). As explained in sections 5.2.2.1 and 5.2.2.3. The variables age, total assets and portfolio strength[18] were log transformed. The Altman Z-score was winsorized and cube root transformed.

	Bankrupt Cases (N=220)			Non-bankrupt Cases (N=220)		
Variable	**Median**	**Mean**	**Std. Deviation**	**Median**	**Mean**	**Std. Deviation**
1.Age	22,0	32,6	28,0	26,5	38,0	30,4
2.Sales growth	0,0	1,6	12,2	0,1	0,1	0,5
3.Size	60,083	559,918	1 461,733	215,183	3 481,897	14 578,411
4.Altman Z-Score	-0,3	-22,7	122,8	2,5	-1 393,8	18 078,7
5.Portfolio strength	0,7	154,8	1 146,9	15,7	1 127,6	4 648,4
6.Portfolio strength growth	0,0	0,3	1,4	0,0	0,3	1,2

Table 7 - Median, Mean and Standard Deviation of Variables

Correlation

In order to investigate the relationship between continuous variables, a bivariate correlation analysis was performed. In order to examine potential implications for t-test and regression

[17] Except the applied interaction terms ”portfolio strength X industry techn. focus”, ”portfolio strength X age”, ”portfolio strength X size” and the dichotomous variable industry techn. focus.

[18] As described in Section 5.2.2, patent portfolio strength was log transformed as suggested by Whittaker et al. (2005).

analysis, the variables were if applicable included after transformation. The results are shown in table 8.

The direction of the relationship between age and sales growth (-0,023) and age and patent portfolio strength growth (-0,115) is negative. The *percentage of variance*[19] that age shares with these two variables is low – 0,05% for sales growth and 1,3% for portfolio strength growth respectively. The latter comes at a significance level of 0,05 whereas the former does not seem to be of significance.

The same weak relationship seems to hold for sales growth and portfolio strength (-0,070) as well as size and portfolio strength growth (-0,013), both without significance. Accordingly, also the interaction terms formed with age and portfolio strength (-0,041) as well as size and portfolio strength (-0,068) exhibit a weak negative correlation with portfolio strength growth. In line with the negative correlation between sales growth and portfolio strength, also all interaction terms display a negative correlation with sales growth. All in all, the direction of the relationship does not incur too many surprises. Generally, growth seems to be negatively related to high values of age and size or portfolio strength, supporting the notion that old and big companies are often more mature, not exhibiting high growth or even negative growth rates. Interestingly though, the statistical *strength of the relationship* is considered rather low in the sample except for the strong positive relationships between size and the Altman Z-Score (0,690) and size and portfolio strength (0,501) or the interaction term portfolio strength x industry technology focus (0,500), supporting the notion that bigger companies might be less inclined to fail and display higher levels of portfolio strength. Accordingly, these variables share between 25% and 48% of their variance.

Generally, there seems to be a highly *significant level* of correlation between company age and all other variables except sales growth, sometime even for rather small correlations. High significance even for rather small correlation can however be influenced by the large sample (Pallant, 2007). Similar significance levels to age were reached for company size excluding portfolio strength growth. Also correlation is significant for all interaction terms if analyzed

[19] The shared percentage of variance or *coefficient of determination* is calculated by squating the r-value. Example: r=0,2 translates into a coefficient of determination of 0,04 or 4% (0,2x0,2).

together with portfolio strength. This comes however at no surprise as the portfolio strength always represents one of the interaction variables. All in all, the sometimes strong relationships together with high levels of significance suggest that multicollinearity might be an issue for these variables even after they have been centered.

Correlations (N=440)									
Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
1.Age	1								
2.Sales Growth	-,023	1							
3.Size	,285***	,020	1						
4.Altman Z-Score	,269***	,031	,690***	1					
5.Portfolio strength	,189***	-,070	,501***	,255***	1				
6.Portfolio strength growth	-,115**	,002	-,013	,052	,048	1			
7.Portfolio strength X industry techn. focus	,143***	-,028	,500***	,257***	,865***	,011	1		
8.Portfolio strength X age	,132***	-,006	,136***	,053	,176***	-,041	,180***	1	
9.Portfolio strength X size	,125***	-,053	,148***	,066	,558***	-,068	,499***	,368***	1

***. Correlation is significant at the 0.01 level
**. Correlation is significant at the 0.05 level

Table 8 - Correlation of Variables

Patenting

Due to the particular focus in patent resources as a determinant of competitive advantage, it seems reasonable to preliminary describe the patenting activity of the sampled companies. Figure 3 presents an overview of the patent portfolio size for the entire sample one year prior to bankruptcy[20].

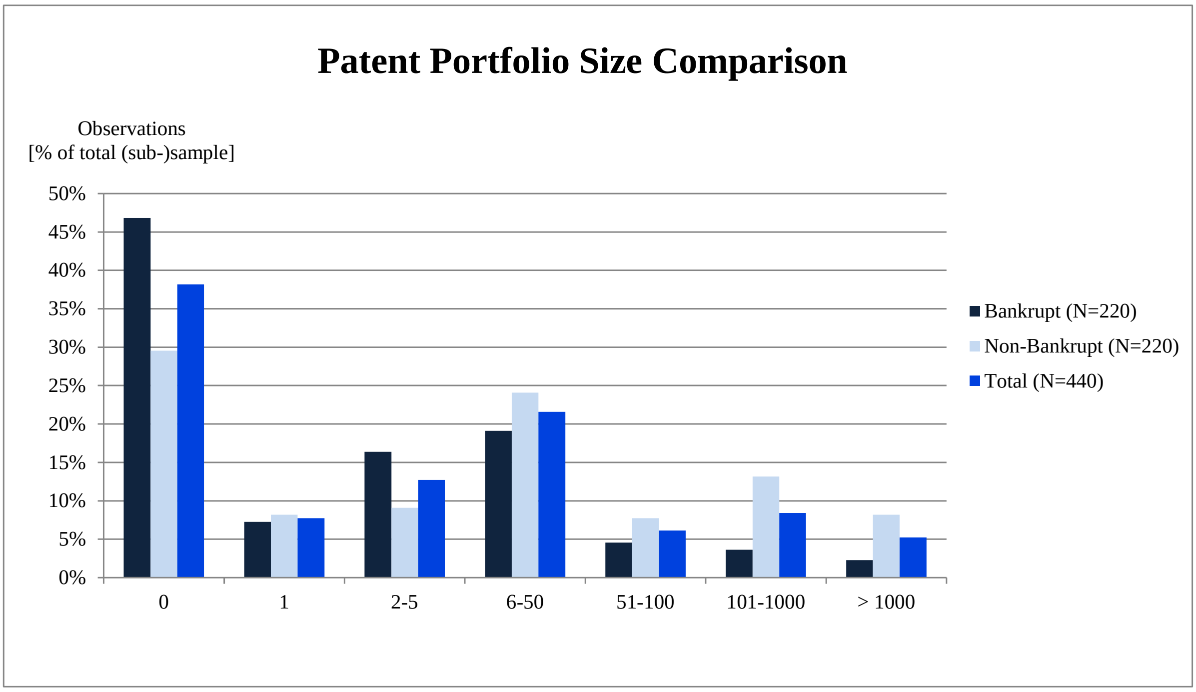

Figure 3 - Patent Portfolio Size Comparison

It is noteworthy that few companies exhibit very big patent portfolios, suggesting a generally high patent concentration. Even more interesting, nearly half of the companies that filed for bankruptcy did not own a single patent in comparison to less than 30% of the non-bankrupt firms. This could somewhat support the hypothesis that patents matter when it comes to bankruptcy and survival. However, as argued before, companies without or with only few patents may display different strategies, they might for example simply license-in patents from other firms. Nevertheless, the distribution provides a first glance at the companies' patent portfolios.

[20] Note: as explained in the methodology part, non-bankrupt firms were matched time wise. Hence, the year bankruptcy resembles the reference year for non-bankrupt years, too.

6.2. Univariate analysis

The univariate analysis is conducted to identify systematic differences between the bankruptcy sample and the non-bankrupt control sample. The method chosen are independent sample t-tests as the comparison is made between two independent groups (Pallant, 2007). The t-tests reveal whether or not differences in the average values that are observed between the bankruptcy group and the control group are coincidental.

Table 9 provides an overview of the results from the t-tests.

	Bankrupt Cases (N=220)	Non-bankrupt Cases (N=220)	Mean	Sig.
	Mean	Mean	Difference	(2-tailed)
log(Age)	1,397	1,491	0,094	0,001 ***
Sales growth	1,592	0,137	-1,455	0,079 *
log(Size)	1,800	2,148	0,348	0,004 ***
CubicRoot(Altman Z-Score)	-0,544	0,450	0,994	0,000 ***
log(Portfolio strength)	-0,694	0,694	1,388	0,000 ***
Portfolio strength growth	0,308	0,283	-0,024	0,847

Table 9 - Results of T-tests

****,** and * indicate significance at the 1%, 5% and 10% level respectively*

Sales Growth

Comparing the average compound annual sales growth of the bankrupt firms with the control group indicates a large difference. While non-bankrupt firms grow in sales on average at approximately 14% per year, bankrupt firm exhibit sales growth rates of around 159% on average annually. The t-test shows that this difference is weakly significant at the 10% level. This result indicates that the firms that went bankrupt grew on average significantly stronger than firms did not go bankrupt.

Patent portfolio strength growth

The average three-year patent portfolio strength growth rate of non-bankrupt firms is around 28%. Bankrupt firms in contrast have an average 3-year growth rate of 31%. The t-test, however, indicates no statistical significance for this deviation in growth rates. Consequently, it cannot be deducted from the t-test that patent portfolios of bankrupt firms differ in growth rates from non-bankrupt firms.

Age

The distribution of values for the firm age was highly skewed. In order to run t-tests, the variable was log-transformed as explained. The result is highly significant at 1% percent level. The interpretation is due to the transformation of the variable difficult. An indication of the difference in years is, however, given in the descriptive statistics section. Overall, it can be concluded that bankrupt firms are on average younger than non-bankrupt firms and this differences is highly significant.

Altman Z-Score

The variable representing the Altman Z-Score has been transformed as indicated above. Consequently, interpreting the difference between the average values for bankrupt and non-bankrupt firms is difficult. What can be deducted with certainty, however, is that from a statistical standpoint, there is a highly significant difference at the 1% level. Firms within the group of filing for bankruptcy have a significantly lower Z-Score than those firms not going bankrupt.

Patent portfolio strength

The t-test for the variable patent portfolio strength reveals a highly significant difference between bankrupt and non-bankrupt firms. On average the bankrupt firms have lower patent portfolio strength and this difference is significant at the 1% level. The interpretation is due to the transformation of the variable difficult.

Total Assets

The t-test for total assets reveals a highly significant difference at the 1% level between bankrupt and non-bankrupt firms. Companies filing for bankruptcy have on average significantly less assets than those firms not filing for bankruptcy. Due to the transformation of this variable, the difference in dollar terms is hard to interpret. The descriptive statistics in section 6.1. showed a difference on average of USD 2.9bn. This can be viewed as indication for the difference in dollar terms.

In summary, the t-tests have revealed information on the significance of differences in the mean values between bankrupt and non-bankrupt firms. Based on this, preliminary conclusions about the first two hypotheses (not containing any moderator effects) can be drawn (table 9). Hypothesis 1 seems supported due to the significant differences in patent portfolio strength. On the other hand, no conclusions can be drawn for hypothesis 2 yet. In the following, all five hypotheses will be tested through logistic regression analysis.

6.3. Multivariate analysis

The multivariate analysis is applied in order to test our hypotheses. The t-tests already revealed insights about potential differences between the bankruptcy firms and firms in the control group and gave first hints about the hypotheses. The logistic regression, in contrast, indicates how well the independent variable(s) explain the likelihood to go bankrupt while controlling for other factors. An overview of the statistical results can be obtained in table 10.

	Model 1		**Model 2**		**Model 3**		**Model 4**		**Model 5**		**Model 6**		**Model 7**	
	Only Altman Z-Score		*All control variables*		*H1: Portfolio strength*		*H2: Portfolio strength growth*		*H3: Portfolio strength X industry techn. focus*		*H4: Portfolio strength X age*		*H5: Portfolio strength X size*	
n = 440	**B**	**OR**	**B**	**OR**	**B**	**OR**	**B**	**OR**	**B**	**OR**	**B**	**OR**	**B**	**OR**
Constant	-0,005	0,995	-0,187	0,829	-0,603 ***	0,547	-0,192	0,825	-0,434 **	0,648	-0,565 ***	0,568	-0,444 **	0,642
	(0,099)		(0,179)		(0,204)		(0,180)		(0,221)		(0,205)		(0,216)	
Control variables														
CubicRoot(Altman Z-Score)	-0,288 ***	0,750	-0,392 ***	0,676	-0,476 ***	0,621	-0,394 ***	0,674	-0,484 ***	0,616	-0,487 ***	0,614	-0,462 ***	0,630
	(0,054)		(0,078)		(0,083)		(0,078)		(0,084)		(0,084)		(0,083)	
Industry techn. focus			0,036	1,037	0,683 ***	1,980	0,033	1,034	0,538 **	1,712	0,646 **	1,907	0,626 **	1,870
			(0,216)		(0,257)		(0,216)		(0,265)		(0,257)		(0,258)	
log(Age)[c]			-0,394	0,675	-0,363	0,695	-0,382	0,683	-0,413	0,662	-0,344	0,709	-0,319	0,727
			(0,361)		(0,378)		(0,363)		(0,380)		(0,390)		(0,381)	
Sales growth			0,487 ***	1,627	0,412 ***	1,509	0,487 ***	1,627	0,431 ***	1,538	0,468 ***	1,598	0,423 ***	1,527
			(0,154)		(0,149)		(0,154)		(0,152)		(0,156)		(0,151)	
log(Total Assets)[c]			0,212 *	1,237	0,605 ***	1,831	0,214 *	1,239	0,624 ***	1,867	0,614 ***	1,847	0,532 ***	1,703
			(0,112)		(0,143)		(0,112)		(0,145)		(0,143)		(0,150)	
Independent variables														
H 1: log(Portfolio strength)[c]					-0,299 ***	0,742			-0,172 *	0,842	-0,293 ***	0,746	-0,224 ***	0,799
					(0,056)				(0,096)		(0,057)		(0,065)	
H 2: Portfolio strength growth							0,023	1,023						
							(0,079)							
H 3: log(Portfolio strength)[c] X industry techn. focus[c]									-0,166	0,847				
									(0,107)					
H 4: log(Portfolio strength)[c] X log(Age)[c]											-0,407 ***	0,666		
											(0,156)			
H 5: log(Portfolio strength)[c] X log(Total Assets)[c]													-0,086 **	0,917
													(0,039)	
Model Fit														
LR chi^2	30,727 ***		58,903 ***		90,596 ***		58,988 ***		92,874 ***		98,208 ***		96,035 ***	
Hosmer and Lemeshow Test	65,212 ***		4,381		4,476		4,902		6,091		5,282		6,636	
Percentage correctly classified	63,18%		66,82%		70,23%		66,59%		68,86%		70,00%		69,55%	
McFadden R^2	0,050		0,097		0,149		0,097		0,152		0,161		0,157	
Likelihood ratio test														
Basis: Model 1	-		28,176 ***		59,869 ***		28,260 ***		62,147 ***		67,481 ***		65,308 ***	
Basis: Model 2	-		-		31,693 ***		0,084		33,971 ***		39,305 ***		37,132 ***	
Basis: Model 3	-		-		-		-		2,278		7,612 ***		5,439 **	

Table 10 - Overview of Logistic Regression Results

B = regression coefficient, OR = odds ratio; values in brackets represent standard errors
****, ** and * indicate significance at the 1%, 5% and 10% level respectively (for regression coefficients, LR chi^2, Hosmer & Lemeshow Test and Likelihood Ratio Test*
[c] = variable centered by its mean

Model 1 – Altman Z-score

Model 1 was calculated for comparison reasons only. As explained in section 5.2.2., the Altman Z-Score (Altman, 1968) is the most popular predictor of corporate bankruptcy and is usually attributed great explanatory power. In order to put our findings into perspective, Model 1 functions as a reference point to see whether or not each model has more explanatory power than the Z-Score on its own.

The results of this model are inconclusive. The LR chi^2 of 30,727, $p < 0,01$ indicates an overall significant model compared to a model with no predictors. However, the Hosmer and Lemeshow test[21] reveals the opposite suggesting a weak goodness of fit. Also, the McFadden R^2 is low with a value of 0.05, indicating that the model is able to only explain around 5% of the dependent variable's variance. The model classified 63% of the analyzed cases correctly as either bankrupt or non-bankrupt, this is a slight improvement compared to a model without any predictors that classifies 52% correctly. The beta of the Altman Z-score variable is negative and significant (1% level), meaning that an increase of the Altman Z-score (respectively its cubic root) leads to a reduced probability of bankruptcy. Similarly, the odds ratio indicates that one unit increase in the cubic root of the Z-score reduces the odds of bankruptcy by the factor 0.75.

Overall, the predictive power of this model is problematic but it confirms the negative relationship between the Z-score and the probability of bankruptcy as expected from previous research.

Model 2 – All control variables

This model contains all control variables of this analysis. Similar to model 1, it is also used as a basis for comparison with regard to our findings in the following models. As explained in section 5.2.2., the choice of the variables reflects the results from previous research on factors explaining corporate bankruptcy. The LR chi^2 test for the model and the Hosmer and Lemeshow Test indicate an overall fit of the model. The McFadden R^2 of 0.10 is low but indicates an improvement in explanatory power compared to model 1. Similarly, the percentage of correctly classified cases increased to 67%. The likelihood ratio test confirms a statistically significant improvement compared to model 1. Three of the control variables in

[21] As mentioned above, an insignificant ($p > 0,05$) value for the Hosmer and Lemeshow Test indicates a good model fit (Pallant. 2007).

this model show significant values. As for model 1, the cubic root of the Z-Score shows a highly significant ($p < 0.01$) and negative beta. The beta for sales growth is positive with high significance ($p < 0.01$). Also, the logarithm of total assets shows a weakly significant ($p < 0,1$) and positive beta.

Model 3 – H1: Portfolio strength

Model 3 is used to test the first hypothesis. It contains all control variables and the (logarithm of) patent portfolio strength as independent variable. Looking at the statistical results of the model, the LR chi^2 and Hosmer and Lemeshow test indicate an overall significant model. The number of correctly classified cases increases to 70% and the McFadden R^2 to 15% in comparison to the previous models. The likelihood ratio test shows significant ($p < 0.01$) improvements in explanatory value compared to model 1 (only Z-Score) and the model 2 (all control variables). All but the variable for age are significant ($p < 0.01$) – the indicated negative relationship for age fits the expectations, however, the result is not significant. Similar as in model 1 and 2, the cubic root of the Altman Z-Score is negatively related to the probability of bankruptcy. However, the “impact” of this variable is stronger than in the previous models. An increase by one unit reduces the odds of bankruptcy by the factor 0.621. The industry focus positively influences the bankruptcy probability, i.e. the odds of going bankrupt are 1.98 times larger for high-tech than for low-tech firms – all other factors constant. Sales growth and size in (logarithm of) total assets have a positive impact as well – an increase by one unit increases bankruptcy odds by the factor 1.509 and 1.831 respectively. The (logarithm of) patent portfolio strength relates to the first hypothesis. The beta is negative and highly significant ($p < 0.01$). **This result confirms the hypothesis (H1)** that the likelihood of bankruptcy decreases with increasing patent strength. Interpreting the odds ratio, the probability of bankruptcy decreases ceteris paribus by the factor 0.742 for each unit of increase in the (logarithm of the) portfolio strength.

Model 4 – H2: Portfolio strength growth

Similarly to model 3, model 4 includes all control variables but tests hypothesis 2 relating to the growth in patent portfolio strength. The LR chi^2 test and the Hosmer and Lemeshow test indicate significance of the model. The percentage of correctly classified cases is 67% and McFadden R^2 is similar to model 2 at 10%. The likelihood ratio test suggests a significant (p

< 0.01) improvement to model 1, but no significant improvement to model 2. Significance, impact and direction of variables included resemble those of model 2. The variable for patent portfolio growth shows a minimal positive impact with no statistical significance. Consequently, a negative relationship between patent portfolio strength growth and likelihood of bankruptcy according to **hypothesis 2 cannot be confirmed**.

Model 5 – H3: Portfolio strength x industry techn. focus

The fifth model is calculated to test hypothesis 3 that the impact of patent portfolio strength on bankruptcy likelihood is stronger negative for high-tech firms than for low-tech firms. Both tests of overall goodness of fit (LR ch^2 and Hosmer and Lemeshow test) show a significant explanatory value of the model. 69% of cases were correctly classified according to this model and the McFadden R^2 equals 15%. Comparing this model to model 1 and 2 shows in both cases a significant improvement in explanatory value. However, compared to model 3 no significant improvement was found. The control variables show all a significant impact except firm age. The Z-Score has a negative impact at the 1% significance level. The impact of industry technology focus is positive and significant ($p < 0.05$), sales growth and total assets have a positive impact too and are highly significant ($p < 0.01$). Similar model 3, patent portfolio strength has a negative impact, significance is however only weak ($p < 0.10$). The interaction term of patent portfolio strength and industry focus tests a potential moderator effect as hypothesized above. The p-value of 0.12 is above the significance threshold of 0.10, therefore, no statistically significant effect can be found and **hypothesis 3 cannot be confirmed**. However, the negative beta value indicates the general tendency that the impact of patent strength is higher in high-tech industries than in non-high-tech industries. As the variables involved are centered, the indicated but still insignificant effect can be interpreted as follows. If a firm is in a high tech industry and has above average patent strength, the likelihood of bankruptcy decreases. On the other hand, it increases for below average patent strength. For a low-tech firm in turn, the interaction term equals zero and the effect remains on the same level as in model 3. Hence, the effect of patent strength is indicated to be stronger (negative) for high-tech firms, as hypothesized above. Nevertheless, it is pointed out again that the statistical insignificance does not allow to general inference from this result.

Model 6 – H4: Patent portfolio strength x age

Model 6 tests a potential moderator effect of age on the relationship between patent portfolio strength and bankruptcy probability, according to hypothesis 4.

Overall, the model is the significant as indicated by LR chi^2 and Hosmer and Lemeshow test. The model classified 70% of cases correctly and the McFadden R^2 is with 16% the highest of all models tested. The likelihood ratio test shows significant ($p < 0.01$) improvements compared to model 1, 2 and 3. The significance, direction and impact of the control variables resemble those of model 3 closely, except for industry technology focus being significant only at a 5% level. Patent portfolio strength has a highly significant ($p < 0.01$), negative impact as seen in model 3. The interaction term between patent portfolio strength and firm age is highly significant and negative. This means the interaction term for above average aged firms is negative, meaning the impact of patent portfolio strength is overall stronger negative. On the other hand, if firm age is below average, the interaction term is positive and the effect of patent portfolio strength overall is weaker negative or even positive. **This is contradicting the hypothesis (H4)** that the impact of patent portfolio strength is stronger negative for young firms and weaker negative for old firms.

Model 7 – H5: Patent portfolio strength x size

The last model tests the moderator effect of firm size on the relationship between patent portfolio strength and likelihood of bankruptcy. According to the LR chi^2 and Hosmer and Lemeshow test, the model is overall significant. 70% of cases were correctly classified and the McFadden R^2 is 16%. The likelihood ratio test shows significant improvements compared to models 1, 2 and 3. The control variables are very similar to model 6 in terms of significance, direction and strength of relationship. As in model 6 and 3, patent portfolio strength is highly significant and has a negative impact on bankruptcy probability. The interaction term between patent portfolio strength and firm size is negative and significant at a 5% level. For firms of above average size the interaction term is negative, increasing the negative impact of patent portfolio strength. For firms of below average size the interaction variable is positive and, therefore, reducing the negative impact of patent portfolio strength or possibly turning it into a positive impact. This means that the generally negative relationship between patent strength and bankruptcy likelihood increases with (above average) firm size. Therefore, **hypothesis 5 cannot be confirmed from these findings.**

6.4. Summary of results

Following a brief summary of the most important research results is provided before moving on to the discussion of these results.

The **descriptive statistics** revealed an overall even industry distribution of bankruptcies within our sample. Only *Oil and Gas Extraction* (SIC 13XX), *Chemicals and Allied Products* (SIC 28XX), and *Electronic and other Electrical Equipment and Components, except Computer Equipment* (SIC 36XX) were found stand out, accounting together for approximately 45% of all analyzed bankruptcies.

The temporal analysis found the number of bankruptcies to increase during the years of the Global Financial Crisis in 2008 and 2009 to altogether about 47% of analyzed cases.

The correlation analysis showed significant and high correlation between variables in the same regression model only for *Size* and *Altman Z-Score, Portfolio strength and Industry techn. focus* as well as between *Portfolio strength* and *Portfolio strength X industry techn. focus* and *Portfolio strength X size*.

The analysis of patenting activity indicated that non-bankrupt firms might control on average more patents.

Examining the results of the **t-tests**, significant differences found annual sales growth (bankrupt firms showing on average higher growth rates), firm age (bankrupt firms being on average younger), Altman Z-Score (bankrupt firms having on average lower Z-Scores), patent portfolio strength (bankrupt firms having on average weaker patent portfolios) and total assets (bankrupt firms being on average smaller). These findings seem to support hypotheses 1 and 2.

Logistic regression analysis confirmed - in line with *hypothesis 1*- that patent portfolio strength is significantly negatively related to bankruptcy likelihood. Growth in patent portfolio strength, however, was not found to significantly impact bankruptcy probability, hence, not confirming *hypothesis 2*. A moderator effect of industry technology focus on the relationship between patent portfolio strength and bankruptcy likelihood was not confirmed, contradicting *hypothesis 3*. Such moderator effect was however found for firm age and firm size on the relationship between portfolio strength and bankruptcy likelihood. However, contradicting *hypothesis 4* and *5*, the impact of portfolio strength is stronger for older and larger firm.

Overall all models are found to be significant even though most models indicate a rather low explanatory power according to McFadden R^2. Nevertheless, inclusion of patent portfolio strength related variables leads in almost all models to improvements in model fit, compared to the Altman Z-score by itself or in combination with other control variables.

7. Discussion

This study answers the research question, whether or not patent portfolio strength can explain the occurrence of corporate bankruptcy, justified by the knowledge-based view. The previous chapter presented the results from our analysis. These suggest that, overall, patent portfolio strength does seem to have significant explanatory value for the probability of bankruptcy – as expected from the KBV theory. However, our findings are not unambiguous and, therefore, need to be discussed in more detail in the following. Thereafter, potential limitations of this study are examined.

7.1. Results in context of previous research

The particular findings are interpreted and discussed in light of the theoretical substantiation and previous empirical research body in order to draw conclusions on the proposed research question. Further, alternative explanations are provided where applicable.

7.1.1. Patent portfolio strength and corporate bankruptcy

In this study, support was found for the hypothesis (H 1) that patent portfolio strength reduces the likelihood of bankruptcy significantly within technology industries. This finding confirms the argument that patents are not only a strategically important resource that can lead to competitive advantage and superior performance but also a necessary resource to survive in technology industries. Based on the resource-based view (cf. Wernerfelt, 1984; Rumelt, 1984; Barney, 1986, 1991) and the knowledge-based view (cf. Spender, 1996; Grant, 1996; Liebeskind, 1996; Kogut & Zander, 1993, 1996) we argued that patents are crucial resources that make a difference in terms of firm performance. This difference has previously been analyzed and argued for on the positive side of performance. In vein of Thornhill and Amit (2003) and Crutzen and Caillie (2008), we argued that patents also make a difference regarding negative performance. Confirming this hypothesis, our findings validate and further expand the RBV and KBV theory. As argued in section 3.1., previous research in this field might be systematically biased by what is called "undersampling of failure" (Denrell, 2003). As scholars have mostly ignored failing firms, they excluded many relevant observations from their studies. We have attempted to counteract this tendency with our study and found the theory to hold true also for the "dark side" of firm performance. Nevertheless, further research in this direction would be beneficial for the understanding of bankruptcy causes and for the validation of established theories.

Previous empirical research in this field has rarely grounded its hypothesis explicitly in RBV or KBV theory. In this sense, our results are unique as mentioned above. Nevertheless, some scholars have analyzed the relationship between patent-related indicators and corporate bankruptcy, too (cf. Buddelmeyer et al., 2010; Cockburn & Wagner, 2007; Eisdorfer & Hsu, 2011; Levitas et al., 2006) Even though results were ambiguous, some studies (cf. Buddelmeyer et al., 2010; Cockburn & Wagner, 2007) have found patent to reduce the risk of bankruptcy. The empirical results from our analysis are in line with this previous research. However, few scholars have deployed a comparably holistic indicator of patent strength. Therefore, our results further validate their findings.

From a practitioner's point of view, it is interesting to note that the inclusion of patent portfolio strength as independent predictor variable in our analysis led to a significantly improved explanatory power compared to the Altman Z-Score on its own or the Z-Score in combination with other control variables. As described above, we found the model containing only the Altman Z-Score, in fact, of questionable fit. Accordingly, the percentage of correctly classified cases increases from 63% for the Z-Score model to 70% for the holistic model including patent portfolio strength (model 3). This finding is particularly interesting, considering that the Altman Z-Score remains the most prominent indicator for bankruptcy in research and practice (Apergis, Sorros, Artikis, & Zisis, 2011; Dichev, 1998). Our analysis suggests re-evaluating this custom and considering integration of indicators related to patent portfolio strength in predictive models.

Our results also imply that practitioners need to acknowledge the importance of patent resources to mitigate the risk of bankruptcy. In order to avoid competitive disadvantages in technology industries, firms have to accumulate valuable patent assets. Managers need to continuously evaluate their firms' patent portfolio strength and develop strategies that match them. A more discussion on further implications for managers and other stakeholders follows in section 8.1.

7.1.2. Patent portfolio strength growth and corporate bankruptcy

The relationship between patent portfolio strength growth and the occurrence of corporate bankruptcy could not be proved significant from the regression analysis. Neither did the t-test find any significant differences in average patent strength growth rates between bankrupt and non-bankrupt firms. This result contradicts the hypothesis (H 2) that firms with diminishing knowledge resources (i.e. patents) are more likely to go bankrupt. An explanation could be that the absolute level of patent strength moderates a possible impact of patent portfolio strength growth on bankruptcy likelihood. A decline in patent strength might help to explain corporate bankruptcy if the absolute level decreases below a certain threshold. While a decline in patent resources might not be critical for firms that control many and/or patents of high quality, it might be in turn for firms with limited patent strength.

In light of the little research previously performed with regards to growth in patent strength, it is hard to put the above-mentioned possible explanations for the obtained results into context. We therefore suggest that further research analyzes this effect in more detail.

7.1.3. Moderator effect of industry technology focus

The industry's focus on technology was expected to moderate the relationship between patent portfolio strength and bankruptcy likelihood (hypothesis 3). This effect could, however, despite a general tendency not be confirmed as significant. One explanation could be the definition of high-tech industries. We followed Eisdorfer & Hsu (2011) and Kleinknecht & Reinders (2012) in defining high-tech industries as those that show a high propensity to patents. However, a more detailed definition of high-tech (e.g. based on more detailed industry definitions) might be required in order to observe significant differences. Similarly, the definition of low-tech industries as the inverse of high-tech within technology industries might be too wide and unspecific.

Another explanation could be the high correlation between the interaction variable and the patent portfolio strength by itself. To mitigate distortions from collinearity, the variables were centered before including in the regression model and before calculating the interaction variable (Kohler & Kreuter, 2008). As logistic regression analysis is sensitive to multicollinearity (Pallant, 2007) and since collinearity might remain despite centering the variables, the results could be affected by this, which could lead to lower significance of the interaction variable and its factors individually. This would explain why model 5 is the only model in which patent portfolio strength is only weakly significant at the 10% level, compared to the 1% level for the others.

Furthermore, it is interesting to note that the impact of the industry technology focus by itself is significantly positive. This confirms the notion that high-tech industries offer on average higher returns but at the same time show more volatility (cf. Sueyoshi & Goto, 2009; Levitas et al., 2006) but contradicts the empirical findings Cefis & Marsili (2005) that showed technology intensive industries to be favorable for survival.

The regression analysis found firm age to be a significant moderator of the relationship between patent portfolio strength and bankruptcy probability. However, contrarily to hypothesis 4, the negative relationship between patent portfolio strength and bankruptcy probability becomes stronger negative as firm age increases. Patent strength, is consequently more determining for survival of old firms than for young firms. A possible explanation might be the risk of senility with increasing firm age (Agarwal 1997). This might increase the pressure to innovate and control strong knowledge resources as firms mature. Moreover, it can be argued that for young firms other factors – for example access to capital or reputation – determine the probability to survive or fail more significantly than the patent portfolio strength. Differences in patent strength are limited and not the differentiating factor between young failing and surviving firms. Furthermore, patents are usually part of a long-term strategy and have a considerable lead time (Ernst, 2001; Omland 2011). Linking back to the discussion in section 3.1., it might, therefore, be that young firms choose to protect their knowledge through other IP rights or organizational mechanisms.

Moreover, it is noteworthy that the firm age itself does not prove to be a significant variable to explain bankruptcy. It was expected that the likelihood of bankruptcy decrease with firm age, as older firms are thought to be more established on the market, have passed the early and immature phase. This was also indicated by the t-tests but not found to be confirmed by the regression analysis. Buddelmeyer et al. (2010) report a similar finding when studying the survival of young firms. They note "[…] that once we include a comprehensive set of company, industry, and macroeconomic variables in our estimations, the classic positive relationship between company age and survival largely disappears. This supports the contention made by other scholars that it is not age per se which shapes survival—rather, it is other (often unobserved) factors such as the experience of the founding entrepreneur and the capabilities of the workforce."

An important implication for managers is that the importance to develop and maintain strong (knowledge) resources remains high (or even increases) as firms become older. Managers need to be aware of this relationship and actively manage the firm's patent portfolio.

7.1.4. Moderator effect of firm size

The interaction term for firm size and patent portfolio strength suggests that patent portfolio strength has less (negative) impact on the likelihood of bankruptcy for small firms compared to large firms. This contradicts hypothesis 5. It was argued that firm size indicates a firm's total resource and skills accumulation. Consequently, it was expected that large firms control a larger set of resources and are therefore more likely to compensate shortcomings in patent portfolio strength with other resources. Hence, bankruptcy was expected to be less impacted by portfolio strength. Vice versa, it was argued above that smaller firms control fewer resources and are consequently more dependent on resources such as patents.

In order to explain this observation, it is worth looking at the correlation analysis showed in section 6.1. It revealed that patent portfolio strength and firm size are significantly correlated at medium strength. In other words, large firms have stronger patent portfolios than smaller firms. This might not seem surprising, it is however worth noticing. Possibly, smaller firms protect their knowledge rather through organizational mechanisms, like employment of key-knowledge-possessors, or intellectual property rights other than patents. Reasons could be for example, the high costs that are related to establishing patent protection. Firms with smaller assets might not have the financial resource to pursue this protection. Moreover, smaller firms might adapt their strategy to their weak patent portfolio, e.g. through licensing. Going back to the matrix presented in section 3.1., smaller firms tend to be rather on the left side of the x-axis. Differences between surviving and failing firm might be rather observed in their strategies and how they match it to their patent resources. Only considering patent portfolio size does not allow identifying these differences and hence the impact of patent portfolio strength decreases with firm size. In turn, large firms might generally exhibit more variance in their patent portfolio strength and it is easier to attribute differences between failing and surviving firms to this variance in portfolio strength.

Another argument could be that the importance to innovate, which often results in new patents (Kleinknecht & Reinders, 2012), increases with firm size. Henderson, Alamo, Becker, Lawton, Moran and Shapiro (1998) argue that larger firms often become complacent and stiff. If these firms fail to innovate and develop their knowledge base, they risk becoming obsolete. Consequently, it is necessary for large firms to have strong knowledge resources and maintain competitive levels. Smaller or less established firms on the other hand might concentrate on niche markets for which no patent protection is available or possible.

Increasing firm size by itself was found to significantly increase the likelihood of bankruptcy in the regression model. This is contradicting the expectation that bankruptcy probability decreases as firms grow. The t-test, however, indicated a significant size difference between bankrupt and non-bankrupt firms and suggests that bankrupt firms are on average smaller than surviving firms.

As argued in section 7.1.4 the moderation effect of size has relevance for managers and other practitioners. The importance to control strong patent resources increases as firms grow and patent portfolio management remains, therefore, an important issue.

7.2. Critical reflections on potential limitations

Despite the richness of the research findings within this study, some limitations do apply. In the following, four potential limitations are explained. Furthermore, the reader is directed to section 5.4. that discussed directly methodological related limitations of this study.

Firstly, in the light of the theoretical foundation of this study and the implications of the findings for the knowledge- and the resource-based view theory, one has to consider the particular research question. This study investigated if weak or missing patent resources can lead to bankruptcy. Even though this contributes to the further validation of both theories, it cannot to be understood as a general confirmation of them. Even though being considerably valuable, patent resources are only one kind of resource to the firm and other forms of resources exist too. Also, alternative knowledge appropriating, securing and enhancing strategies persist, for example, relating to the concept of tacit knowledge (Polanyi, 1966). Therefore, this study only sheds light on the importance of patent management within technology industries which can be explained by the knowledge- and the resource-based view. Application of these findings to other forms of IP or resources in general has to be carefully evaluated.

Moreover, this study only analyses the effects of patent portfolio strength on bankruptcy likelihood, not accounting for aspects specific to the strategy a particular firm deploys. As explained in section 3.2., this second dimension relates to the patent strength and has importance to determine the causes of bankruptcy (see figure 1). Firms might for example deploy (successful) strategies not requiring the possession of patents but rather, for example, licensing them or protecting knowledge through organizational mechanisms. Hence, firm survival is also contingent on the chosen commercialization strategy and the firm's inherent capabilities to appropriate rents from patent resources. However, as pointed out by Venkatraman (1989), correctly assessing the fit of strategies in order to test theories is hardly possible and can, therefore, lead to inconsistent results. Hence, we chose to exclude this dimension from our analysis. Nevertheless, this is a limitation that needs to be considered.

Thirdly, despite analyzing why firms filed for bankruptcy, it is also advisable to examine the reasons why other companies did not file for bankruptcy, although their patent portfolios "naturally" would have led them to do so. For example, firms might have received "capital injections" by investors who still deemed them a valuable investment. Also some firms might have been bought and/or partially sold off instead of declaring bankruptcy. This cannot be observed by analyzing the data but still possibly distort our empirical results to some extent. Hence, it has to be mentioned as a possible limitation

Last but not least, the problem of cause and effect remains. Building on theory and logical argumentation, we assumed weak patents to be generally the cause of weak performance and corporate bankruptcy, not the effect. However, one could also argue for a reversed causal relationship: Potentially, weakly performing firms might not be able to invest in the accumulation and maintenance of resources, and particularly patents. Hence, they display as result rather than a cause weak patent portfolios and resources bases.

In spite of the aforementioned limitations, this study has provided valuable insights into the underlying causes of bankruptcy. When evaluating this study's implications for future research as well as for managers, investors and policy makers these limitations need to be considered.

8. Conclusion

The present study identified the causes of bankruptcy as understudied field outside the accounting literature and especially within the strategic management area. While scholars within business strategy focused on the determinants of superior performance, this study deployed the knowledge-based view in order to identify the causes of corporate bankruptcy. More specifically, the question was raised whether the level of patent portfolio strength explains the occurrence of bankruptcies and if this could be justified by the knowledge-based view.

In order to answer this question, the second chapter set out the theoretical foundation. It provided an overview of industrial organization theory and resource-based view theory as examples of internal and external schools of thought within strategic management. Following the knowledge-based view theory, as advancement of the resource-based view, was discussed with special regards to patent portfolios as strategically most important (knowledge) resources. The third chapter represents this study's contribution to theory development. It argued for the application of the RBV in general and the KBV in particular to explain inferior performance. It showed how low patent portfolio strength might lead to competitive disadvantages and ultimately bankruptcy. Further, that chapter deducted five hypotheses in order to test the proposed relationship. Chapter four provided a comprehensive overview of patent strength evaluation in theory, previous research and as done throughout this study. The fifth chapter discussed this study's methodology including potential shortcomings. Thereafter, chapter six presented the result of the descriptive statistics, t-tests and logistic regression analysis to test the hypotheses. Finally, chapter eight discussed the findings in light of previous research, theoretical background and practical implications. Further, it outlined potential limitations of this study as well as unanswered aspects.

It was found that the level of patent portfolio strength does significantly explain corporate bankruptcy. More specifically, a negative relationship was found between patent portfolio strength and likelihood to file for bankruptcy (**hypothesis 1**). Further, this relationship is moderated by the firm size (**hypotheses 4**) and age (**hypotheses 5**), i.e. for larger or older firms this relationship becomes stronger negative than for smaller or younger firms. However, no significant moderator effect of the industry's technology (**hypothesis 3**) was found. Furthermore, it was found that the change in patent portfolio strength over 3 years prior to bankruptcy (**hypothesis 2**) does not have a statistically significant impact on the bankruptcy likelihood. Despite rather low indications of model fit (McFadden R^2), all models proof to be statistically significant (LR chi^2). Furthermore, patent portfolio strength increased the explanatory value when added to both, the model containing only the Altman Z-score and the model containing the Z-score and other control variables (likelihood ratio test). Therefore, we conclude that patent portfolio strength is suitable to explain corporate bankruptcy as expected based on the knowledge-based view.

Before rounding this study off with suggestions for further research, the next section will discuss implications of this study for researchers, managers, investors and policy makers.

8.1. Practical implications

This section presents and discusses some practical implications the present research might have for researchers, managers, investors as well as policy makers.

8.1.1. Implications for researchers

The results of the present study have mostly three implications for researchers.

Firstly, the paper contributes to closing a relevant research gap in the field of strategic management. It provides new insights on the causes of corporate bankruptcy and enhances the understanding of this phenomenon. Subsequent researchers can build on these findings and further support the development of theory on bankruptcy causes.

Secondly, this study further validates the RBV and KBV theory. It has shown that these theories are applicable to explain (inferior) performance differences between firms going bankrupt and firms not going bankrupt. This reduces the previously potentially present bias from validating these theories by looking at superior performance differences.

Last but not least, the significant results found can be seen as invitation to scholars from other fields within strategic management, to also challenge the applicability of prevailing theories to all potential observations and not only to successful firms. We agree with Thornhill and Amit's (2003) quote from above (see section 3.1) that management research just like medical research can learn from studying "unhealthy" too rather than studying only healthy cases.

8.1.2. Implications for managers

Managerial implications can also be derived from our findings.

The most apparent implication for managers is the need to acknowledge the important of knowledge resources in the form of patents not only to achieve superior performance but also to prevent bankruptcy. Secondly, firms need to analyze their set of resources and particularly their patent portfolios in order to adapt their strategies accordingly (cf. Omland, 2011). The moderation effects of firm size and age emphasized the importance to maintain strong patent portfolios even as firm grow and mature.

Moreover, looking outside of the own boundaries, managers need to evaluate and monitor also patent portfolios of competitors in order to stay informed about their potential and possible strategies (cf. Ernst & Omland, 2003). Our findings imply that this might allow managers also to draw conclusion about competitor's likelihood to file bankruptcy.

Last but not least, firms with strong patent portfolios might find it beneficial to communicate their patent portfolio strength actively and enhance transparency about these resources. As the general knowledge about role and importance of patent portfolio strength spreads, this might send positive signals to actors in- and outside the company (e.g. potential investors, employees or partners).

8.1.3. Implications for investors

Our findings about the relationship between patent portfolio strength and bankruptcy likelihood offers important implications for equity as well as debt investors. A firm's risk of default is of importance for all its stakeholders. Investors are traditionally among the most concerned stakeholders about a firm's risk of failure. Consequently, much of previous research has focused on the prediction of bankruptcy (cf. Altman, 1968; Ohlson, 1980). Firstly, our findings imply that these stakeholders might find it beneficial to include information about firms' knowledge resources and, specifically, their patent portfolio strength (cf. Munari & Oriani, 2011; Hirschey & Richardson, 2004). We have shown in this study that these resources take on a significant role in the determination of a firm's bankruptcy probability. Secondly, our results indicate that models including measures of patent portfolio strength have significantly higher explanatory power of bankruptcy probability than the Altman Z-score by itself and models including other control variables reflecting previous research.

8.1.4. Implications for policy makers

Implications from our study for policy makers point in the direction that it is important to support the establishment, maintenance and protection of patented resources. As patent resources have been shown to significantly reduce a firm's probability of bankruptcy, policy makers should promote the accumulation of these resources to improve the competitiveness of firms and reduce adverse macroeconomic effects from firm failures.

8.2. Further Research

Our work gives impulses for further work in multiple directions. However, in the following we limit ourselves to suggest a few possibilities for further research only.

Firstly, based on the two-dimensional framework (patent portfolio strength vs. fit of strategy) developed in section 3.1 (see figure 1), we propose that subsequent researchers re-evaluate our findings considering also the fit of strategy dimension. Results from such study are expected to enhance understanding of the causes of corporate bankruptcy and especially the impact of patent portfolio strength.

Moreover, having confirmed the impact of patent portfolio strength on bankruptcy likelihood quantitatively, a qualitative study of individual cases would complement this study well. For example, analyzing individual bankruptcy cases in more detail can shed light on the exact causes and might identify further relevant factors, previously not considered. However, studying bankrupt firms in greater detail after their filing for bankruptcy might pose challenges. Employees for interviews might not be identifiable anymore and non-quantitative data (e.g. subjective memories) might be distorted over time. Nevertheless, a detailed study of individual cases is deemed helpful – possibly also in combination with the previously suggested investigation of strategy fit.

Additionally, additional research could expand its focus beyond patents. By investigating the effects of knowledge resources protected by other IP rights (cf. EPO, 2013) or organizational mechanisms (cf. Liebeskind, 1996) the validity of the KBV in general and specifically to explain bankruptcy might be further enhanced. Moreover, expanding the research focus to other industries might provide valuable insights too. Accordingly, theory development could benefit from the analysis of the impact of knowledge resources on bankruptcy in other industries (e.g. within the service sector) or in more narrowly defined industries (e.g. biotech, semiconductors, or automotive).

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